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Revised June 2018 (5.8.1)
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Chapter 2

Pivotal Greenplum 5.8.1 Release Notes

Updated: June, 2018

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- Experimental Features
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- Supported Platforms
- Pivotal Greenplum Tools and Extensions Compatibility
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- Update for gp_toolkit@gp_bloat_diag Issue
Welcome to Pivotal Greenplum 5.8.1

Pivotal Greenplum Database is a massively parallel processing (MPP) database server that supports next generation data warehousing and large-scale analytics processing. By automatically partitioning data and running parallel queries, it allows a cluster of servers to operate as a single database supercomputer performing tens or hundreds times faster than a traditional database. It supports SQL, MapReduce parallel processing, and data volumes ranging from hundreds of gigabytes, to hundreds of terabytes.

This document contains pertinent release information about Pivotal Greenplum Database 5.8.1. For previous versions of the release notes for Greenplum Database, go to Pivotal Greenplum Database Documentation. For information about Greenplum Database end of life, see Pivotal Greenplum Database end of life policy.

Pivotal Greenplum 5.x software is available for download from the Pivotal Greenplum page on Pivotal Network.

Pivotal Greenplum 5.x is based on the open source Greenplum Database project code.

**Important:** Pivotal Support does **not** provide support for open source versions of Greenplum Database. Only Pivotal Greenplum Database is supported by Pivotal Support.

Pivotal Greenplum 5.8.1 is a minor release that adds and changes several features and resolves some issues.

**Important:** This patch release resolves a timezone issue, and the documentation clarifies Greenplum Database behavior in selecting a timezone to use when no specific timezone is configured. Pivotal recommends that all customers configure a fixed timezone value that is compatible with Greenplum Database and their host system. This prevents Greenplum Database from recalculating a “best match” timezone each time the cluster is restarted. If you have not configured a timezone value, after you upgrade to this release please verify that the selected timezone is acceptable for your deployment. See Configuring Timezone and Localization Settings for more information.
Experimental Features

Because Pivotal Greenplum Database is based on the open source Greenplum Database project code, it includes several experimental features to allow interested developers to experiment with their use on development systems. Feedback will help drive development of these features, and they may become supported in future versions of the product.

**Warning:** Experimental features are not recommended or supported for production deployments. These features may change in or be removed from future versions of the product based on further testing and feedback. Moreover, any features that may be visible in the open source code but that are not described in the product documentation should be considered experimental and unsupported for production use.

Greenplum Database 5.8.1 includes these experimental features:

- The storage plugin for `gpbackup` and `gprestore`.
  - The S3 storage plugin. You can specify the `--plugin-config` option to store a backup on an Amazon Web Services S3 location, and restore the data from the S3 location. See S3 Storage Plugin for `gpbackup` and `gprestore` in the Pivotal Greenplum Database Documentation.
  - Storage plugin framework API. Partners, customers, and OSS developers can develop plugins to use in conjunction with `gpbackup` and `gprestore`. See Backup/Restore Storage Plugin API.
  - Integration with the Pivotal Greenplum-Informatica Connector (experimental). The connector supports high speed data transfer from an Informatica PowerCenter cluster to a Pivotal Greenplum Database cluster for batch and streaming ETL operations. See the Pivotal Greenplum-Informatica Connector (Experimental) Documentation.
  - Recursive WITH Queries (Common Table Expressions). See WITH Queries (Common Table Expressions) in the Pivotal Greenplum Database Documentation.
  - Resource groups remain an experimental feature only on the SuSE 11 platform, due to limited cgroups functionality in the kernel.

SuSE 12 resolves the Linux cgroup issues that caused the performance degradation when Greenplum Database resource groups are enabled.
Differences Compared to Open Source Greenplum Database

Pivotal Greenplum 5.x includes all of the functionality in the open source Greenplum Database project and adds:

- Product packaging and installation script.
- Support for QuickLZ compression. QuickLZ compression is not provided in the open source version of Greenplum Database due to licensing restrictions.
- Support for managing Greenplum Database using Pivotal Greenplum Command Center.
- Support for full text search and text analysis using Pivotal GPText.
- Spark Connector and Gemfire Connector
- Data Direct ODBC/JDBC Drivers
Supported Platforms

Pivotal Greenplum 5.8.1 runs on the following platforms:

- Red Hat Enterprise Linux 64-bit 7.x (See the following Note)
- Red Hat Enterprise Linux 64-bit 6.x
- SuSE Linux Enterprise Server 64-bit 12 SP2 and SP3 with kernel version greater than 4.4.73-5. (See the following Note)
- SuSE Linux Enterprise Server 64-bit 11 SP4 (See the following Note)
- CentOS 64-bit 7.x
- CentOS 64-bit 6.x

Note: For the supported Linux operating systems, Pivotal Greenplum Database is supported on system hosts using either AMD or Intel CPUs based on the x86-64 architecture. Pivotal recommends using a homogeneous set of hardware (system hosts) in a Greenplum Database system.

Important: Significant Greenplum Database performance degradation has been observed when enabling resource group-based workload management on Red Hat 6.x, CentOS 6.x, and SuSE 11 systems. This issue is caused by a Linux cgroup kernel bug. This kernel bug has been fixed in CentOS 7.x and Red Hat 7.x systems.

If you use Red Hat 6 and the performance with resource groups is acceptable for your use case, upgrade your kernel to version 2.6.32-696 or higher to benefit from other fixes to the cgroups implementation.

SuSE 11 does not have a kernel version that resolves this issue; resource groups are still considered to be an experimental feature on this platform. Resource groups are not supported on SuSE 11 for production use. See known issue 149789783.

Pivotal Greenplum on SuSE 12 supports resource groups for production use. SuSE 12 resolves the Linux cgroup kernel issues that caused the performance degradation when Greenplum Database resource groups are enabled.

Note: For Greenplum Database that is installed on Red Hat Enterprise Linux 7.x or CentOS 7.x prior to 7.3, an operating system issue might cause Greenplum Database that is running large workloads to hang in the workload. The Greenplum Database issue is caused by Linux kernel bugs. RHEL 7.3 and CentOS 7.3 resolves the issue.

Note: Greenplum Database on SuSE Linux Enterprise systems does not support these features.

- The PL/Perl procedural language
- The gpmapreduce tool
- The PL/Container language extension
- The Greenplum Platform Extension Framework (PXF)

Greenplum Database support on Dell EMC DCA.

- Pivotal Greenplum Database 5.8.1 is supported on DCA systems that are running DCA software version 3.4 or greater.
- Only Pivotal Greenplum Database is supported on DCA systems. Open source versions of Greenplum Database are not supported.
- FIPS is supported on DCA software version 3.4 and greater with Pivotal Greenplum Database 5.2.0 and greater.

Pivotal Greenplum 5.8.1 supports these Java versions:

- 8.xxx
• 7.xxx
Greenplum Database 5.8.1 software that runs on Linux systems uses OpenSSL 1.0.2l (with FIPS 2.0.16),
cURL 7.54, OpenLDAP 2.4.44, and Python 2.7.12.
Greenplum Database client software that runs on Windows and AIX systems uses OpenSSL 0.9.8zg.
The Greenplum Database s3 external table protocol supports these data sources:
• Amazon Simple Storage Service (Amazon S3)
• Dell EMC Elastic Cloud Storage (ECS), an Amazon S3 compatible service
Pivotal Greenplum 5.8.1 supports Data Domain Boost on Red Hat Enterprise Linux.
This table lists the versions of Data Domain Boost SDK and DDOS supported by Pivotal Greenplum 5.x.

Table 1: Data Domain Boost Compatibility

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<td>6.1 (all versions)</td>
</tr>
<tr>
<td>5.8.0</td>
<td>3.0.0.3&lt;sup&gt;1&lt;/sup&gt;</td>
<td>6.0 (all versions)</td>
</tr>
<tr>
<td>5.7.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: In addition to the DDOS versions listed in the previous table, Pivotal Greenplum 5.0.0 and later supports all minor patch releases (fourth digit releases) later than the certified version.

<sup>1</sup>Support for Data Domain Boost 3.0.0.3 is deprecated. The DELL EMC end of Primary Support date is December 31, 2017.

<sup>2</sup>The Greenplum Database utilities gpbackup and gprestore support Data Domain DD Boost File System Plug-In (BoostFS) v1.1 with DDOS 6.0 or greater. Data Domain Boost is not supported.

Note: Pivotal Greenplum 5.8.1 does not support the ODBC driver for Cognos Analytics V11.
Connecting to IBM Cognos software with an ODBC driver is not supported. Greenplum Database supports connecting to IBM Cognos software with the DataDirect JDBC driver for Pivotal Greenplum. This driver is available as a download from Pivotal Network.

**Veritas NetBackup**
Pivotal Greenplum 5.8.1 supports backup with Veritas NetBackup version 7.7.3. See *Backing Up Databases with Veritas NetBackup*.

**Supported Platform Notes**
The following notes describe platform support for Pivotal Greenplum. Please send any questions or comments to Pivotal Support at https://support.pivotal.io.

• The only file system supported for running Greenplum Database is the XFS file system. All other file systems are explicitly *not* supported by Pivotal.
• Greenplum Database is supported on all 1U and 2U commodity servers with local storage. Special purpose hardware that is not commodity may be supported at the full discretion of Pivotal Product Management based on the general similarity of the hardware to commodity servers.

• Greenplum Database is supported on network or shared storage if the shared storage is presented as a block device to the servers running Greenplum Database and the XFS file system is mounted on the block device. Network file systems are not supported. When using network or shared storage, Greenplum Database mirroring must be used in the same way as with local storage, and no modifications may be made to the mirroring scheme or the recovery scheme of the segments. Other features of the shared storage such as de-duplication and/or replication are not directly supported by Pivotal Greenplum Database, but may be used with support of the storage vendor as long as they do not interfere with the expected operation of Greenplum Database at the discretion of Pivotal.

• Greenplum Database is supported when running on virtualized systems, as long as the storage is presented as block devices and the XFS file system is mounted for the storage of the segment directories.

• A minimum of 10-gigabit network is required for a system configuration to be supported by Pivotal.

• Greenplum Database is supported on Amazon Web Services (AWS) servers using either Amazon instance store (Amazon uses the volume names ephemeral[0-20]) or Amazon Elastic Block Store (Amazon EBS) storage. If using Amazon EBS storage the storage should be RAID of Amazon EBS volumes and mounted with the XFS file system for it to be a supported configuration.

• For Red Hat Enterprise Linux 7.2 or CentOS 7.2, the default systemd setting RemoveIPC=yes removes IPC connections when non-system users logout. This causes the Greenplum Database utility gpinit system to fail with semaphore errors. To avoid this issue, see "Setting the Greenplum Recommended OS Parameters" in the Greenplum Database Installation Guide.
Pivotal Greenplum Tools and Extensions Compatibility

- **Client Tools**
- **Extensions**
- **Pivotal Greenplum Data Connectors**
- **Pivotal GPText Compatibility**
- **Pivotal Greenplum Command Center**

**Client Tools**

Greenplum releases a number of client tool packages on various platforms that can be used to connect to Greenplum Database and the Greenplum Command Center management tool. The following table describes the compatibility of these packages with this Greenplum Database release.

Tool packages are available from *Pivotal Network*.

**Table 2: Pivotal Greenplum 5.8.1 Tools Compatibility**

<table>
<thead>
<tr>
<th>Tool</th>
<th>Description of Contents</th>
<th>Tool Version(s)</th>
<th>Server Version(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pivotal Greenplum Clients</td>
<td>Greenplum Database Command-Line Interface (psql)</td>
<td>5.8</td>
<td>5.x</td>
</tr>
<tr>
<td>Pivotal Greenplum Loaders</td>
<td>Greenplum Database Parallel Data Loading Tools (gpfdist, gpload)</td>
<td>5.8</td>
<td>5.x</td>
</tr>
<tr>
<td>Pivotal Greenplum Command Center</td>
<td>Greenplum Database management tool</td>
<td>4.0.0</td>
<td>5.7.0 and later</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.3.2</td>
<td>5.0.0 and later</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2.2</td>
<td>5.0.0 - 5.2.x</td>
</tr>
<tr>
<td>Pivotal Greenplum Workload Manager&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Greenplum Database query monitoring and management tool</td>
<td>1.8.0</td>
<td>5.0.0</td>
</tr>
</tbody>
</table>

The Greenplum Database Client Tools and Load Tools are supported on the following platforms:

- AIX 7.2 (64-bit) (Client and Load Tools only)<sup>2</sup>
- Red Hat Enterprise Linux x86_64 6.x (RHEL 6)
- SuSE Linux Enterprise Server x86_64 SLES 11 SP4, or SLES 12 SP2/SP3
- Windows 10 (32-bit and 64-bit)
- Windows 8 (32-bit and 64-bit)
- Windows Server 2012 (32-bit and 64-bit)
- Windows Server 2012 R2 (32-bit and 64-bit)
- Windows Server 2008 R2 (32-bit and 64-bit)

**Note:**<sup>1</sup> For Pivotal Greenplum Command Center 4.0.0 and later, workload management is an integrated Command Center feature rather than the separate tool Pivotal Greenplum Workload Manager.

<sup>2</sup> For Greenplum Database 5.4.1 and earlier 5.x releases, download the AIX Client and Load Tools package either from the Greenplum Database 5.8.1 file collection or the Greenplum Database 5.0.0 file collection on *Pivotal Network*.
## Extensions

### Table 3: Pivotal Greenplum 5.8.1 Extensions Compatibility

<table>
<thead>
<tr>
<th>Pivotal Greenplum Extension</th>
<th>Versions</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADlib machine learning for Greenplum Database 5.x</td>
<td>MADlib 1.14</td>
</tr>
<tr>
<td>PL/Java for Greenplum Database 5.x</td>
<td>PL/Java 1.4.2, 1.4.0</td>
</tr>
<tr>
<td>PL/R for Greenplum Database 5.6.x</td>
<td>2.3.2</td>
</tr>
<tr>
<td>PostGIS Spatial and Geographic Objects for Greenplum Database 5.x</td>
<td>2.1.5+pivotal.1</td>
</tr>
<tr>
<td>Python Data Science Module Package for Greenplum Database 5.x</td>
<td>1.0.0, 1.1.0</td>
</tr>
<tr>
<td>R Data Science Library Package for Greenplum Database 5.x</td>
<td>1.0.0</td>
</tr>
<tr>
<td>PL/Container for Greenplum Database 5.x</td>
<td>1.1, 1.2</td>
</tr>
</tbody>
</table>

**Note:**

1. For information about MADlib support and upgrade information, see the [MADlib FAQ](#). For information on installing the MADlib extension in Greenplum Database, see [Greenplum MADlib Extension for Analytics](#) in the Greenplum Database Reference Guide.

2. Before upgrading to MADlib 1.13, you must remove some leftover `knn` functions. For information on upgrading MADlib, see [Greenplum MADlib Extension for Analytics](#) in the Greenplum Database Reference Guide.

3. For information about the Python package, including the modules provided, see the [Python Data Science Module Package](#) in the Greenplum Database Documentation.

4. For information about the R package, including the libraries provided, see the [R Data Science Library Package](#) in the Greenplum Database Documentation.

5. The PostGIS extension package version 2.1.5+pivotal.1 is compatible only with Greenplum Database 5.5.0 and later.

6. To upgrade from PL/Container 1.0 to PL/Container 1.1 and later, you must drop the PL/Container 1.0 language before registering the new version of PL/Container. For information on upgrading the PL/Container extension in Greenplum Database, see [PL/Container Language Extension](#) in the Greenplum Database Reference Guide.

7. PL/Container version 1.2 can utilize the new resource group capabilities introduced in Greenplum Database 5.8.1. If you downgrade to a Greenplum Database system that uses PL/Container 1.1 or earlier, you must use `plcontainer runtime-edit` to remove any `resource_group_id` settings from the PL/Container runtime configuration file. See [Upgrading from PL/Container 1.1](#).

These Greenplum Database extensions are installed with Pivotal Greenplum Database:

- Fuzzy String Match Extension
- PL/Python Extension
- pgcrypto Extension
**Pivotal Greenplum Data Connectors**

- Greenplum Platform Extension Framework (PXF) - PXF, integrated with Greenplum Database 5.8.1, provides access to HDFS, Hive, and HBase external data stores. Refer to *Accessing External Data with PXF* in the *Greenplum Database Administrator Guide* for PXF configuration and usage information.
  
  **Note:** PXF is available only for supported Red Hat and CentOS platforms. PXF is not available for supported SuSE platforms.

- Greenplum-Spark Connector - The Pivotal Greenplum-Spark Connector supports high speed, parallel data transfer from Greenplum Database to an Apache Spark cluster. The Greenplum-Spark Connector is available as a separate download from *Pivotal Network*. Refer to the *Greenplum-Spark Connector documentation* for compatibility and usage information.

- Gemfire-Greenplum Connector - The Pivotal Gemfire-Greenplum Connector supports the transfer of data between a GemFire region and a Greenplum Database cluster. The Gemfire-Greenplum Connector is available as a separate download from *Pivotal Network*. Refer to the *Gemfire-Greenplum Connector documentation* for compatibility and usage information.

**Pivotal GPText Compatibility**

Pivotal Greenplum Database 5.8.1 is compatible with Pivotal GPText version 2.1.3 and later.

**Pivotal Greenplum Command Center**

See the *Greenplum Command Center documentation* for GPCC and Greenplum Workload Manager compatibility information, see the Pivotal Greenplum Command Center 3.x and 2.x *Release Notes*.

**Note:** For Pivotal Greenplum Command Center 4.0.0 and later, workload management is an integrated Command Center feature rather than the separate tool Pivotal Greenplum Workload Manager.
Hadoop Distribution Compatibility

Greenplum Database provides access to HDFS with `gphdfs` and the Greenplum Platform Extension Framework (PXF).

**PXF Hadoop Distribution Compatibility**

PXF supports Cloudera, Hortonworks Data Platform, and generic Apache Hadoop distributions.

If you plan to access JSON format data stored in a Cloudera Hadoop cluster, PXF requires a Cloudera version 5.8 or later Hadoop distribution.

**gphdfs Hadoop Distribution Compatibility**

The supported Hadoop distributions for `gphdfs` are listed below:

<table>
<thead>
<tr>
<th>Hadoop Distribution</th>
<th>Version</th>
<th>gp_hadoop_target_version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloudera</td>
<td>CDH 5.x</td>
<td>cdh</td>
</tr>
<tr>
<td>Hortonworks Data Platform</td>
<td>HDP 2.x</td>
<td>hdp</td>
</tr>
<tr>
<td>MapR</td>
<td>MapR 4.x, MapR 5.x</td>
<td>mpr</td>
</tr>
<tr>
<td>Apache Hadoop</td>
<td>2.x</td>
<td>hadoop</td>
</tr>
</tbody>
</table>

*Note:* MapR requires the MapR client.
Upgrading to Greenplum Database 5.8.1

The upgrade path supported for this release is Greenplum Database 5.x to Greenplum Database 5.8.1. Upgrading a Greenplum Database 4.3.x release to Pivotal Greenplum 5.x is not supported. See Migrating Data to Pivotal Greenplum 5.x.

Note: If you are upgrading Greenplum Database on a DCA system, see Pivotal Greenplum on DCA Systems.

Prerequisites

Before starting the upgrade process, Pivotal recommends performing the following checks.

• Verify the health of the Greenplum Database host hardware, and that you verify that the hosts meet the requirements for running Greenplum Database. The Greenplum Database gpcheckperf utility can assist you in confirming the host requirements.

  Note: If you need to run the gpcheckcat utility, Pivotal recommends running it a few weeks before the upgrade and that you run gpcheckcat during a maintenance period. If necessary, you can resolve any issues found by the utility before the scheduled upgrade.

  The utility is in $GPHOME/bin. Pivotal recommends that Greenplum Database be in restricted mode when you run gpcheckcat utility. See the Greenplum Database Utility Guide for information about the gpcheckcat utility.

  If gpcheckcat reports catalog inconsistencies, you can run gpcheckcat with the -g option to generate SQL scripts to fix the inconsistencies.

  After you run the SQL scripts, run gpcheckcat again. You might need to repeat the process of running gpcheckcat and creating SQL scripts to ensure that there are no inconsistencies. Pivotal recommends that the SQL scripts generated by gpcheckcat be run on a quiescent system. The utility might report false alerts if there is activity on the system.

  Important: If the gpcheckcat utility reports errors, but does not generate a SQL script to fix the errors, contact Pivotal support. Information for contacting Pivotal Support is at https://support.pivotal.io.

  • During the migration process from Greenplum Database 5.0.0, a backup is made of some files and directories in $MASTER_DATA_DIRECTORY. Pivotal recommends that files and directories that are not used by Greenplum Database be backed up, if necessary, and removed from the $MASTER_DATA_DIRECTORY before migration. For information about the Greenplum Database migration utilities, see the Greenplum Database Documentation.

  For information about supported versions of Greenplum Database extensions, see Pivotal Greenplum Tools and Extensions Compatibility.

If you are utilizing Data Domain Boost, you have to re-enter your DD Boost credentials after upgrading to Greenplum Database 5.8.1 as follows:

```
gpcrondump --ddboost-host ddboost_hostname --ddboost-user ddboost_user --ddboost-backupdir backup_directory
```

Note: If you do not reenter your login credentials after an upgrade, your backup will never start because the Greenplum Database cannot connect to the Data Domain system. You will receive an error advising you to check your login credentials.

If you have configured the Greenplum Platform Extension Framework (PXF) in your previous Greenplum Database installation, you must stop the PXF service and back up PXF configuration files before upgrading to a new version of Greenplum Database. Refer to PXF Pre-Upgrade Actions for instructions.

If you do not plan to use PXF, or you have not yet configured PXF, no action is necessary.
Upgrading from 5.x to 5.8.1

An upgrade from 5.x to 5.8.1 involves stopping Greenplum Database, updating the Greenplum Database software binaries, upgrading and restarting Greenplum Database. If you are using Greenplum Database extension packages there are additional requirements. See Prerequisites in the previous section.

**Note:** If you have databases that were created with Greenplum Database 5.3.0 or an earlier 5.x release, upgrade the `gp_bloat_diag` function and view in the `gp_toolkit` schema. For information about the issue and how check a database for the issue, see Update for `gp_toolkit.gp_bloat_diag` Issue.

**Note:** If the Greenplum Command Center database `gpperfmon` is installed in your Greenplum Database system, the migration process changes the distribution key of the Greenplum Database `log_alert_*` tables to the `logtime` column. The redistribution of the table data might take some time the first time you start Greenplum Database after migration. The change occurs only the first time you start Greenplum Database after a migration.

1. Log in to your Greenplum Database master host as the Greenplum administrative user:

   ```bash
   $ su - gpadmin
   ```

2. Perform a smart shutdown of your current Greenplum Database 5.x system (there can be no active connections to the database). This example uses the `-a` option to disable confirmation prompts:

   ```bash
   $ gpstop -a
   ```

3. Run the binary installer for 5.8.1 on the Greenplum Database master host.

   When prompted, choose an installation location in the same base directory as your current installation. For example:

   ```bash
   /usr/local/greenplum-db-5.8.1
   ```

   If you install Greenplum Database with the rpm (as `root`), the installation directory is `/usr/local/greenplum-db-5.8.1`.

   For the rpm installation, update the permissions for the new installation. For example, run this command as `root` to change user and group of the installed files to `gpadmin`.

   ```bash
   # chown -R gpadmin:gpadmin /usr/local/greenplum*
   ```

4. If your Greenplum Database deployment uses LDAP authentication, manually edit the `/usr/local/greenplum-db/greenplum_path.sh` file to add the line:

   ```bash
   export LDAPCONF=/etc/openldap/ldap.conf
   ```

5. Edit the environment of the Greenplum Database superuser (`gpadmin`) and make sure you are sourcing the `greenplum_path.sh` file for the new installation. For example change the following line in `.bashrc` or your chosen profile file:

   ```bash
   source /usr/local/greenplum-db-5.0.0/greenplum_path.sh
   ```

   to:

   ```bash
   source /usr/local/greenplum-db-5.8.1/greenplum_path.sh
   ```

   Or if you are sourcing a symbolic link (`/usr/local/greenplum-db`) in your profile files, update the link to point to the newly installed version. For example:

   ```bash
   $ rm /usr/local/greenplum-db
   ```
$ ln -s /usr/local/greenplum-db-5.8.1 /usr/local/greenplum-db

6. Source the environment file you just edited. For example:

$ source ~/.bashrc

7. Run the `gpseginstall` utility to install the 5.8.1 binaries on all the segment hosts specified in the `hostfile`. For example:

$ gpseginstall -f hostfile

8. Use the Greenplum Database `gppkg` utility to install Greenplum Database extensions. If you were previously using any Greenplum Database extensions such as pgcrypto, PL/R, PL/Java, PL/Perl, and PostGIS, download the corresponding packages from Pivotal Network, and install using this utility. See the Greenplum Database Documentation for `gppkg` usage details.

9. After all segment hosts have been upgraded, you can log in as the `gpadmin` user and restart your Greenplum Database system:

# su - gpadmin
$ gpstart

10. If you are utilizing Data Domain Boost, you have to re-enter your DD Boost credentials after upgrading from Greenplum Database to 5.8.1 as follows:

    gpcrondump --ddboost-host ddboost_hostname --ddboost-user ddboost_user
    --ddboost-backupdir backup_directory

    Note: If you do not reenter your login credentials after an upgrade, your backup will never start because the Greenplum Database cannot connect to the Data Domain system. You will receive an error advising you to check your login credentials.

11. If you configured PXF in your previous Greenplum Database installation, you must re-initialize the PXF service after you upgrade Greenplum Database. Refer to Upgrading PXF for instructions.

**Troubleshooting a Failed Upgrade**

If you experience issues during the migration process and have active entitlements for Greenplum Database that were purchased through Pivotal, contact Pivotal Support. Information for contacting Pivotal Support is at https://support.pivotal.io.

Be prepared to provide the following information:

- A completed Upgrade Procedure.
- Log output from `gpcheckcat` (located in `~/gpAdminLogs`
Migrating Data to Pivotal Greenplum 5.x

Upgrading a Pivotal Greenplum Database 4.x system directly to Pivotal Greenplum Database 5.x is not supported.

You can migrate existing data to Greenplum Database 5.x using standard backup and restore procedures (gpcrondump and gpdbrestore) or by using gptransfer if both clusters will run side-by-side.

Follow these general guidelines for migrating data:

• Make sure that you have a complete backup of all data in the Greenplum Database 4.3.x cluster, and that you can successfully restore the Greenplum Database 4.3.x cluster if necessary.

• You must install and initialize a new Greenplum Database 5.x cluster using the version 5.x gpinitsystem utility.

  **Note:** Unless you modify file locations manually, gpdbrestore only supports restoring data to a cluster that has an identical number of hosts and an identical number of segments per host, with each segment having the same content_id as the segment in the original cluster. If you initialize the Greenplum Database 5.x cluster using a configuration that is different from the version 4.3 cluster, then follow the steps outlined in Restoring to a Different Greenplum System Configuration to manually update the file locations.

• If you intend to install Greenplum Database 5.x on the same hardware as your 4.3.x system, you will need enough disk space to accommodate over 5 times the original data set (2 full copies of the primary and mirror data sets, plus the original backup data in ASCII format). Keep in mind that the ASCII backup data will require more disk space than the original data, which may be stored in compressed binary format. Offline backup solutions such as Dell EMC Data Domain or Veritas NetBackup can reduce the required disk space on each host.

• Use the version 5.x gpdbrestore utility to load the 4.3.x backup data into the new cluster.

• If the Greenplum Database 5.x cluster resides on separate hardware from the 4.3.x cluster, you can optionally use the version 5.x gptransfer utility to migrate the 4.3.x data. You must initiate the gptransfer operation from the version 5.x cluster, pulling the older data into the newer system.

On a Greenplum Database system with FIPS enabled, validating table data with MD5 (specifying the option --validate=md5) is not available. Use the option sha256 to validate table data.

Validating table data with SHA-256 (specifying the option --validate=sha256) requires the Greenplum Database pgcrypto extension. The extension is included with Pivotal Greenplum 5.x. The extension package must be installed on supported Pivotal Greenplum 4.3.x systems. Support for pgcrypto functions in a Greenplum 4.3.x database is not required.

• Greenplum Database 5.x removes automatic implicit casts between the text type and other data types. When you migrate from Greenplum Database version 4.3.x to version 5.x, this change in behavior may impact existing applications and queries. Refer to About Implicit Text Casting in Greenplum Database in the Greenplum Database Installation Guide for information, including a discussion about supported and unsupported workarounds.

• After migrating data you may need to modify SQL scripts, administration scripts, and user-defined functions as necessary to account for changes in Greenplum Database version 5.x. Look for Upgrade Action Required entries in the Pivotal Greenplum 5.0.0 Release Notes for features that may necessitate post-migration tasks.
Pivotal Greenplum on DCA Systems

On supported Dell EMC DCA systems, you can install Pivotal Greenplum 5.8.1, or you can upgrade from Pivotal Greenplum 5.x to 5.8.1.

Only Pivotal Greenplum Database is supported on DCA systems. Open source versions of Greenplum Database are not supported.

- Installing the Pivotal Greenplum 5.8.1 Software Binaries on DCA Systems
- Upgrading from 5.x to 5.8.1 on DCA Systems

**Important:** Upgrading Pivotal Greenplum Database 4.3.x to Pivotal Greenplum 5.8.1 is not supported. See Migrating Data to Pivotal Greenplum 5.x.

### Installing the Pivotal Greenplum 5.8.1 Software Binaries on DCA Systems

**Important:** This section is for installing Pivotal Greenplum 5.8.1 only on DCA systems. Also, see the information on the DELL EMC support site (requires login).

For information about installing Pivotal Greenplum on non-DCA systems, see the Greenplum Database Installation Guide.

### Prerequisites

- Ensure your DCA system supports Pivotal Greenplum 5.8.1. See Supported Platforms.
- Ensure Greenplum Database 4.3.x is not installed on your system.

Installing Pivotal Greenplum 5.8.1 on a DCA system with an existing Greenplum Database 4.3.x installation is not supported. For information about uninstalling Greenplum Database software, see your Dell EMC DCA documentation.

### Installing Pivotal Greenplum 5.8.1

1. Download or copy the Greenplum Database DCA installer file `greenplum-db-appliance-5.8.1-RHEL6-x86_64.bin` to the Greenplum Database master host.
2. As root, run the DCA installer for 5.8.1 on the Greenplum Database master host and specify the file `hostfile` that lists all hosts in the cluster, one host name per line. If necessary, copy `hostfile` to the directory containing the installer before running the installer.

   This example command runs the installer for Greenplum Database 5.8.1.

   ```
   # ./greenplum-db-appliance-5.8.1-RHEL6-x86_64.bin hostfile
   ```

### Upgrading from 5.x to 5.8.1 on DCA Systems

Upgrading Pivotal Greenplum from 5.x to 5.8.1 on a Dell EMC DCA system involves stopping Greenplum Database, updating the Greenplum Database software binaries, and restarting Greenplum Database.

**Important:** This section is only for upgrading to Pivotal Greenplum 5.8.1 on DCA systems. For information about upgrading on non-DCA systems, see Upgrading to Greenplum Database 5.8.1.

**Note:** If you have databases that were created with Greenplum Database 5.3.0 or an earlier 5.x release, upgrade the `gp_bloat_diag` function and view in the `gp_toolkit` schema. For information about the issue and how check a database for the issue, see Update for `gp_toolkit.gp_bloat_diag` Issue.
1. Log in to your Greenplum Database master host as the Greenplum administrative user (gpadmin):

   ```
   # su - gpadmin
   ```

2. Download or copy the installer file `greenplum-db-appliance-5.8.1-RHEL6-x86_64.bin` to the Greenplum Database master host.

3. Perform a smart shutdown of your current Greenplum Database 5.x system (there can be no active connections to the database). This example uses the `-a` option to disable confirmation prompts:

   ```
   $ gpstop -a
   ```

4. As root, run the Greenplum Database DCA installer for 5.8.1 on the Greenplum Database master host and specify the file `hostfile` that lists all hosts in the cluster. If necessary, copy `hostfile` to the directory containing the installer before running the installer.

   This example command runs the installer for Greenplum Database 5.8.1 for Red Hat Enterprise Linux 6.x.

   ```
   # ./greenplum-db-appliance-5.8.1-RHEL6-x86_64.bin hostfile
   ```

   The file `hostfile` is a text file that lists all hosts in the cluster, one host name per line.

5. Install Greenplum Database extension packages. For information about installing a Greenplum Database extension package, see `gppkg` in the *Greenplum Database Utility Guide*.

6. After all segment hosts have been upgraded, you can log in as the `gpadmin` user and restart your Greenplum Database system:

   ```
   # su - gpadmin
   $ gpstart
   ```

7. If you are utilizing Data Domain Boost, you have to re-enter your DD Boost credentials after upgrading to Greenplum Database 5.8.1 as follows:

   ```
   gpcrondump --ddboost-host `ddboost_hostname` --ddboost-user `ddboost_user` --ddboost-backupdir `backup_directory`
   ```

   **Note:** If you do not reenter your login credentials after an upgrade, your backup will never start because the Greenplum Database cannot connect to the Data Domain system. You will receive an error advising you to check your login credentials.
Resolved Issues

For issues resolved in prior 5.x releases, refer to the corresponding release notes. Release notes are available from the Pivotal Greenplum page on Pivotal Network or on the Pivotal Greenplum Database documentation site at Release Notes.

5.8.1 Release
The listed issue is resolved in Pivotal Greenplum Database 5.8.1.

29368 - Catalog and Metadata
In some cases during Greenplum Database system initialization, Greenplum Database generated a PANIC due to a timezone issue. The timezone used by Greenplum Database is selected from a set of internally stored PostgreSQL timezones. Greenplum Database selects the timezone by matching a PostgreSQL timezone with the user specified timezone, or the host system timezone.

The PANIC was caused when Greenplum Database could not match the host system timezone with an internal PostgreSQL timezone. The PANIC occurred on Dell EMC DCA systems because Greenplum Database could not match the dca_setup utility default timezone that includes leap second information.

This issue has been resolved. Now in the specified situation, Greenplum Database returns a warning and sets the Greenplum Database time zone as GMT with a time offset based on information from the host system.

Note: Greenplum Database cannot correctly match system timezones that include leap second information. You must manually configure the timezone to a compatible setting. See 158011506.

5.8.0 Release
These listed issues are resolved in Pivotal Greenplum Database 5.8.0.

29320 - catalog and metadata
The Greenplum Database timezone was not set correctly. The timezone was set to GMT. Greenplum Database did not use the timezone value in the postgresql.conf, or the operating system timezone if the value is not set in postgresql.conf.

This issue has been resolved. Now the timezone is set correctly.

29319 - Query Planner
For queries that contain a percentile function and are against a partitioned table, the Greenplum Database legacy planner generated a PANIC. The legacy planner did not handle memory properly while generating a multistage aggregate plan and caused a PANIC.

The issue has been resolved. Legacy planner memory management has been improved for the specified type of query.

29316 - gpbackup/ gprestore
The gprestore utility failed when attempting to restore a database when the PL/Java language is installed in the database. The gpbackup utility did not correctly back up the installed PL/Java language.

This issue has been resolved. Now gpbackup correctly backs up the installed PL/Java language.

29301 - gpbackup/ gprestore
In some cases when restoring tables that own sequences with `gprestore` utility, the utility returned an error. The `gpbackup` utility did not correctly backup sequences when backing up a set of tables (including or excluding tables) and some of the tables owned sequences.

This issue has been resolved. Now `gpbackup` correctly backs up sequences that are owned by tables in the specified situation.

**29299** - `gpcrondump/ gpdbgrestore`

The Greenplum Database `gpdbgrestore` utility failed when restoring a backup from a Data Domain Boost system to a system where the Greenplum Database DBID information has changed. For example, a segment instance failed over to a mirror segment between the backup and restore operation.

This issue has been resolved. The `gpdbgrestore` utility has been enhanced to restore backups from Data Domain Boost system in the specified situation.

**29286** - Analyze

A Greenplum Database superuser (gpadmin) could not perform an analyze operation on a table that is owned by a Greenplum Database non-supersuer. This issue was caused by a PostgreSQL 8.4 update that was incorporated into Greenplum Database.

This issue has been resolved. The PostgreSQL 8.4 change has been modified to work with Greenplum Database.

**29285** - Query Planner

For queries that contain a `FULL JOIN` and the join included columns of the type `varchar`, the query returned an error. The error occurred because Greenplum Database did handle type conversions properly when generating the query plan. This caused the error during query execution.

This issue has been fixed. The handling of type conversions has been improved for the specified type of queries.

**29283** - Query Optimizer

GPORCA optimization performance has been improved for queries that contain a predicate that performs a comparison with an constant array with a large number of elements where the array elements are sets of constants.

This issue has been resolved. GPORCA optimization performance has been improved for the specified type of queries.

**29275** - Query Optimizer

For some multiple join queries, GPORCA incorrectly disabled the minimum cardinality based join ordering whenever the join associativity threshold was met to improve optimization processing. This caused GPORCA to generate a suboptimal plan for some multiple join queries.

This issue has been resolved. GPORCA has improved join processing for multiple join queries.

**29269** - Internationalization

In some cases when the Greenplum Database encoding was different than the client encoding, the client received an invalid byte sequence for encoding when communicating with a database. The incorrect Greenplum Database encoding conversion function was called.

This issue has been resolved. Now the correct function is called.

**29259** - `gprecoverset`
There were `gprecoverseg` performance issues when the utility was run to recover large number of Greenplum Database segment instances. Some `gprecoverseg` tests were performed sequentially on segments.

This issue has been resolved. To improve performance, some tests performed by the utility are now performed on segments instances in parallel.

26529 - **Query Optimizer**

For GORCA, cardinality for a join that includes a predicate of the form \( f(a) = b \) was estimated using a constant scale factor. This estimate resulted in an overestimation of the cardinality, and in some cases, choosing an inferior query plan.

This issue has been resolved. GPORCA has been improved to generate cardinality estimate of the specified type of predicate and results in a better plan being selected.

29206 - **Query Planner**

For some queries that contained window functions and predicates, legacy query planner created a query plan that did not push the predicate below the window function when appropriate. This caused a performance regression.

This issue has been resolved. The predicate pushdown evaluation performed by query planner has been improved for the specified type of query.

156558904 - **GPPC**

Applications that used Greenplum Partner Connector (GPPC) library, could not be compiled. GPPC header and make file issues prevented the application from compiling.

This issue has been resolved. The GPPC header and make files have been updated in the Pivotal Greenplum Database 5.8.0 installation files.
Known Issues and Limitations

Pivotal Greenplum 5.x has these limitations:

- Upgrading a Greenplum Database 4.3.x release to Pivotal Greenplum 5.x is not supported. See Migrating Data to Pivotal Greenplum 5.x.
- Some features are works-in-progress and are considered to be experimental features. Pivotal does not support using experimental features in a production environment. See Experimental Features.
- Greenplum Database 4.3.x packages are not compatible with Pivotal Greenplum 5.x.

The following table lists key known issues in Pivotal Greenplum 5.x.

Table 5: Key Known Issues in Pivotal Greenplum 5.x

<table>
<thead>
<tr>
<th>Issue</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>158011506</td>
<td>Catalog and Metadata</td>
<td>In some cases, the timezone used by Greenplum Database might be different than the host system timezone, or the Greenplum Database timezone set by a user. In some rare cases, times used and displayed by Greenplum Database might be slightly different than the host system time. The timezone used by Greenplum Database is selected from a set of internally stored PostgreSQL timezones. Greenplum Database selects the timezone by matching a PostgreSQL timezone with the user specified time zone, or the host system time zone. For example, when selecting a default timezone, Greenplum Database uses an algorithm to select a PostgreSQL timezones based on the host system timezone. If the system timezone includes leap second information, Greenplum Database cannot match the system timezone with a PostgreSQL timezone. Greenplum Database calculates a best match with a PostgreSQL timezone based on information from the host system. Workaround: Set the Greenplum Database and host system timezones to a timezone that is supported by both Greenplum Database and the host system. For example, you can show and set the Greenplum Database timezone with the gpconfig utility. These commands show the Greenplum Database timezone and set the timezone to US/Pacific.</td>
</tr>
</tbody>
</table>

```
# gpconfig -s TimeZone
# gpconfig -c TimeZone 'US/Pacific'
```
You must restart Greenplum Database after changing the timezone. The command gpstop -ra restarts Greenplum Database.

The Greenplum Database catalog view pg_timezone_names provides Greenplum Database timezone information.
<table>
<thead>
<tr>
<th>Issue</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>26589</td>
<td>Storage: Catalog and Metadata</td>
<td>Greenplum Database does not acquire a lock on a schema when creating a table inside the schema. A concurrent DROP of the schema and CREATE TABLE operation will result in a leaked object (an orphan table or orphan relation columns) in the system catalog and possibly on disk. For example, a relation created as <code>CREATE TABLE foobar (col1 int)</code> during a concurrent DROP may leak either the table itself or the <code>col1</code> attribute object. These leaked objects do not affect any future queries. The catalog inconsistencies can be detected with the <code>gpcheckcat</code> utility.  <strong>Workaround:</strong> To block a concurrent DROP from occurring, acquire and hold a ROW SHARE lock on the row of the <code>pg_namespace</code> catalog table that corresponds to the schema. For example, this transaction acquires a ROW SHARE lock on the <code>pg_namespace</code> catalog table row for the schema <code>my_schema</code>.  <code>begin; SELECT nspname FROM pg_namespace WHERE nspname = 'my_schema' FOR SHARE; ... end;</code> During the transaction, the lock prevents the schema from being dropped.</td>
</tr>
<tr>
<td>N/A</td>
<td>PXF</td>
<td>PXF is available only for supported Red Hat and CentOS platforms. PXF is not available for supported SuSE platforms.</td>
</tr>
<tr>
<td>151135629</td>
<td>COPY command</td>
<td>When the ON SEGMENT clause is specified, the COPY command does not support specifying a SELECT statement in the COPY TO clause. For example, this command is not supported.  <code>COPY (SELECT * FROM testtbl) TO '/tmp/mytst&lt;SEGID&gt;' ON SEGMENT</code></td>
</tr>
<tr>
<td>29064</td>
<td>Storage: DDL</td>
<td>The money data type accepts out-of-range values as negative values, and no error message is displayed.  <strong>Workaround:</strong> Use only in-range values for the money data type (32-bit for Greenplum Database 4.x, or 64-bit for Greenplum Database 5.x). Or, use an alternative data type such as numeric or decimal.</td>
</tr>
<tr>
<td>Issue</td>
<td>Category</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>3290</td>
<td>JSON</td>
<td>The <code>to_json()</code> function is not implemented as a callable function. Attempting to call the function results in an error. For example:</td>
</tr>
</tbody>
</table>

```
tutorial=# select to_json('Fred said "Hi. "':text);
ERROR: function to_json(text) does not exist
LINE 1: select to_json('Fred said "Hi."':text);
^  
HINT: No function matches the given name and argument types. You might need to add explicit type casts.
```

**Workaround:** Greenplum Database invokes `to_json()` internally when casting to the json data type, so perform a cast instead. For example: `SELECT '{"foo":"bar"}':json;` Greenplum Database also provides the `array_to_json()` and `row_to_json()` functions.
Testing of the resource groups feature has found that a kernel panic can occur when using the default kernel in RHEL/CentOS system. The problem occurs due to a problem in the kernel cgroups implementation, and results in a kernel panic backtrace similar to:

```
[81375.325947] BUG: unable to handle kernel NULL pointer dereference at 00000000000000010
[81375.325986] IP: [<ffffffff812f94b1>] rb_next+0x1/0x50 [81375.326014] PGD 0 [81375.326025]
Oops: 0000 [#1] SMP [81375.326041] Modules
linked in: veth ipt_MASQUERADE
 nf_nat_masquerade_ipv4 iptable_nat nf_conntrack_ipv4 nf_defrag_ipv4 nf_nat_ipv4 xt_addrtype
 iptable_filter xt_conntrack nf_nat nf_conntrack bridge stp l1c intel_powerclamp
coretemp
 intel_rapl dm_thin_pool dm_persistent_data
dm_bio_prison dm牖io kvm_intel kvm crc32_pclmul
 ghash_clmulni_intel aesni_intel l1w
gf128mul glue_helper ablк_helper cryptd iTCO wdtdc
 iTCO_vendor_support ses enclosure ipmi ssif
 pcsprkr lpc_ich sg sb_edac md_core edac_core
 mei_me ipmi_s1 s1 wmi ipmi_mshandler
 shpchp acpi_power_meter acpi_pad ip_tables xfs
 libcrc32c sd_mod crc_t10dif cct10dif immensely
genrc mqag200 syscopyarea sysfilirect
 cct10dif_pclmul
 sysimgblt cct10dif_common crc32c_intel
 drm_kms_helper ixgbe ttm mdio ahci igb libahci
 drm ptp
 pps_core libata dca i2c_algo_bit [81375.326369]
 I2c_core megaraid_sas dm_mirror
 dm_region_hash dm_log dm_mod [81375.326369]
 CPU: 17 PID: 0 Comm: swapper/17 Not tainted
 3.10.0-327.el7.x86_64 #1 [81375.326422]
 Hardware name: Cisco Systems Inc
 2.0.8b.0.080620151546 08/06/2015 [81375.326459]
task:
 ffff88140ec5ec50 ti: ffff88140ed10000 task.
ti: ffff88140ed10000 [81375.326485] RIP:
 0010:[<ffffffff812f94b1>]
 [<ffffffff812f94b1>] rb_next+0x1/0x50 [81375.326514] RSP:
 0018:ffff88140ed1e10 EFLAGS: 00010046
[81375.326534] RAX: 0000000000000000 RBX: 0000000000000000
 RCX: 0000000000000000 RDX: 0000000000000000
[81375.326559] R8: ffff88282fd4800 RSI: ffff88280bc0f140 RDI: 0000000000000010
[81375.326584] RBP: ffff88140d3e58 R0B: 0000000000000000
 R09: 0000000000000000 R08: 0000000000000000
[81375.326609] R10: 0000000000000000  R11: 0000000000000000
 R12: ffff88280be7000 R13: 0000000000000000
 R14: 0000000000000000 R15: 0000000000b6f979
[81375.326659] FS: 0000000000000000 (0000)
 GS: ffff88282fl0000 (0000)
 knlGS: 0000000000000000 [81375.326688] CS: 0010
 DS: 0000 ES: 0000
```
<table>
<thead>
<tr>
<th>Issue</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CR0: 00000000080050033 [81375.326708] CR2: 00000000000000010 CR3: 000000000194a000 CR4: 00000000001407e0 [81375.326733] DR0: 0000000000000000 DR1: 0000000000000000 DR2: 0000000000000000 [81375.326758] DR3: 0000000000000000 DR6: 0000000000000000 DR7: 0000000000000000 [81375.326783] Stack: [81375.326792] ffff88140ed13e58 ffff88282f1d4780 ffff88282f1d4780 [81375.326826] ffff88282f1d4780 ffff88282f1d4780 0000000000000011 ffff88140ed1000 [81375.326861] 0000000000000000 ffff88140ed13eb8 ffffffff8163a10a ffff88140ec500 [81375.326895] Call Trace: [81375.326912] [fffffff8010bf539] ? pick_next_task_fair +0x129/0x1d0 [81375.326940] [fffffff8163b9e9] __schedule+0x12a/0x900 [81375.326961] [fffffff8163b9e9] schedule_preempt_disabled +0x29/0x70 [81375.326987] [fffffff810d6244] cpu_startup_entry+0x184/0x290 [81375.327011] [fffffff810475fa] start_secondary +0x1ba/0x230 [81375.327032] Code: e5 48 89 c0 75 07 eb 19 66 90 48 89 d0 48 8b 50 10 48 85 d2 75 f4 48 8b 50 08 48 85 d2 75 eb 5d c3 31 c0 5d c3 0f 1f 44 00 00 55 &lt;48&gt; 8b 17 48 89 e5 48 39 d7 74 3b 48 8b 47 08 48 85 c0 75 0e eb [81375.327157] RIP [fffffff812f94b1] rb_next+0x1/0x50 [81375.327179] RSP [fffffff8140ed13e10] [81375.327192] CR2: 0000000000000010</td>
</tr>
</tbody>
</table>

**Workaround:** Upgrade to the latest-available kernel for your Red Hat or CentOS release to avoid the above system panic.
<table>
<thead>
<tr>
<th>Issue</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>149789783</td>
<td>Resource Groups</td>
<td>Significant Pivotal Greenplum performance degradation has been observed when enabling resource group-based workload management on Red Hat 6.x, CentOS 6.x, and SuSE 11 systems. This issue is caused by a Linux cgroup kernel bug. This kernel bug has been fixed in CentOS 7.x and Red Hat 7.x systems. When resource groups are enabled on systems with an affected kernel, there can be a delay of 1 second or longer when starting a transaction or a query. The delay is caused by a Linux cgroup kernel bug where a synchronization mechanism called <code>synchronize_sched</code> is abused when a process is attached to a cgroup. See <a href="http://www.spinics.net/lists/cgroups/msg05708.html">http://www.spinics.net/lists/cgroups/msg05708.html</a> and <a href="https://lkml.org/lkml/2013/1/14/97">https://lkml.org/lkml/2013/1/14/97</a> for more information. The issue causes single attachment operations to take longer and also causes all concurrent attachments to be executed in sequence. For example, one process attachment could take about 0.01 second. When concurrently attaching 100 processes, the fastest process attachment takes 0.01 second and the slowest takes about 1 second. Pivotal Greenplum performs process attachments when a transaction or queries are started. So the performance degradation is dependent on concurrent started transactions or queries, and not related to concurrent running queries. Also Pivotal Greenplum has optimizations to bypass the rewriting when a QE is reused by multiple queries in the same session. <strong>Workaround:</strong> This bug does not affect CentOS 7.x and Red Hat 7.x systems. If you use Red Hat 6 and the performance with resource groups is acceptable for your use case, upgrade your kernel to version 2.6.32-696 or higher to benefit from other fixes to the cgroups implementation. SuSE 11 does not have a kernel version that resolves this issue; resource groups are still considered to be an experimental feature on this platform. Resource groups are not supported on SuSE 11 for production use.</td>
</tr>
<tr>
<td>Issue</td>
<td>Category</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| 150906510  | Backup and Restore     | Greenplum Database 4.3.15.0 and later backups contain the following line in the backup files: SET `gp_strict_xml_parse = false;`  

However, Greenplum Database 5.0.0 does not have a parameter named `gp_strict_xml_parse`. When you restore the 4.3 backup set to the 5.0.0 cluster, you may see the warning:  

```
[WARNING]:-gpdbrestore finished but ERRORS were found, please check the restore report file for details
```

Also, the report file may contain the error:  

```
ERROR: unrecognized configuration parameter "gp_strict_xml_parse"
```

These warnings and errors do not affect the restoration procedure, and can be ignored.
Update for gp_toolkit.gp_bloat_diag Issue

In Greenplum Database 5.3.0 or an earlier 5.x release, Greenplum Database returned an integer out of range error in some cases when performing a query against the gp_toolkit.gp_bloat_diag view. The issue was resolved in Greenplum Database 5.4.0 (resolved issue 26518).

When updating Greenplum Database, the gp_toolkit.gp_bloat_diag function and view must be updated in databases created with a Greenplum Database 5.3.0 or an earlier 5.x release. This issue has been fixed in databases created with Greenplum Database 5.4.0 and later.

To check whether the gp_toolkit.gp_bloat_diag function and view in a database requires an update, run the psql command \df to display information about the gp_toolkit.gp_bloat_diag function.

\df gp_toolkit.gp_bloat_diag

If the data type for btdexppages is integer, an update is required. If the data type is numeric an update is not required. In this example, the btdexppages data type is integer and requires an update.

List of functions

List of functions

<table>
<thead>
<tr>
<th>Schema</th>
<th>gp_toolkit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>gp_bloat_diag</td>
</tr>
<tr>
<td>Result data type</td>
<td>record</td>
</tr>
<tr>
<td>Argument data types</td>
<td>btdrelpages integer, btdexppages integer, aotable boolean, OUT bltidx integer, OUT bltdiag text</td>
</tr>
<tr>
<td>Type</td>
<td>normal</td>
</tr>
</tbody>
</table>

Run the following script to update the function and view to fix the issue on each database that was created with Greenplum Database 5.3.0 or an earlier 5.x release.

As the gpadmin user, follow these steps.

1. Copy the script into a text file on the Greenplum Database master.
2. Run the script on each database that requires the update.

   This example updates gp_toolkit.gp_bloat_diag function and view in the database mytest and assumes that the script is in the update_bloat_diag.sql in the gpadmin home directory.

   psql -f /home/gpadmin/update_bloat_diag.sql -d mytest

Run the script during a low activity period. Running the script during a high activity period does not affect database functionality but might affect performance.

Script to Update gp_toolkit.gp_bloat_diag Function and View

BEGIN;
CREATE OR REPLACE FUNCTION gp_toolkit.gp_bloat_diag(btdrelpages int,
           btdexppages numeric, aotable bool,
           OUT bltidx int, OUT bltdiag text)
AS $$
SELECT bloatidx,
    CASE
        WHEN bloatidx = 0
            THEN 'no bloat detected':text
        WHEN bloatidx = 1
            THEN 'bloat detected':text
    END
$$
END;
THEN 'moderate amount of bloat suspected'::text
WHEN bloatidx = 2
THEN 'significant amount of bloat suspected'::text
WHEN bloatidx = -1
THEN 'diagnosis inconclusive or no bloat suspected'::text
END AS bloatdiag
FROM
(
  SELECT
    CASE
      WHEN $3 = 't' THEN 0
      WHEN $1 < 10 AND $2 = 0 THEN -1
      WHEN $2 = 0 THEN 2
      WHEN $1 < $2 THEN 0
      WHEN ($1/$2)::numeric > 10 THEN 2
      WHEN ($1/$2)::numeric > 3 THEN 1
      ELSE -1
    END AS bloatidx
  ) AS bloatmapping
$$
LANGUAGE SQL READS SQL DATA;

GRANT EXECUTE ON FUNCTION gp_toolkit.gp_bloat_diag(int, numeric, bool, OUT int, OUT text) TO public;

CREATE OR REPLACE VIEW gp_toolkit.gp_bloat_diag AS
SELECT
  btdrelid AS bdirelid,
  fnnspname AS bdinspname,
  fnrelname AS bdirelname,
  btdrelpages AS bdirelpages,
  btdexppages AS bdiexppages,
  bltdiag(bd) AS bdidiag
FROM
(
  SELECT
    fn.*, beg.*,
    gp_toolkit.gp_bloat_diag(btdrelpages::int, btdexppages::numeric, iao.iaotype::bool) AS bd
  FROM
    gp_toolkit.gp_bloat_expected_pages beg,
    pg_catalog.pg_class pgc,
    gp_toolkit.__gp_fullname fn,
    gp_toolkit.__gp_is_append_only iao
  WHERE beg.btdrelid = pgc.oid
  AND pgc.oid = fn.fnoid
  AND iao.iaoooid = pgc.oid
) as bloatsummary
WHERE bltdiag(bd) > 0;

GRANT SELECT ON TABLE gp_toolkit.gp_bloat_diag TO public;
COMMIT;
Chapter 3

Pivotal Greenplum 5.8.0 Release Notes

Updated: June, 2018

- Welcome to Pivotal Greenplum 5.8.0
- New Features
- Changed Feature
- Experimental Features
- Differences Compared to Open Source Greenplum Database
- Supported Platforms
- Pivotal Greenplum Tools and Extensions Compatibility
- Hadoop Distribution Compatibility
- Upgrading to Greenplum Database 5.8.0
- Migrating Data to Pivotal Greenplum 5.x
- Pivotal Greenplum on DCA Systems
- Resolved Issues
- Known Issues and Limitations
- Update for gp_toolkit.gp_bloat_diag Issue
Welcome to Pivotal Greenplum 5.8.0

Pivotal Greenplum Database is a massively parallel processing (MPP) database server that supports next generation data warehousing and large-scale analytics processing. By automatically partitioning data and running parallel queries, it allows a cluster of servers to operate as a single database supercomputer performing tens or hundreds times faster than a traditional database. It supports SQL, MapReduce parallel processing, and data volumes ranging from hundreds of gigabytes, to hundreds of terabytes.

This document contains pertinent release information about Pivotal Greenplum Database 5.8.0. For previous versions of the release notes for Greenplum Database, go to Pivotal Greenplum Database Documentation. For information about Greenplum Database end of life, see Pivotal Greenplum Database end of life policy.

Pivotal Greenplum 5.x software is available for download from the Pivotal Greenplum page on Pivotal Network.

Pivotal Greenplum 5.x is based on the open source Greenplum Database project code.

**Important:** Pivotal Support does not provide support for open source versions of Greenplum Database. Only Pivotal Greenplum Database is supported by Pivotal Support.

Pivotal Greenplum 5.8.0 is a minor release that adds and changes several features and resolves some issues.
New Features

Greenplum Database 5.8.0 includes these new features and enhancements.

- **GPORCA Optimization Improvement**
- **Limit Slices Generated by a Query**
- **Control gpfidsts SSL certificate authentication**
- **Resource Group Global Shared Memory**
- **PL/Container Resource Management using Resource Groups**

### GPORCA Optimization Improvement

GPORCA optimization performance has been improved for queries that contain a predicate that performs a comparison with an constant array with a large number of elements where the array elements are sets of constants. For example, the `IN` list of this predicate contains a list of two elements that are sets of three constants.

```sql
... WHERE (c1, c2, c3) IN ((100,'a','c'), (200,'b','d'))
```

In previous releases, GPORCA performance was poor and consumed a significant amount memory attempting to optimize the specified type of query.

Also, based on analysis of query optimization performance, the default value for the Greenplum Database server configuration parameter `optimizer_array_expansion_threshold` has been changed to 100. The change improves optimization performance. See Changed Feature.

### Limit Slices Generated by a Query

The Greenplum Database server configuration parameter `gp_max_slices` specifies the maximum number of slices (portions of a query plan that are executed on segment instances) that can be generated by a query. If the query generates more than the specified number of slices, Greenplum Database returns an error and does not execute the query. The default value is 0, no maximum value.

Executing a query that generates a large number of slices might affect Greenplum Database performance. For example, a query that contains `UNION` or `UNION ALL` operators over several complex views can generate a large number of slices. You can run `EXPLAIN ANALYZE` on the query to view slice statistics for the query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - INT_MAX</td>
<td>0</td>
<td>master&lt;br&gt;session&lt;br&gt;reload</td>
</tr>
</tbody>
</table>

### Resource Group Global Shared Memory

Greenplum Database now allocates unreserved resource group memory to a global shared memory pool. With this feature, Greenplum Database allocates memory from the resource group global shared pool to individual queries on a first-come first-served basis.
PL/Container Resource Management using Resource Groups

You can now use Greenplum Database resource groups to manage memory and CPU resources for external components such as PL/Container. With PL/Container version 1.2 and Greenplum Database version 5.8.0, you can limit and manage the CPU and memory resources of running PL/Container instances. For more information about managing PL/Container resources, see About PL/Container Resource Management. To configure PL/Container to use resource groups, refer to Configuring Resource Groups for PL/Container.

Note: PL/Container version 1.2 can utilize the new resource group capabilities introduced in Greenplum Database 5.8.0. If you downgrade to a Greenplum Database system that uses PL/Container 1.1 or earlier, you must use plcontainer runtime-edit to remove any resource_group_id settings from the PL/Container runtime configuration file. See Upgrading from PL/Container 1.1.

Control gpfdist SSL certificate authentication

When a Greenplum Database external table is defined with the gpfdist protocol to use SSL security, the Greenplum Database server configuration parameter verify_gpfdists_cert controls whether SSL certificate authentication is enabled. The default is true, SSL authentication is enabled when Greenplum Database communicates with the gpfdist utility to either read data from or write data to an external data source.

The value false disables SSL certificate authentication. These SSL exceptions are ignored:

- The self-signed SSL certificate that is used by gpfdist is not trusted by Greenplum Database.
- The host name contained in the SSL certificate does not match the host name that is running gpfdist.

You can set the value to false to disable authentication when testing the communication between the Greenplum Database external table and the gpfdist utility that is serving the external data.

Warning: Disabling SSL certificate authentication exposes a security risk by not validating the gpfdists SSL certificate.

For information about the gpfdist protocol, see gpfdists:// Protocol in the Greenplum Database Administrator Guide. For information about running the gpfdist utility, see gpfdist in the Greenplum Database Utility Guide.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>true</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>
Changed Feature

Greenplum Database 5.8.0 includes this changed feature.

- For the Greenplum Database server configuration parameter `optimizer_array_expansion_threshold`, the default value has changed to 100. When GPORCA optimizes a query, this parameter limits the optimization process based on the number of constants in the array.

  In previous releases, the default value was 25.

- MADlib 1.14 is compatible with Greenplum Database 5.8.0.
Experimental Features

Because Pivotal Greenplum Database is based on the open source Greenplum Database project code, it includes several experimental features to allow interested developers to experiment with their use on development systems. Feedback will help drive development of these features, and they may become supported in future versions of the product.

Warning: Experimental features are not recommended or supported for production deployments. These features may change in or be removed from future versions of the product based on further testing and feedback. Moreover, any features that may be visible in the open source code but that are not described in the product documentation should be considered experimental and unsupported for production use.

Greenplum Database 5.8.0 includes these experimental features:

- The storage plugin for gpbackup and gprestore.
- The S3 storage plugin. You can specify the --plugin-config option to store a backup on an Amazon Web Services S3 location, and restore the data from the S3 location. See S3 Storage Plugin for gpbackup and gprestore in the Pivotal Greenplum Database Documentation.
- Storage plugin framework API. Partners, customers, and OSS developers can develop plugins to use in conjunction with gpbackup and gprestore. See Backup/Restore Storage Plugin API.
- Integration with the Pivotal Greenplum-Informatica Connector (experimental). The connector supports high speed data transfer from an Informatica PowerCenter cluster to a Pivotal Greenplum Database cluster for batch and streaming ETL operations. See the Pivotal Greenplum-Informatica Connector (Experimental) Documentation.
- Recursive WITH Queries (Common Table Expressions). See WITH Queries (Common Table Expressions) in the Pivotal Greenplum Database Documentation.
- Resource groups remain an experimental feature only on the SuSE 11 platform, due to limited cgroups functionality in the kernel.

SuSE 12 resolves the Linux cgroup issues that caused the performance degradation when Greenplum Database resource groups are enabled.
Differences Compared to Open Source Greenplum Database

Pivotal Greenplum 5.x includes all of the functionality in the open source Greenplum Database project and adds:

- Product packaging and installation script.
- Support for QuickLZ compression. QuickLZ compression is not provided in the open source version of Greenplum Database due to licensing restrictions.
- Support for managing Greenplum Database using Pivotal Greenplum Command Center.
- Support for full text search and text analysis using Pivotal GPText.
- Spark Connector and Gemfire Connector
- Data Direct ODBC/JDBC Drivers
Supported Platforms

Pivotal Greenplum 5.8.0 runs on the following platforms:

- Red Hat Enterprise Linux 64-bit 7.x (See the following Note)
- Red Hat Enterprise Linux 64-bit 6.x
- SuSE Linux Enterprise Server 64-bit 12 SP2 and SP3 with kernel version greater than 4.4.73-5. (See the following Note)
- SuSE Linux Enterprise Server 64-bit 11 SP4 (See the following Note)
- CentOS 64-bit 7.x
- CentOS 64-bit 6.x

Note: For the supported Linux operating systems, Pivotal Greenplum Database is supported on system hosts using either AMD or Intel CPUs based on the x86-64 architecture. Pivotal recommends using a homogeneous set of hardware (system hosts) in a Greenplum Database system.

Important: Significant Greenplum Database performance degradation has been observed when enabling resource group-based workload management on Red Hat 6.x, CentOS 6.x, and SuSE 11 systems. This issue is caused by a Linux cgroup kernel bug. This kernel bug has been fixed in CentOS 7.x and Red Hat 7.x systems.

If you use Red Hat 6 and the performance with resource groups is acceptable for your use case, upgrade your kernel to version 2.6.32-696 or higher to benefit from other fixes to the cgroups implementation.

SuSE 11 does not have a kernel version that resolves this issue; resource groups are still considered to be an experimental feature on this platform. Resource groups are not supported on SuSE 11 for production use. See known issue 149789783.

Pivotal Greenplum on SuSE 12 supports resource groups for production use. SuSE 12 resolves the Linux cgroup kernel issues that caused the performance degradation when Greenplum Database resource groups are enabled.

Note: For Greenplum Database that is installed on Red Hat Enterprise Linux 7.x or CentOS 7.x prior to 7.3, an operating system issue might cause Greenplum Database that is running large workloads to hang in the workload. The Greenplum Database issue is caused by Linux kernel bugs. RHEL 7.3 and CentOS 7.3 resolves the issue.

Note: Greenplum Database on SuSE Linux Enterprise systems does not support these features.
- The PL/Perl procedural language
- The gpmapreduce tool
- The PL/Container language extension
- The Greenplum Platform Extension Framework (PXF)

Greenplum Database support on Dell EMC DCA.

Note: This release of Pivotal Greenplum Database is not certified for use on Dell EMC DCA systems, because of an incompatibility in configuring timezone information. This issue is being tracked in issue 29368. DCA customers should continue to use Greenplum Database version 5.4.1 or earlier until this issue is resolved in later releases of the product.

Pivotal Greenplum 5.8.0 supports these Java versions:

- 8.xxx
- 7.xxx
Greenplum Database 5.8.0 software that runs on Linux systems uses OpenSSL 1.0.2l (with FIPS 2.0.16), cURL 7.54, OpenLDAP 2.4.44, and Python 2.7.12.

Greenplum Database client software that runs on Windows and AIX systems uses OpenSSL 0.9.8zg.

The Greenplum Database s3 external table protocol supports these data sources:

- Amazon Simple Storage Service (Amazon S3)
- Dell EMC Elastic Cloud Storage (ECS), an Amazon S3 compatible service

Pivotal Greenplum 5.8.0 supports Data Domain Boost on Red Hat Enterprise Linux.

This table lists the versions of Data Domain Boost SDK and DDOS supported by Pivotal Greenplum 5.x.

Table 6: Data Domain Boost Compatibility

<table>
<thead>
<tr>
<th>Pivotal Greenplum</th>
<th>Data Domain Boost(^2)</th>
<th>DDOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.8.0</td>
<td>3.3</td>
<td>6.1 (all versions)</td>
</tr>
<tr>
<td>5.7.0</td>
<td>3.0.0.3(^1)</td>
<td>6.0 (all versions)</td>
</tr>
<tr>
<td>5.4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** In addition to the DDOS versions listed in the previous table, Pivotal Greenplum 5.0.0 and later supports all minor patch releases (fourth digit releases) later than the certified version.

\(^1\)Support for Data Domain Boost 3.0.0.3 is deprecated. The DELL EMC end of Primary Support date is December 31, 2017.

\(^2\)The Greenplum Database utilities gpbackup and gprestore support Data Domain DD Boost File System Plug-In (BoostFS) v1.1 with DDOS 6.0 or greater. Data Domain Boost is not supported.

**Note:** Pivotal Greenplum 5.8.0 does not support the ODBC driver for Cognos Analytics V11.

Connecting to IBM Cognos software with an ODBC driver is not supported. Greenplum Database supports connecting to IBM Cognos software with the DataDirect JDBC driver for Pivotal Greenplum. This driver is available as a download from Pivotal Network.

**Veritas NetBackup**

Pivotal Greenplum 5.8.0 supports backup with Veritas NetBackup version 7.7.3. See Backing Up Databases with Veritas NetBackup.

**Supported Platform Notes**

The following notes describe platform support for Pivotal Greenplum. Please send any questions or comments to Pivotal Support at https://support.pivotal.io.

- The only file system supported for running Greenplum Database is the XFS file system. All other file systems are explicitly not supported by Pivotal.
- Greenplum Database is supported on all 1U and 2U commodity servers with local storage. Special purpose hardware that is not commodity may be supported at the full discretion of Pivotal Product Management based on the general similarity of the hardware to commodity servers.
- Greenplum Database is supported on network or shared storage if the shared storage is presented as a block device to the servers running Greenplum Database and the XFS file system is mounted.
on the block device. Network file systems are not supported. When using network or shared storage, Greenplum Database mirroring must be used in the same way as with local storage, and no modifications may be made to the mirroring scheme or the recovery scheme of the segments. Other features of the shared storage such as de-duplication and/or replication are not directly supported by Pivotal Greenplum Database, but may be used with support of the storage vendor as long as they do not interfere with the expected operation of Greenplum Database at the discretion of Pivotal.

- Greenplum Database is supported when running on virtualized systems, as long as the storage is presented as block devices and the XFS file system is mounted for the storage of the segment directories.
- A minimum of 10-gigabit network is required for a system configuration to be supported by Pivotal.
- Greenplum Database is supported on Amazon Web Services (AWS) servers using either Amazon instance store (Amazon uses the volume names ephemeral[0-20]) or Amazon Elastic Block Store (Amazon EBS) storage. If using Amazon EBS storage the storage should be RAID of Amazon EBS volumes and mounted with the XFS file system for it to be a supported configuration.
- For Red Hat Enterprise Linux 7.2 or CentOS 7.2, the default systemd setting RemoveIPC=yes removes IPC connections when non-system users logout. This causes the Greenplum Database utility gpinitsystem to fail with semaphore errors. To avoid this issue, see "Setting the Greenplum Recommended OS Parameters" in the Greenplum Database Installation Guide.
Pivotal Greenplum Tools and Extensions Compatibility

- **Client Tools**
- **Extensions**
- **Pivotal Greenplum Data Connectors**
- **Pivotal GPText Compatibility**
- **Pivotal Greenplum Command Center**

**Client Tools**

Greenplum releases a number of client tool packages on various platforms that can be used to connect to Greenplum Database and the Greenplum Command Center management tool. The following table describes the compatibility of these packages with this Greenplum Database release.

Tool packages are available from *Pivotal Network*.

**Table 7: Pivotal Greenplum 5.8.0 Tools Compatibility**

<table>
<thead>
<tr>
<th>Tool</th>
<th>Description of Contents</th>
<th>Tool Version(s)</th>
<th>Server Version(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pivotal Greenplum Clients</td>
<td>Greenplum Database Command-Line Interface (psql)</td>
<td>5.8</td>
<td>5.x</td>
</tr>
<tr>
<td>Pivotal Greenplum Loaders</td>
<td>Greenplum Database Parallel Data Loading Tools (gpfdist, gpload)</td>
<td>5.8</td>
<td>5.x</td>
</tr>
<tr>
<td>Pivotal Greenplum Command Center</td>
<td>Greenplum Database management tool</td>
<td>4.0.0, 3.3.2, 3.2.2</td>
<td>5.7.0 and later, 5.0.0 and later, 5.0.0 - 5.2.x</td>
</tr>
<tr>
<td>Pivotal Greenplum Workload Manager(^1)</td>
<td>Greenplum Database query monitoring and management tool</td>
<td>1.8.0</td>
<td>5.0.0</td>
</tr>
</tbody>
</table>

The Greenplum Database Client Tools and Load Tools are supported on the following platforms:

- AIX 7.2 (64-bit) (Client and Load Tools only)\(^2\)
- Red Hat Enterprise Linux x86_64 6.x (RHEL 6)
- SuSE Linux Enterprise Server x86_64 SLES 11 SP4, or SLES 12 SP2/SP3
- Windows 10 (32-bit and 64-bit)
- Windows 8 (32-bit and 64-bit)
- Windows Server 2012 (32-bit and 64-bit)
- Windows Server 2012 R2 (32-bit and 64-bit)
- Windows Server 2008 R2 (32-bit and 64-bit)

**Note:** For Pivotal Greenplum Command Center 4.0.0 and later, workload management is an integrated Command Center feature rather than the separate tool Pivotal Greenplum Workload Manager.

\(^1\) For Greenplum Database 5.4.1 and earlier 5.x releases, download the AIX Client and Load Tools package either from the Greenplum Database 5.8.0 file collection or the Greenplum Database 5.0.0 file collection on *Pivotal Network*.
Table 8: Pivotal Greenplum 5.8.0 Extensions Compatibility

<table>
<thead>
<tr>
<th>Pivotal Greenplum Extension</th>
<th>Versions</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADlib machine learning for Greenplum Database 5.x</td>
<td>MADlib 1.14</td>
</tr>
<tr>
<td>PL/Java for Greenplum Database 5.x</td>
<td>PL/Java 1.4.2, 1.4.0</td>
</tr>
<tr>
<td>PL/R for Greenplum Database 5.6.x</td>
<td>2.3.2</td>
</tr>
<tr>
<td>PostGIS Spatial and Geographic Objects for Greenplum Database 5.x</td>
<td>2.1.5+pivotal.1</td>
</tr>
<tr>
<td>Python Data Science Module Package for Greenplum Database 5.x</td>
<td>1.0.0, 1.1.0</td>
</tr>
<tr>
<td>R Data Science Library Package for Greenplum Database 5.x</td>
<td>1.0.0</td>
</tr>
<tr>
<td>PL/Container for Greenplum Database 5.x</td>
<td>1.1, 1.2</td>
</tr>
</tbody>
</table>

**Note:**

1. For information about MADlib support and upgrade information, see the MADlib FAQ. For information on installing the MADlib extension in Greenplum Database, see Greenplum MADlib Extension for Analytics in the Greenplum Database Reference Guide.

2. Before upgrading to MADlib 1.13, you must remove some leftover knn functions. For information on upgrading MADlib, see Greenplum MADlib Extension for Analytics in the Greenplum Database Reference Guide.

3. For information about the Python package, including the modules provided, see the Python Data Science Module Package in the Greenplum Database Documentation.

4. For information about the R package, including the libraries provided, see the R Data Science Library Package in the Greenplum Database Documentation.

5. The PostGIS extension package version 2.1.5+pivotal.1 is compatible only with Greenplum Database 5.5.0 and later.

6. To upgrade from PL/Container 1.0 to PL/Container 1.1 and later, you must drop the PL/Container 1.0 language before registering the new version of PL/Container. For information on upgrading the PL/Container extension in Greenplum Database, see PL/Container Language Extension in the Greenplum Database Reference Guide.

7. PL/Container version 1.2 can utilize the new resource group capabilities introduced in Greenplum Database 5.8.0. If you downgrade to a Greenplum Database system that uses PL/Container 1.1 or earlier, you must use plcontainer runtime-edit to remove any resource_group_id settings from the PL/Container runtime configuration file. See Upgrading from PL/Container 1.1.

These Greenplum Database extensions are installed with Pivotal Greenplum Database

- Fuzzy String Match Extension
- PL/Python Extension
- pgcrypto Extension
**Pivotal Greenplum Data Connectors**

- Greenplum Platform Extension Framework (PXF) - PXF, integrated with Greenplum Database 5.8.0, provides access to HDFS, Hive, and HBase external data stores. Refer to *Accessing External Data with PXF* in the *Greenplum Database Administrator Guide* for PXF configuration and usage information.
  
  **Note:** PXF is available only for supported Red Hat and CentOS platforms. PXF is not available for supported SuSE platforms.

- Greenplum-Spark Connector - The Pivotal Greenplum-Spark Connector supports high speed, parallel data transfer from Greenplum Database to an Apache Spark cluster. The Greenplum-Spark Connector is available as a separate download from *Pivotal Network*. Refer to the *Greenplum-Spark Connector documentation* for compatibility and usage information.

- Gemfire-Greenplum Connector - The Pivotal Gemfire-Greenplum Connector supports the transfer of data between a GemFire region and a Greenplum Database cluster. The Gemfire-Greenplum Connector is available as a separate download from *Pivotal Network*. Refer to the *Gemfire-Greenplum Connector documentation* for compatibility and usage information.

**Pivotal GPTText Compatibility**

Pivotal Greenplum Database 5.8.0 is compatible with Pivotal GPTText version 2.1.3 and later.

**Pivotal Greenplum Command Center**

See the *Greenplum Command Center documentation* for GPCC and Greenplum Workload Manager compatibility information, see the Pivotal Greenplum Command Center 3.x and 2.x *Release Notes*.

**Note:** For Pivotal Greenplum Command Center 4.0.0 and later, workload management is an integrated Command Center feature rather than the separate tool Pivotal Greenplum Workload Manager.
Hadoop Distribution Compatibility

Greenplum Database provides access to HDFS with gphdfs and the Greenplum Platform Extension Framework (PXF).

PXF Hadoop Distribution Compatibility

PXF supports Cloudera, Hortonworks Data Platform, and generic Apache Hadoop distributions.

If you plan to access JSON format data stored in a Cloudera Hadoop cluster, PXF requires a Cloudera version 5.8 or later Hadoop distribution.

gphdfs Hadoop Distribution Compatibility

The supported Hadoop distributions for gphdfs are listed below:

Table 9: Supported gphdfs Hadoop Distributions

<table>
<thead>
<tr>
<th>Hadoop Distribution</th>
<th>Version</th>
<th>gp_hadoop_target_version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloudera</td>
<td>CDH 5.x</td>
<td>cdh</td>
</tr>
<tr>
<td>Hortonworks Data Platform</td>
<td>HDP 2.x</td>
<td>hdp</td>
</tr>
<tr>
<td>MapR</td>
<td>MapR 4.x, MapR 5.x</td>
<td>mpr</td>
</tr>
<tr>
<td>Apache Hadoop</td>
<td>2.x</td>
<td>hadoop</td>
</tr>
</tbody>
</table>

Note: MapR requires the MapR client.
Upgrading to Greenplum Database 5.8.0

The upgrade path supported for this release is Greenplum Database 5.x to Greenplum Database 5.8.0. Upgrading a Greenplum Database 4.3.x release to Pivotal Greenplum 5.x is not supported. See Migrating Data to Pivotal Greenplum 5.x.

Prerequisites

Before starting the upgrade process, Pivotal recommends performing the following checks.

- Verify the health of the Greenplum Database host hardware, and that you verify that the hosts meet the requirements for running Greenplum Database. The Greenplum Database gpcheckperf utility can assist you in confirming the host requirements.

  Note: If you need to run the gpcheckcat utility, Pivotal recommends running it a few weeks before the upgrade and that you run gpcheckcat during a maintenance period. If necessary, you can resolve any issues found by the utility before the scheduled upgrade.

  The utility is in $GPHOME/bin. Pivotal recommends that Greenplum Database be in restricted mode when you run gpcheckcat utility. See the Greenplum Database Utility Guide for information about the gpcheckcat utility.

  If gpcheckcat reports catalog inconsistencies, you can run gpcheckcat with the -g option to generate SQL scripts to fix the inconsistencies.

  After you run the SQL scripts, run gpcheckcat again. You might need to repeat the process of running gpcheckcat and creating SQL scripts to ensure that there are no inconsistencies. Pivotal recommends that the SQL scripts generated by gpcheckcat be run on a quiescent system. The utility might report false alerts if there is activity on the system.

  Important: If the gpcheckcat utility reports errors, but does not generate a SQL script to fix the errors, contact Pivotal support. Information for contacting Pivotal Support is at https://support.pivotal.io.

- During the migration process from Greenplum Database 5.0.0, a backup is made of some files and directories in $MASTER_DATA_DIRECTORY. Pivotal recommends that files and directories that are not used by Greenplum Database be backed up, if necessary, and removed from the $MASTER_DATA_DIRECTORY before migration. For information about the Greenplum Database migration utilities, see the Greenplum Database Documentation.

For information about supported versions of Greenplum Database extensions, see Pivotal Greenplum Tools and Extensions Compatibility.

If you are utilizing Data Domain Boost, you have to re-enter your DD Boost credentials after upgrading to Greenplum Database 5.8.0 as follows:

```
gpcrondump --ddboost-host ddboost_hostname --ddboost-user ddboost_user --ddboost-backupdir backup_directory
```

Note: If you do not reenter your login credentials after an upgrade, your backup will never start because the Greenplum Database cannot connect to the Data Domain system. You will receive an error advising you to check your login credentials.

If you have configured the Greenplum Platform Extension Framework (PXF) in your previous Greenplum Database installation, you must stop the PXF service and back up PXF configuration files before upgrading to a new version of Greenplum Database. Refer to PXF Pre-Upgrade Actions for instructions.

If you do not plan to use PXF, or you have not yet configured PXF, no action is necessary.
# Upgrading from 5.x to 5.8.0

An upgrade from 5.x to 5.8.0 involves stopping Greenplum Database, updating the Greenplum Database software binaries, upgrading and restarting Greenplum Database. If you are using Greenplum Database extension packages there are additional requirements. See Prerequisites in the previous section.

**Note:** If you have databases that were created with Greenplum Database 5.3.0 or an earlier 5.x release, upgrade the `gp_bloat_diag` function and view in the `gp_toolkit` schema. For information about the issue and how check a database for the issue, see Update for `gp_toolkit.gp_bloat_diag` Issue.

**Note:** If the Greenplum Command Center database `gpperfmon` is installed in your Greenplum Database system, the migration process changes the distribution key of the Greenplum Database `log_alert_*` tables to the `logtime` column. The redistribution of the table data might take some time the first time you start Greenplum Database after migration. The change occurs only the first time you start Greenplum Database after a migration.

1. Log in to your Greenplum Database master host as the Greenplum administrative user:

   
   ```
   $ su - gpadmin
   ```

2. Perform a smart shutdown of your current Greenplum Database 5.x system (there can be no active connections to the database). This example uses the `-a` option to disable confirmation prompts:

   ```
   $ gpstop -a
   ```

3. Run the binary installer for 5.8.0 on the Greenplum Database master host.

   When prompted, choose an installation location in the same base directory as your current installation. For example:

   ```
   /usr/local/greenplum-db-5.8.0
   ```

   If you install Greenplum Database with the rpm (as root), the installation directory is `/usr/local/greenplum-db-5.8.0`.

   For the rpm installation, update the permissions for the new installation. For example, run this command as root to change user and group of the installed files to gpadmin.

   ```
   # chown -R gpadmin:gpadmin /usr/local/greenplum*
   ```

4. If your Greenplum Database deployment uses LDAP authentication, manually edit the `/usr/local/greenplum-db/greenplum_path.sh` file to add the line:

   ```
   export LDAPCONF=/etc/openldap/ldap.conf
   ```

5. Edit the environment of the Greenplum Database superuser (gpadmin) and make sure you are sourcing the `greenplum_path.sh` file for the new installation. For example change the following line in `.bashrc` or your chosen profile file:

   ```
   source /usr/local/greenplum-db-5.0.0/greenplum_path.sh
   ```

   to:

   ```
   source /usr/local/greenplum-db-5.8.0/greenplum_path.sh
   ```

   Or if you are sourcing a symbolic link (`/usr/local/greenplum-db`) in your profile files, update the link to point to the newly installed version. For example:

   ```
   $ rm /usr/local/greenplum-db
$ ln -s /usr/local/greenplum-db-5.8.0 /usr/local/greenplum-db

6. Source the environment file you just edited. For example:

$ source ~/.bashrc

7. Run the `gpseginstall` utility to install the 5.8.0 binaries on all the segment hosts specified in the `hostfile`. For example:

$ gpseginstall -f hostfile

8. Use the Greenplum Database `gppkg` utility to install Greenplum Database extensions. If you were previously using any Greenplum Database extensions such as pgcrypto, PL/R, PL/Java, PL/Perl, and PostGIS, download the corresponding packages from Pivotal Network, and install using this utility. See the Greenplum Database Documentation for `gppkg` usage details.

9. After all segment hosts have been upgraded, you can log in as the `gpadmin` user and restart your Greenplum Database system:

# su - gpadmin
$ gpstart

10. If you are utilizing Data Domain Boost, you have to re-enter your DD Boost credentials after upgrading from Greenplum Database to 5.8.0 as follows:

   gpcrondump --ddboost-host ddboost_hostname --ddboost-user ddboost_user --ddboost-backupdir backup_directory

   **Note:** If you do not reenter your login credentials after an upgrade, your backup will never start because the Greenplum Database cannot connect to the Data Domain system. You will receive an error advising you to check your login credentials.

11. If you configured PXF in your previous Greenplum Database installation, you must re-initialize the PXF service after you upgrade Greenplum Database. Refer to Upgrading PXF for instructions.

**Troubleshooting a Failed Upgrade**

If you experience issues during the migration process and have active entitlements for Greenplum Database that were purchased through Pivotal, contact Pivotal Support. Information for contacting Pivotal Support is at https://support.pivotal.io.

Be prepared to provide the following information:

- A completed Upgrade Procedure.
- Log output from `gpcheckcat` (located in `/gpAdminLogs`)
Migrating Data to Pivotal Greenplum 5.x

Upgrading a Pivotal Greenplum Database 4.x system directly to Pivotal Greenplum Database 5.x is not supported.

You can migrate existing data to Greenplum Database 5.x using standard backup and restore procedures (gpcrondump and gpdbrestore) or by using gptransfer if both clusters will run side-by-side.

Follow these general guidelines for migrating data:

• Make sure that you have a complete backup of all data in the Greenplum Database 4.3.x cluster, and that you can successfully restore the Greenplum Database 4.3.x cluster if necessary.
• You must install and initialize a new Greenplum Database 5.x cluster using the version 5.x gpinitsystem utility.

  Note: Unless you modify file locations manually, gpdbrestore only supports restoring data to a cluster that has an identical number of hosts and an identical number of segments per host, with each segment having the same content_id as the segment in the original cluster. If you initialize the Greenplum Database 5.x cluster using a configuration that is different from the version 4.3 cluster, then follow the steps outlined in Restoring to a Different Greenplum System Configuration to manually update the file locations.

• If you intend to install Greenplum Database 5.x on the same hardware as your 4.3.x system, you will need enough disk space to accommodate over 5 times the original data set (2 full copies of the primary and mirror data sets, plus the original backup data in ASCII format). Keep in mind that the ASCII backup data will require more disk space than the original data, which may be stored in compressed binary format. Offline backup solutions such as Dell EMC Data Domain or Veritas NetBackup can reduce the required disk space on each host.
• Use the version 5.x gpdbrestore utility to load the 4.3.x backup data into the new cluster.
• If the Greenplum Database 5.x cluster resides on separate hardware from the 4.3.x cluster, you can optionally use the version 5.x gptransfer utility to migrate the 4.3.x data. You must initiate the gptransfer operation from the version 5.x cluster, pulling the older data into the newer system.

On a Greenplum Database system with FIPS enabled, validating table data with MD5 (specifying the option --validate=md5) is not available. Use the option sha256 to validate table data.

Validating table data with SHA-256 (specifying the option --validate=sha256) requires the Greenplum Database pgcrypto extension. The extension is included with Pivotal Greenplum 5.x. The extension package must be installed on supported Pivotal Greenplum 4.3.x systems. Support for pgcrypto functions in a Greenplum 4.3.x database is not required.

• Greenplum Database 5.x removes automatic implicit casts between the text type and other data types. When you migrate from Greenplum Database version 4.3.x to version 5.x, this change in behavior may impact existing applications and queries. Refer to About Implicit Text Casting in Greenplum Database in the Greenplum Database Installation Guide for information, including a discussion about supported and unsupported workarounds.
• After migrating data you may need to modify SQL scripts, administration scripts, and user-defined functions as necessary to account for changes in Greenplum Database version 5.x. Look for Upgrade Action Required entries in the Pivotal Greenplum 5.0.0 Release Notes for features that may necessitate post-migration tasks.
Pivotal Greenplum on DCA Systems

**Note:** This release of Pivotal Greenplum Database is not certified for use on Dell EMC DCA systems, because of an incompatibility in configuring timezone information. This issue is being tracked in [issue 29368](#). DCA customers should continue to use Greenplum Database version 5.4.1 or earlier until this issue is resolved in later releases of the product.
Resolved Issues

The listed issues that are resolved in Pivotal Greenplum Database 5.8.0.

For issues resolved in prior 5.x releases, refer to the corresponding release notes. Release notes are available from the Pivotal Greenplum page on Pivotal Network or on the Pivotal Greenplum Database documentation site at Release Notes.

29320 - catalog and metadata

The Greenplum Database timezone was not set correctly. The timezone was set to GMT. Greenplum Database did not use the timezone value in the postgresql.conf, or the operating system timezone if the value is not set in postgresql.conf.

This issue has been resolved. Now the timezone is set correctly.

29319 - Query Planner

For queries that contain a percentile function and are against a partitioned table, the Greenplum Database legacy planner generated a PANIC. The legacy planner did not handle memory properly while generating a multistage aggregate plan and caused a PANIC.

The issue has been resolved. Legacy planner memory management has been improved for the specified type of query.

29316 - gpbackup/ gprestore

The gprestore utility failed when attempting to restore a database when the PL/Java language is installed in the database. The gpbackup utility did not correctly back up the installed PL/Java language.

This issue has been resolved. Now gpbackup correctly backs up the installed PL/Java language.

29301 - gpbackup/ gprestore

In some cases when restoring tables that own sequences with gprestore utility, the utility returned an error. The gpbackup utility did not correctly backup sequences when backing up a set of tables (including or excluding tables) and some of the tables owned sequences.

This issue has been resolved. Now gpbackup correctly backs up sequences that are owned by tables in the specified situation.

29299 - gpcrondump/ gpdbrestore

The Greenplum Database gpdbrestore utility failed when restoring a backup from a Data Domain Boost system to a system where the Greenplum Database DBID information has changed. For example, a segment instance failed over to a mirror segment between the backup and restore operation.

This issue has been resolved. The gpdbrestore utility has been enhanced to restore backups from Data Domain Boost system in the specified situation.

29286 - Analyze

A Greenplum Database superuser (gpadmin) could not perform an analyze operation on a table that is owned by a Greenplum Database non-supersuer. This issue was cause when the fix for security vulnerability CVE-2009-4136 was not correctly ported to Greenplum Database.

This issue has been resolved. The fix for security vulnerability has been correctly ported to Greenplum Database.

29285 - Query Planner
For queries that contain a **FULL JOIN** and the join included columns of the type `varchar`, the query returned an error. The error occurred because Greenplum Database did handle type conversions properly when generating the query plan. This caused the error during query execution.  
This issue has been fixed. The handling of type conversions has been improved for the specified type of queries.

29283 - **Query Optimizer**  
GPORCA optimization performance has been improved for queries that contain a predicate that performs a comparison with an constant array with a large number of elements where the array elements are sets of constants.  
This issue has been resolved. GPORCA optimization performance has been improved for the specified type of queries. See [New Features](#).

29275 - **Query Optimizer**  
For some multiple join queries, GPORCA incorrectly disabled the minimum cardinality based join ordering whenever the join associativity threshold was met to improve optimization processing. This caused GPORCA to generate a suboptimal plan for some multiple join queries.  
This issue has been resolved. GPORCA has improved join processing for multiple join queries.

29269 - **Internationalization**  
In some cases when the Greenplum Database encoding was different than the client encoding, the client received an invalid byte sequence for encoding when communicating with a database. The incorrect Greenplum Database encoding conversion function was called.  
This issue has been resolved. Now the correct function is called.

29259 - **gprecoverseg**  
There were `gprecoverseg` performance issues when the utility was run to recover large number of Greenplum Database segment instances. Some `gprecoverseg` tests were performed sequentially on segments.  
This issue has been resolved. To improve performance, some tests performed by the utility are now performed on segments instances in parallel.

26529 - **Query Optimizer**  
For GORCA, cardinality for a join that includes a predicate of the form \( f(a) = b \) was estimated using a constant scale factor. This estimate resulted in an overestimation of the cardinality, and in some cases, choosing an inferior query plan.  
This issue has been resolved. GPORCA has been improved to generate cardinality estimate of the specified type of predicate and results in a better plan being selected.

29206 - **Query Planner**  
For some queries that contained window functions and predicates, legacy query planner created a query plan that did not push the predicate below the window function when appropriate. This caused a performance regression.  
This issue has been resolved. The predicate pushdown evaluation performed by query planner has been improved for the specified type of query.

156558904 - **GPPC**  
Applications that used Greenplum Partner Connector (GPPC) library, could not be compiled. GPPC header and make file issues prevented the application from compiling.  
This issue has been resolved. The GPPC header and make files have been updated in the Pivotal Greenplum Database 5.8.0 installation files.
# Known Issues and Limitations

Pivotal Greenplum 5.x has these limitations:

- Upgrading a Greenplum Database 4.3.x release to Pivotal Greenplum 5.x is not supported. See [Migrating Data to Pivotal Greenplum 5.x](#).
- Some features are works-in-progress and are considered to be experimental features. Pivotal does not support using experimental features in a production environment. See [Experimental Features](#).
- Greenplum Database 4.3.x packages are not compatible with Pivotal Greenplum 5.x.

The following table lists key known issues in Pivotal Greenplum 5.x.

## Table 10: Key Known Issues in Pivotal Greenplum 5.x

<table>
<thead>
<tr>
<th>Issue</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>29368</td>
<td>Storage: Catalog and Metadata</td>
<td>In some cases during Greenplum Database system initialization, Greenplum Database generates a PANIC due a timezone issue. The timezone used by Greenplum Database is selected from a set of internally stored PostgreSQL timezones. Greenplum Database selects the timezone by matching a PostgreSQL timezone with the user specified time zone, or the host system time zone. The PANIC is caused when Greenplum Database cannot match the host system timezone with an internal PostgreSQL timezone. The PANIC occurs on Dell EMC DCA systems because the <code>dca_setup</code> utility defaults to using a leap second aware timezone, which fails to match any timezones in Greenplum Database.</td>
</tr>
<tr>
<td>Issue</td>
<td>Category</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>---------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| 26589   | Storage: Catalog and Metadata         | Greenplum Database does not acquire a lock on a schema when creating a table inside the schema. A concurrent DROP of the schema and CREATE TABLE operation will result in a leaked object (an orphan table or orphan relation columns) in the system catalog and possibly on disk. For example, a relation created as  
  ```sql
  CREATE TABLE foobar (col1 int)
  ```
  during a concurrent DROP may leak either the table itself or the `col1` attribute object. These leaked objects do not affect any future queries. The catalog inconsistencies can be detected with the `gpcheckcat` utility.  
  **Workaround:** To block a concurrent DROP from occurring, acquire and hold a ROW SHARE lock on the row of the `pg_namespace` catalog table that corresponds to the schema. For example, this transaction acquires a ROW SHARE lock on the `pg_namespace` catalog table row for the schema `my_schema`.  
  ```sql
  begin; 
  SELECT nspname FROM pg_namespace WHERE nspname = 'my_schema' FOR SHARE; 
  ... 
  end;
  ```
  During the transaction, the lock prevents the schema from being dropped. |
| N/A     | PXF                                   | PXF is available only for supported Red Hat and CentOS platforms. PXF is not available for supported SuSE platforms.                                                                                                                                                                                                                 |
| 151135629 | COPY command                          | When the ON SEGMENT clause is specified, the COPY command does not support specifying a SELECT statement in the COPY TO clause. For example, this command is not supported.  
  ```sql
  COPY (SELECT * FROM testtbl) TO '/tmp/mytst<SEGID>' ON SEGMENT
  ```                                                                                                                                                                                                 |
<table>
<thead>
<tr>
<th>Issue</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3290</td>
<td>JSON</td>
<td>The <code>to_json()</code> function is not implemented as a callable function. Attempting to call the function results in an error. For example:</td>
</tr>
</tbody>
</table>

    tutorial=# select to_json('Fred said "Hi. "':text);
    ERROR: function to_json(text) does not exist
    LINE 1: select to_json('Fred said "Hi."':text);
    ^
    HINT: No function matches the given name and argument types. You might need to add explicit type casts. |

**Workaround:** Greenplum Database invokes `to_json()` internally when casting to the json data type, so perform a cast instead. For example: `SELECT '{"foo":"bar"}'::json;` Greenplum Database also provides the `array_to_json()` and `row_to_json()` functions.
<table>
<thead>
<tr>
<th>Issue</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>148119917</td>
<td>Resource Groups</td>
<td>Testing of the resource groups feature has found that a kernel panic can occur when using the default kernel in RHEL/CentOS system. The problem occurs due to a problem in the kernel cgroups implementation, and results in a kernel panic backtrace similar to:</td>
</tr>
</tbody>
</table>

```
[81375.325947] BUG: unable to handle kernel NULL pointer dereference at 00000000000000010
[81375.325986] IP: [:<ffffffff812f94b1>] rb_next+0x1/0x50 [81375.326014] PGD 0 [81375.326025] 
Oops: 0000 [#1] SMP [81375.326041] Modules 
linked in: veth ipt_MASQUERADE 
nf_nat_masquerade_ipv4 iptable_nat nf_conntrack_ipv4 nf_defrag_ipv4 nf_nat_ipv4 xt_addrtype 
iptable_filter xt_conntrack nf_nat nf_conntrack bridge stp l1c intel_powerclamp coretemp 
intel_rapl dm_thin_pool dmpersistent_data 
dm_bio_prison dm_bufio kvm_intel kvm crc32 pclmul 
ghash_clmulni_intel aesni_intel lrw 
gf128mul glue_helper ablk_helper cryptd iTCO_wdt 
ITCO_vendor_support ses enclosure ipmi_ssis 
pcspkr lpc_ich sg sb_edac mfd_core edac_core 
mei_me ipmi_si mel wmi ipmi_mshandler 
shpchp acpi_power_meter acpi_pad ip_tables xfs 
libcrc32c sd_mod crc_t10dif crc10dif_generic mqag200 syscopyarea sysfillrect 
crct10dif_pclmul 
sysimgblt crct10dif_common crc32c_intel 
drm_kms_helper ixgbe ttm mdio ahci igb libsdb dm ptp 
pps_core libata dca i2c_algo_bit [81375.326369] I2c_core megaraid_sas dm_mirror 
dm_region_hash dm_log dm_mod [81375.326396] 
CPU: 17 PID: 0 Comm: swapper/T? Not tainted 
3.10.0-327.el7.x86_64 #1 [81375.326422] 
Hardware name: Cisco Systems Inc 
2.0.8b.0.080620151546 08/06/2015 [81375.326459] 
task: ffff88140ecec500 ti: ffff88140ed10000 task. 
ti: ffff88140ed10000 [81375.326485] RIP: 
0010: [:<ffffffff812f94b1>] 
[<ffffffff812f94b1>] rb_next+0x1/0x50 [81375.326514] RSP: 
0010: ffff88140ed13e10 EFLAGS: 00010046 
[81375.326534] RAX: 0000000000000000 RCX: 0000000000000000 
[81375.326559] RDX: ffff88282f1d4800 RSI: 
ffff88280bc0f140 RDI: 0000000000000010 
[81375.326584] RBX: ffff88140ed13e58 R8B: 
0000000000000000 R9B: 0000000000000001 
[81375.326609] R10: 0000000000000001 R11: 
0000080000000001 R12: ffff88280be7000 
[81375.326634] R13: 0000000000000001 R14: 
0000000000000001 R15: 0000000000000001b6f979 
[81375.326659] FS: 0000000000000000 (0000) 
GS: ffff88282f1c0000 (0000) 
knlGS: 0000000000000000 [81375.326688] CS: 0010 
DS: 0000 ES: 0000 
```
<table>
<thead>
<tr>
<th>Issue</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
</table>

**Workaround:** Upgrade to the latest-available kernel for your Red Hat or CentOS release to avoid the above system panic.
<table>
<thead>
<tr>
<th>Issue</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>149789783</td>
<td>Resource Groups</td>
<td>Significant Pivotal Greenplum performance degradation has been observed when enabling resource group-based workload management on Red Hat 6.x, CentOS 6.x, and SuSE 11 systems. This issue is caused by a Linux cgroup kernel bug. This kernel bug has been fixed in CentOS 7.x and Red Hat 7.x systems. When resource groups are enabled on systems with an affected kernel, there can be a delay of 1 second or longer when starting a transaction or a query. The delay is caused by a Linux cgroup kernel bug where a synchronization mechanism called synchronize_sched is abused when a process is attached to a cgroup. See <a href="http://www.spinics.net/lists/cgroups/msg05708.html">http://www.spinics.net/lists/cgroups/msg05708.html</a> and <a href="https://lkml.org/lkml/2013/1/14/97">https://lkml.org/lkml/2013/1/14/97</a> for more information. The issue causes single attachment operations to take longer and also causes all concurrent attachments to be executed in sequence. For example, one process attachment could take about 0.01 second. When concurrently attaching 100 processes, the fastest process attachment takes 0.01 second and the slowest takes about 1 second. Pivotal Greenplum performs process attachments when a transaction or queries are started. So the performance degradation is dependent on concurrent started transactions or queries, and not related to concurrent running queries. Also Pivotal Greenplum has optimizations to bypass the rewriting when a QE is reused by multiple queries in the same session. <strong>Workaround:</strong> This bug does not affect CentOS 7.x and Red Hat 7.x systems. If you use Red Hat 6 and the performance with resource groups is acceptable for your use case, upgrade your kernel to version 2.6.32-696 or higher to benefit from other fixes to the cgroups implementation. SuSE 11 does not have a kernel version that resolves this issue; resource groups are still considered to be an experimental feature on this platform. Resource groups are not supported on SuSE 11 for production use.</td>
</tr>
<tr>
<td>Issue</td>
<td>Category</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>150906510</td>
<td>Backup and Restore</td>
<td>Greenplum Database 4.3.15.0 and later backups contain the following line in the backup files:</td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>                                                                             SET gp_strict_xml_parse = false;                                                                                 </code></td>
</tr>
<tr>
<td></td>
<td></td>
<td>However, Greenplum Database 5.0.0 does not have a parameter named gp_strict_xml_parse. When you restore the 4.3 backup set to the 5.0.0 cluster, you may see the warning:</td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>[WARNING]:--gpdbrestore finished but ERRORS were found, please check the restore report file for details </code></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Also, the report file may contain the error:</td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>ERROR: unrecognized configuration parameter &quot;gp_strict_xml_parse&quot; </code></td>
</tr>
<tr>
<td></td>
<td></td>
<td>These warnings and errors do not affect the restoration procedure, and can be ignored.</td>
</tr>
</tbody>
</table>
Update for gp_toolkit.gp_bloat_diag Issue

In Greenplum Database 5.3.0 or an earlier 5.x release, Greenplum Database returned an integer out of range error in some cases when performing a query against the gp_toolkit.gp_bloat_diag view. The issue was resolved in Greenplum Database 5.4.0 (resolved issue 26518).

When updating Greenplum Database, the gp_toolkit.gp_bloat_diag function and view must be updated in databases created with a Greenplum Database 5.3.0 or an earlier 5.x release. This issue has been fixed in databases created with Greenplum Database 5.4.0 and later.

To check whether the gp_toolkit.gp_bloat_diag function and view in a database requires an update, run the psql command \df to display information about the gp_toolkit.gp_bloat_diag function.

\df gp_toolkit.gp_bloat_diag

If the data type for btdexppages is integer, an update is required. If the data type is numeric an update is not required. In this example, the btdexppages data type is integer and requires an update.

<table>
<thead>
<tr>
<th>Schema</th>
<th>gp_toolkit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>gp_bloat_diag</td>
</tr>
<tr>
<td>Result data type</td>
<td>record</td>
</tr>
<tr>
<td>Argument data types</td>
<td>btdrelpages integer, btdexppages integer, aotable boolean, OUT bltidx integer, OUT bltdiag text</td>
</tr>
<tr>
<td>Type</td>
<td>normal</td>
</tr>
</tbody>
</table>

Run the following script to update the function and view to fix the issue on each database that was created with Greenplum Database 5.3.0 or an earlier 5.x release.

As the gpadmin user, follow these steps.

1. Copy the script into a text file on the Greenplum Database master.
2. Run the script on each database that requires the update.

This example updates gp_toolkit.gp_bloat_diag function and view in the database mytest and assumes that the script is in the update_bloat_diag.sql in the gpadmin home directory.

psql -f /home/gpadmin/update_bloat_diag.sql -d mytest

Run the script during a low activity period. Running the script during a high activity period does not affect database functionality but might affect performance.

Script to Update gp_toolkit.gp_bloat_diag Function and View

BEGIN;
CREATE OR REPLACE FUNCTION gp_toolkit.gp_bloat_diag(btdrelpages int,
           btdexppages numeric, aotable bool,
           OUT bltidx int, OUT bltdiag text)
AS $$
SELECT bltidx,
CASE
  WHEN bltidx = 0
    THEN 'no bloat detected':::text
  WHEN bltidx = 1
    THEN 'bloat detected':::text
  WHEN bltidx = 2
    THEN 'bloat detected':::text
  ELSE 'bloat suspicious':::text
END;
$$

END;
THEN 'moderate amount of bloat suspected'::text
WHEN bloatidx = 2
THEN 'significant amount of bloat suspected'::text
WHEN bloatidx = -1
THEN 'diagnosis inconclusive or no bloat suspected'::text
END AS bloatdiag
FROM
(SELECT
CASE
WHEN $3 = 't' THEN 0
WHEN $1 < 10 AND $2 = 0 THEN -1
WHEN $2 = 0 THEN 2
WHEN $1 < $2 THEN 0
WHEN ($1/$2)::numeric > 10 THEN 2
WHEN ($1/$2)::numeric > 3 THEN 1
ELSE -1
END AS bloatidx
) AS bloatmapping

$$
LANGUAGE SQL READS SQL DATA;

GRANT EXECUTE ON FUNCTION gp_toolkit.gp_bloat_diag(int, numeric, bool, OUT int, OUT text) TO public;

CREATE OR REPLACE VIEW gp_toolkit.gp_bloat_diag AS
SELECT
btdrelid AS bdirelid,
fnnspname AS bdinspname,
fnrelname AS bdirelname,
btdrelpages AS bdirelpages,
btdexppages AS bdiexppages,
bltdiag(bd) AS bdidiag
FROM
(SELECT
fn.*, beg.*,
gp_toolkit.gp_bloat_diag(btdrelpages::int, btdexppages::numeric, iao.iaotype::bool) AS bd
FROM
 gp_toolkit.gp_bloat_expected_pages beg,
 pg_catalog.pg_class pgc,
gp_toolkit.__gp_fullname fn,
gp_toolkit.__gp_is_append_only iao
WHERE beg.btdrelid = pgc.oid
AND pgc.oid = fn.fnoid
AND iao.iaoid = pgc.oid
) as bloatsummary
WHERE bltidx(bd) > 0;

GRANT SELECT ON TABLE gp_toolkit.gp_bloat_diag TO public;
COMMIT;
Chapter 5

Greenplum Database Installation Guide

Information about installing and configuring Greenplum Database software and configuring Greenplum Database host machines.
Introduction to Greenplum

High-level overview of the Greenplum Database system architecture.

Greenplum Database stores and processes large amounts of data by distributing the load across several servers or hosts. A logical database in Greenplum is an array of individual PostgreSQL databases working together to present a single database image. The master is the entry point to the Greenplum Database system. It is the database instance to which users connect and submit SQL statements. The master coordinates the workload across the other database instances in the system, called segments, which handle data processing and storage. The segments communicate with each other and the master over the interconnect, the networking layer of Greenplum Database.

Greenplum Database is a software-only solution; the hardware and database software are not coupled. Greenplum Database runs on a variety of commodity server platforms from Greenplum-certified hardware vendors. Performance depends on the hardware on which it is installed. Because the database is distributed across multiple machines in a Greenplum Database system, proper selection and configuration of hardware is vital to achieving the best possible performance.

This chapter describes the major components of a Greenplum Database system and the hardware considerations and concepts associated with each component: The Greenplum Master, The Segments and The Interconnect. Additionally, a system may have optional ETL Hosts for Data Loading and Greenplum Performance Monitoring for monitoring query workload and performance.

The Greenplum Master

The master is the entry point to the Greenplum Database system. It is the database server process that accepts client connections and processes the SQL commands that system users issue. Users connect to Greenplum Database through the master using a PostgreSQL-compatible client program such as psql or ODBC.

The master maintains the system catalog (a set of system tables that contain metadata about the Greenplum Database system itself), however the master does not contain any user data. Data resides only on the segments. The master authenticates client connections, processes incoming SQL commands, distributes the work load between segments, coordinates the results returned by each segment, and presents the final results to the client program.

Because the master does not contain any user data, it has very little disk load. The master needs a fast, dedicated CPU for data loading, connection handling, and query planning because extra space is often necessary for landing load files and backup files, especially in production environments. Customers may decide to also run ETL and reporting tools on the master, which requires more disk space and processing power.

Master Redundancy

You may optionally deploy a backup or mirror of the master instance. A backup master host serves as a warm standby if the primary master host becomes nonoperational. You can deploy the standby master on a designated redundant master host or on one of the segment hosts.

The standby master is kept up to date by a transaction log replication process, which runs on the standby master host and synchronizes the data between the primary and standby master hosts. If the primary master fails, the log replication process shuts down, and an administrator can activate the standby master in its place. When an the standby master is active, the replicated logs are used to reconstruct the state of the master host at the time of the last successfully committed transaction.
Since the master does not contain any user data, only the system catalog tables need to be synchronized between the primary and backup copies. When these tables are updated, changes automatically copy over to the standby master so it is always synchronized with the primary.

**Figure 1: Master Mirroring in Greenplum Database**

**The Segments**

In Greenplum Database, the *segments* are where data is stored and where most query processing occurs. User-defined tables and their indexes are distributed across the available segments in the Greenplum Database system; each segment contains a distinct portion of the data. Segment instances are the database server processes that serve segments. Users do not interact directly with the segments in a Greenplum Database system, but do so through the master.

In the reference Greenplum Database hardware configurations, the number of segment instances per segment host is determined by the number of effective CPUs or CPU core. For example, if your segment hosts have two dual-core processors, you may have two or four primary segments per host. If your segment hosts have three quad-core processors, you may have three, six or twelve segments per host. Performance testing will help decide the best number of segments for a chosen hardware platform.

**Segment Redundancy**

When you deploy your Greenplum Database system, you have the option to configure *mirror* segments. Mirror segments allow database queries to fail over to a backup segment if the primary segment becomes unavailable. Mirroring is a requirement for Pivotal-supported production Greenplum Database systems.

A mirror segment must always reside on a different host than its primary segment. Mirror segments can be arranged across the hosts in the system in one of two standard configurations, or in a custom configuration you design. The default configuration, called *group* mirroring, places the mirror segments for all primary segments on a host on one other host. Another option, called *spread* mirroring, spreads mirrors for each host's primary segments over the remaining hosts. Spread mirroring requires that there be more hosts in the system than there are primary segments on the host. On hosts with multiple network interfaces, the primary and mirror segments are distributed equally among the interfaces. **Figure 2: Data Mirroring in Greenplum Database** shows how table data is distributed across the segments when the default group mirroring option is configured.

**Segment Failover and Recovery**

When mirroring is enabled in a Greenplum Database system, the system automatically fails over to the mirror copy if a primary copy becomes unavailable. A Greenplum Database system can remain operational if a segment instance or host goes down only if all portions of data are available on the remaining active segments.

If the master cannot connect to a segment instance, it marks that segment instance as *invalid* in the Greenplum Database system catalog. The segment instance remains invalid and out of operation until an administrator brings that segment back online. An administrator can recover a failed segment while the system is up and running. The recovery process copies over only the changes that were missed while the segment was nonoperational.

If you do not have mirroring enabled and a segment becomes invalid, the system automatically shuts down. An administrator must recover all failed segments before operations can continue.
Example Segment Host Hardware Stack

Regardless of the hardware platform you choose, a production Greenplum Database processing node (a segment host) is typically configured as described in this section.

The segment hosts do the majority of database processing, so the segment host servers are configured in order to achieve the best performance possible from your Greenplum Database system. Greenplum Database's performance will be as fast as the slowest segment server in the array. Therefore, it is important to ensure that the underlying hardware and operating systems that are running Greenplum Database are all running at their optimal performance level. It is also advised that all segment hosts in a Greenplum Database array have identical hardware resources and configurations.

Segment hosts should also be dedicated to Greenplum Database operations only. To get the best query performance, you do not want Greenplum Database competing with other applications for machine or network resources.

The following diagram shows an example Greenplum Database segment host hardware stack. The number of effective CPUs on a host is the basis for determining how many primary Greenplum Database segment instances to deploy per segment host. This example shows a host with two effective CPUs (one dual-core CPU). Note that there is one primary segment instance (or primary/mirror pair if using mirroring) per CPU core.

Figure 3: Example Greenplum Database Segment Host Configuration

Example Segment Disk Layout

Each CPU is typically mapped to a logical disk. A logical disk consists of one primary file system (and optionally a mirror file system) accessing a pool of physical disks through an I/O channel or disk controller. The logical disk and file system are provided by the operating system. Most operating systems provide the ability for a logical disk drive to use groups of physical disks arranged in RAID arrays.

Figure 4: Logical Disk Layout in Greenplum Database

Depending on the hardware platform you choose, different RAID configurations offer different performance and capacity levels. Greenplum supports and certifies a number of reference hardware platforms and operating systems. Check with your sales account representative for the recommended configuration on your chosen platform.

The Interconnect

The interconnect is the networking layer of Greenplum Database. When a user connects to a database and issues a query, processes are created on each of the segments to handle the work of that query. The interconnect refers to the inter-process communication between the segments, as well as the network infrastructure on which this communication relies. The interconnect uses a standard 10 Gigabit Ethernet switching fabric.

By default, Greenplum Database interconnect uses UDP (User Datagram Protocol) with flow control for interconnect traffic to send messages over the network. The Greenplum software does the additional packet verification and checking not performed by UDP, so the reliability is equivalent to TCP (Transmission Control Protocol), and the performance and scalability exceeds that of TCP. For information about the types of interconnect supported by Greenplum Database, see server configuration parameter gp_interconnect_type in the Greenplum Database Reference Guide.
Interconnect Redundancy

A highly available interconnect can be achieved by deploying dual 10 Gigabit Ethernet switches on your network, and redundant 10 Gigabit connections to the Greenplum Database master and segment host servers.

Network Interface Configuration

A segment host typically has multiple network interfaces designated to Greenplum interconnect traffic. The master host typically has additional external network interfaces in addition to the interfaces used for interconnect traffic.

Depending on the number of interfaces available, you will want to distribute interconnect network traffic across the number of available interfaces. This is done by assigning segment instances to a particular network interface and ensuring that the primary segments are evenly balanced over the number of available interfaces.

This is done by creating separate host address names for each network interface. For example, if a host has four network interfaces, then it would have four corresponding host addresses, each of which maps to one or more primary segment instances. The /etc/hosts file should be configured to contain not only the host name of each machine, but also all interface host addresses for all of the Greenplum Database hosts (master, standby master, segments, and ETL hosts).

With this configuration, the operating system automatically selects the best path to the destination. Greenplum Database automatically balances the network destinations to maximize parallelism.

Figure 5: Example Network Interface Architecture

Switch Configuration

When using multiple 10 Gigabit Ethernet switches within your Greenplum Database array, evenly divide the number of subnets between each switch. In this example configuration, if we had two switches, NICs 1 and 2 on each host would use switch 1 and NICs 3 and 4 on each host would use switch 2. For the master host, the host name bound to NIC 1 (and therefore using switch 1) is the effective master host name for the array. Therefore, if deploying a warm standby master for redundancy purposes, the standby master should map to a NIC that uses a different switch than the primary master.

Figure 6: Example Switch Configuration

ETL Hosts for Data Loading

Greenplum supports fast, parallel data loading with its external tables feature. By using external tables in conjunction with Greenplum Database's parallel file server (gpfdist), administrators can achieve maximum parallelism and load bandwidth from their Greenplum Database system. Many production systems deploy designated ETL servers for data loading purposes. These machines run the Greenplum parallel file server (gpfdist), but not Greenplum Database instances.

One advantage of using the gpfdist file server program is that it ensures that all of the segments in your Greenplum Database system are fully utilized when reading from external table data files.

The gpfdist program can serve data to the segment instances at an average rate of about 350 MB/s for delimited text formatted files and 200 MB/s for CSV formatted files. Therefore, you should consider the following options when running gpfdist in order to maximize the network bandwidth of your ETL systems:
If your ETL machine is configured with multiple network interface cards (NICs) as described in *Network Interface Configuration*, run one instance of *gpfdist* on your ETL host and then define your external table definition so that the host name of each NIC is declared in the *LOCATION* clause (see *CREATE EXTERNAL TABLE* in the *Greenplum Database Reference Guide*). This allows network traffic between your Greenplum segment hosts and your ETL host to use all NICs simultaneously.

**Figure 7: External Table Using Single gpfdist Instance with Multiple NICs**

- Run multiple *gpfdist* instances on your ETL host and divide your external data files equally between each instance. For example, if you have an ETL system with two network interface cards (NICs), then you could run two *gpfdist* instances on that machine to maximize your load performance. You would then divide the external table data files evenly between the two *gpfdist* programs.

**Figure 8: External Tables Using Multiple gpfdist Instances with Multiple NICs**

### Greenplum Performance Monitoring

Greenplum Database includes a dedicated system monitoring and management database, named gpperfmon, that administrators can install and enable. When this database is enabled, data collection agents on each segment host collect query status and system metrics. At regular intervals (typically every 15 seconds), an agent on the Greenplum master requests the data from the segment agents and updates the gpperfmon database. Users can query the gpperfmon database to see the stored query and system metrics. For more information see the "gpperfmon Database Reference" in the *Greenplum Database Reference Guide*.

Greenplum Command Center is an optional web-based performance monitoring and management tool for Greenplum Database, based on the gpperfmon database. Administrators can install Command Center separately from Greenplum Database.

**Figure 9: Greenplum Performance Monitoring Architecture**
Estimating Storage Capacity

To estimate how much data your Greenplum Database system can accommodate, use these measurements as guidelines. Also keep in mind that you may want to have extra space for landing backup files and data load files on each segment host.

Calculating Usable Disk Capacity

To calculate how much data a Greenplum Database system can hold, you have to calculate the usable disk capacity per segment host and then multiply that by the number of segment hosts in your Greenplum Database array. Start with the raw capacity of the physical disks on a segment host that are available for data storage \((\text{raw\_capacity})\), which is:

\[
\text{disk\_size} \times \text{number\_of\_disks}
\]

Account for file system formatting overhead (roughly 10 percent) and the RAID level you are using. For example, if using RAID-10, the calculation would be:

\[
(\text{raw\_capacity} \times 0.9) / 2 = \text{formatted\_disk\_space}
\]

For optimal performance, do not completely fill your disks to capacity, but run at 70% or lower. So with this in mind, calculate the usable disk space as follows:

\[
\text{formatted\_disk\_space} \times 0.7 = \text{usable\_disk\_space}
\]

Once you have formatted RAID disk arrays and accounted for the maximum recommended capacity \((\text{usable\_disk\_space})\), you will need to calculate how much storage is actually available for user data \((U)\). If using Greenplum Database mirrors for data redundancy, this would then double the size of your user data \((2 \times U)\). Greenplum Database also requires some space be reserved as a working area for active queries. The work space should be approximately one third the size of your user data \((\text{work\_space} = U / 3)\):

- With mirrors: \((2 \times U) + U/3 = \text{usable\_disk\_space}\)
- Without mirrors: \(U + U/3 = \text{usable\_disk\_space}\)

Guidelines for temporary file space and user data space assume a typical analytic workload. Highly concurrent workloads or workloads with queries that require very large amounts of temporary space can benefit from reserving a larger working area. Typically, overall system throughput can be increased while decreasing work area usage through proper workload management. Additionally, temporary space and user space can be isolated from each other by specifying that they reside on different tablespaces.

In the Greenplum Database Administrator Guide, see these topics:

- "Managing Workload and Resources" for information about workload management
- "Creating and Managing Tablespaces" for information about moving the location of temporary files
- "Monitoring System State" for information about monitoring Greenplum Database disk space usage

Calculating User Data Size

As with all databases, the size of your raw data will be slightly larger once it is loaded into the database. On average, raw data will be about 1.4 times larger on disk after it is loaded into the database, but could be smaller or larger depending on the data types you are using, table storage type, in-database compression, and so on.
• Page Overhead - When your data is loaded into Greenplum Database, it is divided into pages of 32KB each. Each page has 20 bytes of page overhead.

• Row Overhead - In a regular 'heap' storage table, each row of data has 24 bytes of row overhead. An 'append-optimized' storage table has only 4 bytes of row overhead.

• Attribute Overhead - For the data values itself, the size associated with each attribute value is dependent upon the data type chosen. As a general rule, you want to use the smallest data type possible to store your data (assuming you know the possible values a column will have).

• Indexes - In Greenplum Database, indexes are distributed across the segment hosts as is table data. The default index type in Greenplum Database is B-tree. Because index size depends on the number of unique values in the index and the data to be inserted, precalculating the exact size of an index is impossible. However, you can roughly estimate the size of an index using these formulas.

| B-tree: | unique_values * (data_type_size + 24 bytes) |
| Bitmap: | (unique_values * number_of_rows * 1 bit * compression_ratio / 8) + (unique_values * 32) |

Calculating Space Requirements for Metadata and Logs

On each segment host, you will also want to account for space for Greenplum Database log files and metadata:

• System Metadata — For each Greenplum Database segment instance (primary or mirror) or master instance running on a host, estimate approximately 20 MB for the system catalogs and metadata.

• Write Ahead Log — For each Greenplum Database segment (primary or mirror) or master instance running on a host, allocate space for the write ahead log (WAL). The WAL is divided into segment files of 64 MB each. At most, the number of WAL files will be:

\[2 \times \text{checkpoint\_segments} + 1\]

You can use this to estimate space requirements for WAL. The default checkpoint\_segments setting for a Greenplum Database instance is 8, meaning 1088 MB WAL space allocated for each segment or master instance on a host.

• Greenplum Database Log Files — Each segment instance and the master instance generates database log files, which will grow over time. Sufficient space should be allocated for these log files, and some type of log rotation facility should be used to ensure that log files do not grow too large.

• Command Center Data — The data collection agents utilized by Command Center run on the same set of hosts as your Greenplum Database instance and utilize the system resources of those hosts. The resource consumption of the data collection agent processes on these hosts is minimal and should not significantly impact database performance. Historical data collected by the collection agents is stored in its own Command Center database (named gpperfmon) within your Greenplum Database system. Collected data is distributed just like regular database data, so you will need to account for disk space in the data directory locations of your Greenplum segment instances. The amount of space required depends on the amount of historical data you would like to keep. Historical data is not automatically truncated. Database administrators must set up a truncation policy to maintain the size of the Command Center database.
Configuring Your Systems and Installing Greenplum

Describes how to prepare your operating system environment for Greenplum, and install the Greenplum Database software binaries on all of the hosts that will comprise your Greenplum Database system.

Perform the following tasks in order:

1. Make sure your systems meet the System Requirements
2. Setting the Greenplum Recommended OS Parameters
3. (master only) Creating the Greenplum Database Administrative User Account
4. (master only) Installing the Greenplum Database Software
5. Installing and Configuring Greenplum on all Hosts
6. (Optional) Installing Oracle Compatibility Functions
7. (Optional) Installing Optional Modules
8. (Optional) Installing Greenplum Database Extensions
9. (Optional) Installing and Configuring the Greenplum Platform Extension Framework (PXF)
10. Creating the Data Storage Areas
11. Synchronizing System Clocks
12. Next Steps

Unless noted, these tasks should be performed for all hosts in your Greenplum Database array (master, standby master and segments).

You can install and configure Greenplum Database on virtual servers provided by the Amazon Elastic Compute Cloud (Amazon EC2) web service. For information about using Greenplum Database in an Amazon EC2 environment, see Amazon EC2 Configuration.

Important: When data loss is not acceptable for a Pivotal Greenplum Database cluster, master and segment mirroring must be enabled in order for the cluster to be supported by Pivotal. Without mirroring, system and data availability is not guaranteed, Pivotal will make best efforts to restore a cluster in this case. For information about master and segment mirroring, see About Redundancy and Failover in the Greenplum Database Administrator Guide.

Note: For information about upgrading Pivotal Greenplum Database from a previous version, see the Greenplum Database Release Notes for the release that you are installing.

System Requirements

The following table lists minimum recommended specifications for servers intended to support Greenplum Database on Linux systems in a production environment. All servers in your Greenplum Database system must have the same hardware and software configuration. Greenplum also provides hardware build guides for its certified hardware platforms. It is recommended that you work with a Greenplum Systems Engineer to review your anticipated environment to ensure an appropriate hardware configuration for Greenplum Database.
## Table 11: System Prerequisites for Greenplum Database 5.0

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating System</td>
<td>SUSE Linux Enterprise Server 64-bit 12 SP2 or SP3, with kernel 4.4.73-5.1 or newer</td>
</tr>
<tr>
<td></td>
<td>SUSE Linux Enterprise Server 64-bit 11 SP4</td>
</tr>
<tr>
<td></td>
<td>CentOS 64-bit 6.x or 7.x</td>
</tr>
<tr>
<td></td>
<td>Red Hat Enterprise Linux (RHEL) 64-bit 6.x or 7.x</td>
</tr>
<tr>
<td></td>
<td><strong>Note:</strong> See the <em>Greenplum Database Release Notes</em> for current supported platform information.</td>
</tr>
<tr>
<td>File Systems</td>
<td>• xfs required for data storage on SUSE Linux and Red Hat (ext3 supported for root file system)</td>
</tr>
<tr>
<td>Minimum CPU</td>
<td>Pentium Pro compatible (P3/Athlon and above)</td>
</tr>
<tr>
<td>Minimum Memory</td>
<td>16 GB RAM per server</td>
</tr>
<tr>
<td>Disk Requirements</td>
<td>• 150MB per host for Greenplum installation</td>
</tr>
<tr>
<td></td>
<td>• Approximately 300MB per segment instance for meta data</td>
</tr>
<tr>
<td></td>
<td>• Appropriate free space for data with disks at no more than 70% capacity</td>
</tr>
<tr>
<td></td>
<td>• High-speed, local storage</td>
</tr>
<tr>
<td>Network Requirements</td>
<td>10 Gigabit Ethernet within the array</td>
</tr>
<tr>
<td></td>
<td>Dedicated, non-blocking switch</td>
</tr>
<tr>
<td></td>
<td>NIC bonding is recommended when multiple interfaces are present</td>
</tr>
<tr>
<td>Software and Utilities</td>
<td>zlib compression libraries</td>
</tr>
<tr>
<td></td>
<td>bash shell</td>
</tr>
<tr>
<td></td>
<td>GNU tars</td>
</tr>
<tr>
<td></td>
<td>GNU zip</td>
</tr>
<tr>
<td></td>
<td>GNU sed (used by Greenplum Database gpinitsystem)</td>
</tr>
<tr>
<td></td>
<td>perl</td>
</tr>
<tr>
<td></td>
<td>secure shell</td>
</tr>
</tbody>
</table>

**Important:** SSL is supported only on the Greenplum Database master host system. It is not supported on the segment host systems.

**Important:** For all Greenplum Database host systems, the SELinux must be disabled. You should also disable firewall software such as `iptables` (on systems such as RHEL 6.x and CentOS 6.x) or `firewalld` (on systems such as RHEL 7.x and CentOS 7.x). You can enable firewall software if it is required for security purposes. For information about enabling and configuring `iptables`, see *Enabling iptables*. For information about enabling and configuring `firewalld` see the list of instructions here:
• This command checks the status of SELinux when run as root:

```bash
# sestatus
SELinuxstatus: disabled
```

You can disable SELinux by editing the `/etc/selinux/config` file. As root, change the value of the SELINUX parameter in the config file and reboot the system:

```bash
SELINUX=disabled
```

For information about disabling firewall software, see the documentation for the firewall or your operating system. For information about disabling SELinux, see the SELinux documentation.

• This command checks the status of `iptables` when run as root:

```bash
#/sbin/chkconfig --list iptables
```

This is the output if `iptables` is disabled.

```bash
iptables 0:off 1:off 2:off 3:off 4:off 5:off 6:off
```

One method of disabling `iptables` is to become root, run this command, and then reboot the system:

```bash
#/sbin/chkconfig iptables off
```

• This command checks the status of `firewalld` when run as root:

```bash
# systemctl status firewalld
```

This is the output if `firewalld` is disabled.

```bash
* firewalld.service - firewalld - dynamic firewall daemon
   Loaded: loaded (/usr/lib/systemd/system/firewalld.service;
   disabled; vendor preset: enabled)
   Active: inactive (dead)
```

These commands disable `firewalld` when run as root:

```bash
# systemctl stop firewalld.service
# systemctl disable firewalld.service
```

**Setting the Greenplum Recommended OS Parameters**

Greenplum requires the certain Linux operating system (OS) parameters be set on all hosts in your Greenplum Database system (masters and segments).

In general, the following categories of system parameters need to be altered:

• **Shared Memory** - A Greenplum Database instance will not work unless the shared memory segment for your kernel is properly sized. Most default OS installations have the shared memory values set too low for Greenplum Database. On Linux systems, you must also disable the OOM (out of memory) killer. For information about Greenplum Database shared memory requirements, see the Greenplum Database server configuration parameter `shared_buffers` in the *Greenplum Database Reference Guide*.

• **Network** - On high-volume Greenplum Database systems, certain network-related tuning parameters must be set to optimize network connections made by the Greenplum interconnect.

• **User Limits** - User limits control the resources available to processes started by a user's shell. Greenplum Database requires a higher limit on the allowed number of file descriptors that a single
process can have open. The default settings may cause some Greenplum Database queries to fail because they will run out of file descriptors needed to process the query.

**Linux System Settings**

- Edit the `/etc/hosts` file and make sure that it includes the host names and all interface address names for every machine participating in your Greenplum Database system.
- Set the following parameters in the `/etc/sysctl.conf` file and reboot:

```
kernel.shmmax = 5000000000
kernel.shmmni = 4096
kernel.shmall = 4000000000
kernel.sem = 250 512000 100 2048
kernel.sysrq = 1
kernel.core_uses_pid = 1
kernel.msgmnb = 65536
kernel.msgmax = 65536
kernel.msgmni = 2048
net.ipv4.tcp_syncookies = 1
net.ipv4.conf.default.accept_source_route = 0
net.ipv4.tcp_tw_recycle = 1
net.ipv4.tcp_max_syn_backlog = 4096
net.ipv4.conf.all.arp_filter = 1
net.ipv4.ip_local_port_range = 10000 65535
net.core.netdev_max_backlog = 10000
net.core.rmem_max = 2097152
net.core.wmem_max = 2097152
vm.overcommit_memory = 2
```

**Note:** When `vm.overcommit_memory` is `2`, you specify a value for `vm.overcommit_ratio`. For information about calculating the value for `vm.overcommit_ratio` when using resource queue-based resource management, see the Greenplum Database server configuration parameter `gp_vmem_protect_limit` in the *Greenplum Database Reference Guide*. If you are using resource group-based resource management, the operating system `vm.overcommit_ratio` default value is a good starting point.

To avoid port conflicts between Greenplum Database and other applications when initializing Greenplum Database, do not specify Greenplum Database ports in the range specified by the operating system parameter `net.ipv4.ip_local_port_range`. For example, if `net.ipv4.ip_local_port_range = 10000 65535`, you could set the Greenplum Database base port numbers to these values.

```
PORT_BASE = 6000
MIRROR_PORT_BASE = 7000
REPLICATION_PORT_BASE = 8000
MIRROR_REPLICATION_PORT_BASE = 9000
```

For information about the port ranges that are used by Greenplum Database, see `gpinitsystem`.

- Set the following parameters in the `/etc/security/limits.conf` file:

```
* soft nofile 65536
* hard nofile 65536
* soft nproc 131072
* hard nproc 131072
```

For Red Hat Enterprise Linux (RHEL) 6.x and CentOS 6.x, parameter values in the `/etc/security/limits.d/90-nproc.conf` file override the values in the `limits.conf` file. If a parameter value is set in both `conf` files, ensure that the parameter is set properly in the `90-nproc.conf` file. The Linux module `pam_limits` sets user limits by reading the values from the `limits.conf` file and then from the
90-nproc.conf file. For information about PAM and user limits, see the documentation on PAM and pam_limits.

- XFS is the preferred file system on Linux platforms for data storage. The following XFS mount options are recommended:
  
  rw,nodev,noatime,nobarrier,inode64

  See the manual page (man) for the `mount` command for more information about using that command (man mount opens the man page).

  The XFS options can also be set in the `/etc/fstab` file. This example entry from an `fstab` file specifies the XFS options.

  ```
  /dev/data /data xfs nodev,noatime,nobarrier,inode64 0 0
  ```

- Each disk device file should have a read-ahead (`blockdev`) value of 16384.

  To verify the read-ahead value of a disk device:

  ```
  # /sbin/blockdev --getra devname
  ```

  For example:

  ```
  # /sbin/blockdev --getra /dev/sdb
  ```

  To set blockdev (read-ahead) on a device:

  ```
  # /sbin/blockdev --setra bytes devname
  ```

  For example:

  ```
  # /sbin/blockdev --setra 16384 /dev/sdb
  ```

  See the manual page (man) for the `blockdev` command for more information about using that command (man blockdev opens the man page).

- The Linux disk I/O scheduler for disk access supports different policies, such as CFQ, AS, and deadline.

  The `deadline` scheduler option is recommended. To specify a scheduler until the next system reboot, run the following:

  ```
  # echo schedulername > /sys/block/devname/queue/scheduler
  ```

  For example:

  ```
  # echo deadline > /sys/block/sbd/queue/scheduler
  ```

  You can specify the I/O scheduler at boot time with the `elevator` kernel parameter. Add the parameter `elevator=deadline` to the kernel command in the file `/boot/grub/grub.conf`, the GRUB boot loader configuration file. This is an example kernel command from a `grub.conf` file on RHEL 6.x or CentOS 6.x. The command is on multiple lines for readability.

  ```
  kernel /vmlinuz-2.6.18-274.3.1.el5 ro root=LABEL=/
  elevator=deadline
  crashkernel=128M@16M quiet console=ttys1 console=ttyS1,115200 panic=30 transparent_hugepage=never
  initrd /initrd-2.6.18-274.3.1.el5.img
  ```
To specify the I/O scheduler at boot time on systems that use `grub2` such as RHEL 7.x or CentOS 7.x, use the system utility `grubby`. This command adds the parameter when run as root.

```bash
# grubby --update-kernel=ALL --args="elevator=deadline"
```

After adding the parameter, reboot the system.

This `grubby` command displays kernel parameter settings.

```bash
# grubby --info=ALL
```

For more information about the `grubby` utility, see your operating system documentation. If the `grubby` command does not update the kernels, see the Note at the end of the section.

- **Disable Transparent Huge Pages (THP).** RHEL 6.0 or higher enables THP by default. THP degrades Greenplum Database performance. One way to disable THP on RHEL 6.x is by adding the parameter `transparent_hugepage=never` to the `kernel` command in the file `/boot/grub/grub.conf`, the GRUB boot loader configuration file. This is an example kernel command from a `grub.conf` file. The command is on multiple lines for readability:

```bash
kernel /vmlinuz-2.6.18-274.3.1.el5 ro root=LABEL=/
elevator=deadline crashkernel=128M@16M quiet console=tty1
console=ttyS1,115200 panic=30 transparent_hugepage=never
initrd /initrd-2.6.18-274.3.1.el5.img
```

On systems that use `grub2` such as RHEL 7.x or CentOS 7.x, use the system utility `grubby`. This command adds the parameter when run as root.

```bash
# grubby --update-kernel=ALL --args="transparent_hugepage=never"
```

After adding the parameter, reboot the system.

This `cat` command checks the state of THP. The output indicates that THP is disabled.

```bash
$ cat /sys/kernel/mm/*transparent_hugepage/enabled
always [never]
```

For more information about Transparent Huge Pages or the `grubby` utility, see your operating system documentation. If the `grubby` command does not update the kernels, see the Note at the end of the section.

- **Disable IPC object removal for RHEL 7.2 or CentOS 7.2.** The default `systemd` setting `RemoveIPC=yes` removes IPC connections when non-system user accounts log out. This causes the Greenplum Database utility `gpinitsystem` to fail with semaphore errors. Perform one of the following to avoid this issue.

  - **When you add the `gpadmin` operating system user account to the master node in Creating the Greenplum Database Administrative User Account,** create the user as a system account. You must also add the `gpadmin` user as a system account on the segment hosts manually or using the `gpseginstall` command (described in later installation step Installing and Configuring Greenplum on all Hosts).

    **Note:** When you run the `gpseginstall` utility as the root user to install Greenplum Database on host systems, the utility creates the `gpadmin` operating system user as a system account on the hosts.

  - **Disable `RemoveIPC`.** Set this parameter in `/etc/systemd/logind.conf` on the Greenplum Database host systems.

    `RemoveIPC=no`
The setting takes effect after restarting the `systemd-login` service or rebooting the system. To restart the service, run this command as the root user:

```
service systemd-logind restart
```

- Certain Greenplum Database management utilities including `gpexpand`, `gpinitsystem`, and `gpaddmirrors`, utilize secure shell (SSH) connections between systems to perform their tasks. In large Greenplum Database deployments, cloud deployments, or deployments with a large number of segments per host, these utilities may exceed the host's maximum threshold for unauthenticated connections. When this occurs, you receive errors such as: `ssh_exchange_identification: Connection closed by remote host`.

To increase this connection threshold for your Greenplum Database deployment, update the SSH `MaxStartups` configuration parameter in one of the `/etc/ssh/sshd_config` or `/etc/sshd_config` SSH daemon configuration files.

If you specify `MaxStartups` using a single integer value, you identify the maximum number of concurrent unauthenticated connections. For example:

```
MaxStartups 200
```

If you specify `MaxStartups` using the "`start:rate:full`" syntax, you enable random early connection drop by the SSH daemon. `start` identifies the maximum number of unauthenticated SSH connection attempts allowed. Once `start` number of unauthenticated connection attempts is reached, the SSH daemon refuses `rate` percent of subsequent connection attempts. `full` identifies the maximum number of unauthenticated connection attempts after which all attempts are refused. For example:

```
Max Startups 10:30:200
```

Restart the SSH daemon after you update `MaxStartups`. For example, on a CentOS 6 system, run the following command as the root user:

```
# service sshd restart
```

For detailed information about SSH configuration options, refer to the SSH documentation for your Linux distribution.

- On some SUSE Linux Enterprise Server platforms, the Greenplum Database utility `gpssh` fails with the error message `out of pty devices`. A workaround is to add Greenplum Database operating system users, for example `gpadmin`, to the tty group. On SUSE systems, tty is required to run `gpssh`.

  **Note:** If the `grubby` command does not update the kernels of a RHEL 7.x or CentOS 7.x system, you can manually update all kernels on the system. For example, to add the parameter `transparent_hugepage=never` to all kernels on a system.

1. Add the parameter to the `GRUB_CMDLINE_LINUX` line in the file parameter in `/etc/default/grub`.

   - `GRUB_TIMEOUT=5`
   - `GRUB_DISTRIBUTOR="$(sed 's, release .*$,,g' /etc/system-release)"`
   - `GRUB_DEFAULT=saved`
   - `GRUB_DISABLE_SUBMENUB=true`
   - `GRUB_TERMINAL_OUTPUT="console"`
   - `GRUB_CMDLINE_LINUX="crashkernel=auto rd.lvm.lv=cl/root rd.lvm.lv=cl/swap rhgb quiet transparent_hugepage=never"`
   - `GRUB_DISABLE_RECOVERY="true"`

2. As root, run the `grub2-mkconfig` command to update the kernels.

   ```
   # grub2-mkconfig -o /boot/grub2/grub.cfg
   ```
3. Reboot the system.

**Creating the Greenplum Database Administrative User Account**

You must create a dedicated operating system user account on the master node to run Greenplum Database. You administer Greenplum Database as this operating system user. This user account is named, by convention, **gpadmin**.

You cannot run the Greenplum Database server as **root**.

The **gpadmin** user account must have permission to access the services and directories required to install and run Greenplum Database.

To create the **gpadmin** operating system user account on the Greenplum Database master node and set the account password, run the `groupadd`, `useradd`, and `passwd` commands as the **root** user.

**Note:** If you are installing Greenplum Database on RHEL 7.2 or CentOS 7.2 and chose to disable IPC object removal by creating the **gpadmin** user as a system account, provide both the **-r** and the **-m <home_dir>** options to the `useradd` command.

For example:

```
# groupadd gpadmin
# useradd gpadmin -g gpadmin
# passwd gpadmin
New password: <changeme>
Retype new password: <changeme>
```

**Installing the Greenplum Database Software**

To configure your systems for Greenplum Database, the master host machine required the utilities found in `$GPHOME/bin` of the Greenplum Database software installation. Pivotal distributes the Greenplum Database software both as a downloadable RPM file and as a binary installer. You can use either distribution method to install the software on the master host machine.

If you do not have root access on the master host machine, run the binary installer as the **gpadmin** user and install the software into a directory in which you have write permission.

**Installing the RPM Distribution**

1. Log in as **root** on the machine that will become the Greenplum Database master host.
2. Download or copy the RPM distribution file to the master host machine. The RPM distribution filename has the format `greenplum-db-<version>-<platform>.rpm` where `<platform>` is similar to RHEL7-x86_64 (Red Hat 64-bit) or SuSE12-x86_64 (SuSe Linux 64 bit).
3. Install the local RPM file:

```
# rpm -Uvh ./greenplum-db-<version>-<platform>.rpm
Preparing...                ###########################################
[100%]
1:greenplum-db                      ###########################################
[100%]
```

The RPM installation copies the Greenplum Database software into a version-specific directory, `/usr/local/greenplum-db-<version>`.

4. Change the ownership and group of the installed files to **gpadmin**:

```
# chown -R gpadmin /usr/local/greenplum*
# chgrp -R gpadmin /usr/local/greenplum*
```
5. To perform additional required system configuration tasks and to install Greenplum Database on other hosts, go to the next task *Installing and Configuring Greenplum on all Hosts.*

### Installing the Binary Distribution

1. Log in as root on the machine that will become the Greenplum Database master host.
   
   If you do not have root access on the master host machine, run the binary installer as the `gpadmin` user and install the software into a directory in which you have write permission.
   
2. Download or copy the Binary Installation distribution file to the master host machine. The Binary Installer distribution filename has the format `greenplum-db-<version>-<platform>.zip` where `<platform>` is similar to `RHEL7-x86_64` (Red Hat 64-bit) or `SuSE12-x86_64` (SuSe Linux 64 bit).
   
3. Unzip the installer file:

   ```
   # unzip greenplum-db-<version>-<platform>.zip
   ```

4. Launch the installer using `bash`:

   ```
   # /bin/bash greenplum-db-<version>-<platform>.bin
   ```

5. The installer prompts you to accept the Greenplum Database license agreement. Type `yes` to accept the license agreement.

6. The installer prompts you to provide an installation path. Press ENTER to accept the default install path (`/usr/local/greenplum-db-<version>`), or enter an absolute path to a custom install location. You must have write permission to the location you specify.

7. The installer installs the Greenplum Database software and creates a `greenplum-db` symbolic link one directory level above the version-specific installation directory. The symbolic link is used to facilitate patch maintenance and upgrades between versions. The installed location is referred to as `$GPHOME`.

8. If you installed as root, change the ownership and group of the installed files to `gpadmin`:

   ```
   # chown -R gpadmin /usr/local/greenplum*
   # chgrp -R gpadmin /usr/local/greenplum*
   ```

9. To perform additional required system configuration tasks and to install Greenplum Database on other hosts, go to the next task *Installing and Configuring Greenplum on all Hosts.*

### About Your Greenplum Database Installation

- `greenplum_path.sh` — This file contains the environment variables for Greenplum Database. See *Setting Greenplum Environment Variables.*
- `bin` — This directory contains the Greenplum Database management utilities. This directory also contains the PostgreSQL client and server programs, most of which are also used in Greenplum Database.
- `docs/cli_help` — This directory contains help files for Greenplum Database command-line utilities.
- `docs/cli_help/gpconfigs` — This directory contains sample `gpinitdb` configuration files and host files that can be modified and used when installing and initializing a Greenplum Database system.
- `docs/javadoc` — This directory contains javadocs for the gNet extension (gphdfs protocol). The jar files for the gNet extension are installed in the `$GPHOME/lib/hadoop` directory.
- `etc` — Sample configuration file for OpenSSL and a sample configuration file to be used with the `gpcheck` management utility.
- `ext` — Bundled programs (such as Python) used by some Greenplum Database utilities.
- `include` — The C header files for Greenplum Database.
- `lib` — Greenplum Database and PostgreSQL library files.
- `sbin` — Supporting/Internal scripts and programs.
- `share` — Shared files for Greenplum Database.
**Installing and Configuring Greenplum on all Hosts**

When run as root, `gpseginstall` copies the Greenplum Database installation from the current host and installs it on a list of specified hosts, creates the Greenplum operating system user account (typically named `gpadmin`), sets the account password (default is `changeme`), sets the ownership of the Greenplum Database installation directory, and exchanges ssh keys between all specified host address names (both as root and as the specified user account).

**Note:** If you are setting up a single node system, you can still use `gpseginstall` to perform the required system configuration tasks on the current host. In this case, the `hostfile_exkeys` should have only the current host name.

### To install and configure Greenplum Database on all specified hosts

1. Log in to the master host as `root`:
   ```bash
   $ su -
   ```

2. Source the path file from your master host's Greenplum Database installation directory:
   ```bash
   # source /usr/local/greenplum-db/greenplum_path.sh
   ```

3. Create a file called `hostfile_exkeys` that has the machine configured host names and host addresses (interface names) for each host in your Greenplum system (master, standby master and segments). Make sure there are no blank lines or extra spaces. For example, if you have a master, standby master and three segments with two unbonded network interfaces per host, your file would look something like this:

   ```plaintext
   mdw
   mdw-1
   mdw-2
   smdw
   smdw-1
   smdw-2
   sdw1
   sdw1-1
   sdw1-2
   sdw2
   sdw2-1
   sdw2-2
   sdw3
   sdw3-1
   sdw3-2
   ```

   Check the `/etc/hosts` file on your systems for the correct host names to use for your environment.

   The Greenplum Database segment host naming convention is `sdwN` where `sdw` is a prefix and `N` is an integer. For example, segment host names would be `sdw1`, `sdw2` and so on. NIC bonding is recommended for hosts with multiple interfaces, but when the interfaces are not bonded, the convention is to append a dash (`-`) and number to the host name. For example, `sdw1-1` and `sdw1-2` are the two interface names for host `sdw1`.

4. Run the `gpseginstall` utility referencing the `hostfile_exkeys` file you just created. This example runs the utility as root. The utility creates the Greenplum operating system user account `gpadmin` as a system account on all hosts and sets the account password to `changeme` for that user on all segment hosts.

   ```bash
   # gpseginstall -f hostfile_exkeys
   ```
Use the `-u` and `-p` options to specify a different operating system account name and password. See `gpseginstall` for option information and running the utility as a non-root user.

Recommended security best practices:

- Do not use the default password option for production environments.
- Change the password immediately after installation.

### Confirming Your Installation

To make sure the Greenplum software was installed and configured correctly, run the following confirmation steps from your Greenplum master host. If necessary, correct any problems before continuing on to the next task.

1. Log in to the master host as `gpadmin`:
   ```
   $ su - gpadmin
   ```

2. Source the path file from Greenplum Database installation directory:
   ```
   # source /usr/local/greenplum-db/greenplum_path.sh
   ```

3. Use the `gpssh` utility to see if you can login to all hosts without a password prompt, and to confirm that the Greenplum software was installed on all hosts. Use the `hostfile_exkeys` file you used for installation. For example:
   ```
   $ gpssh -f hostfile_exkeys -e ls -l $GPHOME
   ```

   If the installation was successful, you should be able to log in to all hosts without a password prompt. All hosts should show that they have the same contents in their installation directories, and that the directories are owned by the `gpadmin` user.

   If you are prompted for a password, run the following command to redo the ssh key exchange:
   ```
   $ gpssh-exkeys -f hostfile_exkeys
   ```

### Installing Oracle Compatibility Functions

_optional_. Many Oracle Compatibility SQL functions are available in Greenplum Database. These functions target PostgreSQL.

Before using any Oracle Compatibility Functions, you need to run the installation script `$GPHOME/share/postgresql/contrib/orafunc.sql` once for each database. For example, to install the functions in `database testdb`, use the command

```
$ psql -d testdb -f $GPHOME/share/postgresql/contrib/orafunc.sql
```

To uninstall Oracle Compatibility Functions, use the script:

```
$GPHOME/share/postgresql/contrib/uninstall_orafunc.sql
```

**Note:** The following functions are available by default and can be accessed without running the Oracle Compatibility installer: `sinh, tanh, cosh` and `decode`.

For more information about Greenplum's Oracle compatibility functions, see "Oracle Compatibility Functions" in the *Greenplum Database Utility Guide*. 
Installing Optional Modules

dblink

The PostgreSQL dblink module provides simple connections to other Greenplum Database databases from installations with the same major version number residing either on the same database host, or on a remote host. Greenplum Database provides dblink support for database users to perform short ad hoc queries in other databases. It is not intended as a replacement for external tables or administrative tools such as gptransfer.

Before you can use dblink functions, run the installation script $GPHOME/share/postgresql/contrib/dblink.sql in each database where you want the ability to query other databases:

```
$ psql -d testdb -f $GPHOME/share/postgresql/contrib/dblink.sql
```

See dblink Functions for basic information about using dblink to query other databases. See dblink in the PostgreSQL documentation for more information about individual functions.

pgcrypto

Greenplum Database is installed with an optional module of encryption/decryption functions called pgcrypto. The pgcrypto functions allow database administrators to store certain columns of data in encrypted form. This adds an extra layer of protection for sensitive data, as data stored in Greenplum Database in encrypted form cannot be read by anyone who does not have the encryption key, nor can it be read directly from the disks.

Note: The pgcrypto functions run inside the database server, which means that all the data and passwords move between pgcrypto and the client application in clear-text. For optimal security, consider also using SSL connections between the client and the Greenplum master server.

Before you can use pgcrypto functions, run the installation script $GPHOME/share/postgresql/contrib/pgcrypto.sql in each database where you want the ability to query other databases:

```
$ psql -d testdb -f $GPHOME/share/postgresql/contrib/pgcrypto.sql
```

See pgcrypto in the PostgreSQL documentation for more information about individual functions.

Installing Greenplum Database Extensions

Optional. Use the Greenplum package manager (gppkg) to install Greenplum Database extensions such as PL/Java, PL/R, PostGIS, and MADlib, along with their dependencies, across an entire cluster. The package manager also integrates with existing scripts so that any packages are automatically installed on any new hosts introduced into the system following cluster expansion or segment host recovery.

See gppkg for more information, including usage.

Extension packages can be downloaded from the Greenplum Database page on Pivotal Network. The extension documentation in the Greenplum Database Reference Guide contains information about installing extension packages and using extensions.

- Greenplum PL/R Language Extension
- Greenplum PL/Java Language Extension
- Greenplum MADlib Extension for Analytics
- Greenplum PostGIS Extension

Important: If you intend to use an extension package with Greenplum Database 5.0.0 you must install and use a Greenplum Database extension package (gppkg files and contrib modules) that is
built for Greenplum Database 5.0.0. Any custom modules that were used with earlier versions must be rebuilt for use with Greenplum Database 5.0.0.

**Installing and Configuring the Greenplum Platform Extension Framework (PXF)**

*Optional.* If you do not plan to use PXF, no action is necessary.

If you plan to use PXF, refer to *Installing and Configuring PXF* for instructions.

**Creating the Data Storage Areas**

Every Greenplum Database master and segment instance has a designated storage area on disk that is called the *data directory* location. This is the file system location where the directories that store segment instance data will be created. The master host needs a data storage location for the master data directory. Each segment host needs a data directory storage location for its primary segments, and another for its mirror segments.

**Creating a Data Storage Area on the Master Host**

A data storage area is required on the Greenplum Database master host to store Greenplum Database system data such as catalog data and other system metadata.

To create the data directory location on the master:

The data directory location on the master is different than those on the segments. The master does not store any user data, only the system catalog tables and system metadata are stored on the master instance, therefore you do not need to designate as much storage space as on the segments.

1. Create or choose a directory that will serve as your master data storage area. This directory should have sufficient disk space for your data and be owned by the `gpadmin` user and group. For example, run the following commands as `root`:

   ```bash
   # mkdir /data/master
   # chown gpadmin /data/master
   # gpssh -h smdw -e 'mkdir /data/master'
   # gpssh -h smdw -e 'chown gpadmin /data/master'
   ```

**Creating Data Storage Areas on Segment Hosts**

Data storage areas are required on the Greenplum Database segment hosts for primary segments. Separate storage areas are required for mirror segments.

To create the data directory locations on all segment hosts:

1. On the master host, log in as `root`:

   ```bash
   # su
   ```
2. Create a file called `hostfile_gpssh_segonly`. This file should have only one machine configured host name for each segment host. For example, if you have three segment hosts:

```
sdw1
sdw2
sdw3
```

3. Using `gpssh`, create the primary and mirror data directory locations on all segment hosts at once using the `hostfile_gpssh_segonly` file you just created. For example:

```
# source /usr/local/greenplum-db-5.0.x.x/greenplum_path.sh
# gpssh -f hostfile_gpssh_segonly -e 'mkdir /data/primary'
# gpssh -f hostfile_gpssh_segonly -e 'mkdir /data/mirror'
# gpssh -f hostfile_gpssh_segonly -e 'chown gpadmin /data/primary'
# gpssh -f hostfile_gpssh_segonly -e 'chown gpadmin /data/mirror'
```

---

**Synchronizing System Clocks**

You should use NTP (Network Time Protocol) to synchronize the system clocks on all hosts that comprise your Greenplum Database system. See [www.ntp.org](http://www.ntp.org) for more information about NTP.

NTP on the segment hosts should be configured to use the master host as the primary time source, and the standby master as the secondary time source. On the master and standby master hosts, configure NTP to point to your preferred time server.

**To configure NTP**

1. On the master host, log in as root and edit the `/etc/ntp.conf` file. Set the `server` parameter to point to your data center's NTP time server. For example (if 10.6.220.20 was the IP address of your data center's NTP server):

```
server 10.6.220.20
```

2. On each segment host, log in as root and edit the `/etc/ntp.conf` file. Set the first `server` parameter to point to the master host, and the second `server` parameter to point to the standby master host. For example:

```
server mdw prefer
server smdw
```

3. On the standby master host, log in as root and edit the `/etc/ntp.conf` file. Set the first `server` parameter to point to the primary master host, and the second `server` parameter to point to your data center's NTP time server. For example:

```
server mdw prefer
server 10.6.220.20
```

4. On the master host, use the NTP daemon synchronize the system clocks on all Greenplum hosts. For example, using `gpssh`:

```
# gpssh -f hostfile_gpssh_allhosts -v -e 'ntpd'
```

---

**Enabling iptables**

On Linux systems, you can configure and enable the `iptables` firewall to work with Greenplum Database.
**Note:** Greenplum Database performance might be impacted when `iptables` is enabled. You should test the performance of your application with `iptables` enabled to ensure that performance is acceptable.

For more information about `iptables` see the `iptables` and firewall documentation for your operating system.

**How to Enable `iptables`**

1. As `gpadmin`, the Greenplum Database administrator, run this command on the Greenplum Database master host to stop Greenplum Database:
   
   ```
   $ gpstop -a
   ```

2. On the Greenplum Database hosts:
   a. Update the file `/etc/sysconfig/iptables` based on the *Example iptables Rules*.
   b. As root user, run these commands to enable `iptables`:
      
      ```
      # chkconfig iptables on
      # service iptables start
      ```

3. As `gpadmin`, run this command on the Greenplum Database master host to start Greenplum Database:
   
   ```
   $ gpstart -a
   ```

   **Warning:** After enabling `iptables`, this error in the `/var/log/messages` file indicates that the setting for the `iptables` table is too low and needs to be increased.

   ```
   ip_conntrack: table full, dropping packet.
   ```

   As root user, run this command to view the `iptables` table value:
   
   ```
   # sysctl net.ipv4.netfilter.ip_conntrack_max
   ```

   The following is the recommended setting to ensure that the Greenplum Database workload does not overflow the `iptables` table. The value might need to be adjusted for your hosts:

   ```
   net.ipv4.netfilter.ip_conntrack_max=6553600
   ```

   You can update `/etc/sysctl.conf` file with the value. For setting values in the file, see *Setting the Greenplum Recommended OS Parameters*.

   To set the value until the next reboots run this command as root.

   ```
   # sysctl net.ipv4.netfilter.ip_conntrack_max=6553600
   ```

**Example iptables Rules**

When `iptables` is enabled, `iptables` manages the IP communication on the host system based on configuration settings (rules). The example rules are used to configure `iptables` for Greenplum Database master host, standby master host, and segment hosts.

- *Example Master and Standby Master iptables Rules*
- *Example Segment Host iptables Rules*

The two sets of rules account for the different types of communication Greenplum Database expects on the master (primary and standby) and segment hosts. The rules should be added to the `/etc/sysconfig/iptables` file of the Greenplum Database hosts. For Greenplum Database, `iptables` rules should allow the following communication:
• For customer facing communication with the Greenplum Database master, allow at least `postgres` and `28080` (eth1 interface in the example).
• For Greenplum Database system interconnect, allow communication using `tcp`, `udp`, and `icmp` protocols (eth4 and eth5 interfaces in the example).

The network interfaces that you specify in the `iptables` settings are the interfaces for the Greenplum Database hosts that you list in the `hostfile_gpinitsystem` file. You specify the file when you run the `gpinitssystem` command to initialize a Greenplum Database system. See Initializing a Greenplum Database System for information about the `hostfile_gpinitsystem` file and the `gpinitssystem` command.
• For the administration network on a Greenplum DCA, allow communication using `ssh`, `snmp`, `ntp`, and `icmp` protocols. (eth0 interface in the example).

In the `iptables` file, each append rule command (lines starting with `-A`) is a single line.

The example rules should be adjusted for your configuration. For example:
• The append command, the `-A` lines and connection parameter `-i` should match the connectors for your hosts.
• the CIDR network mask information for the source parameter `-s` should match the IP addresses for your network.

**Example Master and Standby Master iptables Rules**

Example `iptables` rules with comments for the `/etc/sysconfig/iptables` file on the Greenplum Database master host and standby master host.

```
*filter
# Following 3 are default rules. If the packet passes through
# the rule set it gets these rule.
# Drop all inbound packets by default.
# Drop all forwarded (routed) packets.
# Let anything outbound go through.
:INPUT DROP [0:0]
:FORWARD DROP [0:0]
:OUTPUT ACCEPT [0:0]
# Accept anything on the loopback interface.
-A INPUT -i lo -j ACCEPT
# If a connection has already been established allow the
# remote host packets for the connection to pass through.
-A INPUT -m state --state ESTABLISHED,RELATED -j ACCEPT
# These rules let all tcp and udp through on the standard
# interconnect IP addresses and on the interconnect interfaces.
# NOTE: gpsyncmaster uses random tcp ports in the range 1025 to 65535
# and Greenplum Database uses random udp ports in the range 1025 to 65535.
-A INPUT -i eth4 -p udp -s 192.0.2.0/22 -j ACCEPT
-A INPUT -i eth5 -p udp -s 198.51.100.0/22 -j ACCEPT
-A INPUT -i eth4 -p tcp -s 192.0.2.0/22 -j ACCEPT --syn -m state --state NEW
-A INPUT -i eth5 -p tcp -s 198.51.100.0/22 -j ACCEPT --syn -m state --state NEW
# Allow snmp connections on the admin network on Greenplum DCA.
-A INPUT -i eth0 -p udp --dport snmp -s 203.0.113.0/21 -j ACCEPT
-A INPUT -i eth0 -p tcp --dport snmp -s 203.0.113.0/21 -j ACCEPT --syn -m state --state NEW
# Allow udp/tcp ntp connections on the admin network on Greenplum DCA.
-A INPUT -i eth0 -p udp --dport ntp -s 203.0.113.0/21 -j ACCEPT
-A INPUT -i eth0 -p tcp --dport ntp -s 203.0.113.0/21 -j ACCEPT --syn -m state --state NEW
# Allow ssh on all networks (This rule can be more strict).
-A INPUT -p tcp --dport ssh -j ACCEPT --syn -m state --state NEW
# Allow Greenplum Database on all networks.
-A INPUT -p tcp --dport postgres -j ACCEPT --syn -m state --state NEW
```
# Allow Greenplum Command Center on the customer facing network.
-A INPUT -i eth1 -p tcp --dport 28080 -j ACCEPT --syn --m state --state NEW

# Allow ping and any other icmp traffic on the interconnect networks.
-A INPUT -i eth4 -p icmp -s 192.0.2.0/22 -j ACCEPT
-A INPUT -i eth5 -p icmp -s 198.51.100.0/22 -j ACCEPT

# Allow ping only on the admin network on Greenplum DCA.
-A INPUT -i eth0 -p icmp --icmp-type echo-request -s 203.0.113.0/21 -j ACCEPT

# Log an error if a packet passes through the rules to the default INPUT rule (a DROP).
-A INPUT -m limit --limit 5/min -j LOG --log-prefix "iptables denied: " --log-level 7

COMMIT

Example Segment Host iptables Rules

Example iptables rules for the /etc/sysconfig/iptables file on the Greenplum Database segment hosts. The rules for segment hosts are similar to the master rules with fewer interfaces and fewer udp and tcp services.

*filter
:INPUT DROP
:FORWARD DROP
:OUTPUT ACCEPT
-A INPUT -i lo -j ACCEPT
-A INPUT -m state --state ESTABLISHED,RELATED -j ACCEPT
-A INPUT -i eth2 -p udp -s 192.0.2.0/22 -j ACCEPT
-A INPUT -i eth3 -p udp -s 198.51.100.0/22 -j ACCEPT
-A INPUT -i eth2 -p tcp -s 192.0.2.0/22 -j ACCEPT --syn --m state --state NEW
-A INPUT -i eth3 -p tcp -s 198.51.100.0/22 -j ACCEPT --syn --m state --state NEW
-A INPUT -i eth0 -p udp --dport snmp -s 203.0.113.0/21 -j ACCEPT
-A INPUT -i eth0 -p tcp --dport snmp -j ACCEPT --syn --m state --state NEW
-A INPUT -p tcp --dport ssh -j ACCEPT --syn --m state --state NEW
-A INPUT -i eth2 -p icmp -s 192.0.2.0/22 -j ACCEPT
-A INPUT -i eth3 -p icmp -s 198.51.100.0/22 -j ACCEPT
-A INPUT -i eth0 -p icmp --icmp-type echo-request -s 203.0.113.0/21 -j ACCEPT
-A INPUT -m limit --limit 5/min -j LOG --log-prefix "iptables denied: " --log-level 7

COMMIT

Amazon EC2 Configuration (Amazon Web Services)

You can install and configure Greenplum Database on virtual servers provided by the Amazon Elastic Compute Cloud (Amazon EC2) web service. Amazon EC2 is a service provided by Amazon Web Services (AWS). The following overview information describes how to install Greenplum Database in an Amazon EC2 environment.

About Amazon EC2

You can use Amazon EC2 to launch as many virtual servers as you need, configure security and networking, and manage storage. An EC2 instance is a virtual server in the AWS cloud virtual computing environment.

EC2 instances are manged by AWS. AWS isolates your EC2 instances from other users in a virtual private cloud (VPC) and lets you control access to the instances. You can configure instance features such as operating system, network connectivity (network ports and protocols, IP address access), access to the to the Internet, and size and type of disk storage.
When you launch an instance, you use a preconfigured template for your instance, known as an Amazon Machine Image (AMI). The AMI packages the bits you need for your server (including the operating system and additional software). You can use images supplied by Amazon or use customized images. You launch instances in an Availability Zone of an AWS region. An Availability Zone is a distinct location within a region that are engineered to be insulated from failures in other Availability Zones.


### Launching EC2 Instances with the EC2 Console

You can launch instances, configure, start, stop, and terminate (delete) virtual servers, with the Amazon EC2 Console. When you launch instances, you select these features.

**Amazon Machine Image (AMI)**

An AMI is a template that contains the software configuration (operating system, application server, and applications).

**For Greenplum Database** - Select an AMI that runs a supported operating system. See the [Greenplum Database Release Notes](http://docs.aws.amazon.com/AWSEC2/latest/UserGuide/concepts.html) for the release that you are installing.


**EC2 Instance Type**

A predefined set performance characteristics. Instance types comprise varying combinations of CPU, memory, default storage, and networking capacity. You can modify storage options when you add storage.

**For Greenplum Database** - The instance type must be an EBS-Optimized instance type when using Amazon EBS storage for Greenplum Database. See Configure storage for information about Greenplum Database storage requirements. For information about EBS-Optimized instances, see the Amazon documentation about EBS-Optimized instances. For sufficient network performance, the instance type must also support EC2 enhanced networking. For information about EC2 enhanced networking, see the Amazon documentation about [Enhanced Networking on Linux Instances](http://docs.aws.amazon.com/AWSEC2/latest/UserGuide/instance-types.html).

The instances should be in a single VPC and subnet. Instances are always assigned a VPC internal IP address and can be assigned a public IP address for external and Internet access.

The internal IP address is used for Greenplum Database communication between hosts. You can also use the internal IP address to access an instance from another instance within the EC2 VPC. For information about configuring launched instances to communicate with each other, see [Working with EC2 Instances](http://docs.aws.amazon.com/AWSEC2/latest/UserGuide/working-with-instances.html).

A public IP address for the instance and an Internet gateway configured for the EC2 VPC are required for accessing the instance from an external source and for the instance to access the Internet. Internet access is required when installing Linux packages. When you launch a set of instances, you can enable or disable the automatic assignment of public IP addresses when the instances are started.

If automatic assignment of public IP addresses is enabled, instances are always assigned a public IP address when the instance starts. If automatic assignment of public IP addresses is disabled, you can associate a public IP address with the EC2 elastic IP, and temporarily associate public IP addresses to an instance to connect and configure the instance.

To control whether a public IP is assigned when launching an instance, see the Amazon documentation about [Subnet Public IP Addressing](http://docs.aws.amazon.com/AWSEC2/latest/UserGuide/using-elastic-ip-associate.html).

**EC2 Instance Details**
Information about starting, running, and stopping EC2 instances, such as number of instances of the same AMI, network information, and EC2 VPC and subnet membership.

Configure storage
Adjust and add storage. For example, you can change the size of root volume and add volumes.

For Greenplum Database - Greenplum Database supports either EC2 instance store or Amazon EBS storage in a production environment.

- EC2 instance store provides temporary block-level storage. This storage is located on disks that are physically attached to the host computer. With instance store, powering off the instance causes data loss. Soft reboots preserve instance store data. However, EC2 instance store can provide higher and more consistent I/O performance.

- EBS storage provides block level storage volumes with long-term persistence. EBS storage must be mounted with the XFS file system for it to be a supported configuration. All other file systems are explicitly not supported by Pivotal.

There are several classes of EBS. For Greenplum Database, select the EBS volume type gp2 for root and swap partitions and st1 for data. See the Amazon documentation about Block Device Mapping.

For more information about the Amazon storage types, see Notes.

Create Tag
An optional label that consists of a case-sensitive key-value pair that is used for organizing searching a large number of EC2 resources.

Security Group
A set of firewall rules that control the network traffic for instances.

For external access to an instance with ssh, create a rule that enables ssh for inbound network traffic.

Working with EC2 Instances
After the EC2 instances have started, you connect to and configure the instances. The Instances page of the EC2 Console lists the running instances and network information. If the instance does not have a public IP address, you can create an Elastic IP and associate it with the instance. See About Amazon Elastic IP Addresses.

To access EC2 instances, AWS uses public-key cryptography to secure the login information for your instance. A Linux instance has no password; you use a key pair to log in to your instance securely. You specify the name of the key pair when you launch your instance, then provide the private key when you log in using SSH. See the Amazon documentation about EC2 Key Pairs.

A key pair consists of a public key that AWS stores, and a private key file that you store. Together, they allow you to connect to your instance securely.

This example logs into an into EC2 instance from an external location with the private key file my-test.pem and user ec2-user. The user ec2-user is the default user for some Linux AMI templates. This example assumes that the instance is configured with a public IP address 192.0.2.82 and that the pem file is the private key file that is used to access the instance.

```
ssh -i my-test.pem ec2-user@192.0.2.82
```

You can also copy the private key file to your home .ssh directory as the id_rsa file. This example, creates and configures the id_rsa file.

```
cp my-test.pem ~/.ssh/id_rsa
chmod 400 .ssh/id_rsa
```
You can also copy the `id_rsa` to your EC2 instances. This `scp` command copies the file to the `.ssh` directory of the `ec2-user`.

```
scp ~/.ssh/id_rsa ec2-user@192.0.2.86:~/.ssh/id_rsa
```

**Note:** `gpssh-exkeys` is not used with Greenplum Database hosts that are EC2 instances. You must copy the private key file to the `.ssh` directory in the user home directory for each instance.

This example logs into an EC2 instance using the `id_rsa` file.

```
ssh ec2-user@192.0.2.82
```

After the key file is installed on all Greenplum Database hosts you can use Greenplum Database utilities such as `gpseginstall`, `gpssh`, and `gpscp` that access multiple Greenplum Database hosts.

Before installing Greenplum Database, you configure the EC2 instances as you would a local host server machines. Configure the host operating system, configure host network information (for example, update the `/etc/hosts` file), set operating system parameters, and install operating system packages. For information about how to prepare your operating system environment for Greenplum Database, see *Configuring Your Systems and Installing Greenplum*.

These example commands use yum to install the Linux packages `zlib`, `sed`, `unzip`, and `vim`.

```
sudo yum install -y zlib
sudo yum install -y sed
sudo yum install -y unzip
sudo yum install -y vim
```

This example uploads Greenplum Database install file to an EC2 instance to the `ec2-user` home directory.

```
scp greenplum-db-5.0.0-build-1-RHEL6-x86_64.zip ec2-user@192.0.2.82:~/.
```

These example commands log into the instance and run the Greenplum Database install file that is in `ec2-user` home directory as the as `ec2-user`.

```
ssh ec2-user@192.0.2.82
unzip greenplum-db-5.0.0-build-1-RHEL6-x86_64.zip
./greenplum-db-5.0.0-build-1-RHEL6-x86_64.bin
```

This example command runs the `gpseginstall` utility that specifies the user as `ec2-user`. This example assumes the file `my-hosts` contains the instances that are used as Greenplum Database segment hosts and that the instances have been prepared for Greenplum Database.

```
gpseginstall -u ec2-user -f my-hosts
```

**Note:** During the Greenplum Database installation process, you might see `ssh` messages to confirm the authenticity of host connections. Enter `yes` to confirm the authenticity.

### About Amazon Machine Image (AMI)

An Amazon Machine Image (AMI) is a template that contains a software configuration (for example, an operating system, an application server, and applications). From an AMI, you launch an *instance*, which is a copy of the AMI running as a virtual server in the cloud. You can launch multiple instances of an AMI.

After you launch an instance, it acts like a traditional host, and you can interact with it as you would any computer. You have complete control of your instances; you can use `sudo` to run commands that require root privileges.
You can create a customized Amazon EBS-backed Linux AMI from an instance that you've launched from an existing Amazon EBS-backed Linux AMI. After you've customized the instance to suit your needs, create and register a new AMI, which you can use to launch new instances with these customizations.

For information about AMI, see the Amazon documentation about AMIs.

### About Amazon Elastic IP Addresses

An EC2 Elastic IP address is a public IP address that you can allocate (create) for your account. You can associate it to and disassociate it from instances as you require, and it's allocated to your account until you choose to release it.

Your default VPC is configured with an Internet gateway. When you allocate an EC2 Elastic IP address, AWS configures the VPC to allow internet access to the IP address using the gateway.

To enable an instance in your VPC to communicate with the Internet, it must have a public IP address or an EC2 Elastic IP address that's associated with a private IP address on your instance.

To ensure that your instances can communicate with the Internet, you must also attach an Internet gateway to your EC2 VPC. For information about VPC Internet Gateways, see the Amazon documentation about Internet gateways.

For information about EC2 Elastic IP addresses and how to use them, see see the Amazon documentation about Elastic IP Addresses.

### Notes

- The Greenplum Database utility `gpssh-exkeys` is not used with Greenplum Database hosts that are EC2 instances. You must copy the private key file to the `.ssh` directory in the user home directory for each instance.
- When you use Amazon EBS storage for Greenplum Database storage, the storage must be mounted with the XFS file system for it to be a supported configuration.

For information about EBS storage, see the Amazon documentation about Amazon EBS. Also, see the Amazon EC2 documentation for configuring the Amazon EBS volumes and managing storage and file systems used with EC2 instances.

- For an EC2 instance with instance store, the virtual devices for instance store volumes are `ephemeralN` (n is between 0 and 23). On an instance running CentOS the instance store block device names appear as `/dev/xvdletter`. A RAID0 configuration is recommended with ephemeral disks because there are more disks than segments on each host.

An example of an EC2 instance type that is configured with instance store and that showed acceptable performance is the `d2.8xlarge` instance type configured with four `raid0` volumes of 6 disks each.

For information about EC2 instance store, see the Amazon documentation about EC2 Instance Store.

- These are default ports in a Greenplum Database environment. These ports need to be open in the security group to allow access from a source external to a VPC.

<table>
<thead>
<tr>
<th>Port</th>
<th>Used by this application</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>ssh - connect to host with ssh</td>
</tr>
<tr>
<td>5432</td>
<td>Greenplum Database (master)</td>
</tr>
<tr>
<td>28080</td>
<td>Greenplum Command Center</td>
</tr>
</tbody>
</table>

- For a non-default VPC you can configure the VPC with an internet gateway for the VPC and allocate Elastic IP address for the VPC. AWS will automatically configure the Elastic IP for internet access. For information about EC2 internet gateways, see the Amazon documentation about Internet Gateways.

- A **placement group** is a logical grouping of instances within a single Availability Zone. Using placement groups enables applications to participate in a low-latency, 10 Gbps network. Placement groups are recommended for applications that benefit from low network latency, high network throughput, or both.
Placement Groups provide the ability for EC2 instances to be separated from other instances. However, configuring instances in different placement groups can improve performance but might create a configuration where an instance in a placement group cannot be replaced.

See the Amazon documentation about Placement Groups.

- Amazon EC2 provides enhanced networking capabilities using single root I/O virtualization (SR-IOV) on some instance types. Enabling enhanced networking on your instance results in higher performance (packets per second), lower latency, and lower jitter.

To enable enhanced networking on your Red Hat and CentOS RHEL/CentOS instance, you must ensure that the kernel has the ixgbevf module version 2.14.2 or higher is installed and that the sriovNetSupport attribute is set.

For information about EC2 enhanced networking, see the Amazon documentation about Enhanced Networking on Linux Instances.

**References**

References to AWS and EC2 features and related information.

- AWS - https://aws.amazon.com/
- Amazon S3 (secure, durable, scalable object storage) - https://aws.amazon.com/s3/.

With AWS CloudFormation, you can create templates to simplify provisioning and management of related AWS resources.

**Next Steps**

After you have configured the operating system environment and installed the Greenplum Database software on all of the hosts in the system, the next steps are:

- Validating Your Systems
- Initializing a Greenplum Database System
Installing the Data Science Packages

Information about installing the Greenplum Database Python and R Data Science Packages.

Python Data Science Module Package

Greenplum Database provides a collection of data science-related Python modules that can be used with the Greenplum Database PL/Python language. You can download these modules in .gppkg format from Pivotal Network.

This section contains the following information:

- Python Data Science Modules
- Installing the Python Data Science Module Package
- Uninstalling the Python Data Science Module Package

For information about the Greenplum Database PL/Python Language, see Greenplum PL/Python Language Extension.

Python Data Science Modules

Modules provided in the Python Data Science package include:

Table 12: Data Science Modules

<table>
<thead>
<tr>
<th>Module Name</th>
<th>Description/Used For</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beautiful Soup</td>
<td>Navigating HTML and XML</td>
</tr>
<tr>
<td>Gensim</td>
<td>Topic modeling and document indexing</td>
</tr>
<tr>
<td>Keras (RHEL/CentOS 7 only)</td>
<td>Deep learning</td>
</tr>
<tr>
<td>Lifelines</td>
<td>Survival analysis</td>
</tr>
<tr>
<td>lxml</td>
<td>XML and HTML processing</td>
</tr>
<tr>
<td>NLTK</td>
<td>Natural language toolkit</td>
</tr>
<tr>
<td>NumPy</td>
<td>Scientific computing</td>
</tr>
<tr>
<td>Pandas</td>
<td>Data analysis</td>
</tr>
<tr>
<td>Pattern-en</td>
<td>Part-of-speech tagging</td>
</tr>
<tr>
<td>pyLDAvis</td>
<td>Interactive topic model visualization</td>
</tr>
<tr>
<td>PyMC3</td>
<td>Statistical modeling and probabilistic machine learning</td>
</tr>
<tr>
<td>scikit-learn</td>
<td>Machine learning data mining and analysis</td>
</tr>
<tr>
<td>SciPy</td>
<td>Scientific computing</td>
</tr>
<tr>
<td>spaCy</td>
<td>Large scale natural language processing</td>
</tr>
<tr>
<td>StatsModels</td>
<td>Statistical modeling</td>
</tr>
<tr>
<td>Tensorflow (RHEL/CentOS 7 only)</td>
<td>Numerical computation using data flow graphs</td>
</tr>
<tr>
<td>XGBoost</td>
<td>Gradient boosting, classifying, ranking</td>
</tr>
</tbody>
</table>
Installing the Python Data Science Module Package

Before you install the Python Data Science Module package, make sure that your Greenplum Database is running, you have sourced `greenplum_path.sh`, and that the `$MASTER_DATA_DIRECTORY` and `$GPHOME` environment variables are set.

**Note:** The PyMC3 module depends on Tk. If you want to use PyMC3, you must install the `tk` OS package on every node in your cluster. For example:

```bash
$ yum install tk
```

1. Locate the Python Data Science module package that you built or downloaded. The file name format of the package is `DataSciencePython-<version>-relhel<N>-x86_64.gppkg`.
2. Copy the package to the Greenplum Database master host.
3. Use the `gppkg` command to install the package. For example:

```bash
$ gppkg -i DataSciencePython-<version>-relhel<N>-x86_64.gppkg
```

`gppkg` installs the Python Data Science modules on all nodes in your Greenplum Database cluster. The command also updates the `PYTHONPATH`, `PATH`, and `LD_LIBRARY_PATH` environment variables in your `greenplum_path.sh` file.

4. Restart Greenplum Database. You must re-source `greenplum_path.sh` before restarting your Greenplum cluster:

```bash
$ source /usr/local/greenplum-db/greenplum_path.sh
$ gpstop -r
```

The Greenplum Database Python Data Science Modules are installed in the following directory:

```
$GPHOME/ext/DataSciencePython/lib/python2.7/site-packages/
```

Uninstalling the Python Data Science Module Package

Use the `gppkg` utility to uninstall the Python Data Science Module package. You must include the version number in the package name you provide to `gppkg`.

To determine your Python Data Science Module package version number and remove this package:

```bash
$ gppkg -q --all | grep DataSciencePython
DataSciencePython-<version>
$ gppkg -r DataSciencePython-<version>
```

The command removes the Python Data Science modules from your Greenplum Database cluster. It also updates the `PYTHONPATH`, `PATH`, and `LD_LIBRARY_PATH` environment variables in your `greenplum_path.sh` file to their pre-installation values.

Re-source `greenplum_path.sh` and restart Greenplum Database after you remove the Python Data Science Module package:

```bash
$ . /usr/local/greenplum-db/greenplum_path.sh
$ gpstop -r
```

**Note:** When you uninstall the Python Data Science Module package from your Greenplum Database cluster, any UDFs that you have created that import Python modules installed with this package will return an error.
**R Data Science Library Package**

R packages are modules that contain R functions and data sets. Greenplum Database provides a collection of data science-related R libraries that can be used with the Greenplum Database PL/R language. You can download these libraries in .gppkg format from Pivotal Network.

This chapter contains the following information:

- **R Data Science Libraries**
- **Installing the R Data Science Library Package**
- **Uninstalling the R Data Science Library Package**

For information about the Greenplum Database PL/R Language, see [Greenplum PL/R Language Extension](#).

### R Data Science Libraries

Libraries provided in the R Data Science package include:

<table>
<thead>
<tr>
<th>abind</th>
<th>glmnet</th>
<th>quantreg</th>
</tr>
</thead>
<tbody>
<tr>
<td>adabag</td>
<td>gplots</td>
<td>R2jags</td>
</tr>
<tr>
<td>arm</td>
<td>gtable</td>
<td>R6</td>
</tr>
<tr>
<td>assertthat</td>
<td>gtools</td>
<td>randomForest</td>
</tr>
<tr>
<td>BH</td>
<td>hms</td>
<td>RColorBrewer</td>
</tr>
<tr>
<td>bitops</td>
<td>hybridHclust</td>
<td>Rcpp</td>
</tr>
<tr>
<td>car</td>
<td>igraph</td>
<td>RcppEigen</td>
</tr>
<tr>
<td>caret</td>
<td>labeling</td>
<td>readr</td>
</tr>
<tr>
<td>caTools</td>
<td>lattice</td>
<td>reshape2</td>
</tr>
<tr>
<td>coda</td>
<td>lazyeval</td>
<td>rjags</td>
</tr>
<tr>
<td>colorspace</td>
<td>lme4</td>
<td>RobustRankAggreg</td>
</tr>
<tr>
<td>compHclust</td>
<td>lmtest</td>
<td>ROCR</td>
</tr>
<tr>
<td>curl</td>
<td>magrittr</td>
<td>rpart</td>
</tr>
<tr>
<td>data.table</td>
<td>MASS</td>
<td>RPostgreSQL</td>
</tr>
<tr>
<td>DBI</td>
<td>Matrix</td>
<td>sandwich</td>
</tr>
<tr>
<td>dichromat</td>
<td>MCMCPack</td>
<td>scales</td>
</tr>
<tr>
<td>digest</td>
<td>minqa</td>
<td>SparseM</td>
</tr>
<tr>
<td>dplyr</td>
<td>MTS</td>
<td>stringi</td>
</tr>
<tr>
<td>e1071</td>
<td>munsell</td>
<td>stringr</td>
</tr>
<tr>
<td>flashClust</td>
<td>neuralnet</td>
<td>survival</td>
</tr>
<tr>
<td>forecast</td>
<td>nloptr</td>
<td>tibble</td>
</tr>
<tr>
<td>foreign</td>
<td>nnet</td>
<td>tseries</td>
</tr>
<tr>
<td>gdata</td>
<td>pbkrtest</td>
<td>zoo</td>
</tr>
<tr>
<td>ggplot2</td>
<td>plyn</td>
<td></td>
</tr>
</tbody>
</table>
Installing the R Data Science Library Package

Before you install the R Data Science Library package, make sure that your Greenplum Database is running, you have sourced `greenplum_path.sh`, and that the `$MASTER_DATA_DIRECTORY` and `$GPHOME` environment variables are set.

1. Locate the R Data Science library package that you built or downloaded.
   
   The file name format of the package is `DataScienceR-<version>-relhel<N>-x86_64.gppkg`.

2. Copy the package to the Greenplum Database master host.

3. Use the `gppkg` command to install the package. For example:

   ```
   $ gppkg -i DataScienceR-<version>-relhel<N>-x86_64.gppkg
   ```

   gppkg installs the R Data Science libraries on all nodes in your Greenplum Database cluster. The command also sets the `R_LIBS_USER` environment variable and updates the `PATH` and `LD_LIBRARY_PATH` environment variables in your `greenplum_path.sh` file.

4. Restart Greenplum Database. You must re-source `greenplum_path.sh` before restarting your Greenplum cluster:

   ```
   $ source /usr/local/greenplum-db/greenplum_path.sh
   $ gpstop -r
   ```

   The Greenplum Database R Data Science Modules are installed in the following directory:

   `$GPHOME/ext/DataScienceR/library`

   **Note:** `rjags` libraries are installed in the `$GPHOME/ext/DataScienceR/extlib/lib` directory. If you want to use `rjags` and your `$GPHOME` is not `/usr/local/greenplum-db`, you must perform additional configuration steps to create a symbolic link from `$GPHOME` to `/usr/local/greenplum-db` on each node in your Greenplum Database cluster. For example:

   ```
   $ gpssh -f all_hosts -e 'ln -s $GPHOME /usr/local/greenplum-db'
   $ gpssh -f all_hosts -e 'chown -h gpadmin /usr/local/greenplum-db'
   ```

Uninstalling the R Data Science Library Package

Use the `gppkg` utility to uninstall the R Data Science Library package. You must include the version number in the package name you provide to `gppkg`.

To determine your R Data Science Library package version number and remove this package:

```
$ gppkg -q --all | grep DataScienceR
DataScienceR-<version>
$ gppkg -r DataScienceR-<version>
```

The command removes the R Data Science libraries from your Greenplum Database cluster. It also removes the `R_LIBS_USER` environment variable and updates the `PATH` and `LD_LIBRARY_PATH` environment variables in your `greenplum_path.sh` file to their pre-installation values.

Re-source `greenplum_path.sh` and restart Greenplum Database after you remove the R Data Science Library package:

```
$ . /usr/local/greenplum-db/greenplum_path.sh
$ gpstop -r
```
**Note:** When you uninstall the R Data Science Library package from your Greenplum Database cluster, any UDFs that you have created that use R libraries installed with this package will return an error.
Validating Your Systems

Validate your operating system settings, hardware, and network.

Greenplum provides the following utilities to validate the configuration and performance of your systems:

- gpcheck
- gpcheckperf

These utilities can be found in $GPHOME/bin of your Greenplum installation.

The following tests should be run prior to initializing your Greenplum Database system.

Validating OS Settings

Greenplum provides a utility called gpcheck that can be used to verify that all hosts in your array have the recommended OS settings for running a production Greenplum Database system. To run gpcheck:

1. Log in on the master host as the gpadmin user.
2. Source the greenplum_path.sh path file from your Greenplum installation. For example:

   $ source /usr/local/greenplum-db/greenplum_path.sh

3. Create a file called hostfile_gpcheck that has the machine-configured host names of each Greenplum host (master, standby master and segments), one host name per line. Make sure there are no blank lines or extra spaces. This file should just have a single host name per host. For example:

   mdw
   smdw
   sdw1
   sdw2
   sdw3

4. Run the gpcheck utility using the host file you just created. For example:

   $ gpcheck -f hostfile_gpcheck -m mdw -s smdw

5. After gpcheck finishes verifying OS parameters on all hosts (masters and segments), you might be prompted to modify certain OS parameters before initializing your Greenplum Database system.

Validating Hardware Performance

Greenplum provides a management utility called gpcheckperf, which can be used to identify hardware and system-level issues on the machines in your Greenplum Database array. gpcheckperf starts a session on the specified hosts and runs the following performance tests:

- Network Performance (gpnetbench*)
- Disk I/O Performance (dd test)
- Memory Bandwidth (stream test)

Before using gpcheckperf, you must have a trusted host setup between the hosts involved in the performance test. You can use the utility gpssh-exkeys to update the known host files and exchange public keys between hosts if you have not done so already. Note that gpcheckperf calls to gpssh and gpscp, so these Greenplum utilities must be in your $PATH.

Validating Network Performance

To test network performance, run gpcheckperf with one of the network test run options: parallel pair test (-r N), serial pair test (-r n), or full matrix test (-r M). The utility runs a network benchmark program
that transfers a 5 second stream of data from the current host to each remote host included in the test. By default, the data is transferred in parallel to each remote host and the minimum, maximum, average and median network transfer rates are reported in megabytes (MB) per second. If the summary transfer rate is slower than expected (less than 100 MB/s), you can run the network test serially using the -r n option to obtain per-host results. To run a full-matrix bandwidth test, you can specify -r M which will cause every host to send and receive data from every other host specified. This test is best used to validate if the switch fabric can tolerate a full-matrix workload.

Most systems in a Greenplum Database array are configured with multiple network interface cards (NICs), each NIC on its own subnet. When testing network performance, it is important to test each subnet individually. For example, considering the following network configuration of two NICs per host:

<table>
<thead>
<tr>
<th>Greenplum Host</th>
<th>Subnet1 NICs</th>
<th>Subnet2 NICs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment 1</td>
<td>sdw1-1</td>
<td>sdw1-2</td>
</tr>
<tr>
<td>Segment 2</td>
<td>sdw2-1</td>
<td>sdw2-2</td>
</tr>
<tr>
<td>Segment 3</td>
<td>sdw3-1</td>
<td>sdw3-2</td>
</tr>
</tbody>
</table>

You would create four distinct host files for use with the `gpcheckperf` network test:

<table>
<thead>
<tr>
<th>hostfile_gpchecknet_ic1</th>
<th>hostfile_gpchecknet_ic2</th>
</tr>
</thead>
<tbody>
<tr>
<td>sdw1-1</td>
<td>sdw1-2</td>
</tr>
<tr>
<td>sdw2-1</td>
<td>sdw2-2</td>
</tr>
<tr>
<td>sdw3-1</td>
<td>sdw3-2</td>
</tr>
</tbody>
</table>

You would then run `gpcheckperf` once per subnet. For example (if testing an even number of hosts, run in parallel pairs test mode):

```sh
$ gpcheckperf -f hostfile_gpchecknet_ic1 -r N -d /tmp > subnet1.out
$ gpcheckperf -f hostfile_gpchecknet_ic2 -r N -d /tmp > subnet2.out
```

If you have an odd number of hosts to test, you can run in serial test mode (-r n).

### Validating Disk I/O and Memory Bandwidth

To test disk and memory bandwidth performance, run `gpcheckperf` with the disk and stream test run options (-r ds). The disk test uses the `dd` command (a standard UNIX utility) to test the sequential throughput performance of a logical disk or file system. The memory test uses the STREAM benchmark program to measure sustainable memory bandwidth. Results are reported in MB per second (MB/s).

#### To run the disk and stream tests

1. Log in on the master host as the `gpadmin` user.
2. Source the `greenplum_path.sh` path file from your Greenplum installation. For example:

   ```sh
   $ source /usr/local/greenplum-db/greenplum_path.sh
   ```

3. Create a host file named `hostfile_gpcheckperf` that has one host name per segment host. Do not include the master host. For example:

   ```sh
sdw1
   ```
4. Run the `gpcheckperf` utility using the `hostfile_gpcheckperf` file you just created. Use the `-d` option to specify the file systems you want to test on each host (you must have write access to these directories). You will want to test all primary and mirror segment data directory locations. For example:

```
$ gpcheckperf -f hostfile_gpcheckperf -r ds -D \\
   -d /data1/primary -d /data2/primary \\
   -d /data1/mirror -d /data2/mirror
```

5. The utility may take a while to perform the tests as it is copying very large files between the hosts. When it is finished you will see the summary results for the Disk Write, Disk Read, and Stream tests.
Configuring Timezone and Localization Settings

Describes the available timezone and localization features of Greenplum Database.

Configuring the Timezone

Greenplum Database selects a timezone to use from a set of internally stored PostgreSQL timezones. The available PostgreSQL timezones are taken from the Internet Assigned Numbers Authority (IANA) Time Zone Database, and Greenplum Database updates its list of available timezones as necessary when the IANA database changes for PostgreSQL.

Greenplum selects the timezone by matching a PostgreSQL timezone with the user specified time zone, or the host system time zone if no time zone is configured. For example, when selecting a default timezone, Greenplum uses an algorithm to select a PostgreSQL timezone based on the host system timezone files. If the system timezone includes leap second information, Greenplum Database cannot match the system timezone with a PostgreSQL timezone. In this case, Greenplum Database calculates a "best match" with a PostgreSQL timezone based on information from the host system.

As a best practice, configure the Greenplum Database and the host system to use a known, supported timezone. This prevents Greenplum Database from recalculating a "best match" timezone each time the cluster is restarted, using the current system timezone and Greenplum timezone files (which may have been updated from the IANA database since the last restart). Use the `gpconfig` utility to show and set the Greenplum Database timezone. For example, these commands show the Greenplum Database timezone and set the timezone to US/Pacific.

```
# gpconfig -s TimeZone
# gpconfig -c TimeZone 'US/Pacific'
```

You must restart Greenplum Database after changing the timezone. The command `gpstop -ra` restarts Greenplum Database. The catalog view `pg_timezone_names` provides Greenplum Database timezone information.

About Locale Support in Greenplum Database

Greenplum Database supports localization with two approaches:

- Using the locale features of the operating system to provide locale-specific collation order, number formatting, and so on.
- Providing a number of different character sets defined in the Greenplum Database server, including multiple-byte character sets, to support storing text in all kinds of languages, and providing character set translation between client and server.

Locale support refers to an application respecting cultural preferences regarding alphabets, sorting, number formatting, etc. Greenplum Database uses the standard ISO C and POSIX locale facilities provided by the server operating system. For additional information refer to the documentation of your operating system.

Locale support is automatically initialized when a Greenplum Database system is initialized. The initialization utility, `gpinitsystem`, will initialize the Greenplum array with the locale setting of its execution environment by default, so if your system is already set to use the locale that you want in your Greenplum Database system then there is nothing else you need to do.
When you are ready to initiate Greenplum Database and you want to use a different locale (or you are not sure which locale your system is set to), you can instruct `gpinitsystem` exactly which locale to use by specifying the `-n locale` option. For example:

```
$ gpinitsystem -c gp_init_config -n sv_SE
```

See *Initializing a Greenplum Database System* for information about the database initialization process.

The example above sets the locale to Swedish (sv) as spoken in Sweden (SE). Other possibilities might be `en_US` (U.S. English) and `fr_CA` (French Canadian). If more than one character set can be useful for a locale then the specifications look like this: `cs_CZ.ISO8859-2`. What locales are available under what names on your system depends on what was provided by the operating system vendor and what was installed. On most systems, the command `locale -a` will provide a list of available locales.

Occasionally it is useful to mix rules from several locales, for example use English collation rules but Spanish messages. To support that, a set of locale subcategories exist that control only a certain aspect of the localization rules:

- **LC_COLLATE** — String sort order
- **LC_CTYPE** — Character classification (What is a letter? Its upper-case equivalent?)
- **LC_MESSAGES** — Language of messages
- **LC_MONETARY** — Formatting of currency amounts
- **LC_NUMERIC** — Formatting of numbers
- **LC_TIME** — Formatting of dates and times

If you want the system to behave as if it had no locale support, use the special locale `C` or `POSIX`.

The nature of some locale categories is that their value has to be fixed for the lifetime of a Greenplum Database system. That is, once `gpinitsystem` has run, you cannot change them anymore. `LC_COLLATE` and `LC_CTYPE` are those categories. They affect the sort order of indexes, so they must be kept fixed, or indexes on text columns will become corrupt. Greenplum Database enforces this by recording the values of `LC_COLLATE` and `LC_CTYPE` that are seen by `gpinitsystem`. The server automatically adopts those two values based on the locale that was chosen at initialization time.

The other locale categories can be changed as desired whenever the server is running by setting the server configuration parameters that have the same name as the locale categories (see the *Greenplum Database Reference Guide* for more information on setting server configuration parameters). The defaults that are chosen by `gpinitsystem` are written into the master and segment `postgresql.conf` configuration files to serve as defaults when the Greenplum Database system is started. If you delete these assignments from the master and each segment `postgresql.conf` files then the server will inherit the settings from its execution environment.

Note that the locale behavior of the server is determined by the environment variables seen by the server, not by the environment of any client. Therefore, be careful to configure the correct locale settings on each Greenplum Database host (master and segments) before starting the system. A consequence of this is that if client and server are set up in different locales, messages may appear in different languages depending on where they originated.

Inheriting the locale from the execution environment means the following on most operating systems: For a given locale category, say the collation, the following environment variables are consulted in this order until one is found to be set: `LC_ALL`, `LC_COLLATE` (the variable corresponding to the respective category), `LANG`. If none of these environment variables are set then the locale defaults to `C`.

Some message localization libraries also look at the environment variable `LANGUAGE` which overrides all other locale settings for the purpose of setting the language of messages. If in doubt, please refer to the documentation for your operating system, in particular the documentation about `gettext`, for more information.

Native language support (NLS), which enables messages to be translated to the user's preferred language, is not enabled in Greenplum Database for languages other than English. This is independent of the other locale support.
Locale Behavior

The locale settings influence the following SQL features:

- Sort order in queries using `ORDER BY` on textual data
- The ability to use indexes with `LIKE` clauses
- The `upper`, `lower`, and `initcap` functions
- The `to_char` family of functions

The drawback of using locales other than `C` or `POSIX` in Greenplum Database is its performance impact. It slows character handling and prevents ordinary indexes from being used by `LIKE`. For this reason use locales only if you actually need them.

Troubleshooting Locales

If locale support does not work as expected, check that the locale support in your operating system is correctly configured. To check what locales are installed on your system, you may use the command `locale -a` if your operating system provides it.

Check that Greenplum Database is actually using the locale that you think it is. `LC_COLLATE` and `LC_CTYPE` settings are determined at initialization time and cannot be changed without redoing `gpinitsystem`. Other locale settings including `LC_MESSAGES` and `LC_MONETARY` are initially determined by the operating system environment of the master and/or segment host, but can be changed after initialization by editing the `postgresql.conf` file of each Greenplum master and segment instance. You can check the active locale settings of the master host using the `SHOW` command. Note that every host in your Greenplum Database array should be using identical locale settings.

Character Set Support

The character set support in Greenplum Database allows you to store text in a variety of character sets, including single-byte character sets such as the ISO 8859 series and multiple-byte character sets such as EUC (Extended Unix Code), UTF-8, and Mule internal code. All supported character sets can be used transparently by clients, but a few are not supported for use within the server (that is, as a server-side encoding). The default character set is selected while initializing your Greenplum Database array using `gpinitsystem`. It can be overridden when you create a database, so you can have multiple databases each with a different character set.

Table 15: Greenplum Database Character Sets

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Language</th>
<th>Server?</th>
<th>Bytes/Char</th>
<th>Aliases</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIG5</td>
<td>Big Five</td>
<td>Traditional Chinese</td>
<td>No</td>
<td>1-2</td>
<td>WIN950, Windows950</td>
</tr>
<tr>
<td>EUC_CN</td>
<td>Extended UNIX Code-CN</td>
<td>Simplified Chinese</td>
<td>Yes</td>
<td>1-3</td>
<td></td>
</tr>
</tbody>
</table>

1 Not all APIs support all the listed character sets. For example, the JDBC driver does not support `MULE_INTERNAL`, `LATIN6`, `LATIN8`, and `LATIN10`. 
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Language</th>
<th>Server?</th>
<th>Bytes/Char</th>
<th>Aliases</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUC_TW</td>
<td>Extended UNIX Code-TW</td>
<td>Traditional Chinese, Taiwanese</td>
<td>Yes</td>
<td>1-3</td>
<td></td>
</tr>
<tr>
<td>GB18030</td>
<td>National Standard</td>
<td>Chinese</td>
<td>No</td>
<td>1-2</td>
<td></td>
</tr>
<tr>
<td>GBK</td>
<td>Extended National Standard</td>
<td>Simplified Chinese</td>
<td>No</td>
<td>1-2</td>
<td>WIN936, Windows936</td>
</tr>
<tr>
<td>ISO_8859_5</td>
<td>ISO 8859-5, ECMA 113</td>
<td>Latin/Cyrillic</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>ISO_8859_6</td>
<td>ISO 8859-6, ECMA 114</td>
<td>Latin/Arabic</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>ISO_8859_7</td>
<td>ISO 8859-7, ECMA 118</td>
<td>Latin/Greek</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>ISO_8859_8</td>
<td>ISO 8859-8, ECMA 121</td>
<td>Latin/Hebrew</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>JOHAB</td>
<td>JOHA</td>
<td>Korean (Hangul)</td>
<td>Yes</td>
<td>1-3</td>
<td></td>
</tr>
<tr>
<td>KOI8</td>
<td>KOI8-R(U)</td>
<td>Cyrillic</td>
<td>Yes</td>
<td>1</td>
<td>KOI8R</td>
</tr>
<tr>
<td>LATIN1</td>
<td>ISO 8859-1, ECMA 94</td>
<td>Western European</td>
<td>Yes</td>
<td>1</td>
<td>ISO88591</td>
</tr>
<tr>
<td>LATIN2</td>
<td>ISO 8859-2, ECMA 94</td>
<td>Central European</td>
<td>Yes</td>
<td>1</td>
<td>ISO88592</td>
</tr>
<tr>
<td>LATIN3</td>
<td>ISO 8859-3, ECMA 94</td>
<td>South European</td>
<td>Yes</td>
<td>1</td>
<td>ISO88593</td>
</tr>
<tr>
<td>LATIN4</td>
<td>ISO 8859-4, ECMA 94</td>
<td>North European</td>
<td>Yes</td>
<td>1</td>
<td>ISO88594</td>
</tr>
<tr>
<td>LATIN5</td>
<td>ISO 8859-9, ECMA 128</td>
<td>Turkish</td>
<td>Yes</td>
<td>1</td>
<td>ISO88599</td>
</tr>
<tr>
<td>LATIN6</td>
<td>ISO 8859-10, ECMA 144</td>
<td>Nordic</td>
<td>Yes</td>
<td>1</td>
<td>ISO885910</td>
</tr>
<tr>
<td>LATIN7</td>
<td>ISO 8859-13</td>
<td>Baltic</td>
<td>Yes</td>
<td>1</td>
<td>ISO885913</td>
</tr>
<tr>
<td>LATIN8</td>
<td>ISO 8859-14</td>
<td>Celtic</td>
<td>Yes</td>
<td>1</td>
<td>ISO885914</td>
</tr>
<tr>
<td>LATIN9</td>
<td>ISO 8859-15</td>
<td>LATIN1 with Euro and accents</td>
<td>Yes</td>
<td>1</td>
<td>ISO885915</td>
</tr>
<tr>
<td>LATIN10</td>
<td>ISO 8859-16, ASRO SR 14111</td>
<td>Romanian</td>
<td>Yes</td>
<td>1</td>
<td>ISO885916</td>
</tr>
<tr>
<td>MULE_INTERNAL</td>
<td>Mule internal code</td>
<td>Multilingual Emacs</td>
<td>Yes</td>
<td>1-4</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
<td>Language</td>
<td>Server?</td>
<td>Bytes/Char</td>
<td>Aliases</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------</td>
<td>----------</td>
<td>---------</td>
<td>------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>SJIS</td>
<td>Shift JIS</td>
<td>Japanese</td>
<td>No</td>
<td>1-2</td>
<td>Mskanji, ShiftJIS, WIN932, Windows932</td>
</tr>
<tr>
<td>SQL_ASCII</td>
<td>unspecified</td>
<td>any</td>
<td>No</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>UHC</td>
<td>Unified Hangul Code</td>
<td>Korean</td>
<td>No</td>
<td>1-2</td>
<td>WIN949, Windows949</td>
</tr>
<tr>
<td>UTF8</td>
<td>Unicode, 8-bit</td>
<td>all</td>
<td>Yes</td>
<td>1-4</td>
<td>Unicode</td>
</tr>
<tr>
<td>WIN866</td>
<td>Windows CP866</td>
<td>Cyrillic</td>
<td>Yes</td>
<td>1</td>
<td>ALT</td>
</tr>
<tr>
<td>WIN874</td>
<td>Windows CP874</td>
<td>Thai</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WIN1250</td>
<td>Windows CP1250</td>
<td>Central European</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WIN1251</td>
<td>Windows CP1251</td>
<td>Cyrillic</td>
<td>Yes</td>
<td>1</td>
<td>WIN</td>
</tr>
<tr>
<td>WIN1252</td>
<td>Windows CP1252</td>
<td>Western European</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WIN1253</td>
<td>Windows CP1253</td>
<td>Greek</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WIN1254</td>
<td>Windows CP1254</td>
<td>Turkish</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WIN1255</td>
<td>Windows CP1255</td>
<td>Hebrew</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WIN1256</td>
<td>Windows CP1256</td>
<td>Arabic</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WIN1257</td>
<td>Windows CP1257</td>
<td>Baltic</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WIN1258</td>
<td>Windows CP1258</td>
<td>Vietnamese</td>
<td>Yes</td>
<td>1</td>
<td>ABC, TCVN, TCVN5712, VSCII</td>
</tr>
</tbody>
</table>

**Setting the Character Set**

gpinitsystem defines the default character set for a Greenplum Database system by reading the setting of the 'ENCODING' parameter in the gp_init_config file at initialization time. The default character set is UNICODE or UTF8.

---

2 The SQL_ASCII setting behaves considerably differently from the other settings. Byte values 0-127 are interpreted according to the ASCII standard, while byte values 128-255 are taken as uninterpreted characters. If you are working with any non-ASCII data, it is unwise to use the SQL_ASCII setting as a client encoding. SQL_ASCII is not supported as a server encoding.
You can create a database with a different character set besides what is used as the system-wide default. For example:

```
=> CREATE DATABASE korean WITH ENCODING 'EUC_KR';
```

**Important:** Although you can specify any encoding you want for a database, it is unwise to choose an encoding that is not what is expected by the locale you have selected. The `LC_COLLATE` and `LC_CTYPE` settings imply a particular encoding, and locale-dependent operations (such as sorting) are likely to misinterpret data that is in an incompatible encoding.

Since these locale settings are frozen by `gpinitsystem`, the apparent flexibility to use different encodings in different databases is more theoretical than real.

One way to use multiple encodings safely is to set the locale to `C` or `POSIX` during initialization time, thus disabling any real locale awareness.

## Character Set Conversion Between Server and Client

Greenplum Database supports automatic character set conversion between server and client for certain character set combinations. The conversion information is stored in the master `pg_conversion` system catalog table. Greenplum Database comes with some predefined conversions or you can create a new conversion using the SQL command `CREATE CONVERSION`.

### Table 16: Client/Server Character Set Conversions

<table>
<thead>
<tr>
<th>Server Character Set</th>
<th>Available Client Character Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIG5</td>
<td>not supported as a server encoding</td>
</tr>
<tr>
<td>EUC_CN</td>
<td>EUC_CN, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>EUC_JP</td>
<td>EUC_JP, MULE_INTERNAL, SJIS, UTF8</td>
</tr>
<tr>
<td>EUC_KR</td>
<td>EUC_KR, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>EUC_TW</td>
<td>EUC_TW, BIG5, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>GB18030</td>
<td>not supported as a server encoding</td>
</tr>
<tr>
<td>GBK</td>
<td>not supported as a server encoding</td>
</tr>
<tr>
<td>ISO_8859_5</td>
<td>ISO_8859_5, KOI8, MULE_INTERNAL, UTF8, WIN866, WIN1251</td>
</tr>
<tr>
<td>ISO_8859_6</td>
<td>ISO_8859_6, UTF8</td>
</tr>
<tr>
<td>ISO_8859_7</td>
<td>ISO_8859_7, UTF8</td>
</tr>
<tr>
<td>ISO_8859_8</td>
<td>ISO_8859_8, UTF8</td>
</tr>
<tr>
<td>JOHAB</td>
<td>JOHAB, UTF8</td>
</tr>
<tr>
<td>KOI8</td>
<td>KOI8, ISO_8859_5, MULE_INTERNAL, UTF8, WIN866, WIN1251</td>
</tr>
<tr>
<td>LATIN1</td>
<td>LATIN1, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>LATIN2</td>
<td>LATIN2, MULE_INTERNAL, UTF8, WIN1250</td>
</tr>
<tr>
<td>LATIN3</td>
<td>LATIN3, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>LATIN4</td>
<td>LATIN4, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>LATIN5</td>
<td>LATIN5, UTF8</td>
</tr>
<tr>
<td>Server Character Set</td>
<td>Available Client Character Sets</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>LATIN6</td>
<td>LATIN6, UTF8</td>
</tr>
<tr>
<td>LATIN7</td>
<td>LATIN7, UTF8</td>
</tr>
<tr>
<td>LATIN8</td>
<td>LATIN8, UTF8</td>
</tr>
<tr>
<td>LATIN9</td>
<td>LATIN9, UTF8</td>
</tr>
<tr>
<td>LATIN10</td>
<td>LATIN10, UTF8</td>
</tr>
<tr>
<td>MULE_INTERNAL</td>
<td>MULE_INTERNAL, BIG5, EUC_CN, EUC_JP, EUC_KR, EUC_TW, ISO_8859_5, KOI8, LATIN1 to LATIN4, SJIS, WIN866, WIN1250, WIN1251</td>
</tr>
<tr>
<td>SJIS</td>
<td>not supported as a server encoding</td>
</tr>
<tr>
<td>SQL_ASCII</td>
<td>not supported as a server encoding</td>
</tr>
<tr>
<td>UHC</td>
<td>not supported as a server encoding</td>
</tr>
<tr>
<td>UTF8</td>
<td>all supported encodings</td>
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<td>WIN1257, UTF8</td>
</tr>
<tr>
<td>WIN1258</td>
<td>WIN1258, UTF8</td>
</tr>
</tbody>
</table>

To enable automatic character set conversion, you have to tell Greenplum Database the character set (encoding) you would like to use in the client. There are several ways to accomplish this:

- **Using the `\encoding` command in psql**, which allows you to change client encoding on the fly.
- **Using `SET client_encoding TO`.** Setting the client encoding can be done with this SQL command:

  ```sql
  => SET CLIENT_ENCODING TO 'value';
  ```

To query the current client encoding:

  ```sql
  => SHOW client_encoding;
  ```

To return to the default encoding:

  ```sql
  => RESET client_encoding;
  ```
• Using the `PGCLIENTENCODING` environment variable. When `PGCLIENTENCODING` is defined in the client's environment, that client encoding is automatically selected when a connection to the server is made. (This can subsequently be overridden using any of the other methods mentioned above.)

• Setting the configuration parameter `client_encoding`. If `client_encoding` is set in the master `postgresql.conf` file, that client encoding is automatically selected when a connection to Greenplum Database is made. (This can subsequently be overridden using any of the other methods mentioned above.)

If the conversion of a particular character is not possible — suppose you chose EUC_JP for the server and LATIN1 for the client, then some Japanese characters do not have a representation in LATIN1 — then an error is reported.

If the client character set is defined as `SQL_ASCII`, encoding conversion is disabled, regardless of the server's character set. The use of `SQL_ASCII` is unwise unless you are working with all-ASCII data. `SQL_ASCII` is not supported as a server encoding.
Initializing a Greenplum Database System

Describes how to initialize a Greenplum Database database system.

The instructions in this chapter assume you have already installed the Greenplum Database software on all of the hosts in the system according to the instructions in Configuring Your Systems and Installing Greenplum.

This chapter contains the following topics:

- Overview
- Initializing Greenplum Database
- Next Steps

Overview

Because Greenplum Database is distributed, the process for initializing a Greenplum Database management system (DBMS) involves initializing several individual PostgreSQL database instances (called segment instances in Greenplum).

Each database instance (the master and all segments) must be initialized across all of the hosts in the system in such a way that they can all work together as a unified DBMS. Greenplum provides its own version of initdb called gpinitsystem, which takes care of initializing the database on the master and on each segment instance, and starting each instance in the correct order.

After the Greenplum Database database system has been initialized and started, you can then create and manage databases as you would in a regular PostgreSQL DBMS by connecting to the Greenplum master.

Initializing Greenplum Database

These are the high-level tasks for initializing Greenplum Database:

1. Make sure you have completed all of the installation tasks described in Configuring Your Systems and Installing Greenplum.
2. Create a host file that contains the host addresses of your segments. See Creating the Initialization Host File.
4. By default, Greenplum Database will be initialized using the locale of the master host system. Make sure this is the correct locale you want to use, as some locale options cannot be changed after initialization. See Configuring Timezone and Localization Settings for more information.
5. Run the Greenplum Database initialization utility on the master host. See Running the Initialization Utility.

Creating the Initialization Host File

The gpinitsystem utility requires a host file that contains the list of addresses for each segment host. The initialization utility determines the number of segment instances per host by the number host addresses listed per host times the number of data directory locations specified in the gpinitsystem_config file.

This file should only contain segment host addresses (not the master or standby master). For segment machines with multiple, unbonded network interfaces, this file should list the host address names for each interface — one per line.

Note: The Greenplum Database segment host naming convention is sdwN where sdw is a prefix and N is an integer. For example, sdw2 and so on. If hosts have multiple unbonded NICs, the
convention is to append a dash (−) and number to the host name. For example, sdw1-1 and sdw1-2 are the two interface names for host sdw1. However, NIC bonding is recommended to create a load-balanced, fault-tolerant network.

**To create the initialization host file**

1. Log in as gpadmin.

   ```
   $ su - gpadmin
   ```

2. Create a file named `hostfile_gpinitsystem`. In this file add the host address name(s) of your segment host interfaces, one name per line, no extra lines or spaces. For example, if you have four segment hosts with two unbonded network interfaces each:

   ```
   sdw1-1
   sdw1-2
   sdw2-1
   sdw2-2
   sdw3-1
   sdw3-2
   sdw4-1
   sdw4-2
   ```

3. Save and close the file.

   **Note:** If you are not sure of the host names and/or interface address names used by your machines, look in the `/etc/hosts` file.

**Creating the Greenplum Database Configuration File**

Your Greenplum Database configuration file tells the `gpinitsystem` utility how you want to configure your Greenplum Database system. An example configuration file can be found in `$GPHOME/docs/cli_help/gpconfigs/gpinitsystem_config`.

**To create a gpinitsystem_config file**

1. Log in as gpadmin.

   ```
   $ su - gpadmin
   ```

2. Make a copy of the `gpinitsystem_config` file to use as a starting point. For example:

   ```
   $ cp $GPHOME/docs/cli_help/gpconfigs/gpinitsystem_config \
   /home/gpadmin/gpconfigs/gpinitsystem_config
   ```

3. Open the file you just copied in a text editor.

   Set all of the required parameters according to your environment. See `gpinitsystem` for more information. A Greenplum Database system must contain a master instance and at least two segment instances (even if setting up a single node system).

   The `DATA_DIRECTORY` parameter is what determines how many segments per host will be created. If your segment hosts have multiple network interfaces, and you used their interface address names in your host file, the number of segments will be evenly spread over the number of available interfaces.

   Here is an example of the required parameters in the `gpinitsystem_config` file:

   ```
   ARRAY_NAME="EMC Greenplum DW"
   SEG_PREFIX=gpseg
   PORT_BASE=40000
   declare -a DATA_DIRECTORY=(/data1/primary /data1/primary \
   /data1/primary /data2/primary /data2/primary /data2/primary)
   ```
MASTER_HOSTNAME=mdw
MASTER_DIRECTORY=/data/master
MASTER_PORT=5432
TRUSTED_SHELL=ssh
CHECK_POINT_SEGMENTS=8
ENCODING=UNICODE

4. (Optional) If you want to deploy mirror segments, uncomment and set the mirroring parameters according to your environment. Here is an example of the optional mirror parameters in the gpinitsystem_config file:

MIRROR_PORT_BASE=50000
REPLICATION_PORT_BASE=41000
MIRROR_REPLICATION_PORT_BASE=51000
declare -a MIRROR_DATA_DIRECTORY=(/data1/mirror /data1/mirror /data1/mirror /data2/mirror /data2/mirror /data2/mirror)

Note: You can initialize your Greenplum system with primary segments only and deploy mirrors later using the gpaddmirrors utility.

5. Save and close the file.

Running the Initialization Utility

The gpinitsystem utility will create a Greenplum Database system using the values defined in the configuration file.

To run the initialization utility

1. Run the following command referencing the path and file name of your initialization configuration file (gpinitsystem_config) and host file (hostfile_gpinitsystem). For example:

   $ cd ~
   $ gpinitsystem -c gpconfigs/gpinitsystem_config -h gpconfigs/hostfile_gpinitsystem

   For a fully redundant system (with a standby master and a spread mirror configuration) include the -s and -S options. For example:

   $ gpinitsystem -c gpconfigs/gpinitsystem_config -h gpconfigs/hostfile_gpinitsystem \
   -s standby_master_hostname -S

2. The utility will verify your setup information and make sure it can connect to each host and access the data directories specified in your configuration. If all of the pre-checks are successful, the utility will prompt you to confirm your configuration. For example:

   => Continue with Greenplum creation? Yy/Nn

3. Press y to start the initialization.

4. The utility will then begin setup and initialization of the master instance and each segment instance in the system. Each segment instance is set up in parallel. Depending on the number of segments, this process can take a while.

5. At the end of a successful setup, the utility will start your Greenplum Database system. You should see:

   => Greenplum Database instance successfully created.
Troubleshooting Initialization Problems

If the utility encounters any errors while setting up an instance, the entire process will fail, and could possibly leave you with a partially created system. Refer to the error messages and logs to determine the cause of the failure and where in the process the failure occurred. Log files are created in `~/gpAdminLogs`.

Depending on when the error occurred in the process, you may need to clean up and then try the gpinitsystem utility again. For example, if some segment instances were created and some failed, you may need to stop `postgres` processes and remove any utility-created data directories from your data storage area(s). A backout script is created to help with this cleanup if necessary.

Using the Backout Script

If the gpinitsystem utility fails, it will create the following backout script if it has left your system in a partially installed state:

`~/gpAdminLogs/backout_gpinitsystem_<user>_<timestamp>`

You can use this script to clean up a partially created Greenplum Database system. This backout script will remove any utility-created data directories, `postgres` processes, and log files. After correcting the error that caused gpinitsystem to fail and running the backout script, you should be ready to retry initializing your Greenplum Database array.

The following example shows how to run the backout script:

```
$ sh backout_gpinitsystem_gpadmin_20071031_121053
```

Setting Greenplum Environment Variables

You must configure your environment on the Greenplum Database master (and standby master). A `greenplum_path.sh` file is provided in your `$GPHOME` directory with environment variable settings for Greenplum Database. You can source this file in the `gpadmin` user's startup shell profile (such as `.bashrc`).

The Greenplum Database management utilities also require that the `MASTER_DATA_DIRECTORY` environment variable be set. This should point to the directory created by the gpinitsystem utility in the master data directory location.

Note: The `greenplum_path.sh` script changes the operating environment in order to support running the Greenplum Database-specific utilities. These same changes to the environment can negatively affect the operation of other system-level utilities, such as `ps` or `yum`. Use separate accounts for performing system administration and database administration, instead of attempting to perform both functions as `gpadmin`.

To set up your user environment for Greenplum

1. Make sure you are logged in as `gpadmin`:

```
$ su - gpadmin
```

2. Open your profile file (such as `.bashrc`) in a text editor. For example:

```
$ vi ~/.bashrc
```

3. Add lines to this file to source the `greenplum_path.sh` file and set the `MASTER_DATA_DIRECTORY` environment variable. For example:

```
source /usr/local/greenplum-db/greenplum_path.sh
```
export MASTER_DATA_DIRECTORY=/data/master/gpseg-1

4. (Optional) You may also want to set some client session environment variables such as PGPORT, PGUSER and PGDATABASE for convenience. For example:

   export PGPORT=5432
   export PGUSER=gpadmin export PGDATABASE=default_login_database_name

5. (Optional) If you use RHEL 7 or CentOS 7, add the following line to the end of the .bashrc file to enable using the ps command in the greenplum_path.sh environment:

   export LD_PRELOAD=/lib64/libz.so.1 ps

6. Save and close the file.
7. After editing the profile file, source it to make the changes active. For example:

   $ source ~/.bashrc

8. If you have a standby master host, copy your environment file to the standby master as well. For example:

   $ cd ~
   $ scp .bashrc standby_hostname:`pwd`

   **Note:** The .bashrc file should not produce any output. If you wish to have a message display to users upon logging in, use the .profile file instead.

### Next Steps

After your system is up and running, the next steps are:

- **Allowing Client Connections**
- **Creating Databases and Loading Data**

### Allowing Client Connections

After a Greenplum Database is first initialized it will only allow local connections to the database from the gpadmin role (or whatever system user ran gpinitsystem). If you would like other users or client machines to be able to connect to Greenplum Database, you must give them access. See the *Greenplum Database Administrator Guide* for more information.

### Creating Databases and Loading Data

After verifying your installation, you may want to begin creating databases and loading data. See *Defining Database Objects* and *Loading and Unloading Data* in the *Greenplum Database Administrator Guide* for more information about creating databases, schemas, tables, and other database objects in Greenplum Database and loading your data.
About Implicit Text Casting in Greenplum Database

Greenplum Database version 4.3.x is based on PostgreSQL version 8.2. Greenplum Database version 5.x is based on PostgreSQL version 8.3. PostgreSQL 8.3 removed automatic implicit casts between the text type and other data types. When you migrate from Greenplum Database version 4.3.x to version 5.x, this change in behavior may impact existing applications and queries.

A cast specifies how to perform a conversion between two data types. Greenplum Database versions 4.3.x and 5.x support three types of casts:

- **Assignment cast** - Greenplum Database implicitly invokes a cast in assignment contexts when you create the cast between two data types using the `CREATE CAST ... AS ASSIGNMENT` statement.
- **Implicit cast** - Greenplum Database invokes a cast implicitly in any assignment or expression context when you create the cast between two data types using the `CREATE CAST ... AS IMPLICIT` statement. *Greenplum Database 4.3.x also automatically adds an implicit cast from and to text for any data type.*
- **Explicit cast** - Greenplum Database explicitly applies a cast when you create a cast between two data types using the `CAST(x AS typename)` or `x::typename` syntax.

**What is different in Greenplum Database 5.x?**

Greenplum Database 5.x does not automatically implicitly cast between text and other data types. Greenplum Database 5.x also treats certain automatic implicit casts differently than version 4.3.x, and in some cases does not handle them at all. *Applications or queries that you wrote for Greenplum Database 4.3.x that rely on automatic implicit casting may fail on Greenplum Database version 5.x.*

(The term *implicit cast*, when used in the remainder of this section, refers to implicit casts automatically applied by Greenplum Database.)

- Greenplum Database 5.x has downgraded implicit casts in the to-text type direction; these casts are now treated as assignment casts. A cast from a data type to the text type will continue to work in Greenplum Database 5.x if used in assignment contexts.
- Greenplum Database 5.x no longer automatically provides an implicit cast in the to-text type direction that can be used in expression contexts. Additionally, Greenplum Database 5.x no longer provides implicit casts in the from-text type direction. When such expressions or assignments are encountered, Greenplum Database 5.x returns an error and the following message:

```
HINT: No operator matches the given name and argument type(s). You might need to add explicit type casts.
```

To illustrate, suppose you create two tables:

```sql
CREATE TABLE foo (a INT);
CREATE TABLE bar (b TEXT);
```

The following examples demonstrate certain types of text comparison queries that will fail on Greenplum Database 5.x.

**Note:** This is not an exhaustive list of failure scenarios.

- Queries that reference text type and non-text type columns in an expression. For example:

```sql
SELECT * FROM foo, bar WHERE foo.a = bar.b;
```

```
ERROR: operator does not exist: integer = text
LINE 1: SELECT * FROM foo, bar WHERE foo.a = bar.b;
```

```
HINT: No operator matches the given name and argument type(s). You might need to add explicit type casts.
```
• Queries that mix the text type and non-text type columns in function and aggregate arguments. For example:

```sql
CREATE FUNCTION concat(TEXT, TEXT)
RETURNS TEXT AS $$
  SELECT $1 || $2
$$ STRICT LANGUAGE SQL;
```

```sql
SELECT concat('a'::TEXT, 2);
```

**ERROR:** function concat(text, integer) does not exist
**LINE 1:** select concat('a'::text, 2);

**HINT:** No function matches the given name and argument types. You might need to add explicit type casts.

• Queries that perform comparisons between a text type column and a non-quoted literal such as an integer, number, float, or oid. For example:

```sql
SELECT * FROM bar WHERE b = 123;
```

**ERROR:** operator does not exist: text = integer
**LINE 1:** select * from bar where a = 123;

**HINT:** No operator matches the given name and argument type(s). You might need to add explicit type casts.

• Queries that perform comparisons between a date type column or literal and an integer-like column. (Greenplum Database internally converts date types to the text type.) For example:

```sql
SELECT * FROM foo WHERE a = '20130101'::DATE;
```

**ERROR:** operator does not exist: integer = date
**LINE 1:** select * from foo where a = '20130101'::date;

**HINT:** No operator matches the given name and argument type(s). You might need to add explicit type casts.

The only supported workaround for the implicit casting differences between Greenplum Database versions 4.3.x and 5.x is to analyze failing applications and queries and update the application or query to use explicit casts to fix the failures.

If rewriting the application or query is not feasible, you may choose to temporarily work around the change in behaviour introduced by the removal of automatic implicit casts in Greenplum Database 5.x. There are two well-known workarounds to this PostgreSQL issue:

• Re-create the implicit casts (described in [Readding implicit casts in PostgreSQL 8.3](#)).
• Create missing operators (described in [Problems and workaround recreating implicit casts using 8.3+](#)).

The workaround to re-create the implicit casts is not recommended as it breaks concatenation functionality. With the create missing operators workaround, you create the operators and functions that implement the comparison expressions that are failing in your applications and queries.

**Workaround: Manually Creating Missing Operators**

**Warning:** Use this workaround only to aid migration to Greenplum Database 5.x for evaluation purposes. Do not use this workaround in a production environment.

When you create an operator, you identify the data types of the left operand and the right operand. You also identify the name of a function that Greenplum Database invokes to evaluate the operator expression between the specified data types. The operator function evaluates the expression by performing either to-text or from-text conversion using the INPUT/OUTPUT methods of the data types involved. By creating operators for each (text type, other data type) and (other data type, text type) combination, you effectively implement the casts that are missing in Greenplum Database 5.x.
To implement this workaround, complete the following tasks after you install Greenplum Database 5.x:

1. Identify and note the names of the Greenplum 5.x databases in which you want to create the missing operators. Consider applying this workaround to all databases in your Greenplum Database deployment.

2. Identify a schema in which to create the operators and functions. Use a schema other than pg_catalog to ensure that these objects are included in a pg_dump or gpbackup of the database. This procedure will use a schema named cast_fix for illustrative purposes.

3. Review the blog entry Problems and workaround recreating implicit casts using 8.3+. The blog discusses this temporary workaround to the casting issue, i.e. creating missing operators. It also references a SQL script that you can run to create a set of equality (=) operators and functions for several text and other data type comparisons.

4. Download the 8.3 operator workaround.sql script referenced on the blog page, noting the location to which the file was downloaded on your local system.

5. The 8.3 operator workaround.sql script creates the equality operators and functions. Open the script in the editor of your choice, and examine the contents. For example, using the vi editor:

   ```
   vi 8.3 operator workaround.sql
   ```

   Notice that the script creates the operators and functions in the pg_catalog schema.

6. Replace occurrences of pg_catalog in the script with the name of the schema that you identified in Step 2, and then save the file and exit the editor. (You will create this schema in an upcoming step if the schema does not already exist.) For example:

   ```
   :s/pg_catalog/cast_fix/g
   :wq
   ```

7. Analyze your failing queries, identifying the operators and from-type and to-type data type comparisons that are the source of the failures. Compare this list to the contents of the 8.3 operator workaround.sql script, and identify the minimum set of additional operators and left_type/right_type expression combinations that you must support.

8. For each operator and left_type/right_type combination that you identify in the previous step, add CREATE statements for the following objects to the 8.3 operator workaround.sql script:

   a. Create the function that implements the left_type operator right_type comparison. For example, to create a function that implements the greater than (>) operator for text (left_type) to integer (right_type) comparison:

      ```
      CREATE FUNCTION cast_fix.textgtint(text, integer) 
      RETURNS boolean STRICT IMMUTABLE LANGUAGE SQL AS $$
      SELECT textin(int4out($2)) > $1;
      $$;
      ```

      Be sure to schema-qualify the function name.

   b. Create the operator. For example, to create a greater than (>) operator for text (left_type) to integer (right_type) type comparison that specifies the function you created above:

      ```
      CREATE OPERATOR cast_fix.> (PROCEDURE=cast_fix.textgtint, LEFTARG=text, RIGHTARG=integer, COMMUTATOR=OPERATOR(cast_fix.>)
      ```

      Be sure to schema-qualify the operator and function names.

   c. You must create another operator and function if you want the operator to work in reverse (i.e. using the example above, if you want a greater than operator for integer (left_type) to text (right_type) comparison.)

9. For each database that you identified in Step 1, add the missing operators. For example:
a. Connect to the database as an administrative user. For example:

```
$ psql -d database1 -U gpadmin
```

b. Create the schema if it does not already exist. For example:

```
CREATE SCHEMA cast_fix;
```

c. Run the script. For example, if you downloaded the file to the `/tmp` directory:

```
\i '/tmp/8.3 operator workaround.sql'
```

You must create the schema and run the script for every new database that you create in your Greenplum Database cluster.

10. Identify and note the names of the users/roles to which you want to provide this capability. Consider exposing this to all roles in your Greenplum Database deployment.

11. For each role that you identified in Step 10, add the schema to the role's `search_path`. For example:

```
SHOW search_path;
ALTER ROLE bill SET search_path TO existing_search_path, cast_fix;
```

If required, also grant schema-level permissions to the role.
Installation Management Utilities

References for the command-line management utilities used to install and initialize a Greenplum Database system.

For a full reference of all Greenplum Database utilities, see the *Greenplum Database Utility Guide*.

The following Greenplum Database management utilities are located in $GPHOME/bin.

- gpactivatestandby
- gpaddmirrors
- gpcheck *(deprecated)*
- gpcheckperf
- gpdeletesystem
- gpinitstandby
- gpinitsystem
- gppkg
- gpscp
- gpsegreginstall
- gpssh
- gpssh-exkeys
- gpstart
- gpstop
- gptransfer
Greenplum Environment Variables

Reference of the environment variables to set for Greenplum Database.
Set these in your user's startup shell profile (such as ~/.bashrc or ~/.bash_profile), or in /etc/profile if you want to set them for all users.

Required Environment Variables

Note: GPHOME, PATH and LD_LIBRARY_PATH can be set by sourcing the greenplum_path.sh file from your Greenplum Database installation directory

GPHOME
This is the installed location of your Greenplum Database software. For example:

```
GPHOME=/usr/local/greenplum-db-4.3.x.x
export GPHOME
```

PATH
Your PATH environment variable should point to the location of the Greenplum Database bin directory. For example:

```
PATH=$GPHOME/bin:$PATH
export PATH
```

LD_LIBRARY_PATH
The LD_LIBRARY_PATH environment variable should point to the location of the Greenplum Database/PostgreSQL library files. For example:

```
LD_LIBRARY_PATH=$GPHOME/lib
export LD_LIBRARY_PATH
```

MASTER_DATA_DIRECTORY
This should point to the directory created by the gpinitsystem utility in the master data directory location. For example:

```
MASTER_DATA_DIRECTORY=/data/master/gpseg-1
export MASTER_DATA_DIRECTORY
```

Optional Environment Variables

The following are standard PostgreSQL environment variables, which are also recognized in Greenplum Database. You may want to add the connection-related environment variables to your profile for convenience, so you do not have to type so many options on the command line for client connections. Note that these environment variables should be set on the Greenplum Database master host only.
**PGAPPNAME**

The name of the application that is usually set by an application when it connects to the server. This name is displayed in the activity view and in log entries. The `PGAPPNAME` environmental variable behaves the same as the `application_name` connection parameter. The default value for `application_name` is `psql`. The name cannot be longer than 63 characters.

**PGDATABASE**

The name of the default database to use when connecting.

**PGHOST**

The Greenplum Database master host name.

**PGHOSTADDR**

The numeric IP address of the master host. This can be set instead of or in addition to `PGHOST` to avoid DNS lookup overhead.

**PGPASSWORD**

The password used if the server demands password authentication. Use of this environment variable is not recommended for security reasons (some operating systems allow non-root users to see process environment variables via `ps`). Instead consider using the `~/.pgpass` file.

**PGPASSFILE**

The name of the password file to use for lookups. If not set, it defaults to `~/.pgpass`. See the topic about The Password File in the PostgreSQL documentation for more information.

**PGOPTIONS**

Sets additional configuration parameters for the Greenplum Database master server.

**PGPORT**

The port number of the Greenplum Database server on the master host. The default port is 5432.

**PGUSER**

The Greenplum Database user name used to connect.

**PGDATESTYLE**

Sets the default style of date/time representation for a session. (Equivalent to `SET datestyle TO...`)

**PGTZ**

Sets the default time zone for a session. (Equivalent to `SET timezone TO...`)

**PGCLIENTENCODING**

Sets the default client character set encoding for a session. (Equivalent to `SET client_encoding TO...`)
Chapter 7

Greenplum Database Administrator Guide

Information about configuring, managing and monitoring Greenplum Database installations, and administering, monitoring, and working with databases. The guide also contains information about Greenplum Database architecture and concepts such as parallel processing.
Greenplum Database Concepts

This section provides an overview of Greenplum Database components and features such as high availability, parallel data loading features, and management utilities.

This section contains the following topics:

• About the Greenplum Architecture
• About Management and Monitoring Utilities
• About Parallel Data Loading
• About Redundancy and Failover in Greenplum Database
• About Database Statistics in Greenplum Database

About the Greenplum Architecture

Greenplum Database is a massively parallel processing (MPP) database server with an architecture specially designed to manage large-scale analytic data warehouses and business intelligence workloads.

MPP (also known as a shared nothing architecture) refers to systems with two or more processors that cooperate to carry out an operation, each processor with its own memory, operating system and disks. Greenplum uses this high-performance system architecture to distribute the load of multi-terabyte data warehouses, and can use all of a system’s resources in parallel to process a query.

Greenplum Database is based on PostgreSQL open-source technology. It is essentially several PostgreSQL disk-oriented database instances acting together as one cohesive database management system (DBMS). It is based on PostgreSQL 8.3.23, and in most cases is very similar to PostgreSQL with regard to SQL support, features, configuration options, and end-user functionality. Database users interact with Greenplum Database as they would with a regular PostgreSQL DBMS.

Greenplum Database can use the append-optimized (AO) storage format for bulk loading and reading of data, and provides performance advantages over HEAP tables. Append-optimized storage provides checksums for data protection, compression and row/column orientation. Both row-oriented or column-oriented append-optimized tables can be compressed.

The main differences between Greenplum Database and PostgreSQL are as follows:

• GPORCA is leveraged for query planning, in addition to the legacy query planner, which is based on the Postgres query planner.
• Greenplum Database can use append-optimized storage.
• Greenplum Database has the option to use column storage, data that is logically organized as a table, using rows and columns that are physically stored in a column-oriented format, rather than as rows. Column storage can only be used with append-optimized tables. Column storage is compressible. It also can provide performance improvements as you only need to return the columns of interest to you. All compression algorithms can be used with either row or column-oriented tables, but Run-Length Encoded (RLE) compression can only be used with column-oriented tables. Greenplum Database provides compression on all Append-Optimized tables that use column storage.

The internals of PostgreSQL have been modified or supplemented to support the parallel structure of Greenplum Database. For example, the system catalog, optimizer, query executor, and transaction manager components have been modified and enhanced to be able to execute queries simultaneously across all of the parallel PostgreSQL database instances. The Greenplum interconnect (the networking layer) enables communication between the distinct PostgreSQL instances and allows the system to behave as one logical database.

Greenplum Database also can use declarative partitions and sub-partitions to implicitly generate partition constraints.
Greenplum Database also includes features designed to optimize PostgreSQL for business intelligence (BI) workloads. For example, Greenplum has added parallel data loading (external tables), resource management, query optimizations, and storage enhancements, which are not found in standard PostgreSQL. Many features and optimizations developed by Greenplum make their way into the PostgreSQL community. For example, table partitioning is a feature first developed by Greenplum, and it is now in standard PostgreSQL.

Greenplum Database queries use a Volcano-style query engine model, where the execution engine takes an execution plan and uses it to generate a tree of physical operators, evaluates tables through physical operators, and delivers results in a query response.

Greenplum Database stores and processes large amounts of data by distributing the data and processing workload across several servers or hosts. Greenplum Database is an array of individual databases based upon PostgreSQL 8.3 working together to present a single database image. The master is the entry point to the Greenplum Database system. It is the database instance to which clients connect and submit SQL statements. The master coordinates its work with the other database instances in the system, called segments, which store and process the data.

The following topics describe the components that make up a Greenplum Database system and how they work together.

**About the Greenplum Master**

The Greenplum Database master is the entry to the Greenplum Database system, accepting client connections and SQL queries, and distributing work to the segment instances.

Greenplum Database end-users interact with Greenplum Database (through the master) as they would with a typical PostgreSQL database. They connect to the database using client programs such as psql or application programming interfaces (APIs) such as JDBC, ODBC or libpq (the PostgreSQL C API).
The master is where the global system catalog resides. The global system catalog is the set of system tables that contain metadata about the Greenplum Database system itself. The master does not contain any user data; data resides only on the segments. The master authenticates client connections, processes incoming SQL commands, distributes workloads among segments, coordinates the results returned by each segment, and presents the final results to the client program.

Greenplum Database uses Write-Ahead Logging (WAL) for master/standby master mirroring. In WAL-based logging, all modifications are written to the log before being applied, to ensure data integrity for any in-process operations.

**Note:** WAL logging is not yet available for segment mirroring.

### About the Greenplum Segments

Greenplum Database segment instances are independent PostgreSQL databases that each store a portion of the data and perform the majority of query processing. When a user connects to the database via the Greenplum master and issues a query, processes are created in each segment database to handle the work of that query. For more information about query processes, see About Greenplum Query Processing.

User-defined tables and their indexes are distributed across the available segments in a Greenplum Database system; each segment contains a distinct portion of data. The database server processes that serve segment data run under the corresponding segment instances. Users interact with segments in a Greenplum Database system through the master.

Segments run on a servers called segment hosts. A segment host typically executes from two to eight Greenplum segments, depending on the CPU cores, RAM, storage, network interfaces, and workloads. Segment hosts are expected to be identically configured. The key to obtaining the best performance from Greenplum Database is to distribute data and workloads evenly across a large number of equally capable segments so that all segments begin working on a task simultaneously and complete their work at the same time.

### About the Greenplum Interconnect

The interconnect is the networking layer of the Greenplum Database architecture.

The interconnect refers to the inter-process communication between segments and the network infrastructure on which this communication relies. The Greenplum interconnect uses a standard Ethernet switching fabric. For performance reasons, a 10-Gigabit system, or faster, is recommended.

By default, the interconnect uses User Datagram Protocol with flow control (UDPIFC) for interconnect traffic to send messages over the network. The Greenplum software performs packet verification beyond what is provided by UDP. This means the reliability is equivalent to Transmission Control Protocol (TCP), and the performance and scalability exceeds TCP. If the interconnect is changed to TCP, Greenplum Database has a scalability limit of 1000 segment instances. With UDPIFC as the default protocol for the interconnect, this limit is not applicable.

### About Management and Monitoring Utilities

Greenplum Database provides standard command-line utilities for performing common monitoring and administration tasks.

Greenplum command-line utilities are located in the $GPHOME/bin directory and are executed on the master host. Greenplum provides utilities for the following administration tasks:

- Installing Greenplum Database on an array
- Initializing a Greenplum Database System
- Starting and stopping Greenplum Database
- Adding or removing a host
- Expanding the array and redistributing tables among new segments
• Managing recovery for failed segment instances
• Managing failover and recovery for a failed master instance
• Backing up and restoring a database (in parallel)
• Loading data in parallel
• Transferring data between Greenplum databases
• System state reporting

Greenplum Database includes an optional performance management database that contains query status information and system metrics. The `gpperfmon_install` management utility creates the database, named `gpperfmon`, and enables data collection agents that execute on the Greenplum Database master and segment hosts. Data collection agents on the segment hosts collect query status from the segments, as well as system metrics such as CPU and memory utilization. An agent on the master host periodically (typically every 15 seconds) retrieves the data from the segment host agents and updates the `gpperfmon` database. Users can query the `gpperfmon` database to see the query and system metrics.

Pivotal provides an optional system monitoring and management tool, Greenplum Command Center, which administrators can install and enable with Greenplum Database. Greenplum Command Center, which depends upon the `gpperfmon` database, provides a web-based user interface for viewing the system metrics and allows administrators to perform additional system management tasks. For more information about Greenplum Command Center, see the Greenplum Command Center documentation.

Figure 11: Greenplum Command Center Architecture

**About Concurrency Control in Greenplum Database**

Greenplum Database uses the PostgreSQL Multiversion Concurrency Control (MVCC) model to manage concurrent transactions for heap tables.

Concurrency control in a database management system allows concurrent queries to complete with correct results while ensuring the integrity of the database. Traditional databases use a two-phase locking protocol that prevents a transaction from modifying data that has been read by another concurrent transaction and prevents any concurrent transaction from reading or writing data that another transaction has updated.
The locks required to coordinate transactions add contention to the database, reducing overall transaction throughput.

Greenplum Database uses the PostgreSQL Multiversion Concurrency Control (MVCC) model to manage concurrency for heap tables. With MVCC, each query operates on a snapshot of the database when the query starts. While it executes, a query cannot see changes made by other concurrent transactions. This ensures that a query sees a consistent view of the database. Queries that read rows can never block waiting for transactions that write rows. Conversely, queries that write rows cannot be blocked by transactions that read rows. This allows much greater concurrency than traditional database systems that employ locks to coordinate access between transactions that read and write data.

Note: Append-optimized tables are managed with a different concurrency control model than the MVCC model discussed in this topic. They are intended for "write-once, read-many" applications that never, or only very rarely, perform row-level updates.

Snapshots

The MVCC model depends on the system's ability to manage multiple versions of data rows. A query operates on a snapshot of the database at the start of the query. A snapshot is the set of rows that are visible at the beginning of a statement or transaction. The snapshot ensures the query has a consistent and valid view of the database for the duration of its execution.

Each transaction is assigned a unique transaction ID (XID), an incrementing 32-bit value. When a new transaction starts, it is assigned the next XID. An SQL statement that is not enclosed in a transaction is treated as a single-statement transaction—the BEGIN and COMMIT are added implicitly. This is similar to autocommit in some database systems.

Note: Greenplum Database assigns XID values only to transactions that involve DDL or DML operations, which are typically the only transactions that require an XID.

When a transaction inserts a row, the XID is saved with the row in the xmin system column. When a transaction deletes a row, the XID is saved in the xmax system column. Updating a row is treated as a delete and an insert, so the XID is saved to the xmax of the current row and the xmin of the newly inserted row. The xmin and xmax columns, together with the transaction completion status, specify a range of transactions for which the version of the row is visible. A transaction can see the effects of all transactions less than xmin, which are guaranteed to be committed, but it cannot see the effects of any transaction greater than or equal to xmax.

Multi-statement transactions must also record which command within a transaction inserted a row (cmin) or deleted a row (cmax) so that the transaction can see changes made by previous commands in the transaction. The command sequence is only relevant during the transaction, so the sequence is reset to 0 at the beginning of a transaction.

XID is a property of the database. Each segment database has its own XID sequence that cannot be compared to the XIDs of other segment databases. The master coordinates distributed transactions with the segments using a cluster-wide session ID number, called gp_session_id. The segments maintain a mapping of distributed transaction IDs with their local XIDs. The master coordinates distributed transactions across all of the segment with the two-phase commit protocol. If a transaction fails on any one segment, it is rolled back on all segments.

You can see the xmin, xmax, cmin, and cmax columns for any row with a SELECT statement:

```
SELECT xmin, xmax, cmin, cmax, * FROM tablename;
```

Because you run the SELECT command on the master, the XIDs are the distributed transactions IDs. If you could execute the command in an individual segment database, the xmin and xmax values would be the segment's local XIDs.
Transaction ID Wraparound

The MVCC model uses transaction IDs (XIDs) to determine which rows are visible at the beginning of a query or transaction. The XID is a 32-bit value, so a database could theoretically execute over four billion transactions before the value overflows and wraps to zero. However, Greenplum Database uses modulo $2^{32}$ arithmetic with XIDs, which allows the transaction IDs to wrap around, much as a clock wraps at twelve o'clock. For any given XID, there could be about two billion past XIDs and two billion future XIDs. This works until a version of a row persists through about two billion transactions, when it suddenly appears to be a new row. To prevent this, Greenplum has a special XID, called FrozenXID, which is always considered older than any regular XID it is compared with. The $\text{xmin}$ of a row must be replaced with FrozenXID within two billion transactions, and this is one of the functions the VACUUM command performs.

Vacuuming the database at least every two billion transactions prevents XID wraparound. Greenplum Database monitors the transaction ID and warns if a VACUUM operation is required.

A warning is issued when a significant portion of the transaction IDs are no longer available and before transaction ID wraparound occurs:

```
WARNING: database "database_name" must be vacuumed within number_of_transactions transactions
```

When the warning is issued, a VACUUM operation is required. If a VACUUM operation is not performed, Greenplum Database stops creating transactions to avoid possible data loss when it reaches a limit prior to when transaction ID wraparound occurs and issues this error:

```
FATAL: database is not accepting commands to avoid wraparound data loss in database "database_name"
```

See Recovering from a Transaction ID Limit Error for the procedure to recover from this error.

The server configuration parameters `xid_warn_limit` and `xid_stop_limit` control when the warning and error are displayed. The `xid_warn_limit` parameter specifies the number of transaction IDs before the `xid_stop_limit` when the warning is issued. The `xid_stop_limit` parameter specifies the number of transaction IDs before wraparound would occur when the error is issued and new transactions cannot be created.

Transaction Isolation Modes

The SQL standard describes three phenomena that can occur when database transactions run concurrently:

- **Dirty read** – a transaction can read uncommitted data from another concurrent transaction.
- **Non-repeatable read** – a row read twice in a transaction can change because another concurrent transaction committed changes after the transaction began.
- **Phantom read** – a query executed twice in the same transaction can return two different sets of rows because another concurrent transaction added rows.

The SQL standard defines four transaction isolation modes that database systems must support:

Table 17: Transaction Isolation Modes

<table>
<thead>
<tr>
<th>Level</th>
<th>Dirty Read</th>
<th>Non-Repeatable</th>
<th>Phantom Read</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read Uncommitted</td>
<td>Possible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Read Committed</td>
<td>Impossible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Repeatable Read</td>
<td>Impossible</td>
<td>Impossible</td>
<td>Possible</td>
</tr>
<tr>
<td>Serializable</td>
<td>Impossible</td>
<td>Impossible</td>
<td>Impossible</td>
</tr>
</tbody>
</table>
The Greenplum Database SQL commands allow you to request READ UNCOMMITTED, READ COMMITTED, or SERIALizable. Greenplum Database treats READ UNCOMMITTED the same as READ COMMITTED. Requesting REPEATABLE READ produces an error; use SERIALizable instead. The default isolation mode is READ COMMITTED.

The difference between READ COMMITTED and SERIALizable is that in READ COMMITTED mode, each statement in a transaction sees only rows committed before the statement started, while in SERIALizable mode, all statements in a transaction see only rows committed before the transaction started.

The READ COMMITTED isolation mode permits greater concurrency and better performance than the SERIALizable mode. It allows non-repeatable reads, where the values in a row retrieved twice in a transaction can differ because another concurrent transaction has committed changes since the transaction began. READ COMMITTED mode also permits phantom reads, where a query executed twice in the same transaction can return two different sets of rows.

The SERIALizable isolation mode prevents both non-repeatable reads and phantom reads, but at the cost of concurrency and performance. Each concurrent transaction has a consistent view of the database taken at the beginning of execution. A concurrent transaction that attempts to modify data modified by another transaction is rolled back. Applications that execute transactions in SERIALizable mode must be prepared to handle transactions that fail due to serialization errors. If SERIALizable isolation mode is not required by the application, it is better to use READ COMMITTED mode.

The SQL standard specifies that concurrent serializable transactions produce the same database state they would produce if executed sequentially. The MVCC snapshot isolation model prevents dirty reads, non-repeatable reads, and phantom reads without expensive locking, but there are other interactions that can occur between some SERIALizable transactions in Greenplum Database that prevent them from being truly serializable. These anomalies can often be attributed to the fact that Greenplum Database does not perform predicate locking, which means that a write in one transaction can affect the result of a previous read in another concurrent transaction.

Transactions that run concurrently should be examined to identify interactions that are not prevented by disallowing concurrent updates of the same data. Problems identified can be prevented by using explicit table locks or by requiring the conflicting transactions to update a dummy row introduced to represent the conflict.

The SQL SET TRANSACTION ISOLATION LEVEL statement sets the isolation mode for the current transaction. The mode must be set before any SELECT, INSERT, DELETE, UPDATE, or COPY statements:

```
BEGIN;
SET TRANSACTION ISOLATION LEVEL SERIALizable;
...
COMMIT;
```

The isolation mode can also be specified as part of the BEGIN statement:

```
BEGIN TRANSACTION ISOLATION LEVEL SERIALizable;
```

The default transaction isolation mode can be changed for a session by setting the `default_transaction_isolation` configuration property.

### Removing Dead Rows from Tables

Updating or deleting a row leaves an expired version of the row in the table. When an expired row is no longer referenced by any active transactions, it can be removed and the space it occupied can be reused. The VACUUM command marks the space used by expired rows for reuse.

When expired rows accumulate in a table, the disk files must be extended to accommodate new rows. Performance suffers due to the increased disk I/O required to execute queries. This condition is called bloat and it should be managed by regularly vacuuming tables.
The `VACUUM` command (without `FULL`) can run concurrently with other queries. It marks the space previously used by the expired rows as free. If the amount of remaining free space is significant, it adds the page to the table's free space map. When Greenplum Database later needs space for new rows, it first consults the table's free space map to find pages with available space. If none are found, new pages will be appended to the file.

`VACUUM` (without `FULL`) does not consolidate pages or reduce the size of the table on disk. The space it recovers is only available through the free space map. To prevent disk files from growing, it is important to run `VACUUM` often enough. The frequency of required `VACUUM` runs depends on the frequency of updates and deletes in the table (inserts only ever add new rows). Heavily updated tables might require several `VACUUM` runs per day, to ensure that the available free space can be found through the free space map. It is also important to run `VACUUM` after running a transaction that updates or deletes a large number of rows.

The `VACUUM FULL` command rewrites the table without expired rows, reducing the table to its minimum size. Every page in the table is checked, and visible rows are moved up into pages which are not yet fully packed. Empty pages are discarded. The table is locked until `VACUUM FULL` completes. This is very expensive compared to the regular `VACUUM` command, and can be avoided or postponed by vacuuming regularly. It is best to run `VACUUM FULL` during a maintenance period. An alternative to `VACUUM FULL` is to recreate the table with a `CREATE TABLE AS` statement and then drop the old table.

The free space map resides in shared memory and keeps track of free space for all tables and indexes. Each table or index uses about 60 bytes of memory and each page with free space consumes six bytes. Two system configuration parameters configure the size of the free space map:

- `max_fsm_pages` sets the maximum number of disk pages that can be added to the shared free space map. Six bytes of shared memory are consumed for each page slot. The default is 200000. This parameter must be set to at least 16 times the value of `max_fsm_relations`.

- `max_fsm_relations` sets the maximum number of relations that will be tracked in the shared memory free space map. This parameter should be set to a value larger than the total number of `tables + indexes + system tables`. The default is 1000. About 60 bytes of memory are consumed for each relation per segment instance. It is better to set the parameter too high than too low.

If the free space map is undersized, some disk pages with available space will not be added to the map, and that space cannot be reused until at least the next `VACUUM` command runs. This causes files to grow.

You can run `VACUUM VERBOSE tablename` to get a report, by segment, of the number of dead rows removed, the number of pages affected, and the number of pages with usable free space.

Query the `pg_class` system table to find out how many pages a table is using across all segments. Be sure to `ANALYZE` the table first to get accurate data.

```
SELECT relname, relpages, reltuples FROM pg_class WHERE relname='tablename';
```

Another useful tool is the `gp_bloat_diag` view in the `gp_toolkit` schema, which identifies bloat in tables by comparing the actual number of pages used by a table to the expected number. See "The gp_toolkit Administrative Schema" in the *Greenplum Database Reference Guide* for more about `gp_bloat_diag`.

**Example of Managing Transaction IDs**

For Greenplum Database, the transaction ID (XID) value an incrementing 32-bit ($2^{32}$) value. The maximum unsigned 32-bit value is 4,294,967,295, or about four billion. The XID values restart at 0 after the maximum is reached. Greenplum Database handles the limit of XID values with two features:
Calculations on XID values using modulo-$2^{32}$ arithmetic that allow Greenplum Database to reuse XID values. The modulo calculations determine the order of transactions, whether one transaction has occurred before or after another, based on the XID.

Every XID value can have up to two billion ($2^{31}$) XID values that are considered previous transactions and two billion ($2^{31} - 1$) XID values that are considered newer transactions. The XID values can be considered a circular set of values with no endpoint similar to a 24 hour clock.

Using the Greenplum Database modulo calculations, as long as two XIDs are within $2^{31}$ transactions of each other, comparing them yields the correct result.

- A frozen XID value that Greenplum Database uses as the XID for current (visible) data rows. Setting a row's XID to the frozen XID performs two functions.
  - When Greenplum Database compares XIDs using the modulo calculations, the frozen XID is always smaller, earlier, when compared to any other XID. If a row's XID is not set to the frozen XID and $2^{31}$ new transactions are executed, the row appears to be executed in the future based on the modulo calculation.
  - When the row's XID is set to the frozen XID, the original XID can be used, without duplicating the XID. This keeps the number of data rows on disk with assigned XIDs below ($2^{32}$).

  Note: Greenplum Database assigns XID values only to transactions that involve DDL or DML operations, which are typically the only transactions that require an XID.

**Simple MVCC Example**

This is a simple example of the concepts of a MVCC database and how it manages data and transactions with transaction IDs. This simple MVCC database example consists of a single table:

- The table is a simple table with 2 columns and 4 rows of data.
- The valid transaction ID (XID) values are from 0 up to 9, after 9 the XID restarts at 0.
- The frozen XID is -2. This is different than the Greenplum Database frozen XID.
- Transactions are performed on a single row.
- Only insert and update operations are performed.
- All updated rows remain on disk, no operations are performed to remove obsolete rows.

The example only updates the amount values. No other changes to the table.

The example shows these concepts.

- How transaction IDs are used to manage multiple, simultaneous transactions on a table.
- How transaction IDs are managed with the frozen XID
- How the modulo calculation determines the order of transactions based on transaction IDs

**Managing Simultaneous Transactions**

This table is the initial table data on disk with no updates. The table contains two database columns for transaction IDs, $x_{\text{min}}$ (transaction that created the row) and $x_{\text{max}}$ (transaction that updated the row). In the table, changes are added, in order, to the bottom of the table.

**Table 18: Example Table**

<table>
<thead>
<tr>
<th>item</th>
<th>amount</th>
<th>$x_{\text{min}}$</th>
<th>$x_{\text{max}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>widget</td>
<td>100</td>
<td>0</td>
<td>null</td>
</tr>
<tr>
<td>giblet</td>
<td>200</td>
<td>1</td>
<td>null</td>
</tr>
<tr>
<td>sprocket</td>
<td>300</td>
<td>2</td>
<td>null</td>
</tr>
<tr>
<td>gizmo</td>
<td>400</td>
<td>3</td>
<td>null</td>
</tr>
</tbody>
</table>
The next table shows the table data on disk after some updates on the amount values have been performed.

- xid = 4: update tbl set amount=208 where item = 'widget'
- xid = 5: update tbl set amount=133 where item = 'sprocket'
- xid = 6: update tbl set amount=16 where item = 'widget'

In the next table, the bold items are the current rows for the table. The other rows are obsolete rows, table data that on disk but is no longer current. Using the xmax value, you can determine the current rows of the table by selecting the rows with null value. Greenplum Database uses a slightly different method to determine current table rows.

<table>
<thead>
<tr>
<th>item</th>
<th>amount</th>
<th>xmin</th>
<th>xmax</th>
</tr>
</thead>
<tbody>
<tr>
<td>widget</td>
<td>100</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>giblet</td>
<td>200</td>
<td>1</td>
<td>null</td>
</tr>
<tr>
<td>sprocket</td>
<td>300</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>gizmo</td>
<td>400</td>
<td>3</td>
<td>null</td>
</tr>
<tr>
<td>widget</td>
<td>208</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>sproket</td>
<td>133</td>
<td>5</td>
<td>null</td>
</tr>
<tr>
<td>widget</td>
<td>16</td>
<td>6</td>
<td>null</td>
</tr>
</tbody>
</table>

The simple MVCC database works with XID values to determine the state of the table. For example, both these independent transactions execute concurrently.

- UPDATE command changes the sprocket amount value to 133 (xmin value 5)
- SELECT command returns the value of sprocket.

During the UPDATE transaction, the database returns the value of sprocket 300, until the UPDATE transaction completes.

**Managing XIDs and the Frozen XID**

For this simple example, the database is close to running out of available XID values. When Greenplum Database is close to running out of available XID values, Greenplum Database takes these actions.

- Greenplum Database issues a warning stating that the database is running out of XID values.

  WARNING: database "database_name" must be vacuumed within number_of_transactions transactions

- Before the last XID is assigned, Greenplum Database stops accepting transactions to prevent assigning an XID value twice and issues this message.

  FATAL: database is not accepting commands to avoid wraparound data loss in database "database_name"

To manage transaction IDs and table data that is stored on disk, Greenplum Database provides the VACUUM command.

- A VACUUM operation frees up XID values so that a table can have more than 10 rows by changing the xmin values to the frozen XID.
- A VACUUM operation manages obsolete or deleted table rows on disk. This database's VACUUM command changes the XID values obsolete to indicate obsolete rows. A Greenplum Database
**VACUUM** operation, without the **FULL** option, deletes the data opportunistically to remove rows on disk with minimal impact to performance and data availability.

For the example table, a **VACUUM** operation has been performed on the table. The command updated table data on disk. This version of the **VACUUM** command performs slightly differently than the Greenplum Database command, but the concepts are the same.

- For the widget and sprocket rows on disk that are no longer current, the rows have been marked as obsolete.
- For the giblet and gizmo rows that are current, the xmin has been changed to the frozen XID.

The values are still current table values (the row's xmax value is **null**). However, the table row is visible to all transactions because the xmin value is frozen XID value that is older than all other XID values when modulo calculations are performed.

After the **VACUUM** operation, the XID values 0, 1, 2, and 3 available for use.

**Table 20: Example Table after VACUUM**

<table>
<thead>
<tr>
<th>item</th>
<th>amount</th>
<th>xmin</th>
<th>xmax</th>
</tr>
</thead>
<tbody>
<tr>
<td>widget</td>
<td>100</td>
<td>obsolete</td>
<td>obsolete</td>
</tr>
<tr>
<td>giblet</td>
<td>200</td>
<td>-2</td>
<td>null</td>
</tr>
<tr>
<td>sprocket</td>
<td>300</td>
<td>obsolete</td>
<td>obsolete</td>
</tr>
<tr>
<td>gizmo</td>
<td>400</td>
<td>-2</td>
<td>null</td>
</tr>
<tr>
<td>widget</td>
<td>208</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>sprocket</td>
<td>133</td>
<td>5</td>
<td>null</td>
</tr>
<tr>
<td>widget</td>
<td>16</td>
<td>6</td>
<td>null</td>
</tr>
</tbody>
</table>

When a row disk with the xmin value of -2 is updated, the xmax value is replaced with the transaction XID as usual, and the row on disk is considered obsolete after any concurrent transactions that access the row have completed.

Obsolete rows can be deleted from disk. For Greenplum Database, the **VACUUM** command, with **FULL** option, does more extensive processing to reclaim disk space.

**Example of XID Modulo Calculations**

The next table shows the table data on disk after more **UPDATE** transactions. The XID values have rolled over and start over at 0. No additional **VACUUM** operations have been performed.

**Table 21: Example Table with Wrapping XID**

<table>
<thead>
<tr>
<th>item</th>
<th>amount</th>
<th>xmin</th>
<th>xmax</th>
</tr>
</thead>
<tbody>
<tr>
<td>widget</td>
<td>100</td>
<td>obsolete</td>
<td>obsolete</td>
</tr>
<tr>
<td>giblet</td>
<td>200</td>
<td>-2</td>
<td>1</td>
</tr>
<tr>
<td>sprocket</td>
<td>300</td>
<td>obsolete</td>
<td>obsolete</td>
</tr>
<tr>
<td>gizmo</td>
<td>400</td>
<td>-2</td>
<td>9</td>
</tr>
<tr>
<td>widget</td>
<td>208</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>sproket</td>
<td>133</td>
<td>5</td>
<td>null</td>
</tr>
<tr>
<td>widget</td>
<td>16</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>
When performing the modulo calculations that compare XIDs, Greenplum Database considers the XIDs of the rows and the current range of available XIDs to determine if XID wrapping has occurred between row XIDs.

For the example table XID wrapping has occurred. The XID 1 for giblet row is a later transaction than the XID 7 for widget row based on the modulo calculations for XID values even though the XID value 7 is larger than 1.

For the widget and sprocket rows, XID wrapping has not occurred and XID 7 is a later transaction than XID 5.

## About Parallel Data Loading

This topic provides a short introduction to Greenplum Database data loading features.

In a large scale, multi-terabyte data warehouse, large amounts of data must be loaded within a relatively small maintenance window. Greenplum supports fast, parallel data loading with its external tables feature. Administrators can also load external tables in single row error isolation mode to filter bad rows into a separate error table while continuing to load properly formatted rows. Administrators can specify an error threshold for a load operation to control how many improperly formatted rows cause Greenplum to abort the load operation.

By using external tables in conjunction with Greenplum Database's parallel file server (gpfdist), administrators can achieve maximum parallelism and load bandwidth from their Greenplum Database system.

<table>
<thead>
<tr>
<th>item</th>
<th>amount</th>
<th>xmin</th>
<th>xmax</th>
</tr>
</thead>
<tbody>
<tr>
<td>widget</td>
<td>222</td>
<td>7</td>
<td>null</td>
</tr>
<tr>
<td>giblet</td>
<td>233</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>gizmo</td>
<td>18</td>
<td>9</td>
<td>null</td>
</tr>
<tr>
<td>giblet</td>
<td>88</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>giblet</td>
<td>44</td>
<td>1</td>
<td>null</td>
</tr>
</tbody>
</table>
Another Greenplum utility, `gpload`, runs a load task that you specify in a YAML-formatted control file. You describe the source data locations, format, transformations required, participating hosts, database destinations, and other particulars in the control file and `gpload` executes the load. This allows you to describe a complex task and execute it in a controlled, repeatable fashion.

**About Redundancy and Failover in Greenplum Database**

This topic provides a high-level overview of Greenplum Database high availability features.

You can deploy Greenplum Database without a single point of failure by mirroring components. The following sections describe the strategies for mirroring the main components of a Greenplum system. For a more detailed overview of Greenplum high availability features, see *Overview of Greenplum Database High Availability*.

**Important:** When data loss is not acceptable for a Pivotal Greenplum Database cluster, master and segment mirroring must be enabled in order for the cluster to be supported by Pivotal. Without mirroring, system and data availability is not guaranteed; Pivotal will make best efforts to restore a cluster in this case.

**About Segment Mirroring**

When you deploy your Greenplum Database system, you can configure *mirror* segments. Mirror segments allow database queries to fail over to a backup segment if the primary segment becomes unavailable. Mirroring is strongly recommended for production systems and required for Pivotal support.

The secondary (mirror) segment must always reside on a different host than its primary segment to protect against a single host failure. In virtualized environments, the secondary (mirror) must always reside on a different storage system than the master. Mirror segments can be arranged over the remaining hosts in the cluster in configurations designed to maximize availability, or minimize the performance degradation when hosts or multiple primary segments fail.

Two standard mirroring configurations are available when you initialize or expand a Greenplum system. The default configuration, called *group mirroring*, places all the mirrors for a host's primary segments on
one other host in the cluster. The other standard configuration, *spread mirroring*, can be selected with a command-line option. Spread mirroring spreads each host's mirrors over the remaining hosts and requires that there are more hosts in the cluster than primary segments per host.

*Figure 13: Spread Mirroring in Greenplum Database* shows how table data is distributed across segments when spread mirroring is configured.

---

**Segment Failover and Recovery**

When mirroring is enabled in a Greenplum Database system, the system will automatically fail over to the mirror segment if a primary copy becomes unavailable. A Greenplum Database system can remain operational if a segment instance or host goes down as long as all the data is available on the remaining active segments.

If the master cannot connect to a segment instance, it marks that segment instance as down in the Greenplum Database system catalog and brings up the mirror segment in its place. A failed segment instance will remain out of operation until an administrator takes steps to bring that segment back online. The *gpstate* utility can be used to identify failed segments. An administrator can recover a failed segment while the system is up and running. The recovery process copies over only the changes that were missed while the segment was out of operation.

If you do not have mirroring enabled, the system will automatically shut down if a segment instance becomes invalid. You must recover all failed segments before operations can continue.

**About Master Mirroring**

You can also optionally deploy a *backup* or *mirror* of the master instance on a separate host from the master node. A backup master host serves as a *warm standby* in the event that the primary master host becomes unoperational. The standby master is kept up to date by a transaction log replication process.
which runs on the standby master host and synchronizes the data between the primary and standby master hosts.

If the primary master fails, the log replication process stops, and the standby master can be activated in its place. The switchover does not happen automatically, but must be triggered externally. Upon activation of the standby master, the replicated logs are used to reconstruct the state of the master host at the time of the last successfully committed transaction. The activated standby master effectively becomes the Greenplum Database master, accepting client connections on the master port (which must be set to the same port number on the master host and the backup master host).

Since the master does not contain any user data, only the system catalog tables need to be synchronized between the primary and backup copies. When these tables are updated, changes are automatically copied over to the standby master to ensure synchronization with the primary master.

![Figure 14: Master Mirroring in Greenplum Database](image)

**About Interconnect Redundancy**

The *interconnect* refers to the inter-process communication between the segments and the network infrastructure on which this communication relies. You can achieve a highly available interconnect using by deploying dual Gigabit Ethernet switches on your network and redundant Gigabit connections to the Greenplum Database host (master and segment) servers. For performance reasons, 10-Gb Ethernet, or faster, is recommended.

**About Database Statistics in Greenplum Database**

An overview of statistics gathered by the *ANALYZE* command in Greenplum Database.

Statistics are metadata that describe the data stored in the database. The query optimizer needs up-to-date statistics to choose the best execution plan for a query. For example, if a query joins two tables and one of them must be broadcast to all segments, the optimizer can choose the smaller of the two tables to minimize network traffic.

The statistics used by the optimizer are calculated and saved in the system catalog by the *ANALYZE* command. There are three ways to initiate an analyze operation:

- You can run the *ANALYZE* command directly.
- You can run the *analyzedb* management utility outside of the database, at the command line.
- An automatic analyze operation can be triggered when DML operations are performed on tables that have no statistics or when a DML operation modifies a number of rows greater than a specified threshold.

These methods are described in the following sections. The *VACUUM ANALYZE* command is another way to initiate an analyze operation, but its use is discouraged because vacuum and analyze are different operations with different purposes.
Calculating statistics consumes time and resources, so Greenplum Database produces estimates by calculating statistics on samples of large tables. In most cases, the default settings provide the information needed to generate correct execution plans for queries. If the statistics produced are not producing optimal query execution plans, the administrator can tune configuration parameters to produce more accurate statistics by increasing the sample size or the granularity of statistics saved in the system catalog. Producing more accurate statistics has CPU and storage costs and may not produce better plans, so it is important to view explain plans and test query performance to ensure that the additional statistics-related costs result in better query performance.

System Statistics

Table Size

The query planner seeks to minimize the disk I/O and network traffic required to execute a query, using estimates of the number of rows that must be processed and the number of disk pages the query must access. The data from which these estimates are derived are the `pg_class` system table columns `reltuples` and `relpages`, which contain the number of rows and pages at the time a `VACUUM` or `ANALYZE` command was last run. As rows are added or deleted, the numbers become less accurate. However, an accurate count of disk pages is always available from the operating system, so as long as the ratio of `reltuples` to `relpages` does not change significantly, the optimizer can produce an estimate of the number of rows that is sufficiently accurate to choose the correct query execution plan.

When the `reltuples` column differs significantly from the row count returned by `SELECT COUNT(*)`, an `analyze` should be performed to update the statistics.

When a `REINDEX` command finishes recreating an index, the `relpages` and `reltuples` columns are set to zero. The `ANALYZE` command should be run on the base table to update these columns.

The `pg_statistic` System Table and `pg_stats` View

The `pg_statistic` system table holds the results of the last `ANALYZE` operation on each database table. There is a row for each column of every table. It has the following columns:

- `starelid`  
  The object ID of the table or index the column belongs to.

- `staatnum`  
  The number of the described column, beginning with 1.

- `stanullfrac`  
  The fraction of the column's entries that are null.

- `stawidth`  
  The average stored width, in bytes, of non-null entries.

- `stadistinct`  
  A positive number is an estimate of the number of distinct values in the column; the number is not expected to vary with the number of rows. A negative value is the number of distinct values divided by the number of rows, that is, the ratio of rows with distinct values for the column, negated. This form is used when the number of distinct values increases with the number of rows. A unique column, for example, has an `n_distinct` value of -1.0. Columns with an average width greater than 1024 are considered unique.

- `stakindN`  
  A code number indicating the kind of statistics stored in the `Nth` slot of the `pg_statistic` row.

- `staopN`  
  An operator used to derive the statistics stored in the `Nth` slot. For example, a histogram slot would show the `<` operator that defines the sort order of the data.
the appropriate kind for the $N$th slot, or NULL if the slot kind does not involve numerical values.

**stavalues**

Column data values of the appropriate kind for the $N$th slot, or NULL if the slot kind does not store any data values. Each array's element values are actually of the specific column's data type, so there is no way to define these columns' types more specifically than `anyarray`.

The statistics collected for a column vary for different data types, so the `pg_statistic` table stores statistics that are appropriate for the data type in four slots, consisting of four columns per slot. For example, the first slot, which normally contains the most common values for a column, consists of the columns `stakind1`, `staop1`, `stanumbers1`, and `stavalues1`.

The `stakindN` columns each contain a numeric code to describe the type of statistics stored in their slot. The `stakind` code numbers from 1 to 99 are reserved for core PostgreSQL data types. Greenplum Database uses code numbers 1, 2, and 3. A value of 0 means the slot is unused. The following table describes the kinds of statistics stored for the three codes.

**Table 22: Contents of pg_statistic "slots"**

<table>
<thead>
<tr>
<th>stakind Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Most CommonValues (MCV) Slot</strong></td>
</tr>
<tr>
<td></td>
<td>• <code>staop</code> contains the object ID of the &quot;=&quot; operator, used to decide whether values are the same or not.</td>
</tr>
<tr>
<td></td>
<td>• <code>stavalues</code> contains an array of the $K$ most common non-null values appearing in the column.</td>
</tr>
<tr>
<td></td>
<td>• <code>stanumbers</code> contains the frequencies (fractions of total row count) of the values in the <code>stavalues</code> array.</td>
</tr>
<tr>
<td></td>
<td>The values are ordered in decreasing frequency. Since the arrays are variable-size, $K$ can be chosen by the statistics collector. Values must occur more than once to be added to the <code>stavalues</code> array; a unique column has no MCV slot.</td>
</tr>
<tr>
<td>2</td>
<td><strong>Histogram Slot</strong> – describes the distribution of scalar data.</td>
</tr>
<tr>
<td></td>
<td>• <code>staop</code> is the object ID of the &quot;&lt;&quot; operator, which describes the sort ordering.</td>
</tr>
<tr>
<td></td>
<td>• <code>stavalues</code> contains $M$ (where $M\geq2$) non-null values that divide the non-null column data values into $M-1$ bins of approximately equal population. The first <code>stavalues</code> item is the minimum value and the last is the maximum value.</td>
</tr>
<tr>
<td></td>
<td>• <code>stanumbers</code> is not used and should be NULL.</td>
</tr>
</tbody>
</table>

If a Most Common Values slot is also provided, then the histogram describes the data distribution after removing the values listed in the MCV array. (It is a *compressed histogram* in the technical parlance). This allows a more accurate representation of the distribution of a column with some very common values. In a column with only a few distinct values, it is possible that the MCV list describes the entire data population; in this case the histogram reduces to empty and should be omitted.
**Table:**

<table>
<thead>
<tr>
<th>stkind Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td><em>Correlation Slot</em> – describes the correlation between the physical order of table tuples and the ordering of data values of this column.</td>
</tr>
<tr>
<td></td>
<td>• staoop is the object ID of the &quot;&lt;&quot; operator. As with the histogram, more than one entry could theoretically appear.</td>
</tr>
<tr>
<td></td>
<td>• stavalues is not used and should be NULL.</td>
</tr>
<tr>
<td></td>
<td>• stanumbers contains a single entry, the correlation coefficient between the sequence of data values and the sequence of their actual tuple positions. The coefficient ranges from +1 to -1.</td>
</tr>
</tbody>
</table>

The `pg_stats` view presents the contents of `pg_statistic` in a friendlier format. The `pg_stats` view has the following columns:

- **schemaname**: The name of the schema containing the table.
- **tablename**: The name of the table.
- **attname**: The name of the column this row describes.
- **null_frac**: The fraction of column entries that are null.
- **avg_width**: The average storage width in bytes of the column's entries, calculated as `avg(pg_column_size(column_name))`.
- **n_distinct**: A positive number is an estimate of the number of distinct values in the column; the number is not expected to vary with the number of rows. A negative value is the number of distinct values divided by the number of rows, that is, the ratio of rows with distinct values for the column, negated. This form is used when the number of distinct values increases with the number of rows. A unique column, for example, has an `n_distinct` value of -1.0. Columns with an average width greater than 1024 are considered unique.
- **most_common_vals**: An array containing the most common values in the column, or null if no values seem to be more common. If the `n_distinct` column is -1, `most_common_vals` is null. The length of the array is the lesser of the number of actual distinct column values or the value of the `default_statistics_target` configuration parameter. The number of values can be overridden for a column using `ALTER TABLE table SET COLUMN column SET STATISTICS N`.
- **most_common_freqs**: An array containing the frequencies of the values in the `most_common_vals` array. This is the number of occurrences of the value divided by the total number of rows. The array is the same length as the `most_common_vals` array. It is null if `most_common_vals` is null.
- **histogram_bounds**: An array of values that divide the column values into groups of approximately the same size. A
**Sampling**

When calculating statistics for large tables, Greenplum Database creates a smaller table by sampling the base table. If the table is partitioned, samples are taken from all partitions.

If the number of rows in the base table is estimated to be less than the value of the `gp_statistics_sampling_threshold` configuration parameter, the entire base table is used to calculate the statistics.

If a sample table is created, the number of rows in the sample is calculated to provide a maximum acceptable relative error. The amount of acceptable error is specified with the `gp_analyze_relative_error` system configuration parameter, which is set to .25 (25%) by default. This is usually sufficiently accurate to generate correct query plans. If `ANALYZE` is not producing good estimates for a table column, you can increase the sample size by setting the `gp_analyze_relative_error` configuration parameter to a lower value. Beware that setting this parameter to a low value can lead to a very large sample size and dramatically increase analyze time.

**Updating Statistics**

Running `ANALYZE` with no arguments updates statistics for all tables in the database. This could take a very long time, so it is better to analyze tables selectively after data has changed. You can also analyze a subset of the columns in a table, for example columns used in joins, `WHERE` clauses, `SORT` clauses, `GROUP BY` clauses, or `HAVING` clauses.

Analyzing a severely bloated table can generate poor statistics if the sample contains empty pages, so it is good practice to vacuum a bloated table before analyzing it.

See the SQL Command Reference in the Greenplum Database Reference Guide for details of running the `ANALYZE` command.

Refer to the Greenplum Database Management Utility Reference for details of running the `analyzedb` command.

**Analyzing Partitioned and Append-Optimized Tables**

When the `ANALYZE` command is run on a partitioned table, it analyzes each leaf-level subpartition, one at a time. You can run `ANALYZE` on just new or changed partition files to avoid analyzing partitions that have not changed. If a table is partitioned, you can analyze just new or changed partitions.

The `analyzedb` command-line utility skips unchanged partitions automatically. It also runs concurrent sessions so it can analyze several partitions concurrently. It runs five sessions by default, but the number of sessions can be set from 1 to 10 with the `-p` command-line option. Each time `analyzedb` runs, it saves state information for append-optimized tables and partitions in the `db_analyze` directory in the master data directory. The next time it runs, `analyzedb` compares the current state of each table with the saved state and skips analyzing a table or partition if it is unchanged. Heap tables are always analyzed.

If GPORCA is enabled (the default), you also need to run `ANALYZE_ROOTPARTITION` to refresh the root partition statistics. GPORCA requires statistics at the root level for partitioned tables. The histogram can be defined only if there is a `max()` aggregate function for the column. The number of groups in the histogram is the same as the `most_common_vals` array size.

Greenplum Database does not calculate the correlation statistic.

Newly created tables and indexes have no statistics. You can check for tables with missing statistics using the `gp_stats_missing` view, which is in the `gp_toolkit` schema:

```
SELECT * from gp_toolkit.gp_stats_missing;
```
legacy optimizer does not use these statistics. Enable GPORCA by setting both the optimizer and optimizer_analyze_root_partition system configuration parameters to on. The root level statistics are then updated when you run ANALYZE or ANALYZE_ROOTPARTITION. The time to run ANALYZE_ROOTPARTITION is similar to the time to analyze a non-partitioned table with the same data since ANALYZE_ROOTPARTITION does not collect statistics on the leaf partitions, the data is only sampled. The analyzedb utility updates root partition statistics by default but you can add the --skip_root_stats option to leave root partition statistics empty if you do not use GPORCA.

Configuring Statistics

There are several options for configuring Greenplum Database statistics collection.

Statistics Target

The statistics target is the size of the most_common_vals, most_common_freqs, and histogram_bounds arrays for an individual column. By default, the target is 25. The default target can be changed by setting a server configuration parameter and the target can be set for any column using the ALTER TABLE command. Larger values increase the time needed to do ANALYZE, but may improve the quality of the legacy query optimizer (planner) estimates.

Set the system default statistics target to a different value by setting the default_statistics_target server configuration parameter. The default value is usually sufficient, and you should only raise or lower it if your tests demonstrate that query plans improve with the new target. For example, to raise the default statistics target from 100 to 150 you can use the gpconfig utility:

```
gpconfig -c default_statistics_target -v 150
```

The statistics target for individual columns can be set with the ALTER TABLE command. For example, some queries can be improved by increasing the target for certain columns, especially columns that have irregular distributions. You can set the target to zero for columns that never contribute to query optimization. When the target is 0, ANALYZE ignores the column. For example, the following ALTER TABLE command sets the statistics target for the notes column in the emp table to zero:

```
ALTER TABLE emp ALTER COLUMN notes SET STATISTICS 0;
```

The statistics target can be set in the range 0 to 1000, or set it to -1 to revert to using the system default statistics target.

Setting the statistics target on a parent partition table affects the child partitions. If you set statistics to 0 on some columns on the parent table, the statistics for the same columns are set to 0 for all children partitions. However, if you later add or exchange another child partition, the new child partition will use either the default statistics target or, in the case of an exchange, the previous statistics target. Therefore, if you add or exchange child partitions, you should set the statistics targets on the new child table.

Automatic Statistics Collection

Greenplum Database can be set to automatically run ANALYZE on a table that either has no statistics or has changed significantly when certain operations are performed on the table. For partitioned tables, automatic statistics collection is only triggered when the operation is run directly on a leaf table, and then only the leaf table is analyzed.

Automatic statistics collection has three modes:

- **none** disables automatic statistics collection.
- **on_no_stats** triggers an analyze operation for a table with no existing statistics when any of the commands CREATE TABLE AS SELECT, INSERT, or COPY are executed on the table.
- **on_change** triggers an analyze operation when any of the commands CREATE TABLE AS SELECT, UPDATE, DELETE, INSERT, or COPY are executed on the table and the number of rows affected
exceeds the threshold defined by the `gp_autostats_on_change_threshold` configuration parameter.

The automatic statistics collection mode is set separately for commands that occur within a procedural language function and commands that execute outside of a function:

- The `gp_autostats_mode` configuration parameter controls automatic statistics collection behavior outside of functions and is set to `on_no_stats` by default.
- The `gp_autostats_mode_in_functions` parameter controls the behavior when table operations are performed within a procedural language function and is set to `none` by default.

With the `on_change` mode, `ANALYZE` is triggered only if the number of rows affected exceeds the threshold defined by the `gp_autostats_on_change_threshold` configuration parameter. The default value for this parameter is a very high value, 2147483647, which effectively disables automatic statistics collection; you must set the threshold to a lower number to enable it. The `on_change` mode could trigger large, unexpected analyze operations that could disrupt the system, so it is not recommended to set it globally. It could be useful in a session, for example to automatically analyze a table following a load.

To disable automatic statistics collection outside of functions, set the `gp_autostats_mode` parameter to `none`:

```
gpconfigure -c gp_autostats_mode -v none
```

To enable automatic statistics collection in functions for tables that have no statistics, change `gp_autostats_mode_in_functions` to `on_no_stats`:

```
gpconfigure -c gp_autostats_mode_in_functions -v on_no_stats
```

Set the `log_autostats` system configuration parameter to `on` if you want to log automatic statistics collection operations.
Managing a Greenplum System

This section describes basic system administration tasks performed by a Greenplum Database system administrator.

This section contains the following topics:

• About the Greenplum Database Release Version Number
• Starting and Stopping Greenplum Database
• Accessing the Database
• Configuring the Greenplum Database System
• Enabling High Availability and Data Consistency Features
• Backing Up and Restoring Databases
• Expanding a Greenplum System
• Migrating Data with gptransfer
• Defining Database Objects
• Routine System Maintenance Tasks

About the Greenplum Database Release Version Number

Greenplum Database version numbers and the way they change identify what has been modified from one Greenplum Database release to the next.

A Greenplum Database release version number takes the format x.y.z, where:

• x identifies the Major version number
• y identifies the Minor version number
• z identifies the Patch version number

Greenplum Database releases that have the same Major release number are guaranteed to be backwards compatible. Greenplum Database increments the Major release number when the catalog changes or when incompatible feature changes or new features are introduced. Previously deprecated functionality may be removed in a major release.

The Minor release number for a given Major release increments when backwards compatible new features are introduced or when a Greenplum Database feature is deprecated. (Previously deprecated functionality will never be removed in a minor release.)

Greenplum Database increments the Patch release number for a given Minor release for backwards-compatible bug fixes.

Starting and Stopping Greenplum Database

In a Greenplum Database DBMS, the database server instances (the master and all segments) are started or stopped across all of the hosts in the system in such a way that they can work together as a unified DBMS.

Because a Greenplum Database system is distributed across many machines, the process for starting and stopping a Greenplum Database system is different than the process for starting and stopping a regular PostgreSQL DBMS.

Use the gpstart and gpstop utilities to start and stop Greenplum Database, respectively. These utilities are located in the $GPHOME/bin directory on your Greenplum Database master host.

Important: Do not issue a kill command to end any Postgres process. Instead, use the database command pg_cancel_backend().
Issuing a `kill -9` or `kill -11` can introduce database corruption and prevent root cause analysis from being performed.

For information about `gpstart` and `gpstop`, see the *Greenplum Database Utility Guide*.

**Starting Greenplum Database**

Start an initialized Greenplum Database system by running the `gpstart` utility on the master instance.

Use the `gpstart` utility to start a Greenplum Database system that has already been initialized by the `gpinitsystem` utility, but has been stopped by the `gpstop` utility. The `gpstart` utility starts Greenplum Database by starting all the Postgres database instances on the Greenplum Database cluster. `gpstart` orchestrates this process and performs the process in parallel.

- Run `gpstart` on the master host to start Greenplum Database:

  ```
  $ gpstart
  ```

**Restarting Greenplum Database**

Stop the Greenplum Database system and then restart it.

The `gpstop` utility with the `-r` option can stop and then restart Greenplum Database after the shutdown completes.

- To restart Greenplum Database, enter the following command on the master host:

  ```
  $ gpstop -r
  ```

**Reloading Configuration File Changes Only**

Reload changes to Greenplum Database configuration files without interrupting the system.

The `gpstop` utility can reload changes to the `pg_hba.conf` configuration file and to runtime parameters in the master `postgresql.conf` file and `pg_hba.conf` file without service interruption. Active sessions pick up changes when they reconnect to the database. Many server configuration parameters require a full system restart (`gpstop -r`) to activate. For information about server configuration parameters, see the *Greenplum Database Reference Guide*.

- Reload configuration file changes without shutting down the system using the `gpstop` utility:

  ```
  $ gpstop -u
  ```

**Starting the Master in Maintenance Mode**

Start only the master to perform maintenance or administrative tasks without affecting data on the segments.

Maintenance mode should only be used with direction from Pivotal Technical Support. For example, you could connect to a database only on the master instance in maintenance mode and edit system catalog settings. For more information about system catalog tables, see the *Greenplum Database Reference Guide*.

1. Run `gpstart` using the `-m` option:

   ```
   $ gpstart -m
   ```

2. Connect to the master in maintenance mode to do catalog maintenance. For example:

   ```
   $ PGOPTIONS='\-c gp_session_role=utility' psql postgres
   ```
3. After completing your administrative tasks, stop the master in utility mode. Then, restart it in production mode.

   `$ gpstop -mr`

   **Warning:**
   Incorrect use of maintenance mode connections can result in an inconsistent system state. Only Technical Support should perform this operation.

### Stopping Greenplum Database

The `gpstop` utility stops or restarts your Greenplum Database system and always runs on the master host. When activated, `gpstop` stops all `postgres` processes in the system, including the master and all segment instances. The `gpstop` utility uses a default of up to 64 parallel worker threads to bring down the Postgres instances that make up the Greenplum Database cluster. The system waits for any active transactions to finish before shutting down. To stop Greenplum Database immediately, use fast mode.

- To stop Greenplum Database:

  `$ gpstop`

- To stop Greenplum Database in fast mode:

  `$ gpstop -M fast`

By default, you are not allowed to shut down Greenplum Database if there are any client connections to the database. Use the `-M fast` option to roll back all in progress transactions and terminate any connections before shutting down.

### Stopping Client Processes

Greenplum Database launches a new backend process for each client connection. A Greenplum Database user with `SUPERUSER` privileges can cancel and terminate these client backend processes.

Canceling a backend process with the `pg_cancel_backend()` function ends a specific queued or active client query. Terminating a backend process with the `pg_terminate_backend()` function terminates a client connection to a database.

The `pg_cancel_backend()` function has two signatures:

- `pg_cancel_backend( pid int4 )`
- `pg_cancel_backend( pid int4, msg text )`

The `pg_terminate_backend()` function has two similar signatures:

- `pg_terminate_backend( pid int4 )`
- `pg_terminate_backend( pid int4, msg text )`

If you provide a `msg`, Greenplum Database includes the text in the cancel message returned to the client. `msg` is limited to 128 bytes; Greenplum Database truncates anything longer.

The `pg_cancel_backend()` and `pg_terminate_backend()` functions return `true` if successful, and `false` otherwise.

To cancel or terminate a backend process, you must first identify the process ID of the backend. You can obtain the process ID from the `procpid` column of the `pg_stat_activity` view. For example, to view the process information associated with all running and queued queries:

```sql
=# SELECT usename, procpid, waiting, current_query, datname
    FROM pg_stat_activity;
```
Sample partial query output:

<table>
<thead>
<tr>
<th>username</th>
<th>procpid</th>
<th>waiting</th>
<th>current_query</th>
<th>datname</th>
</tr>
</thead>
<tbody>
<tr>
<td>sammy</td>
<td>31861</td>
<td>f</td>
<td>&lt;IDLE&gt; in transaction</td>
<td>testdb</td>
</tr>
<tr>
<td>billy</td>
<td>31905</td>
<td>t</td>
<td>SELECT * FROM topten;</td>
<td>testdb</td>
</tr>
</tbody>
</table>

Use the output to identify the process id (procpid) of the query or client connection.

For example, to cancel the pending query identified in the sample output above and include "Admin canceled long-running query." in the message returned to the client:

```sql
=# SELECT pg_cancel_backend(31905 ,'Admin canceled long-running query.');
ERROR:  canceling statement due to user request: "Admin canceled long-running query."
```

**Accessing the Database**

This topic describes the various client tools you can use to connect to Greenplum Database, and how to establish a database session.

**Establishing a Database Session**

Users can connect to Greenplum Database using a PostgreSQL-compatible client program, such as `psql`. Users and administrators always connect to Greenplum Database through the master; the segments cannot accept client connections.

In order to establish a connection to the Greenplum Database master, you will need to know the following connection information and configure your client program accordingly.

**Table 23: Connection Parameters**

<table>
<thead>
<tr>
<th>Connection Parameter</th>
<th>Description</th>
<th>Environment Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application name</td>
<td>The application name that is connecting to the database. The default value, held in the application_name connection parameter is <code>psql</code>.</td>
<td>$PGAPPNAME</td>
</tr>
<tr>
<td>Database name</td>
<td>The name of the database to which you want to connect. For a newly initialized system, use the postgres database to connect for the first time.</td>
<td>$PGDATABASE</td>
</tr>
<tr>
<td>Host name</td>
<td>The host name of the Greenplum Database master. The default host is the local host.</td>
<td>$PGHOST</td>
</tr>
<tr>
<td>Port</td>
<td>The port number that the Greenplum Database master instance is running on. The default is 5432.</td>
<td>$PGPORT</td>
</tr>
<tr>
<td>User name</td>
<td>The database user (role) name to connect as. This is not necessarily the same as your OS user name. Check with your Greenplum administrator if you are not sure what you database user name is. Note that every Greenplum Database system has one superuser account that is created automatically at initialization time. This account has the same name as the OS name of the user who initialized the Greenplum system (typically <code>gpadmin</code>).</td>
<td>$PGUSER</td>
</tr>
</tbody>
</table>

*Connecting with `psql` provides example commands for connecting to Greenplum Database.*
Supported Client Applications

Users can connect to Greenplum Database using various client applications:

- A number of Greenplum Database Client Applications are provided with your Greenplum installation. The `psql` client application provides an interactive command-line interface to Greenplum Database.
- Using standard Database Application Interfaces, such as ODBC and JDBC, users can create their own client applications that interface to Greenplum Database.
- Most client tools that use standard database interfaces, such as ODBC and JDBC, can be configured to connect to Greenplum Database.

Greenplum Database Client Applications

Greenplum Database comes installed with a number of client utility applications located in the `$GPHOME/bin` directory of your Greenplum Database master host installation. The following are the most commonly used client utility applications:

Table 24: Commonly used client applications

<table>
<thead>
<tr>
<th>Name</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>createdb</td>
<td>create a new database</td>
</tr>
<tr>
<td>createlang</td>
<td>define a new procedural language</td>
</tr>
<tr>
<td>createuser</td>
<td>define a new database role</td>
</tr>
<tr>
<td>dropdb</td>
<td>remove a database</td>
</tr>
<tr>
<td>droplang</td>
<td>remove a procedural language</td>
</tr>
<tr>
<td>dropuser</td>
<td>remove a role</td>
</tr>
<tr>
<td>psql</td>
<td>PostgreSQL interactive terminal</td>
</tr>
<tr>
<td>reindexdb</td>
<td>reindex a database</td>
</tr>
<tr>
<td>vacuumdb</td>
<td>garbage-collect and analyze a database</td>
</tr>
</tbody>
</table>

When using these client applications, you must connect to a database through the Greenplum master instance. You will need to know the name of your target database, the host name and port number of the master, and what database user name to connect as. This information can be provided on the command-line using the options `-d`, `-h`, `-p`, and `-U` respectively. If an argument is found that does not belong to any option, it will be interpreted as the database name first.

All of these options have default values which will be used if the option is not specified. The default host is the local host. The default port number is 5432. The default user name is your OS system user name, as is the default database name. Note that OS user names and Greenplum Database user names are not necessarily the same.

If the default values are not correct, you can set the environment variables `PGDATABASE`, `PGHOST`, `PGPORT`, and `PGUSER` to the appropriate values, or use a `psql ~/.pgpass` file to contain frequently-used passwords.

For information about Greenplum Database environment variables, see the Greenplum Database Reference Guide. For information about `psql`, see the Greenplum Database Utility Guide.
Connecting with psql

Depending on the default values used or the environment variables you have set, the following examples show how to access a database via psql:

```
$ psql -d gpdatabase -h master_host -p 5432 -U gpadmin

$ psql gpdatabase

$ psql
```

If a user-defined database has not yet been created, you can access the system by connecting to the postgres database. For example:

```
$ psql postgres
```

After connecting to a database, psql provides a prompt with the name of the database to which psql is currently connected, followed by the string => (or =# if you are the database superuser). For example:

```
gpdbdatabase=>
```

At the prompt, you may type in SQL commands. A SQL command must end with a ; (semicolon) in order to be sent to the server and executed. For example:

```
=> SELECT * FROM mytable;
```

See the Greenplum Reference Guide for information about using the psql client application and SQL commands and syntax.

Using the PgBouncer Connection Pooler

The PgBouncer utility manages connection pools for PostgreSQL and Greenplum Database connections.

The Greenplum Database installation includes the PgBouncer connection pooling software. The following topics describe how to set up and use PgBouncer with Greenplum Database. See the PgBouncer Web site for information about using PgBouncer with PostgreSQL.

• Overview
• Configuring and Starting PgBouncer
• Managing PgBouncer
• Setting up LDAP Authentication with PgBouncer
• Securing PgBouncer Connections with stunnel

Also, see reference information for PgBouncer in the Greenplum Database Utility Guide.

Overview

A database connection pool is a cache of database connections. Once a pool of connections is established, connection pooling eliminates the overhead of creating database connections, so clients connect much faster and the server load is reduced.

The PgBouncer connection pooler, from the PostgreSQL community, is included with Greenplum Database. PgBouncer can manage connection pools for multiple databases, and databases may be on different Greenplum Database clusters or PostgreSQL backends. PgBouncer creates a pool for each database user and database combination. A pooled connection can only be reused for another connection request for the same user and database.
The client application requires no software changes, but connects to the connection pool's host and port instead of the Greenplum Database master host and port. PgBouncer either creates a new database connection or reuses an existing connection. When the client disconnects, the connection is returned to the pool for re-use.

PgBouncer supports the standard connection interface that PostgreSQL and Greenplum Database share. A client requesting a database connection provides the host name and port where PgBouncer is running, as well as the database name, username, and password. PgBouncer looks up the requested database (which may be an alias for the actual database) in its configuration file to find the host name, port, and database name for the database connection. The configuration file entry also determines how to authenticate the user and what database role will be used for the connection—a “forced user” can override the username provided with the client's connection request.

PgBouncer requires an authentication file, a text file that contains a list of users and passwords. Passwords may be either clear text, MD5-encoded, or an LDAP/AD lookup string. You can also set up PgBouncer to query the destination database for users that are not in the authentication file.

PgBouncer shares connections in one of three pool modes:

- **Session pooling** – When a client connects, a connection is assigned to it as long as it remains connected. When the client disconnects, the connection is placed back into the pool.
- **Transaction pooling** – A connection is assigned to a client for the duration of a transaction. When PgBouncer notices the transaction is done, the connection is placed back into the pool. This mode can be used only with applications that do not use features that depend upon a session.
- **Statement pooling** – Statement pooling is like transaction pooling, but multi-statement transactions are not allowed. This mode is intended to enforce autocommit mode on the client and is targeted for PL/Proxy on PostgreSQL.

A default pool mode can be set for the PgBouncer instance and the mode can be overridden for individual databases and users.

By connecting to a virtual pgbouncer database, you can monitor and manage PgBouncer using SQL-like commands. Configuration parameters can be changed without having to restart PgBouncer, and the configuration file can be reloaded to pick up changes.

PgBouncer does not yet support SSL connections. If you want to encrypt traffic between clients and PgBouncer, you can use stunnel, a free software utility that creates TLS-encrypted tunnels using the OpenSSL cryptography library. See [Securing PgBouncer Connections with stunnel](#) for directions.

### Configuring and Starting PgBouncer

PgBouncer can be run on the Greenplum Database master or on another server. If you install PgBouncer on a separate server, you can easily switch clients to the standby master by updating the PgBouncer configuration file and reloading the configuration using the PgBouncer Administration Console.

Follow these steps to set up PgBouncer.

1. Create a PgBouncer configuration file, for example pgbouncer.ini. Here is a simple configuration file:

```
[databases]
postgres = host=127.0.0.1 port=5432 dbname=postgres
mydb = host=127.0.0.1 port=5432 dbname=mydb

[pgbouncer]
pool_mode = session
listen_port = 6543
listen_addr = 127.0.0.1
auth_type = md5
auth_file = users.txt
logfile = pgbouncer.log
pidfile = pgbouncer.pid
```
admin_users = gpadmin

The file is in the .ini file format and has three sections: databases, pgbouncer, and users. The databases section lists databases with their connection details. The pgbouncer section configures the PgBouncer instance.

2. Create an authentication file. The name of the file must match the auth_file parameter in the pgbouncer.ini file, users.txt in this example. Each line contains a user name and password. The format of the password string matches the auth_type parameter in the PgBouncer configuration file. If the auth_type parameter is plain, the password string is a clear text password, for example:

"gpadmin" "gpadmin1234"

The auth_type in the following example is md5, so the authentication field must be MD5-encoded. The format for an MD5-encoded password is:

"md5" + MD5(<password><username>)

You can use the Linux md5sum command to calculate the MD5 string. For example, if the gpadmin password is admin1234 the following command prints the string for the password field:

$ user=gpadmin; passwd=admin1234; echo -n md5; echo $passwd$user | md5sum

md53ce96652dedd8226c498e09ae2d26220

And here is the MD5-encoded entry for the gpadmin user in the PgBouncer authentication file:

"gpadmin" "md53ce96652dedd8226c498e09ae2d26220"

To authenticate users against an LDAP or Active Directory server, the password field contains an LDAP lookup string. For example:

"gpdbuser1" "ldap://10.0.0.11:10389/uid=gpdbuser1,ou=users,ou=system"

For Active Directory, a user entry looks like this example:

"gpdbuser2" "ldap://10.0.0.12:389/gpdbuser2"

See Setting up LDAP Authentication with PgBouncer for the steps to configure PgBouncer to authenticate users with an LDAP server.

For details about the authentication file, see the "Authentication File Format" section of the PgBouncer reference in the Greenplum Database Utility Guide.

3. Launch pgbouncer:

$ $GPHOME/bin/pgbouncer -d pgbouncer.ini

The -d or --daemon option runs PgBouncer as a background process. See the PgBouncer reference in the Greenplum Database Utility Guide for the pgbouncer command syntax and its options.

4. Update client applications to connect to pgbouncer instead of directly to Greenplum Database server. To start psql, for example:

$ psql -p 6543 -U someuser postgres

Server Reset Query

When a connection is returned to the pool, it must be reset to the state of a newly created connection. PgBouncer accomplishes this by issuing a query before returning a connection to the pool. PostgreSQL 8.3 and later have the DISCARD ALL command for this purpose and it is the default reset query for the
standard PgBouncer distribution. Greenplum Database does not support `DISCARD ALL` and if it is used an error is logged.

A reset query can be specified by setting the `server_reset_query` parameter in the PgBouncer configuration file. For Greenplum Database with PgBouncer in session pooling mode, the `server_reset_query` parameter can be set to this query:

```
RESET ALL; SET SESSION AUTHORIZATION DEFAULT
```

This is the default server reset query in the modified version of PgBouncer included with Greenplum Database 4.7.0 and later. Although the default differs from PgBouncer, it helps to ensure that the connection pool is transparent to Greenplum Database users and client applications do not have to be modified to use a connection pool.

For more information about the `server_reset_query` parameter and the PgBouncer configuration file, see the PgBouncer reference in the *Greenplum Database Utility Guide*.

**Managing PgBouncer**

PgBouncer has an administrative console, which is accessed by logging into the `pgbouncer` virtual database. The console accepts SQL-like commands that allow you to monitor, reconfigure, and manage PgBouncer.

Follow these steps to get started with the PgBouncer administrative console.

1. Log in to the `pgbouncer` virtual database with `psql`:

   ```
   $ psql -p 6543 -U username pgbouncer
   
   The username must be set in the `admin_users` parameter in the `pgbouncer.ini` configuration file. You can also log in with the current Unix username if the `pgbouncer` process is running with that user's UID.
   
2. To see the available commands, run the `show help` command:

   ```
   pgbouncer=# show help;
   NOTICE:  Console usage
   DETAIL:    SHOW HELP|CONFIG|DATABASES|POOLS|CLIENTS|SERVERS|VERSION
            SHOW STATS|FDS|SOCKETS|ACTIVE_SOCKETS|LISTS|MEM
            SHOW DNS_HOSTS|DNS_ZONES
            SET key = arg
            RELOAD
            PAUSE [<db>]
            RESUME [<db>]
            DISABLE <db>
            ENABLE <db>
            KILL <db>
            SUSPEND
            SHUTDOWN
   
   3. If you make changes to the `pgbouncer.ini` file, you can reload it with the `RELOAD` command:

   ```
   pgbouncer=# RELOAD;
   ```

   To map clients to server connections, use the `SHOW CLIENTS` and `SHOW SERVERS` views:

   1. Use `ptr` and `link` to map the local client connection to the server connection.
   2. Use `addr` and `port` of the client connection to identify the TCP connection from the client.
   3. Use `local_addr` and `local_port` to identify the TCP connection to the server.
For complete documentation for all of the administration console commands, see the "PgBouncer Administration Console Commands" section of the PgBouncer reference in the Greenplum Database Utility Guide.

**Upgrading PgBouncer**

You can upgrade PgBouncer without dropping connections. Just launch the new PgBouncer process with the `-R` option and the same configuration file:

```bash
$ pgbouncer -R -d config.ini
```

The `-R` (reboot) option causes the new process to connect to the console of the old process through a Unix socket and issue the following commands:

```
SUSPEND;
SHOW FDS;
SHUTDOWN;
```

When the new process sees that the old process is gone, it resumes the work with the old connections. This is possible because the `SHOW FDS` command sends actual file descriptors to the new process. If the transition fails for any reason, kill the new process and the old process will resume.

**Setting up LDAP Authentication with PgBouncer**

You can authenticate Greenplum Database users against your LDAP or Active Directory service when using the PgBouncer connection pooler. When you have LDAP authentication working, you can secure client connections to PgBouncer by setting up stunnel, as described in *Securing PgBouncer Connections with stunnel*.

Before you begin, you must have an LDAP or Active Directory server and a Greenplum Database cluster.

1. Create Greenplum Database users in the LDAP/AD server, for example `gpdbuser1` and `gpdbuser2`.
2. Create the corresponding Greenplum Database users in the database:

   ```
   createuser gpdbuser1
   createuser gpdbuser2
   ```

3. Add the users to the Greenplum Database `pg_hba.conf` file:

   ```
   host     all         gpdbuser1              0.0.0.0/0     trust
   host     all         gpdbuser2              0.0.0.0/0     trust
   ```

4. Create a PgBouncer `config.ini` file with the following contents:

   ```
   [databases]
   * = host=GPDB_host_addr port=GPDB_port
   
   [pgbouncer]
   listen_port = 6432
   listen_addr = 0.0.0.0
   auth_type = plain
   auth_file = users.txt
   logfile = pgbouncer.log
   pidfile = pgbouncer.pid
   ignore_startup_parameters=options
   ```
5. Create the `users.txt` PgBouncer authentication file. The first field is the user name and the second is the LDAP or Active Directory lookup string for the user. For OpenLDAP or ApacheDS, for example, a user entry in the `users.txt` looks like this:

```
"gpdbuser1" "ldap://10.0.0.11:10389/uid=gpdbuser1,ou=users,ou=system"
```

For Active Directory, a user entry looks like this example:

```
"gpdbuser1" "ldap://10.0.0.12:389/gpdbuser1"
```

6. Start PgBouncer with the `config.ini` file you created:

```
$ pgbouncer -d config.ini
```

**Securing PgBouncer Connections with stunnel**

PgBouncer does not have SSL support, so connections between database clients and PgBouncer are not encrypted. To encrypt these connections, you can use stunnel, a free software utility. stunnel is a proxy that uses the OpenSSL cryptographic library to add TLS encryption to network services. Newer versions of stunnel support the PostgreSQL libpq protocol, so Greenplum and PostgreSQL clients can use libpq SSL support to connect securely over the network to a stunnel instance set up as a proxy for PgBouncer. If you use a version of stunnel without libpq support, you need to set up a stunnel instance on both the client and PgBouncer host to create a secure tunnel over the network.

On most platforms, you can install stunnel using the system package manager. For Windows, you can download an installer from [https://www.stunnel.org/index.html](https://www.stunnel.org/index.html). You can also download and install stunnel from source if a packaged version is unavailable, if you want to upgrade to a newer version, or if you want to upgrade to a newer OpenSSL version. The next section provides steps to download, compile, and install OpenSSL and stunnel.

For complete stunnel documentation, visit the [stunnel documentation](https://www.stunnel.org/index.html) web site.

**Installing stunnel From Source**

stunnel requires a version of the OpenSSL development package greater than 1.0. The following instructions download and build OpenSSL and stunnel for Red Hat or CentOS. Be sure to check [https://www.stunnel.org/index.html](https://www.stunnel.org/index.html) and [http://openssl.org](http://openssl.org) for the latest versions.

1. Set the `PREFIX` environment variable to the directory where you want to install stunnel, for example `/usr/local/stunnel` or `/home/gpadmin/stunnel`. If you choose to install stunnel in a system directory, you may need to run the `make install` commands as root.

   ```bash
   export PREFIX=/path/to/install_stunnel
   ```

2. The following commands download, build, and install OpenSSL version 1.0.2c:

   ```bash
   wget ftp://ftp.openssl.org/source/openssl-1.0.2c.tar.gz
   tar xzf openssl-1.0.2c.tar.gz
   cd openssl-1.0.2c
   ./Configure linux-x86_64 --prefix=$PREFIX shared no-asm
   make
   make install_sw
   cd ..
   ```

3. Download, build, and install stunnel with the following commands:

   ```bash
   wget --no-check-certificate https://www.stunnel.org/downloads/stunnel-5.22.tar.gz
   tar xzf stunnel-5.22.tar.gz
   cd stunnel-5.22
   LDFLAGS="-Wl,-rpath,'""$$""ORIGIN/../lib'"
   ```
Setting up Stunnel for PgBouncer

Set up a stunnel instance as a proxy for PgBouncer. The stunnel instance accepts secure connections from database clients on its own port, decrypts the packets and forwards them to the PgBouncer instance on the same host (or on another host in a protected local network). PgBouncer results, including database results from connections managed by PgBouncer, are encrypted and returned over the network to the client.

1. On the server running PgBouncer, create a directory for stunnel configuration files, for example /home/gpadmin/stunnel.
2. Create a certificate and key file to use for authenticating. You can also use an existing certificate and key, or create a new pair with the following `openssl` command:

   ```bash
   $ openssl req -new -x509 -days 3650 -nodes -out stunnel.pem -keyout stunnel.key
   ```

   Move the `stunnel.key` and `stunnel.pem` files into your stunnel configuration directory.
3. Create a stunnel configuration file, for example, `stunnel.conf`, with the following contents:

   ```
   debug = info
   socket = l:TCP_NODELAY=1
   socket = r:TCP_NODELAY=1
   debug = 7
   cert = /PATH/TO/stunnel.pem
   key = /PATH/TO/stunnel.key
   
   [pg-server]
   client=no
   accept = 0.0.0.0:5433          # This is the SSL listening port
   connect = PGHOST:PGPORT      # This is the PgBouncer listen port
   protocol = pgsql
   ```

   See the stunnel configuration file reference for additional configuration options.
4. Run stunnel on the server:

   ```bash
   stunnel /path/to/stunnel-srv.conf
   ```
5. On the client, connect to stunnel on its host and accept port. For example:

   ```bash
   psql -h pgbouncer-host -p stunnel-accept-port database-name
   ```

Database Application Interfaces

You may want to develop your own client applications that interface to Greenplum Database. PostgreSQL provides a number of database drivers for the most commonly used database application programming interfaces (APIs), which can also be used with Greenplum Database. These drivers are available as a separate download. Each driver (except libpq, which comes with PostgreSQL) is an independent PostgreSQL development project and must be downloaded, installed and configured to connect to Greenplum Database. The following drivers are available:
**Table 25: Greenplum Database Interfaces**

<table>
<thead>
<tr>
<th>API</th>
<th>PostgreSQL Driver</th>
<th>Download Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>JDBC</td>
<td>Greenplum DataDirect JDBC Driver</td>
<td><a href="https://network.pivotal.io/products/pivotal-gpdb">https://network.pivotal.io/products/pivotal-gpdb</a></td>
</tr>
<tr>
<td>Perl DBI</td>
<td>pgperl</td>
<td><a href="http://search.cpan.org/dist/DBD-Pg/">http://search.cpan.org/dist/DBD-Pg/</a></td>
</tr>
<tr>
<td>Python DBI</td>
<td>pygresql</td>
<td><a href="http://www.pygresql.org/">http://www.pygresql.org/</a></td>
</tr>
<tr>
<td>libpq C Library</td>
<td>libpq</td>
<td><a href="https://www.postgresql.org/docs/8.3/static/libpq.html">https://www.postgresql.org/docs/8.3/static/libpq.html</a></td>
</tr>
</tbody>
</table>

General instructions for accessing a Greenplum Database with an API are:

1. Download your programming language platform and respective API from the appropriate source. For example, you can get the Java Development Kit (JDK) and JDBC API from Oracle.
2. Write your client application according to the API specifications. When programming your application, be aware of the SQL support in Greenplum Database so you do not include any unsupported SQL syntax.

See the *Greenplum Database Reference Guide* for more information.

Download the appropriate driver and configure connectivity to your Greenplum Database master instance.

**Troubleshooting Connection Problems**

A number of things can prevent a client application from successfully connecting to Greenplum Database. This topic explains some of the common causes of connection problems and how to correct them.

**Table 26: Common connection problems**

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>No <code>pg_hba.conf</code> entry for host or user</td>
<td>To enable Greenplum Database to accept remote client connections, you must configure your Greenplum Database master instance so that connections are allowed from the client hosts and database users that will be connecting to Greenplum Database. This is done by adding the appropriate entries to the <code>pg_hba.conf</code> configuration file (located in the master instance's data directory). For more detailed information, see <a href="#">Allowing Connections to Greenplum Database</a>.</td>
</tr>
<tr>
<td>Greenplum Database is not running</td>
<td>If the Greenplum Database master instance is down, users will not be able to connect. You can verify that the Greenplum Database system is up by running the <code>gpstate</code> utility on the Greenplum master host.</td>
</tr>
</tbody>
</table>
### Problem

<table>
<thead>
<tr>
<th>Network problems</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interconnect timeouts</td>
<td>If users connect to the Greenplum master host from a remote client, network problems can prevent a connection (for example, DNS host name resolution problems, the host system is down, and so on.). To ensure that network problems are not the cause, connect to the Greenplum master host from the remote client host. For example: <code>ping hostname</code>.</td>
</tr>
<tr>
<td></td>
<td>If the system cannot resolve the host names and IP addresses of the hosts involved in Greenplum Database, queries and connections will fail. For some operations, connections to the Greenplum Database master use <code>localhost</code> and others use the actual host name, so you must be able to resolve both. If you encounter this error, first make sure you can connect to each host in your Greenplum Database array from the master host over the network. In the <code>/etc/hosts</code> file of the master and all segments, make sure you have the correct host names and IP addresses for all hosts involved in the Greenplum Database array. The <code>127.0.0.1</code> IP must resolve to <code>localhost</code>.</td>
</tr>
</tbody>
</table>

| Too many clients already | By default, Greenplum Database is configured to allow a maximum of 250 concurrent user connections on the master and 750 on a segment. A connection attempt that causes that limit to be exceeded will be refused. This limit is controlled by the `max_connections` parameter in the `postgresql.conf` configuration file of the Greenplum Database master. If you change this setting for the master, you must also make appropriate changes at the segments. |

### Configuring the Greenplum Database System

Server configuration parameters affect the behavior of Greenplum Database. They are part of the PostgreSQL "Grand Unified Configuration" system, so they are sometimes called "GUCs." Most of the Greenplum Database server configuration parameters are the same as the PostgreSQL configuration parameters, but some are Greenplum-specific.

### About Greenplum Database Master and Local Parameters

Server configuration files contain parameters that configure server behavior. The Greenplum Database configuration file, `postgresql.conf`, resides in the data directory of the database instance.

The master and each segment instance have their own `postgresql.conf` file. Some parameters are `local`: each segment instance examines its `postgresql.conf` file to get the value of that parameter. Set local parameters on the master and on each segment instance.

Other parameters are `master` parameters that you set on the master instance. The value is passed down to (or in some cases ignored by) the segment instances at query run time.

See the Greenplum Database Reference Guide for information about `local` and `master` server configuration parameters.

### Setting Configuration Parameters

Many configuration parameters limit who can change them and where or when they can be set. For example, to change certain parameters, you must be a Greenplum Database superuser. Other parameters can be set only at the system level in the `postgresql.conf` file or require a system restart to take effect.

Many configuration parameters are `session` parameters. You can set session parameters at the system level, the database level, the role level or the session level. Database users can change most session parameters within their session, but some require superuser permissions.

See the Greenplum Database Reference Guide for information about setting server configuration parameters.
**Setting a Local Configuration Parameter**

To change a local configuration parameter across multiple segments, update the parameter in the `postgresql.conf` file of each targeted segment, both primary and mirror. Use the `gpconfig` utility to set a parameter in all Greenplum `postgresql.conf` files. For example:

```
$ gpconfig -c gp_vmem_protect_limit -v 4096
```

Restart Greenplum Database to make the configuration changes effective:

```
$ gpstop -r
```

**Setting a Master Configuration Parameter**

To set a master configuration parameter, set it at the Greenplum Database master instance. If it is also a `session` parameter, you can set the parameter for a particular database, role or session. If a parameter is set at multiple levels, the most granular level takes precedence. For example, session overrides role, role overrides database, and database overrides system.

**Setting Parameters at the System Level**

Master parameter settings in the master `postgresql.conf` file are the system-wide default. To set a master parameter:

1. Edit the `$MASTER_DATA_DIRECTORY/postgresql.conf` file.
2. Find the parameter to set, uncomment it (remove the preceding `#` character), and type the desired value.
3. Save and close the file.
4. For `session` parameters that do not require a server restart, upload the `postgresql.conf` changes as follows:
   ```
   $ gpstop -u
   ```
5. For parameter changes that require a server restart, restart Greenplum Database as follows:
   ```
   $ gpstop -r
   ```

For details about the server configuration parameters, see the *Greenplum Database Reference Guide*.

**Setting Parameters at the Database Level**

Use `ALTER DATABASE` to set parameters at the database level. For example:

```
=# ALTER DATABASE mydatabase SET search_path TO myschema;
```

When you set a session parameter at the database level, every session that connects to that database uses that parameter setting. Settings at the database level override settings at the system level.

**Setting Parameters at the Role Level**

Use `ALTER ROLE` to set a parameter at the role level. For example:

```
=# ALTER ROLE bob SET search_path TO bobschema;
```

When you set a session parameter at the role level, every session initiated by that role uses that parameter setting. Settings at the role level override settings at the database level.
Setting Parameters in a Session

Any session parameter can be set in an active database session using the `SET` command. For example:

```
=# SET statement_mem TO '200MB';
```

The parameter setting is valid for the rest of that session or until you issue a `RESET` command. For example:

```
=# RESET statement_mem;
```

Settings at the session level override those at the role level.

Viewing Server Configuration Parameter Settings

The SQL command `SHOW` allows you to see the current server configuration parameter settings. For example, to see the settings for all parameters:

```
$ psql -c 'SHOW ALL;'
```

`SHOW` lists the settings for the master instance only. To see the value of a particular parameter across the entire system (master and all segments), use the `gpconfig` utility. For example:

```
$ gpconfig --show max_connections
```

Configuration Parameter Categories

Configuration parameters affect categories of server behaviors, such as resource consumption, query tuning, and authentication. The following topics describe Greenplum Database configuration parameter categories.

For details about configuration parameter categories, see the `Greenplum Database Reference Guide`.

Connection and Authentication Parameters

These parameters control how clients connect and authenticate to Greenplum Database. See `Managing Greenplum Database Access` for information about configuring client authentication.

Connection Parameters

<table>
<thead>
<tr>
<th>gp_connection_send_timeout</th>
<th>tcp_keepalives_count</th>
</tr>
</thead>
<tbody>
<tr>
<td>gp_vmem_idle_resource_timeout</td>
<td>tcp_keepalives_idle</td>
</tr>
<tr>
<td>listen_addresses</td>
<td>tcp_keepalives_interval</td>
</tr>
<tr>
<td>max_connections</td>
<td>unix_socket_directory</td>
</tr>
<tr>
<td>max_prepared_transactions</td>
<td>unix_socket_group</td>
</tr>
<tr>
<td>superuser_reserved_connections</td>
<td>unix_socket_permissions</td>
</tr>
</tbody>
</table>

Security and Authentication Parameters

<table>
<thead>
<tr>
<th>authentication_timeout</th>
<th>krb_srvname</th>
</tr>
</thead>
<tbody>
<tr>
<td>db_user_namespace</td>
<td>password_encryption</td>
</tr>
<tr>
<td>krb_caseins_users</td>
<td>password_hash_algorithm</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>krb_server_keyfile</td>
<td>ssl</td>
</tr>
<tr>
<td></td>
<td>ssl_ciphers</td>
</tr>
</tbody>
</table>

**System Resource Consumption Parameters**

**Memory Consumption Parameters**

These parameters control system memory usage. You can adjust `gp_vmem_protect_limit` to avoid running out of memory at the segment hosts during query processing.

```
<table>
<thead>
<tr>
<th>gp_vmem_idle_resource_timeout</th>
<th>max_stack_depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>gp_vmem_protect_limit</td>
<td>shared_buffers</td>
</tr>
<tr>
<td>gp_vmem_protect_segworker_cache_limit</td>
<td>temp_buffers</td>
</tr>
<tr>
<td>gp_workfile_limit_files_per_query</td>
<td></td>
</tr>
<tr>
<td>gp_workfile_limit_per_query</td>
<td></td>
</tr>
<tr>
<td>gp_workfile_limit_per_segment</td>
<td></td>
</tr>
<tr>
<td>max_appendonly_tables</td>
<td></td>
</tr>
<tr>
<td>max_prepared_transactions</td>
<td></td>
</tr>
</tbody>
</table>
```

**Free Space Map Parameters**

These parameters control the sizing of the free space map, which contains expired rows. Use `VACUUM` to reclaim the free space map disk space.

See *Vacuum and Analyze for Query Optimization* for information about vacuuming a database.

- `max_fsm_pages`
- `max_fsm_relations`

**OS Resource Parameters**

- `max_files_per_process`
- `shared_preload_libraries`

**Cost-Based Vacuum Delay Parameters**

*Warning:* Using cost-based vacuum delay is discouraged because it runs asynchronously among the segment instances. The vacuum cost limit and delay is invoked at the segment level without taking into account the state of the entire Greenplum array.

You can configure the execution cost of `VACUUM` and `ANALYZE` commands to reduce the I/O impact on concurrent database activity. When the accumulated cost of I/O operations reaches the limit, the process performing the operation sleeps for a while, then resets the counter and continues execution.

```
vacuum_cost_delay          vacuum_cost_page_hit
vacuum_cost_limit          vacuum_cost_page_miss
vacuum_cost_page_dirty     |
```

**Transaction ID Management Parameters**

- `xid_stop_limit`
• xid_warn_limit

**Query Tuning Parameters**

**GPORCA Configuration Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>optimizer</td>
<td></td>
</tr>
<tr>
<td>optimizer_analyze_root_partition</td>
<td></td>
</tr>
<tr>
<td>optimizer_array_expansion_threshold</td>
<td></td>
</tr>
<tr>
<td>optimizer_cte_inlining_bound</td>
<td></td>
</tr>
<tr>
<td>optimizer_enable_assocativity</td>
<td></td>
</tr>
<tr>
<td>optimizer_control</td>
<td></td>
</tr>
<tr>
<td>optimizer_enable_master_only_queries</td>
<td></td>
</tr>
<tr>
<td>optimizer_force_multistage_agg</td>
<td></td>
</tr>
<tr>
<td>optimizer_force_three_stage_scalar_dqa</td>
<td></td>
</tr>
</tbody>
</table>

**Query Plan Operator Control Parameters**

The following parameters control the types of plan operations the legacy query optimizer can use. Enable or disable plan operations to force the legacy query optimizer to choose a different plan. This is useful for testing and comparing query performance using different plan types.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>enable_bitmapscan</td>
<td></td>
</tr>
<tr>
<td>enable_groupagg</td>
<td></td>
</tr>
<tr>
<td>enable_hashagg</td>
<td></td>
</tr>
<tr>
<td>enable_hashjoin</td>
<td></td>
</tr>
<tr>
<td>enable_indexscan</td>
<td></td>
</tr>
<tr>
<td>enable_mergejoin</td>
<td></td>
</tr>
<tr>
<td>enable_nestloop</td>
<td></td>
</tr>
<tr>
<td>enable_seqscan</td>
<td></td>
</tr>
<tr>
<td>enable_sort</td>
<td></td>
</tr>
<tr>
<td>enable_tidscan</td>
<td></td>
</tr>
<tr>
<td>gp_enable_adaptive_nestloop</td>
<td></td>
</tr>
<tr>
<td>gp_enable_agg_distinct</td>
<td></td>
</tr>
</tbody>
</table>

**Legacy Query Optimizer Costing Parameters**

**Warning:** Do not adjust these query costing parameters. They are tuned to reflect Greenplum Database hardware configurations and typical workloads. All of these parameters are related. Changing one without changing the others can have adverse effects on performance.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cpu_index_tuple_cost</td>
<td></td>
</tr>
<tr>
<td>cpu_operator_cost</td>
<td></td>
</tr>
<tr>
<td>cpu_tuple_cost</td>
<td></td>
</tr>
</tbody>
</table>
Database Statistics Sampling Parameters

These parameters adjust the amount of data sampled by an `ANALYZE` operation. Adjusting these parameters affects statistics collection system-wide. You can configure statistics collection on particular tables and columns by using the `ALTER TABLE SET STATISTICS` clause.

- `default_statistics_target`
- `gp_analyze_relative_error`

Sort Operator Configuration Parameters

- `gp_enable_sort_distinct`
- `gp_enable_sort_limit`

Aggregate Operator Configuration Parameters

- `gp_enable_agg_distinct`
- `gp_enable_agg_distinct_pruning`
- `gp_enable_multiphase_agg`
- `gp_enable_preunique`
- `gp_enable_groupext_distinct_gather`
- `gp_enable_groupext_distinct_pruning`
- `gp_workfile_compress_algorithm`

Join Operator Configuration Parameters

- `join_collapse_limit`
- `gp_adjust_selectivity_for_outerjoins`
- `gp_hashjoin_tuples_per_bucket`
- `gp_statistics_use_fkeys`
- `gp_workfile_compress_algorithm`

Other Legacy Query Optimizer Configuration Parameters

- `fromCollapse_limit`
- `gp_enable_predicate_propagation`
- `gp_max_plan_size`
- `gp_statistics_pullup_from_child_partition`

Error Reporting and Logging Parameters

Log Rotation

- `log_rotation_age`
- `log_rotation_size`
- `log_truncate_on_rotation`

When to Log

- `client_min_messages`
- `gp_interconnect_debug_retry_interval`
- `log_error_verbosity`
- `log_min_error_statement`
- `log_min_messages`
- `log_error_verbosity`
- `optimizer_minidump`
**What to Log**

<table>
<thead>
<tr>
<th>debug_pretty_print</th>
<th>log_executor_stats</th>
</tr>
</thead>
<tbody>
<tr>
<td>debug_print_parse</td>
<td>log_hostname</td>
</tr>
<tr>
<td>debug_print_plan</td>
<td>gp_log_interconnect</td>
</tr>
<tr>
<td>debug_print_prelim_plan</td>
<td>log_parser_stats</td>
</tr>
<tr>
<td>debug_print_rewritten</td>
<td>log_planner_stats</td>
</tr>
<tr>
<td>debug_print_slice_table</td>
<td>log_statement</td>
</tr>
<tr>
<td>log_autostats</td>
<td>log_statement_stats</td>
</tr>
<tr>
<td>log_connections</td>
<td>log_timezone</td>
</tr>
<tr>
<td>log_disconnections</td>
<td>gp_debug_linger</td>
</tr>
<tr>
<td>log_dispatch_stats</td>
<td>gp_log_format</td>
</tr>
<tr>
<td>log_duration</td>
<td>gp_log_gang</td>
</tr>
<tr>
<td></td>
<td>gp_max_csv_line_length</td>
</tr>
<tr>
<td></td>
<td>gp_reraise_signal</td>
</tr>
</tbody>
</table>

**System Monitoring Parameters**

**SNMP Alerts**
The following parameters send SNMP notifications when events occur.

<table>
<thead>
<tr>
<th>gp_snmp_community</th>
<th>gp_snmp_use_inform_or_trap</th>
</tr>
</thead>
<tbody>
<tr>
<td>gp_snmp_monitor_address</td>
<td></td>
</tr>
</tbody>
</table>

**Email Alerts**
The following parameters configure the system to send email alerts for fatal error events, such as a segment going down or a server crash and reset.

<table>
<thead>
<tr>
<th>gp_email_from</th>
<th>gp_email_smtp_userid</th>
</tr>
</thead>
<tbody>
<tr>
<td>gp_email_smtp_password</td>
<td>gp_email_to</td>
</tr>
<tr>
<td>gp_email_smtp_server</td>
<td></td>
</tr>
</tbody>
</table>

**Greenplum Command Center Agent**
The following parameters configure the data collection agents that populate the `gpperfmon` database used by Greenplum Command Center.

<table>
<thead>
<tr>
<th>gp_enable_gpperfmon</th>
<th>gpperfmon_log_alert_level</th>
</tr>
</thead>
<tbody>
<tr>
<td>gp_gpperfmon_send_interval</td>
<td>gpperfmon_port</td>
</tr>
</tbody>
</table>
Runtime Statistics Collection Parameters

These parameters control the server statistics collection feature. When statistics collection is enabled, you can access the statistics data using the `pg_stat` and `pg_statio` family of system catalog views.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>stats_queue_level</td>
<td></td>
</tr>
<tr>
<td>track_activities</td>
<td></td>
</tr>
<tr>
<td>track_counts</td>
<td></td>
</tr>
<tr>
<td>update_process_title</td>
<td></td>
</tr>
</tbody>
</table>

Automatic Statistics Collection Parameters

When automatic statistics collection is enabled, you can run `ANALYZE` automatically in the same transaction as an `INSERT`, `UPDATE`, `DELETE`, `COPY` or `CREATE TABLE...AS SELECT` statement when a certain threshold of rows is affected (`on_change`), or when a newly generated table has no statistics (`on_no_stats`). To enable this feature, set the following server configuration parameters in your Greenplum master `postgresql.conf` file and restart Greenplum Database:

- `gp_autostats_mode`
- `gp_autostats_mode_in_functions`
- `log_autostats`
- `gp_autostats_on_change_threshold`

Warning: Depending on the specific nature of your database operations, automatic statistics collection can have a negative performance impact. Carefully evaluate whether the default setting of `on_no_stats` is appropriate for your system.

Client Connection Default Parameters

Statement Behavior Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>check_function_bodies</td>
<td></td>
</tr>
<tr>
<td>default_tablespace</td>
<td></td>
</tr>
<tr>
<td>default_transaction_isolation</td>
<td></td>
</tr>
<tr>
<td>default_transaction_read_only</td>
<td></td>
</tr>
<tr>
<td>search_path</td>
<td></td>
</tr>
<tr>
<td>statement_timeout</td>
<td></td>
</tr>
<tr>
<td>vacuum_freeze_min_age</td>
<td></td>
</tr>
</tbody>
</table>

Locale and Formatting Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>client_encoding</td>
<td></td>
</tr>
<tr>
<td>DateStyle</td>
<td></td>
</tr>
<tr>
<td>extra_float_digits</td>
<td></td>
</tr>
<tr>
<td>IntervalStyle</td>
<td></td>
</tr>
<tr>
<td>lc_collate</td>
<td></td>
</tr>
<tr>
<td>lc_cctype</td>
<td></td>
</tr>
<tr>
<td>lc_messages</td>
<td></td>
</tr>
<tr>
<td>lc_monetary</td>
<td></td>
</tr>
<tr>
<td>lc_numeric</td>
<td></td>
</tr>
<tr>
<td>lc_time</td>
<td></td>
</tr>
<tr>
<td>TimeZone</td>
<td></td>
</tr>
</tbody>
</table>

Other Client Default Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>dynamic_library_path</td>
<td></td>
</tr>
<tr>
<td>explain.pretty_print</td>
<td></td>
</tr>
<tr>
<td>local_preload_libraries</td>
<td></td>
</tr>
</tbody>
</table>
Lock Management Parameters

- deadlock_timeout
- max_locks_per_transaction

Resource Management Parameters

The following configuration parameters configure Greenplum Database resource queues, query prioritization, memory utilization and concurrency control.

<table>
<thead>
<tr>
<th>gp_resqueue_priority</th>
<th>max_resource_queues</th>
</tr>
</thead>
<tbody>
<tr>
<td>gp_resqueue_priority_cpucores_per_segment</td>
<td>max_resource_portals_per_transaction</td>
</tr>
<tr>
<td>gp_resqueue_priority_sweeper_interval</td>
<td>resource_cleanup_gangs_on_wait</td>
</tr>
<tr>
<td>gp_vmem_idle_resource_timeout</td>
<td>resource_select_only</td>
</tr>
<tr>
<td>gp_vmem_protect_limit</td>
<td>runaway_detector_activation_percent</td>
</tr>
<tr>
<td>gp_vmem_protect_segworker_cache_limit</td>
<td>stats_queue_level</td>
</tr>
<tr>
<td></td>
<td>vmem_process_interrupt</td>
</tr>
</tbody>
</table>

External Table Parameters

The following parameters configure the external tables feature of Greenplum Database.

See Defining External Tables for more information about external tables.

<table>
<thead>
<tr>
<th>gp_external_enable_exec</th>
<th>gp_initial_bad_row_limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>gp_external_max_segs</td>
<td>gp_reject_percent_threshold</td>
</tr>
<tr>
<td></td>
<td>readable_external_table_timeout</td>
</tr>
<tr>
<td></td>
<td>writable_external_table_bufsize</td>
</tr>
</tbody>
</table>

Database Table Parameters

The following parameter configures default option settings for Greenplum Database tables.

See Creating and Managing Tables for more information about Greenplum Database tables.

- gp_create_table_random_default_distribution
- gp_default_storage_options
- gp_enable_exchange_default_partition
- gp_enable_segment_copy_checking

Append-Optimized Table Parameters

The following parameters configure the append-optimized tables feature of Greenplum Database.

See Append-Optimized Storage for more information about append-optimized tables.

- gp_default_storage_options
- max_appendonly_tables
- gp_appendonly_compaction
- gp_appendonly_compaction_threshold
- validate_previous_free_tid
**Database and Tablespace/Filespace Parameters**

The following parameters configure the maximum number of databases, tablespaces, and filespaces allowed in a system.

- `gp_max_tablespaces`
- `gp_max_filespaces`
- `gp_max_databases`

**Past Version Compatibility Parameters**

The following parameters provide compatibility with older PostgreSQL and Greenplum Database versions. You do not need to change these parameters in Greenplum Database.

**PostgreSQL**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>add_missing_from</code></td>
<td><code>regex_flavor</code></td>
</tr>
<tr>
<td><code>array_nulls</code></td>
<td><code>standard_conforming_strings</code></td>
</tr>
<tr>
<td><code>backslash_quote</code></td>
<td><code>transform_null_equals</code></td>
</tr>
<tr>
<td><code>escape_string_warning</code></td>
<td></td>
</tr>
</tbody>
</table>

**Greenplum Database**

- `gp_ignore_error_table`

**Greenplum Array Configuration Parameters**

The parameters in this topic control the configuration of the Greenplum Database array and its components: segments, master, distributed transaction manager, master mirror, and interconnect.

**Interconnect Configuration Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>gp_interconnect_fc_method</code></td>
<td><code>gp_interconnect_setup_timeout</code></td>
</tr>
<tr>
<td><code>gp_interconnect_hash_multiplier</code></td>
<td><code>gp_interconnect_snd_queue_depth</code></td>
</tr>
<tr>
<td><code>gp_interconnect_queue_depth</code></td>
<td><code>gp_interconnect_type</code></td>
</tr>
<tr>
<td><code>gp_max_packet_size</code></td>
<td><code>gp_max_interconnect_type</code></td>
</tr>
</tbody>
</table>

**Note:** Greenplum Database supports only the UDP/IFC and TCP interconnect types.

**Dispatch Configuration Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>gp_cached_segworkers_threshold</code></td>
<td><code>gp_segment_connect_timeout</code></td>
</tr>
<tr>
<td><code>gp_connections_per_thread</code></td>
<td><code>gp_set_proc_affinity</code></td>
</tr>
<tr>
<td><code>gp_enable_direct_dispatch</code></td>
<td></td>
</tr>
</tbody>
</table>

**Fault Operation Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>gp_set_read_only</code></td>
<td><code>gp_fts_probe_threadcount</code></td>
</tr>
<tr>
<td><code>gp_fts_probe_interval</code></td>
<td></td>
</tr>
</tbody>
</table>
**Distributed Transaction Management Parameters**

- gp_max_local_distributed_cache

**Read-Only Parameters**

- gp_command_count
- gp_content
- gp_dbid
- gp_num_contents_in_cluster
- gp_role
- gp_session_id

**Greenplum Master and Segment Mirroring Parameters**

These parameters control the configuration of the replication between Greenplum Database primary master and standby master.

- keep_wal_segments
- repl_catchup_within_range
- replication_timeout
- wal_receiver_status_interval

This parameter controls validation between Greenplum Database primary segment and standby segment during incremental resynchronization.

- filerep_mirrorvalidation_during_resync

**Greenplum Database Extension Parameters**

The parameters in this topic control the configuration of Greenplum Database extensions.

- pljava_classpath
- pljava_classpath_insecure
- pljava_statement_cache_size
- pljava_release_lingering_savepoints
- pljava_vmoptions

**XML Data Parameters**

- xmlbinary
- xmloption

**Enabling High Availability and Data Consistency Features**

The fault tolerance and the high-availability features of Greenplum Database can be configured.

**Important:** When data loss is not acceptable for a Pivotal Greenplum Database cluster, master and segment mirroring must be enabled in order for the cluster to be supported by Pivotal. Without mirroring, system and data availability is not guaranteed; Pivotal will make best efforts to restore a cluster in this case. For information about master and segment mirroring, see *About Redundancy and Failover*.

For information about the utilities that are used to enable high availability, see the *Greenplum Database Utility Guide*. 
Overview of Greenplum Database High Availability

A Greenplum Database cluster can be made highly available by providing a fault-tolerant hardware platform, by enabling Greenplum Database high-availability features, and by performing regular monitoring and maintenance procedures to ensure the health of all system components.

Hardware components will eventually fail, whether due to normal wear or an unexpected circumstance. Loss of power can lead to temporarily unavailable components. A system can be made highly available by providing redundant standbys for components that can fail so that services can continue uninterrupted when a failure does occur. In some cases, the cost of redundancy is higher than users’ tolerance for interruption in service. When this is the case, the goal is to ensure that full service is able to be restored, and can be restored within an expected timeframe.

With Greenplum Database, fault tolerance and data availability is achieved with:

- Hardware level RAID storage protection
- Data storage checksums
- Greenplum segment mirroring
- Master mirroring
- Dual clusters
- Database backup and restore

Hardware level RAID

A best practice Greenplum Database deployment uses hardware level RAID to provide high performance redundancy for single disk failure without having to go into the database level fault tolerance. This provides a lower level of redundancy at the disk level.

Data storage checksums

Greenplum Database uses checksums to verify that data loaded from disk to memory has not been corrupted on the file system.

Greenplum Database has two kinds of storage for user data: heap and append-optimized. Both storage models use checksums to verify data read from the file system and, with the default settings, they handle checksum verification errors in a similar way.

Greenplum Database primary and segment database processes update data on pages in the memory they manage. When a memory page is updated and flushed to disk, checksums are computed and saved with the page. When a page is later retrieved from disk, the checksums are verified and the page is only permitted to enter managed memory if the verification succeeds. A failed checksum verification is an indication of corruption in the file system and causes Greenplum Database to generate an error, aborting the transaction.

The default checksum settings provide the best level of protection from undetected disk corruption propagating into the database and to mirror segments.

Heap checksum support is enabled by default when the Greenplum Database cluster is initialized with the gpinit system management utility. Although it is strongly discouraged, a cluster can be initialized without heap checksum support by setting the HEAP_CHECKSUM parameter to off in the gpinit system cluster configuration file. See gpinit system.

Once initialized, it is not possible to change heap checksum support for a cluster without reinitializing the system and reloading databases.

You can check the read-only server configuration parameter data_checksums to see if heap checksums are enabled in a cluster:

```
$ gpconfig -s data_checksums
```
When a Greenplum Database cluster starts up, the `gpstart` utility checks that heap checksums are consistently enabled or disabled on the master and all segments. If there are any differences, the cluster fails to start. See `gpstart`.

In cases where it is necessary to ignore heap checksum verification errors so that data can be recovered, setting the `ignore_checksum_failure` system configuration parameter to `on` causes Greenplum Database to issue a warning when a heap checksum verification fails, but the page is then permitted to load into managed memory. If the page is updated and saved to disk, the corrupted data could be replicated to the mirror segment. Because this can lead to data loss, setting `ignore_checksum_failure` to `on` should only be done to enable data recovery.

For append-optimized storage, checksum support is one of several storage options set at the time an append-optimized table is created with the `CREATE TABLE` statement. The default storage options are specified in the `gp_default_storage_options` server configuration parameter. The checksum storage option is enabled by default and disabling it is strongly discouraged.

If you choose to disable checksums for an append-optimized table, you can either

- change the `gp_default_storage_options` configuration parameter to include `checksum=false` before creating the table, or
- add the `checksum=false` option to the `WITH storage_options` clause of the `CREATE TABLE` statement.

Note that the `CREATE TABLE` statement allows you to set storage options, including checksums, for individual partition files.

See the `CREATE TABLE` command reference and the `gp_default_storage_options` configuration parameter reference for syntax and examples.

**Segment Mirroring**

Greenplum Database stores data in multiple segments, each of which is a Greenplum Database Postgres instance. The data for each table is spread between the segments based on the distribution policy that is defined for the table in the DDL at the time the table is created. When segment mirroring is enabled, for each segment there is a primary and mirror pair. The primary and mirror perform the same IO operations and store copies of the same data.

The mirror instance for each segment is usually initialized with the `gpinitsystem` utility or the `gpexpand` utility. The mirror runs on a different host than the primary instance to protect from a single machine failure. There are different strategies for assigning mirrors to hosts. When choosing the layout of the primaries and mirrors, it is important to consider the failure scenarios to ensure that processing skew is minimized in the case of a single machine failure.

**Master Mirroring**

There are two masters in a highly available cluster, a primary and a standby. As with segments, the master and standby should be deployed on different hosts so that the cluster can tolerate a single host failure. Clients connect to the primary master and queries can be executed only on the primary master. The secondary master is kept up-to-date by replicating the write-ahead log (WAL) from the primary to the secondary.

If the master fails, the administrator runs the `gpactivatestandby` utility to have the standby master take over as the new primary master. You can configure a virtual IP address for the master and standby so that client programs do not have to switch to a different network address when the current master changes. If the master host fails, the virtual IP address can be swapped to the actual acting master.

**Dual Clusters**

An additional level of redundancy can be provided by maintaining two Greenplum Database clusters, both storing the same data.
Two methods for keeping data synchronized on dual clusters are "dual ETL" and "backup/restore."

Dual ETL provides a complete standby cluster with the same data as the primary cluster. ETL (extract, transform, and load) refers to the process of cleansing, transforming, validating, and loading incoming data into a data warehouse. With dual ETL, this process is executed twice in parallel, once on each cluster, and is validated each time. It also allows data to be queried on both clusters, doubling the query throughput. Applications can take advantage of both clusters and also ensure that the ETL is successful and validated on both clusters.

To maintain a dual cluster with the backup/restore method, create backups of the primary cluster and restore them on the secondary cluster. This method takes longer to synchronize data on the secondary cluster than the dual ETL strategy, but requires less application logic to be developed. Populating a second cluster with backups is ideal in use cases where data modifications and ETL are performed daily or less frequently.

**Backup and Restore**

Making regular backups of the databases is recommended except in cases where the database can be easily regenerated from the source data. Backups should be taken to protect from operational, software, and hardware errors.

Use the `gpcrondump` utility to backup Greenplum databases. `gpcrondump` performs the backup in parallel across segments, so backup performance scales up as hardware is added to the cluster.

When designing a backup strategy, a primary concern is where to store the backup data. The data each segment manages can be backed up on the segment's local storage, but should not be stored there permanently—the backup reduces disk space available to the segment and, more importantly, a hardware failure could simultaneously destroy the segment's live data and the backup. After performing a backup, the backup files should be moved from the primary cluster to separate, safe storage. Alternatively, the backup can be made directly to separate storage.

Additional options are available to backup databases, including the following:

**Data Domain**

Through native API integration backups can be streamed to a Dell EMC Data Domain appliance.

**NetBackup**

Through native API integration, backups can be streamed to a Veritas NetBackup cluster.

**NFS**

If an NFS mount is created on each Greenplum Database host in the cluster, backups can be written directly to the NFS mount. A scale out NFS solution is recommended to ensure that backups do not bottleneck on IO throughput of the NFS device. Dell EMC Isilon is an example that can scale out along side the Greenplum cluster.

**Incremental Backups**

Greenplum Database allows incremental backup at the partition level for append-optimized and column-oriented tables. When you perform an incremental backup, only the partitions for append-optimized and column-oriented tables that have changed since the previous backup are backed up. (Heap tables are always backed up.) Restoring an incremental backup requires restoring the previous full backup and subsequent incremental backups.

Incremental backup is beneficial only when the database contains large, partitioned tables where all but one or a few partitions remain unchanged between backups. An incremental backup saves just the changed partitions and the heap tables. By not backing up the unchanged partitions, the backup size and time can be significantly reduced.
If a large fact table is not partitioned, and a single row is added or changed, the entire table is backed up, and there is no savings in backup size or time. Therefore, incremental backup is only recommended for databases with large, partitioned tables and relatively small dimension tables.

If you maintain dual clusters and use incremental backup, you can populate the second cluster with the incremental backups. Use the --noplan option to achieve this, allowing backups from the primary site to be applied faster.

**Overview of Segment Mirroring**

When Greenplum Database High Availability is enabled, there are two types of segments: primary and mirror. Each primary segment has one corresponding mirror segment. A primary segment receives requests from the master to make changes to the segment's database and then replicates those changes to the corresponding mirror. If a primary segment becomes unavailable, database queries fail over to the mirror segment.

Segment mirroring employs a physical file replication scheme—data file I/O at the primary is replicated to the secondary so that the mirror's files are identical to the primary's files. Data in Greenplum Database are represented with tuples, which are packed into blocks. Database tables are stored in disk files consisting of one or more blocks. A change to a tuple changes the block it is saved in, which is then written to disk on the primary and copied over the network to the mirror. The mirror updates the corresponding block in its copy of the file.

For heap tables, blocks are saved in an in-memory cache until they are evicted to make room for newly changed blocks. This allows the system to read or update a block in memory multiple times without performing expensive disk I/O. When the block is evicted from the cache, it is written to disk and replicated to the secondary. While the block is held in cache, the primary and mirror have different images of the block. However, the databases are still consistent because the transaction log has been replicated. If a mirror takes over for a failed primary, the transactions in its log are applied to the database tables.

Other database objects — for example filesystems, which are tablespaces internally represented with directories—also use file replication to perform various file operations in a synchronous way.

Append-optimized tables do not use the in-memory caching mechanism. Changes made to append-optimized table blocks are replicated to the mirror immediately. Typically, file write operations are asynchronous, while opening, creating, and synchronizing files are "sync-replicated," which means the primary blocks until it receives the acknowledgment from the secondary.

If a primary segment fails, the file replication process stops and the mirror segment automatically starts as the active segment instance. The now active mirror's system state becomes Change Tracking, which means the mirror maintains a system table and change-log of all blocks updated while the primary segment is unavailable. When the failed primary segment is repaired and ready to be brought back online, an administrator initiates a recovery process and the system goes into Resynchronization state. The recovery process applies the logged changes to the repaired primary segment. The system state changes to Synchronized when the recovery process completes.

If the mirror segment fails or becomes inaccessible while the primary is active, the primary's system state changes to Change Tracking, and it tracks changes to be applied to the mirror when it is recovered.

Mirror segments can be placed on hosts in the cluster in different configurations, as long as the primary and mirror instance for a segment are on different hosts. Each host must have the same number of primary and mirror segments. The default mirroring configuration is group mirroring, where the mirror segments for each host's primary segments are placed on one other host. If a single host fails, the number of active primary segments doubles on the host that backs the failed host. Figure 15: Group Segment Mirroring in Greenplum Database illustrates a group mirroring configuration.
Figure 15: Group Segment Mirroring in Greenplum Database

Spread mirroring spreads each host’s mirrors over multiple hosts so that if any single host fails, no other host will have more than one mirror promoted to the active primary segment. Spread mirroring is possible only if there are more hosts than segments per host. Figure 16: Spread Segment Mirroring in Greenplum Database illustrates the placement of mirrors in a spread segment mirroring configuration.
The Greenplum Database utilities that create mirror segments support group and spread segment configurations. Custom mirroring configurations can be described in a configuration file and passed on the command line.

**Overview of Master Mirroring**

You can deploy a backup or mirror of the master instance on a separate host machine or on the same host machine. A backup master or standby master serves as a warm standby if the primary master becomes nonoperational. You create a standby master from the primary master while the primary is online.

The primary master continues to provide service to users while a transactional snapshot of the primary master instance is taken. While the transactional snapshot is taken and deployed on the standby master, changes to the primary master are also recorded. After the snapshot is deployed on the standby master, the updates are deployed to synchronize the standby master with the primary master.

Once the primary master and standby master are synchronized, the standby master is kept up to date by the `walsender` and `walreceiver` replication processes. The `walreceiver` is a standby master process. The `walsender` process is a primary master process. The two processes use Write-Ahead Logging (WAL)-based streaming replication to keep the primary and standby masters synchronized. In WAL logging, all modifications are written to the log before being applied, to ensure data integrity for any in-process operations.

**Note:** WAL logging is not yet available for segment mirroring.

Since the master does not house user data, only system catalog tables are synchronized between the primary and standby masters. When these tables are updated, changes are automatically copied to the standby master to keep it current with the primary.
If the primary master fails, the replication process stops, and an administrator can activate the standby master. Upon activation of the standby master, the replicated logs reconstruct the state of the primary master at the time of the last successfully committed transaction. The activated standby then functions as the Greenplum Database master, accepting connections on the port specified when standby master was initialized.

**Overview of Fault Detection and Recovery**

The Greenplum Database server (*postgres*) subprocess named *ftsprobe* handles fault detection. *ftsprobe* monitors the Greenplum Database array; it connects to and scans all segments and database processes at intervals that you can configure.

If *ftsprobe* cannot connect to a segment, it marks the segment as "down" in the Greenplum Database system catalog. The segment remains nonoperational until an administrator initiates the recovery process.

With mirroring enabled, Greenplum Database automatically fails over to a mirror copy if a primary copy becomes unavailable. The system is operational if a segment instance or host fails provided all data is available on the remaining active segments.

To recover failed segments, an administrator runs the *gprecoverseg* recovery utility. This utility locates the failed segments, verifies they are valid, and compares the transactional state with the currently active segment to determine changes made while the segment was offline. *gprecoverseg* synchronizes the changed database files with the active segment and brings the segment back online. Administrators perform the recovery while Greenplum Database is up and running.

With mirroring disabled, the system automatically shuts down if a segment instance fails. Administrators manually recover all failed segments before operations resume.

See *Detecting a Failed Segment* for a more detailed description of the fault detection and recovery process and configuration options.

**Enabling Mirroring in Greenplum Database**

You can configure your Greenplum Database system with mirroring at setup time using *gpinit* or enable mirroring later using *gpaddmirrors* and *gpinitstandby*. This topic assumes you are adding mirrors to an existing system that was initialized without mirrors.

You can enable the following types of mirroring:

- Enabling Segment Mirroring
- Enabling Master Mirroring
Enabling Segment Mirroring

Mirror segments allow database queries to fail over to a backup segment if the primary segment is unavailable. By default, mirrors are configured on the same array of hosts as the primary segments. You may choose a completely different set of hosts for your mirror segments so they do not share machines with any of your primary segments.

**Important:** During the online data replication process, Greenplum Database should be in a quiescent state, workloads and other queries should not be running.

To add segment mirrors to an existing system (same hosts as primaries)

1. Allocate the data storage area for mirror data on all segment hosts. The data storage area must be different from your primary segments' file system location.
2. Use `gpssh-exkeys` to ensure that the segment hosts can SSH and SCP to each other without a password prompt.
3. Run the `gpaddmirrors` utility to enable mirroring in your Greenplum Database system. For example, to add 10000 to your primary segment port numbers to calculate the mirror segment port numbers:

   ```
   $ gpaddmirrors -p 10000
   ```

   Where `-p` specifies the number to add to your primary segment port numbers. Mirrors are added with the default group mirroring configuration.

To add segment mirrors to an existing system (different hosts from primaries)

1. Ensure the Greenplum Database software is installed on all hosts. See the Greenplum Database Installation Guide for detailed installation instructions.
2. Allocate the data storage area for mirror data on all segment hosts.
3. Use `gpssh-exkeys` to ensure the segment hosts can SSH and SCP to each other without a password prompt.
4. Create a configuration file that lists the host names, ports, and data directories on which to create mirrors. To create a sample configuration file to use as a starting point, run:

   ```
   $ gpaddmirrors -o filename
   ```

   The format of the mirror configuration file is:

   ```
   filespaceOrder=[filespace1_fsname[:filespace2_fsname:...]]
mirror[content]=content:address:port:mir_replication_port:
pri_replication_port:fselocation[:fselocation:...]
   ```

   For example, a configuration for two segment hosts and two segments per host, with no additional filespaces configured besides the default `pg_system` file space:

   ```
   filespaceOrder=
mirror0=0:sdw1-1:52001:53001:54001:/gpdata/mir1/gp0
   mirror1=1:sdw1-2:52002:53002:54002:/gpdata/mir1/gp1
   mirror2=2:sdw2-1:52001:53001:54001:/gpdata/mir1/gp2
   mirror3=3:sdw2-2:52002:53002:54002:/gpdata/mir1/gp3
   ```

5. Run the `gpaddmirrors` utility to enable mirroring in your Greenplum Database system:

   ```
   $ gpaddmirrors -i mirror_config_file
   ```
Where \(-i\) names the mirror configuration file you created.

**Enabling Master Mirroring**

You can configure a new Greenplum Database system with a standby master using `gpinitsystem` or enable it later using `gpinitstandby`. This topic assumes you are adding a standby master to an existing system that was initialized without one.

For information about the utilities `gpinitsystem` and `gpinitstandby`, see the *Greenplum Database Utility Guide*.

**To add a standby master to an existing system**

1. Ensure the standby master host is installed and configured: `gpadmin` system user created, Greenplum Database binaries installed, environment variables set, SSH keys exchanged, and data directory created.
2. Run the `gpinitstandby` utility on the currently active *primary* master host to add a standby master host to your Greenplum Database system. For example:

   ```
   $ gpinitstandby -s smdw
   ```

   Where \(-s\) specifies the standby master host name.
3. To switch operations to a standby master, see *Recovering a Failed Master*.

**To check the status of the master mirroring process (optional)**

You can display the information in the Greenplum Database system view `pg_stat_replication`. The view lists information about the `walsender` process that is used for Greenplum Database master mirroring. For example, this command displays the process ID and state of the `walsender` process:

```
$ psql dbname -c 'SELECT procpid, state FROM pg_stat_replication;'
```

For information about the `pg_stat_replication` system view, see the *Greenplum Database Reference Guide*.

**Detecting a Failed Segment**

With mirroring enabled, Greenplum Database automatically fails over to a mirror segment when a primary segment goes down. Provided one segment instance is online per portion of data, users may not realize a segment is down. If a transaction is in progress when a fault occurs, the in-progress transaction rolls back and restarts automatically on the reconfigured set of segments.

If the entire Greenplum Database system becomes nonoperational due to a segment failure (for example, if mirroring is not enabled or not enough segments are online to access all user data), users will see errors when trying to connect to a database. The errors returned to the client program may indicate the failure. For example:

```
ERROR: All segment databases are unavailable
```

**How Segment Failure is Detected and Managed**

On the Greenplum Database master host, the Postgres `postmaster` process forks a fault probe process, `ftsprobe`. This is sometimes called the FTS (Fault Tolerance Server) process. The `postmaster` process restarts the FTS if it fails.

The FTS runs in a loop with a sleep interval between each cycle. On each loop, the FTS probes each primary segment database by making a TCP socket connection to the segment database using the hostname and port registered in the `gp_segment_configuration` table. If the connection succeeds, the
segment performs a few simple checks and reports back to the FTS. The checks include executing a `stat`
system call on critical segment directories and checking for internal faults in the segment instance. If no
issues are detected, a positive reply is sent to the FTS and no action is taken for that segment database.

If the connection cannot be made, or if a reply is not received in the timeout period, then a retry is
attempted for the segment database. If the configured maximum number of probe attempts fail, the FTS
probes the segment's mirror to ensure that it is up, and then updates the `gp_segment_configuration`
table, marking the primary segment "down" and setting the mirror to act as the primary. The FTS updates
the `gp_configuration_history` table with the operations performed.

When there is only an active primary segment and the corresponding mirror is down, the primary goes
into "Change Tracking Mode." In this mode, changes to the segment are recorded, so the mirror can be
synchronized without performing a full copy of data from the primary to the mirror.

The `gprecoverseg` utility is used to bring up a mirror that is down. By default, `gprecoverseg` performs
an incremental recovery, placing the mirror into resync mode, which starts to replay the recorded changes
from the primary onto the mirror. If the incremental recovery cannot be completed, the recovery fails and
`gprecoverseg` should be run again with the `-F` option, to perform full recovery. This causes the primary
to copy all of the data to the mirror.

You can see the mode—"change tracking", "resync", or "in-sync"—for each segment, as well as the status
"up" or "down", in the `gp_segment_configuration` table.

The `gp_segment_configuration` table also has columns `role` and `preferred_role`. These can
have values of either `p` for primary or `m` for mirror. The `role` column shows the segment database's
current role and the `preferred_role` shows the original role of the segment. In a balanced system the
`role` and `preferred_role` matches for all segments. When they do not match, there may be skew
resulting from the number of active primary segments on each hardware host. To rebalance the cluster
and bring all the segments into their preferred role, the `gprecoverseg` command can be run with the `-r`
option.

There is a set of server configuration parameters that affect FTS behavior:

**gp_fts_probe_threadcount**
- The number of threads used for probing segments. Default: 16

**gp_fts_probe_interval**
- How often, in seconds, to begin a new FTS loop. For example if the setting is 60 and the
  probe loop takes 10 seconds, the FTS process sleeps 50 seconds. If the setting is 60 and
  probe loop takes 75 seconds, the process sleeps 0 seconds. The default is 60, and the
  maximum is 3600.

**gp_fts_probe_timeout**
- Probe timeout between master and segment, in seconds. The default is 20, and the
  maximum is 3600.

**gp_fts_probe_retries**
- The number of attempts to probe a segment. For example if the setting is 5 there will be 4
  retries after the first attempt fails. Default: 5

**gp_log_fts**
- Logging level for FTS. The value may be "off", "terse", "verbose", or "debug". The
  "verbose" setting can be used in production to provide useful data for troubleshooting. The
  "debug" setting should not be used in production. Default: "terse"

**gp_segment_connect_timeout**
- The maximum time (in seconds) allowed for a mirror to respond. Default: 180

In addition to the fault checking performed by the FTS, a primary segment that is unable to send data
to its mirror can change the status of the mirror to down. The primary queues up the data and after
`gp_segment_connect_timeout` seconds passes, indicates a mirror failure, causing the mirror to be
marked down and the primary to go into change tracking mode.
Enabling Alerts and Notifications

To receive notifications of system events such as segment failures, enable email or SNMP alerts. See Enabling System Alerts and Notifications.

Checking for Failed Segments

With mirroring enabled, you may have failed segments in the system without interruption of service or any indication that a failure has occurred. You can verify the status of your system using the gpstate utility. gpstate provides the status of each individual component of a Greenplum Database system, including primary segments, mirror segments, master, and standby master.

To check for failed segments

1. On the master, run the gpstate utility with the -e option to show segments with error conditions:

   $ gpstate -e

   Segments in Change Tracking mode indicate the corresponding mirror segment is down. When a segment is not in its preferred role, the segment does not operate in the role to which it was assigned at system initialization. This means the system is in a potentially unbalanced state, as some segment hosts may have more active segments than is optimal for top system performance.

   See Recovering From Segment Failures for instructions to fix this situation.

2. To get detailed information about a failed segment, check the gp_segment_configuration catalog table. For example:

   $ psql -c "SELECT * FROM gp_segment_configuration WHERE status='d';"

3. For failed segment instances, note the host, port, preferred role, and data directory. This information will help determine the host and segment instances to troubleshoot.

4. To show information about mirror segment instances, run:

   $ gpstate -m

Checking the Log Files for Failed Segments

Log files can provide information to help determine an error's cause. The master and segment instances each have their own log file in pg_log of the data directory. The master log file contains the most information and you should always check it first.

Use the gplogfilter utility to check the Greenplum Database log files for additional information. To check the segment log files, run gplogfilter on the segment hosts using gpssh.

To check the log files

1. Use gplogfilter to check the master log file for WARNING, ERROR, FATAL or PANIC log level messages:

   $ gplogfilter -t

2. Use gpssh to check for WARNING, ERROR, FATAL, or PANIC log level messages on each segment instance. For example:

   $ gpssh -f seg_hosts_file -e 'source /usr/local/greenplum-db/greenplum_path.sh ; gplogfilter -t /data1/primary/*/pg_log/gpdb*.log' > seglog.out
Recovering a Failed Segment

If the master cannot connect to a segment instance, it marks that segment as down in the Greenplum Database system catalog. The segment instance remains offline until an administrator takes steps to bring the segment back online. The process for recovering a failed segment instance or host depends on the failure cause and whether or not mirroring is enabled. A segment instance can be unavailable for many reasons:

- A segment host is unavailable; for example, due to network or hardware failures.
- A segment instance is not running; for example, there is no `postgres` database listener process.
- The data directory of the segment instance is corrupt or missing; for example, data is not accessible, the file system is corrupt, or there is a disk failure.

Figure 18: Segment Failure Troubleshooting Matrix shows the high-level steps for each of the preceding failure scenarios.

![Figure 18: Segment Failure Troubleshooting Matrix](image-url)
Recovering From Segment Failures

Segment host failures usually cause multiple segment failures: all primary or mirror segments on the host are marked as down and nonoperational. If mirroring is not enabled and a segment goes down, the system automatically becomes nonoperational.

To recover with mirroring enabled

1. Ensure you can connect to the segment host from the master host. For example:

   $ ping failed_seg_host_address

2. Troubleshoot the problem that prevents the master host from connecting to the segment host. For example, the host machine may need to be restarted or replaced.

3. After the host is online and you can connect to it, run the gprecoverseg utility from the master host to reactivate the failed segment instances. For example:

   $ gprecoverseg

4. The recovery process brings up the failed segments and identifies the changed files that need to be synchronized. The process can take some time; wait for the process to complete. During this process, database write activity is suspended.

5. After gprecoverseg completes, the system goes into Resynchronizing mode and begins copying the changed files. This process runs in the background while the system is online and accepting database requests.

6. When the resynchronization process completes, the system state is Synchronized. Run the gpstate utility to verify the status of the resynchronization process:

   $ gpstate -m

To return all segments to their preferred role

When a primary segment goes down, the mirror activates and becomes the primary segment. After running gprecoverseg, the currently active segment remains the primary and the failed segment becomes the mirror. The segment instances are not returned to the preferred role that they were given at system initialization time. This means that the system could be in a potentially unbalanced state if segment hosts have more active segments than is optimal for top system performance. To check for unbalanced segments and rebalance the system, run:

   $ gpstate -e

All segments must be online and fully synchronized to rebalance the system. Database sessions remain connected during rebalancing, but queries in progress are canceled and rolled back.

1. Run gpstate -m to ensure all mirrors are Synchronized.

   $ gpstate -m

2. If any mirrors are in Resynchronizing mode, wait for them to complete.

3. Run gprecoverseg with the -r option to return the segments to their preferred roles.

   $ gprecoverseg -r

4. After rebalancing, run gpstate -e to confirm all segments are in their preferred roles.

   $ gpstate -e
To recover from a double fault

In a double fault, both a primary segment and its mirror are down. This can occur if hardware failures on different segment hosts happen simultaneously. Greenplum Database is unavailable if a double fault occurs. To recover from a double fault:

1. Restart Greenplum Database:

$ gpstop -r

2. After the system restarts, run gprecoverseg:

$ gprecoverseg

3. After gprecoverseg completes, use gpstate to check the status of your mirrors:

$ gpstate -m

4. If you still have segments in Change Tracking mode, run a full copy recovery:

$ gprecoverseg -F

If a segment host is not recoverable and you have lost one or more segments, recreate your Greenplum Database system from backup files. See Backing Up and Restoring Databases.

To recover without mirroring enabled

1. Ensure you can connect to the segment host from the master host. For example:

$ ping failed_seg_host_address

2. Troubleshoot the problem that is preventing the master host from connecting to the segment host. For example, the host machine may need to be restarted.

3. After the host is online, verify that you can connect to it and restart Greenplum Database. For example:

$ gpstop -r

4. Run the gpstate utility to verify that all segment instances are online:

$ gpstate

When a segment host is not recoverable

If a host is nonoperational, for example, due to hardware failure, recover the segments onto a spare set of hardware resources. If mirroring is enabled, you can recover a segment from its mirror onto an alternate host using gprecoverseg. For example:

$ gprecoverseg -i recover_config_file

Where the format of recover_config_file is:

```
filespaceOrder=[filespace1_name[:filespace2_name:...]]failed_host_address:port:fselocation [recovery_host_address:port:replication_port:fselocation [:fselocation:...]]
```

For example, to recover to a different host than the failed host without additional filespaces configured (besides the default pg_system filesystem):

```
filespaceOrder=sdw5-2:50002:/gpdata/gpseg2 sdw9-2:50002:53002:/gpdata/gpseg2
```
The `gp_segment_configuration` and `pg_filespace_entry` system catalog tables can help determine your current segment configuration so you can plan your mirror recovery configuration. For example, run the following query:

```
=# SELECT dbid, content, hostname, address, port,
replication_port, fseolocation as datadir
FROM gp_segment_configuration, pg_filespace_entry
WHERE dbid=fseidbid
ORDER BY dbid;
```

The new recovery segment host must be pre-installed with the Greenplum Database software and configured exactly as the existing segment hosts.

**About the Segment Recovery Process**

This topic describes the process for recovering segments, initiated by the `gprecoverseg` management utility. It describes actions `gprecoverseg` performs and how the Greenplum File Replication and FTS (fault tolerance service) processes complete the recovery initiated with `gprecoverseg`.

Although `gprecoverseg` is an online operation, there are two brief periods during which all IO is paused. First, when recovery is initiated, IO is suspended while empty data files are created on the mirror. Second, after data files are synchronized, IO is suspended while system files such as transaction logs are copied from the primary to the mirror. The duration of these pauses is affected primarily by the number of file system files that must be created on the mirror and the sizes of the system flat files that must be copied. The system is online and available while database tables are replicated from the primary to the mirror, and any changes made to the database during recovery are replicated directly to the mirror.

To initiate recovery, the administrator runs the `gprecoverseg` utility. `gprecoverseg` prepares segments for recovery and initiates synchronization. When synchronization is complete and the segment status is updated in the system catalog, the segments are recovered. If the recovered segments are not running in their preferred roles, `gprecoverseg -r` can be used to bring the system back into balance.

Without the `-F` option, `gprecoverseg` recovers segments incrementally, copying only the changes since the mirror entered down status. The `-F` option fully recovers mirrors by deleting their data directories and then synchronizing all persistent data files from the primary to the mirror.

You can run `gpstate -e` to view the mirroring status of the segments before and during the recovery process. The primary and mirror segment statuses are updated as the recovery process proceeds.

Consider a single primary-mirror segment pair where the primary is active and the mirror is down. The following table shows the segment status before beginning recovery of the mirror.

<table>
<thead>
<tr>
<th></th>
<th>preferred_role</th>
<th>role</th>
<th>mode</th>
<th>status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>p (primary)</td>
<td>p (primary)</td>
<td>c (change tracking)</td>
<td>u (up)</td>
</tr>
<tr>
<td>Mirror</td>
<td>m (mirror)</td>
<td>m (mirror)</td>
<td>s (synchronizing)</td>
<td>d (down)</td>
</tr>
</tbody>
</table>

The segments are in their preferred roles, but the mirror is down. The primary is up and is in change tracking mode because it is unable to send changes to its mirror.

**Segment Recovery Preparation**

The `gprecoverseg` utility prepares the segments for recovery and then exits, allowing the Greenplum file replication processes to copy data from the primary to the mirror.

During the `gprecoverseg` execution the following recovery process steps are completed.
1. The down segments are identified.
2. The mirror segment processes are initialized.
3. For full recovery (\(-af\)): 
   - The data directories of the down segments are deleted.
   - A new data directory structure is created.
4. The segment mode in the `gp_segment_configuration` system table is updated to 'r' (resynchronization mode).
5. The backend performs the following:
   - Suspends IO—connections to the master are allowed, but reads and writes from the segment being recovered are not allowed.
   - Scans persistent tables on the primary segment.
   - For each persistent file object (`relfilenode` in the `pg_class` system table), creates a data file on the mirror.

   The greater the number of data files, the longer IO is suspended.

   For incremental recovery, the IO is suspended for a shorter period because only file system objects added (or dropped) on the primary after the mirror was marked down need to be created (or deleted) on the mirror.
6. The `gprecoverseg` script completes.

Once `gprecoverseg` has completed, the segments are in the states shown in the following table.

<table>
<thead>
<tr>
<th>preferred_role</th>
<th>role</th>
<th>mode</th>
<th>status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>p</td>
<td>r</td>
<td>u</td>
</tr>
<tr>
<td>(primary)</td>
<td>(primary)</td>
<td>(resynchronizing)</td>
<td>(up)</td>
</tr>
<tr>
<td>Mirror</td>
<td>m</td>
<td>r</td>
<td>u</td>
</tr>
<tr>
<td>(mirror)</td>
<td>(mirror)</td>
<td>(resynchronizing)</td>
<td>(up)</td>
</tr>
</tbody>
</table>

Data File Replication

Data file resynchronization is performed in the background by file replication processes. Run `gpstate -e` to check the process of resynchronization. The Greenplum system is fully available for workloads while this process completes.

Following are steps in the resynchronization process:

1. Data copy (full and incremental recovery):
   
   After the file system objects are created, data copy is initiated for the affected segments. The ResyncManager process scans the persistent table system catalogs to find the file objects to be synchronized. ResyncWorker processes sync the file objects from the primary to the mirror.

2. Any changes or new data created with database transactions during the data copy are mirrored directly to the mirror.

3. Once data copy has finished synchronizing persistent data files, file replication updates the shared memory state on the current primary segment to 'insync'.

Flat File Replication

During this phase, system files in the primary segment's data directory are copied to the segment data directory. IO is suspended while the following flat files are copied from the primary data directory to the segment data directory:

- `pg_xlog/*`
- `pg_clog/*`
• pg_distributedlog/*
• pg_distributedxidmap/*
• pg_multixact/members
• pg_multixact/offsets
• pg_twophase/*
• global/pg_database
• global/pg_auth
• global/pg_auth_time_constraint

IOSUSPEND ends after these files are copied.

The next time the fault tolerance server (ftsprobe) process on the master wakes, it will set the primary and mirror states to synchronized (mode=s, state=u). A distributed query will also trigger the ftsprobe process to update the state.

When all segment recovery and file replication processes are complete, the segment status in the gp_segment_configuration system table and gp_state -e output is as shown in the following table.

<table>
<thead>
<tr>
<th>preferred_role</th>
<th>role</th>
<th>mode</th>
<th>status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>p</td>
<td>s</td>
<td>u</td>
</tr>
<tr>
<td></td>
<td>(primary)</td>
<td>(synchronized)</td>
<td>(up)</td>
</tr>
<tr>
<td>Mirror</td>
<td>m</td>
<td>s</td>
<td>u</td>
</tr>
<tr>
<td></td>
<td>(mirror)</td>
<td>(synchronized)</td>
<td>(up)</td>
</tr>
</tbody>
</table>

**Factors Affecting Duration of Segment Recovery**

Following are some factors that can affect the duration of the segment recovery process.

- The number of database objects, mainly tables and indexes.
- The number of data files in segment data directories.
- The types of workloads updating data during resynchronization – both DDL and DML (insert, update, delete, and truncate).
- The size of the data.
- The size of system files, such as transaction log files, pg_database, pg_auth, and pg_auth_time_constraint.

**Recovering a Failed Master**

If the primary master fails, log replication stops. Use the gpstate -f command to check the state of standby replication. Use gpactivatestandby to activate the standby master. Upon activation of the standby master, Greenplum Database reconstructs the master host state at the time of the last successfully committed transaction.

**To activate the standby master**

1. Ensure a standby master host is configured for the system. See Enabling Master Mirroring.
2. Run the gpactivatestandby utility from the standby master host you are activating. For example:

   ```
   $ gpactivatestandby -d /data/master/gpseg-1
   ```

   Where -d specifies the data directory of the master host you are activating.

   After you activate the standby, it becomes the active or primary master for your Greenplum Database array.
3. After the utility finishes, run `gpstate` to check the status:

   ```
   $ gpstate -f
   ```

   The newly activated master's status should be `Active`. If you configured a new standby host, its status is `Passive`. When a standby master is not configured, the command displays `-No entries found` and the message indicates that a standby master instance is not configured.

4. After switching to the newly active master host, run `ANALYZE` on it. For example:

   ```
   $ psql dbname -c 'ANALYZE;' 
   ```

5. Optional: If you did not specify a new standby host when running the `gpactivatestandby` utility, use `gpinitstandby` to configure a new standby master at a later time. Run `gpinitstandby` on your active master host. For example:

   ```
   $ gpinitstandby -s new_standby_master_hostname
   ```

**Restoring Master Mirroring After a Recovery**

After you activate a standby master for recovery, the standby master becomes the primary master. You can continue running that instance as the primary master if it has the same capabilities and dependability as the original master host.

You must initialize a new standby master to continue providing master mirroring unless you have already done so while activating the prior standby master. Run `gpinitstandby` on the active master host to configure a new standby master.

You may restore the primary and standby master instances on the original hosts. This process swaps the roles of the primary and standby master hosts, and it should be performed only if you strongly prefer to run the master instances on the same hosts they occupied prior to the recovery scenario.

For information about the Greenplum Database utilities, see the *Greenplum Database Utility Guide*.

**To restore the master and standby instances on original hosts (optional)**

1. Ensure the original master host is in dependable running condition; ensure the cause of the original failure is fixed.

2. On the original master host, move or remove the data directory, `gpseg-1`. This example moves the directory to `backup_gpseg-1`:

   ```
   $ mv /data/master/gpseg-1 /data/master/backup_gpseg-1
   ```

   You can remove the backup directory once the standby is successfully configured.

3. Initialize a standby master on the original master host. For example, run this command from the current master host, `smdw`:

   ```
   $ gpinitstandby -s mdw
   ```

4. After the initialization completes, check the status of standby master, `mdw`, run `gpstate` with the `-f` option to check the status:

   ```
   $ gpstate -f
   ```

   The status should be `In Synch`. 
5. Stop Greenplum Database master instance on the standby master. For example:

```
$ gpstop -m
```

6. Run the `gpactivatestandby` utility from the original master host, mdw, that is currently a standby master. For example:

```
$ gpactivatestandby -d $MASTER_DATA_DIRECTORY
```

Where the `-d` option specifies the data directory of the host you are activating.

7. After the utility completes, run `gpstate` to check the status:

```
$ gpstate -f
```

Verify the original primary master status is `Active`. When a standby master is not configured, the command displays `-No entries found` and the message indicates that a standby master instance is not configured.

8. On the standby master host, move or remove the data directory, `gpseg-1`. This example moves the directory:

```
$ mv /data/master/gpseg-1 /data/master/backup_gpseg-1
```

You can remove the backup directory once the standby is successfully configured.

9. After the original master host runs the primary Greenplum Database master, you can initialize a standby master on the original standby master host. For example:

```
$ gpinitstandby -s smdw
```

**To check the status of the master mirroring process (optional)***

You can display the information in the Greenplum Database system view `pg_stat_replication`. The view lists information about the `walsender` process that is used for Greenplum Database master mirroring. For example, this command displays the process ID and state of the `walsender` process:

```
$ psql dbname -c 'SELECT procpid, state FROM pg_stat_replication;'
```

## Backing Up and Restoring Databases

This topic describes how to use Greenplum backup and restore features.

Performing backups regularly ensures that you can restore your data or rebuild your Greenplum Database system if data corruption or system failure occur. You can also use backups to migrate data from one Greenplum Database system to another.

### Backup and Restore Overview

Greenplum Database supports parallel and non-parallel methods for backing up and restoring databases. Parallel operations scale regardless of the number of segments in your system, because segment hosts each write their data to local disk storage simultaneously. With non-parallel backup and restore operations, the data must be sent over the network from the segments to the master, which writes all of the data to its storage. In addition to restricting I/O to one host, non-parallel backup requires that the master have sufficient local disk storage to store the entire database.

### Parallel Backup with `gpcrondump` and `gpdbrestore`

The Greenplum Database parallel dump utility `gpcrondump` backs up the Greenplum master instance and each active segment instance at the same time.
By default, `gpcrondump` creates dump files in the `db_dumps` subdirectory of each segment instance. On the master, `gpcrondump` creates several dump files, containing database information such as DDL statements, the system catalog tables, and metadata files. On each segment, `gpcrondump` creates one dump file, which contains commands to recreate the data on that segment. Each file created for a backup begins with a 14-digit timestamp key that identifies the backup set the file belongs to.

**Figure 19: Parallel Backups in Greenplum Database**

The `gpdbrestore` parallel restore utility takes the timestamp key generated by `gpcrondump`, validates the backup set, and restores the database objects and data into a distributed database. Parallel restore operations require a complete backup set created by `gpcrondump`, a full backup, and any required incremental backups. As the following figure illustrates, all segments restore data from local backup files simultaneously.

**Figure 20: Parallel Restores in Greenplum Database**
The `gpdbrestore` utility provides flexibility and verification options for use with the automated backup files produced by `gpcrondump` or with backup files moved from the Greenplum cluster to an alternate location. See *Restoring Greenplum Databases*. `gpdbrestore` can also be used to copy files to the alternate location.

**Parallel Backup with gpbackup and gprestore**

`gpbackup` and `gprestore` are new utilities that are designed to improve the performance, functionality, and reliability of backups as compared to `gpcrondump` and `gpdbrestore`. `gpbackup` utilizes `ACCESS SHARE` locks at the individual table level, instead of `EXCLUSIVE` locks on the `pg_class` catalog table. This enables you to execute DML statements during the backup, such as `CREATE`, `ALTER`, `DROP`, and `TRUNCATE` operations, as long as those operations do not target the current backup set.

Backup files created with `gpbackup` are designed to provide future capabilities for restoring individual database objects along with their dependencies, such as functions and required user-defined datatypes. See *Parallel Backup with gpbackup and gprestore* for more information.

**Non-Parallel Backup with pg_dump**

The PostgreSQL `pg_dump` and `pg_dumpall` non-parallel backup utilities can be used to create a single dump file on the master host that contains all data from all active segments.

The PostgreSQL non-parallel utilities should be used only for special cases. They are much slower than using the Greenplum backup utilities since all of the data must pass through the master. Additionally, it is often the case that the master host has insufficient disk space to save a backup of an entire distributed Greenplum database.

The `pg_restore` utility requires compressed dump files created by `pg_dump` or `pg_dumpall`. Before starting the restore, you should modify the `CREATE TABLE` statements in the dump files to include the Greenplum `DISTRIBUTED` clause. If you do not include the `DISTRIBUTED` clause, Greenplum Database assigns default values, which may not be optimal. For details, see `CREATE TABLE` in the *Greenplum Database Reference Guide*.

To perform a non-parallel restore using parallel backup files, you can copy the backup files from each segment host to the master host, and then load them through the master. See *Restoring to a Different Greenplum System Configuration*.
Another non-parallel method for backing up Greenplum Database data is to use the `COPY TO SQL` command to copy all or a portion of a table out of the database to a delimited text file on the master host.

**Parallel Backup with gpcrondump and gpdbrestore**

gpcrondump backs up the Greenplum master instance and each active segment instance at the same time. gpdbrestore takes the timestamp key generated by gpcrondump, validates the backup set, and restores database objects and data into a distributed database.

**Backup and Restore Options**

The Greenplum Database backup and restore utilities support various locations for backup files:

- With the `gpcrondump` utility, backup files may be saved in the default location, the `db_dumps` subdirectory of the master and each segment, or saved to a different directory specified with the `gpcrondump -u` option.
- Both the `gpcrondump` and `gpdbrestore` utilities have integrated support for Dell EMC Data Domain Boost and Veritas NetBackup systems.
- Backup files can be saved through named pipes to any network accessible location.
- Backup files saved to the default location may be moved to an archive server on the network. This allows performing the backup at the highest transfer rates (when segments write the backup data to fast local disk arrays) and then freeing up disk space by moving the files to remote storage.

You can create dumps containing selected database objects:

- You can backup tables belonging to one or more schema you specify on the command line or in a text file.
- You can specify schema to exclude from the backup, as command-line options or in a list provided in a text file.
- You can backup a specified set of tables listed on the command line or in a text file. The table and schema options cannot be used together in a single backup.
- In addition to database objects, `gpcrondump` can backup the configuration files `pg_hba.conf`, `pg_ident.conf`, and `postgresql.conf`, and global database objects, such as roles and tablespaces.

You can create incremental backups:

- An incremental backup contains only append-optimized and column-oriented tables that have changed since the most recent incremental or full backup.
- For partitioned append-optimized tables, only changed append-optimized/column-oriented table partitions are backed up.
- Incremental backups include all heap tables.
- Use the `gpcrondump --incremental` flag to specify an incremental backup.
- Restoring an incremental backup requires a full backup and all subsequent incremental backups, up to the backup you are restoring.

The `gpdbrestore` utility offers many options:

- By default, `gpdbrestore` restores data to the database it was backed up from.
- The `--redirect` flag allows you to restore a backup to a different database.
- The restored database can be dropped and recreated, but the default is to restore into an existing database.
- Selected tables can be restored from a backup by listing the tables on the command line or by listing them in a text file and specifying the text file on the command line.
- You can restore a database from backup files moved to an archive server. The backup files are copied back into place on the master host and each segment host and then restored to the database.
**Backing Up with gpcrondump**

Use `gpcrondump` to backup databases, data, and objects such as database roles and server configuration files.

The `gpcrondump` utility dumps the contents of a Greenplum database to SQL script files on the master and each segment. The script files can then be used to restore the database.

The master backup files contain SQL commands to create the database schema. The segment data dump files contain SQL statements to load the data into the tables. The segment dump files are compressed using gzip. Optionally, the server configuration files `postgresql.conf`, `pg_ident.conf`, and `pg_hba.conf` and global data such as roles and tablespaces can be included in a backup.

The `gpcrondump` utility has one required flag, `-x`, which specifies the database to dump:

```
gpcrondump -x mydb
```

This performs a full backup of the specified database to the default locations.

**Note:** By default, the utility creates the `public.gpcrondump_history` table that contains details of the database dump. If the `public` schema has been deleted from the database, you must specify the `-H` option to prevent `gpcrondump` from returning an error when it attempts to create the table.

By default, `gpcrondump` creates the backup files in the data directory on the master and each segment instance in the `data_directory/db_dumps` directory. You can specify a different backup location using the `-u` flag. For example, the following command will save backup files to the `/backups` directory:

```
gpcrondump mydb -u /backups
```

The `gpcrondump` utility creates the `db_dumps` subdirectory in the specified directory. If there is more than one primary segment per host, all of the segments on the host write their backup files to the same directory. This differs from the default, where each segment writes backups to its own data directory. This can be used to consolidate backups to a single directory or mounted storage device.

In the `db_dumps` directory, backups are saved to a directory in the format `YYYYMMDD`, for example `data_directory/db_dumps/20151012` for a backup created on October 12, 2015. The backup file names in the directory contain a full timestamp for the backup in the format `YYYYMMDDHHMMSS`, for example `gp_dump_0_2_20151012195916.gz`. The `gpdbrestore` command uses the most recent backup by default but you can specify an earlier backup to restore.

The utility creates backup files with this file name format.

```
prefix_gp_dump_content_dbid_timestamp
```

The `content` and `dbid` are identifiers for the Greenplum Database segment instances that are assigned by Greenplum Database. For information about the identifiers, see the Greenplum Database system catalog table `gp_id` in the Greenplum Database Reference Guide.

If you include the `-g` option, `gpcrondump` saves the configuration files with the backup. These configuration files are dumped in the master or segment data directory to `db_dumps/YYYYMMDD/config_files_timestamp.tar`. If `--ddboost` is specified, the backup is located on the default storage unit in the directory specified by `--ddboost-backupdir` when the Data Domain Boost credentials were set. The `-G` option backs up global objects such as roles and tablespaces to a file in the master backup directory named `gp_global__l_1_timestamp`.

If `--ddboost` is specified, the backup is located on the default storage unit in the directory specified by `--ddboost-backupdir` when the Data Domain Boost credentials were set.
There are many more `gpcrondump` options available to configure backups. Refer to the *Greenplum Utility Reference Guide* for information about all of the available options. See *Backing Up Databases with Data Domain Boost* for details of backing up with Data Domain Boost.

**Warning:** Backing up a database with `gpcrondump` while simultaneously running `ALTER TABLE` might cause `gpcrondump` to fail.

Backing up a database with `gpcrondump` while simultaneously running DDL commands might cause issues with locks. You might see either the DDL command or `gpcrondump` waiting to acquire locks.

### Backing Up a Set of Tables

You can create a backup that includes a subset of the schema or tables in a database by using the following `gpcrondump` options:

- `-t schema.tablename` – specify a table to include in the backup. You can use the `-t` option multiple times.
- `--table-file=filename` – specify a file containing a list of tables to include in the backup.
- `-T schema.tablename` – specify a table to exclude from the backup. You can use the `-T` option multiple times.
- `--exclude-table-file=filename` – specify a file containing a list of tables to exclude from the backup.
- `-s schema_name` – include all tables qualified by a specified schema name in the backup. You can use the `-s` option multiple times.
- `--schema-file=filename` – specify a file containing a list of schemas to include in the backup.
- `-S schema_name` – exclude tables qualified by a specified schema name from the backup. You can use the `-S` option multiple times.
- `--exclude-schema-file=filename` – specify a file containing schema names to exclude from the backup.

Only a set of tables or set of schemas can be specified. For example, the `-s` option cannot be specified with the `-t` option.

Refer to *Incremental Backup with Sets* for additional information about using these `gpcrondump` options with incremental backups.

### Creating Incremental Backups

The `gpcrondump` and `gpdbrestore` utilities support incremental backups and restores of append-optimized tables, including column-oriented tables. Use the `gpcrondump` option `--incremental` to create an incremental backup.

An incremental backup only backs up an append-optimized or column-oriented table if one of the following operations was performed on the table after the last full or incremental backup:

- `ALTER TABLE`
- `DELETE`
- `INSERT`
- `TRUNCATE`
- `UPDATE`
- `DROP` and then re-create the table

For partitioned append-optimized tables, only the changed partitions are backed up.

Heap tables are backed up with every full and incremental backup.

Incremental backups are efficient when the total amount of data in append-optimized table partitions or column-oriented tables that changed is small compared to the data has not changed.
Each time `gpcrondump` runs, it creates state files that contain row counts for each append optimized and column-oriented table and partition in the database. The state files also store metadata operations such as truncate and alter. When `gpcrondump` runs with the `--incremental` option, it compares the current state with the stored state to determine if the table or partition should be included in the incremental backup.

A unique 14-digit timestamp key identifies files that comprise an incremental backup set.

To create an incremental backup or to restore data from an incremental backup, you need the complete backup set. A complete backup set consists of a full backup and any incremental backups that were created since the last full backup. When you archive incremental backups, all incremental backups between the last full backup and the target incremental backup must be archived. You must archive all the files created on the master and all segments.

**Important:** For incremental backup sets, a full backup and associated incremental backups, the backup set must be on a single device. For example, a backup set must all be on a Data Domain system. The backup set cannot have some backups on a Data Domain system and others on the local file system or a NetBackup system.

**Note:** You can use a Data Domain server as an NFS file system (without Data Domain Boost) to perform incremental backups.

Changes to the Greenplum Database segment configuration invalidate incremental backups. After you change the segment configuration you must create a full backup before you can create an incremental backup.

### Incremental Backup Example

Each backup set has a key, which is a timestamp taken when the backup is created. For example, if you create a backup on May 14, 2016, the backup set file names contain `20160514hhmmss`. The `hhmmss` represents the time: hour, minute, and second.

For this example, assume you have created both full and incremental backups of the database `mytest`. To create the full backup, you used the following command:

```
gpcrondump -x mytest -u /backupdir
```

Later, after some changes have been made to append optimized tables, you created an incremental backup with the following command:

```
gpcrondump -x mytest -u /backupdir --incremental
```

When you specify the `-u` option, the backups are created in the `/backupdir` directory on each Greenplum Database host. The file names include the following timestamp keys. The full backups have the timestamp key `20160514054532` and `20161114064330`. The other backups are incremental backups.

- `20160514054532` (full backup)
- `20160714095512`
- `20160914081205`
- `20161114064330` (full backup)
- `20170114051246`

To create a new incremental backup, you need both the most recent incremental backup `20170114051246` and the preceding full backup `20161114064330`. Also, you must specify the same `-u` option for any incremental backups that are part of the backup set.

To restore a database with the incremental backup `20160914081205`, you need the incremental backups `20160914081205` and `20160714095512`, and the full backup `20160514054532`. 
To restore the mytest database with the incremental backup 20170114051246, you need only the incremental backup and the full backup 20161114064330. The restore command would be similar to this command.

```
gpdbrestore -t 20170114051246 -u /backupdir
```

**Incremental Backup with Sets**

To back up a set of database tables with incremental backup, identify the backup set with the --prefix option when you create the full backup with gpcrondump. For example, to create incremental backups for tables in the myschema schema, first create a full backup with a prefix, such as myschema:

```
gpcrondump -x mydb -s myschema --prefix myschema
```

The -s option specifies that tables qualified by the myschema schema are to be included in the backup. See Backing Up a Set of Tables for more options to specify a set of tables to back up.

Once you have a full backup you can create an incremental backup for the same set of tables by specifying the gpcrondump --incremental and --prefix options, specifying the prefix you set for the full backup. The incremental backup is automatically limited to only the tables in the full backup. For example:

```
gpcrondump -x mydb --incremental --prefix myschema
```

The following command lists the tables that were included or excluded for the full backup.

```
gpcrondump -x mydb --incremental --prefix myschema --list-filter-tables
```

**Restoring From an Incremental Backup**

When restoring a backup with gpdbrestore, the command-line output displays whether the restore type is incremental or a full database restore. You do not have to specify that the backup is incremental. For example, the following gpdbrestore command restores the most recent backup of the mydb database. gpdbrestore searches the db_dumps directory to locate the most recent dump and displays information about the backup it found.

```
$ gpdbrestore -s mydb
...
20151015:20:10:34:002664 gpdbrestore:mdw:gpadmin-[INFO]:-Greenplum database restore parameters
20151015:20:10:34:002664 gpdbrestore:mdw:gpadmin-[INFO]:-Restore type = Incremental Restore
20151015:20:10:34:002664 gpdbrestore:mdw:gpadmin-[INFO]:-Database to be restored = mydb
20151015:20:10:34:002664 gpdbrestore:mdw:gpadmin-[INFO]:-Drop and re-create db = Off
20151015:20:10:34:002664 gpdbrestore:mdw:gpadmin-[INFO]:-Restore method = Search for latest
20151015:20:10:34:002664 gpdbrestore:mdw:gpadmin-[INFO]:-Restore timestamp = 20151014194445
20151015:20:10:34:002664 gpdbrestore:mdw:gpadmin-[INFO]:-Restore compressed dump = On
20151015:20:10:34:002664 gpdbrestore:mdw:gpadmin-[INFO]:-Restore global objects = Off
20151015:20:10:34:002664 gpdbrestore:mdw:gpadmin-[INFO]:-Array fault tolerance = f
```
gpdbrestore ensures that the full backup and other required incremental backups are available before restoring the backup. With the --list-backup option you can display the full and incremental backup sets required to perform a restore.

If the gpdbrestore option --q is specified, the backup type information is written to the log file. With the gpdbrestore option --noplan, you can restore only the data contained in an incremental backup.

Backup Process and Locks

During backups, the gpcrondump utility locks the pg_class system table and the tables that are backed up. Locking the pg_class table with an EXCLUSIVE lock ensures that no tables are added, deleted, or altered until gpcrondump locks tables that are to be backed up with ACCESS SHARE locks.

The steps below describe the process gpcrondump follows to dump databases, including what happens before locks are placed, while locks are held, and after locks are removed.

If more than one database is specified, this process is executed for each database in sequence.

- gpcrondump parses the command-line arguments and verifies that options and arguments are properly specified.
- If any of the following filter options are specified, gpcrondump prepares filters to determine the set of tables to back up. Otherwise, all tables are included in the backup.
  - -s schema_name – Includes all the tables qualified by the specified schema.
  - -S schema_name – Excludes all tables qualified by the specified schema.
  - --schema-file=filename – Includes all the tables qualified by the schema listed in filename.
  - --exclude-schema-file=filename – Excludes all tables qualified by the schema listed in filename.
  - -t schema.table_name – Dumps the specified table.
  - -T schema.table_name – Excludes the specified table.
  - --table-file=filename – Dumps the tables specified in filename.
  - --exclude-table-file=filename – Dumps all tables except tables specified in filename.
- gpcrondump verifies the backup targets:
  - Verifies that the database exists.
  - Verifies that specified tables or schemas to be dumped exist.
  - Verifies that the current primary for each segment is up.
  - Verifies that the backup directory exists and is writable for the master and each segment.
  - Verifies that sufficient disk space is available to back up each segment. Note that if more than one segment is backed up to the same disk volume, this disk space check cannot ensure there is space available for all segments.
- Places an EXCLUSIVE lock on the catalog table pg_class. The lock permits only concurrent read operations on a table. While the lock is on the catalog table, relations such as tables, indexes, and views cannot be created, altered, or dropped in the database.

  gpcrondump starts a thread to watch for a lock file (dump_dir/gp_lockfile_timestamp) to appear, signaling the parallel backup on the segments has completed.
- gpcrondump locks tables that are to be backed up with an ACCESS SHARE lock.

  An ACCESS SHARE lock only conflicts with an ACCESS EXCLUSIVE lock. The following SQL statements acquire an ACCESS EXCLUSIVE lock:
  - ALTER TABLE
  - CLUSTER
• DROP TABLE
• REINDEX
• TRUNCATE
• VACUUM FULL

• Threads are created and dispatched for the master and segments to perform the database dump.
• When the threads have acquired ACCESS SHARED locks on all the required tables, the dump_dir/ gp_lockfile_timestamp lock file is created, signaling gpcrondump to release the EXCLUSIVE lock on the pg_class catalog table, while tables are being backed up.
• gpcrondump checks the status files for each primary segment for any errors to report. If a dump fails and the -r flag was specified, the backup is rolled back.
• The ACCESS SHARE locks on the target tables are released.
• If the backup succeeded and a post-dump script was specified with the -R option, gpcrondump runs the script now.
• gpcrondump reports the backup status, sends email if configured, and saves the backup status in the public.gpcrondump_history table in the database.

Using Direct I/O

The operating system normally caches file I/O operations in memory because memory access is much faster than disk access. The application writes to a block of memory that is later flushed to the storage device, which is usually a RAID controller in a Greenplum Database system. Whenever the application accesses a block that is still resident in memory, a device access is avoided. Direct I/O allows you to bypass the cache so that the application writes directly to the storage device. This reduces CPU consumption and eliminates a data copy operation. Direct I/O is efficient for operations like backups where file blocks are only handled once.

Note: Direct I/O is supported only on Red Hat, CentOS, and SUSE.

Turning on Direct I/O

Set the gp_backup_directIO system configuration parameter on to enable direct I/O for backups:

```bash
$ gpconfig -c gp_backup_directIO -v on
```

To see if direct I/O is enabled, use this command:

```bash
$ gpconfig -s gp_backup_directIO
```

Decrease network data chunks sent to dump when the database is busy

The gp_backup_directIO_read_chunk_mb configuration parameter sets the size, in MB, of the I/O chunk when direct I/O is enabled. The default chunk size, 20MB, has been tested and found to be optimal. Decreasing it increases the backup time and increasing it results in little change to backup time.

To find the current direct I/O chunk size, enter this command:

```bash
$ gpconfig -s gp_backup_directIO_read_chunk_mb
```

The following example changes the default chunk size to 10MB.

```bash
$ gpconfig -c gp_backup_directIO_read_chunk_mb -v 10
```
Using Named Pipes

Greenplum Database allows the use of named pipes with gpcrondump and gpdbrestore to back up and restore Greenplum databases. When backing up a database with regular files, the files that contain the backup information are placed in directories on the Greenplum Database segments. If segment hosts do not have enough local disk space available to backup to files, you can use named pipes to back up to non-local storage, such as storage on another host on the network or to a backup appliance.

Backing up with named pipes is not supported if the --ddboost option is specified.

To back up a Greenplum database using named pipes

1. Run the gpcrondump command with options -K timestamp and --list-backup-files.

   This creates two text files that contain the names of backup files, one per line. The file names include the timestamp you specified with the -K timestamp option and have the suffixes _pipes and _regular_files. For example:

   ```
   gp_dump_20150519160000_pipes
   gp_dump_20150519160000_regular_files
   ```

   The file names listed in the _pipes file are to be created as named pipes. The file names in the _regular_files file should not be created as named pipes. gpcrondump and gpdbrestore use the information in these files during backup and restore operations.

2. Create named pipes on all Greenplum Database segments using the file names in the generated _pipes file.

3. Redirect the output of each named pipe to the destination process or file object.

4. Run gpcrondump to back up the database using the named pipes.

   To create a complete set of Greenplum Database backup files, the files listed in the _regular_files file must also be backed up.

To restore a database that used named pipes during backup

1. Direct the contents of each backup file to the input of its named pipe, for example cat filename > pipename, if the backup file is accessible as a local file object.

2. Run the gpdbrestore command to restore the database using the named pipes.

Example

This example shows how to back up a database over the network using named pipes and the netcat (nc) Linux command. The segments write backup files to the inputs of the named pipes. The outputs of the named pipes are piped through nc commands, which make the files available on TCP ports. Processes on other hosts can then connect to the segment hosts at the designated ports to receive the backup files. This example requires that the nc package is installed on all Greenplum hosts.

1. Enter the following gpcrondump command to generate the lists of backup files for the testdb database in the /backups directory.

   ```
   $ gpcrondump -x testdb -K 20150519160000 --list-backup-files -u /backups
   ```

2. View the files that gpcrondump created in the /backup directory:

   ```
   $ ls -1R /backups
   /backups:
   total 4
   drwxrwxr-x 3 gpadmin gpadmin 4096 May 19 21:49 db_dumps
   /backups/db_dumps:
   total 4
   drwxrwxr-x 2 gpadmin gpadmin 4096 May 19 21:49 20150519
   ```
3. View the contents of the _pipes file.

```
$ cat /backups/db_dumps/20150519/gp_dump_20150519160000_pipes
sdw1:/backups/db_dumps/20150519/gp_dump_0_2_20150519160000.gz
sdw2:/backups/db_dumps/20150519/gp_dump_1_3_20150519160000.gz
mdw:/backups/db_dumps/20150519/gp_dump_-1_1_20150519160000.gz
mdw:/backups/db_dumps/20150519/gp_dump_-1_1_20150519160000_post_data.gz
```

4. Create the specified named pipes on the Greenplum Database segments. Also set up a reader for the named pipe.

```
gpssh -h sdw1
[sdw1] mkdir -p /backups/db_dumps/20150519/
[sdw1] mkfifo /backups/db_dumps/20150519/gp_dump_0_2_20150519160000.gz
[sdw1] cat /backups/db_dumps/20150519/gp_dump_0_2_20150519160000.gz | nc -l 21000
[sdw1] exit
```

Complete these steps for each of the named pipes listed in the _pipes file. Be sure to choose an available TCP port for each file.

5. On the destination hosts, receive the backup files with commands like the following:

```
nc sdw1 21000 > gp_dump_0_2_20150519160000.gz
```

6. Run gpcrondump to begin the backup:

```
gpcrondump -x testdb -K 20150519160000 -u /backups
```

To restore a database with named pipes, reverse the direction of the backup files by sending the contents of the backup files to the inputs of the named pipes and run the gpdbrestore command:

```
gpdbrestore -x testdb -t 20150519160000 -u /backups
```

**gpdbrestore** reads from the named pipes' outputs.

### Backing Up Databases with Data Domain Boost

Dell EMC Data Domain Boost (DD Boost) is Dell EMC software that can be used with the gpcrondump and gpdbrestore utilities to perform faster backups to the Dell EMC Data Domain storage appliance. Data Domain performs deduplication on the data it stores, so after the initial backup operation, the appliance stores only pointers to data that is unchanged. This reduces the size of backups on disk. When DD Boost is used with gpcrondump, Greenplum Database participates in the deduplication process, reducing the volume of data sent over the network. When you restore files from the Data Domain system with Data Domain Boost, some files are copied to the master local disk and are restored from there, and others are restored directly.

With Data Domain Boost managed file replication, you can replicate Greenplum Database backup images that are stored on a Data Domain system for disaster recover purposes. The gpmfr utility manages the Greenplum Database backup sets that are on the primary and a remote Data Domain system. For information about gpmfr, see the Greenplum Database Utility Guide.

Managed file replication requires network configuration when a replication network is being used between two Data Domain systems:
• The Greenplum Database system requires the Data Domain login credentials to be configured using gpcrondump. Credentials must be created for both the local and remote Data Domain systems.
• When the non-management network interface is used for replication on the Data Domain systems, static routes must be configured on the systems to pass the replication data traffic to the correct interfaces.

Do not use Data Domain Boost with pg_dump or pg_dumpall.

Refer to Data Domain Boost documentation for detailed information.

**Important:** For incremental back up sets, a full backup and the associated incremental backups must be on a single device. For example, a backup set must all be on a file system. The backup set cannot have some backups on the local file system and others on single storage unit of a Data Domain system. For backups on a Data Domain system, the backup set must be in a single storage unit.

**Note:** You can use a Data Domain server as an NFS file system (without Data Domain Boost) to perform incremental backups.

### Data Domain Boost Requirements

Using Data Domain Boost requires the following.

• Data Domain Boost is included only with the commercial release of Pivotal Greenplum Database.
• Purchase and install Dell EMC Data Domain Boost and Replicator licenses on the Data Domain systems.
• Obtain sizing recommendations for Data Domain Boost. Make sure the Data Domain system supports sufficient write and read streams for the number of segment hosts in your Greenplum cluster.

Contact your Dell EMC Data Domain account representative for assistance.

### One-Time Data Domain Boost Credential Setup

There is a one-time process to set up credentials to use Data Domain Boost. Credential setup connects one Greenplum Database instance to one Data Domain instance. If you are using the `gpcrondump --replicate` option or DD Boost managed file replication capabilities for disaster recovery purposes, you must set up credentials for both the local and remote Data Domain systems.

To set up credentials, run `gpcrondump` with the following options:

```bash
--ddboost-host ddboost_hostname --ddboost-user ddboost_user
--ddboost-backupdir backup_directory --ddboost-storage-unit storage_unit_ID
```

The `--ddboost-storage-unit` is optional. If not specified, the storage unit ID is GPDB.

To remove credentials, run `gpcrondump` with the `--ddboost-config-remove` option.

To manage credentials for the remote Data Domain system that is used for backup replication, include the `--ddboost-remote` option with the other `gpcrondump` options. For example, the following options set up credentials for a Data Domain system that is used for backup replication. The system IP address is 192.0.2.230, the user ID is ddboostmyuser, and the location for the backups on the system is GPDB/gp_production:

```bash
--ddboost-host 192.0.2.230 --ddboost-user ddboostmyuser
--ddboost-backupdir gp_production --ddboost-remote
```

For details, see `gpcrondump` in the *Greenplum Database Utility Guide*. 
If you use two or more network connections to connect to the Data Domain system, use `gpcrondump` to set up the login credentials for the Data Domain hostnames associated with the network interfaces. To perform this setup for two network connections, run `gpcrondump` with the following options:

```
--ddboost-host ddboost_hostname1
--ddboost-host ddboost_hostname2 --ddboost-user ddboost_user
--ddboost-backupdir backup_directory
```

### About DD Boost Credential Files

The `gpcrondump` utility is used to schedule DD Boost backup operations. The utility is also used to set, change, or remove one-time credentials and a storage unit ID for DD Boost. The `gpcrondump`, `gpdbrestore`, and `gpmfr` utilities use the DD Boost credentials to access Data Domain systems. DD Boost information is stored in these files.

- `DDBOOST_CONFIG` is used by `gpdbrestore` and `gpcrondump` for backup and restore operations with the Data Domain system. The `gpdbrestore` utility creates or updates the file when you specify Data Domain information with the `--ddboost-host` option.
- `DDBOOST_MFR_CONFIG` is used by `gpmfr` for remote replication operations with the remote Data Domain system. The `gpdbrestore` utility creates or updates the file when you specify Data Domain information with the `--ddboost-host` option and `--ddboost-remote` option.

The configuration files are created in the current user (`gpadmin`) home directory on the Greenplum Database master and segment hosts. The path and file name cannot be changed. Information in the configuration files includes:

- Data Domain host name or IP address
- DD Boost user name
- DD Boost password
- Default Data Domain backup directory (`DDBOOST_CONFIG` only)
- Data Domain storage unit ID: default is `GPDB` (`DDBOOST_CONFIG` only)
- Data Domain default log level: default is `WARNING`
- Data Domain default log size: default is 50

Use the `gpcrondump` option `--ddboost-show-config` to display the current DD Boost configuration information from the Greenplum Database master configuration file. Specify the `--remote` option to display the configuration information for the remote Data Domain system.

### About Data Domain Storage Units

When you use a Data Domain system to perform a backup, restore, or remote replication operation with the `gpcrondump`, `gpdbrestore`, or `gpmfr` utility, the operation uses a storage unit on a Data Domain system. You can specify the storage unit ID when you perform these operations:

- When you set the DD Boost credentials with the `gpcrondump` utility `--ddboost-host` option.

  If you specify the `--ddboost-storage-unit` option, the storage unit ID is written to the Greenplum Database DD Boost configuration file `DDBOOST_CONFIG`. If the storage unit ID is not specified, the default value is `GPDB`.

  If you specify the `--ddboost-storage-unit` option and the `--ddboost-remote` option to set DD Boost credentials for the remote Data Domain server, the storage ID information is ignored. The storage unit ID in the `DDBOOST_CONFIG` file is the default ID that is used for remote replication operations.

- When you perform a backup, restore, or remote replication operation with `gpcrondump`, `gpdbrestore`, or `gpmfr`.

  When you specify the `--ddboost-storage-unit` option, the utility uses the specified Data Domain storage unit for the operation. The value in the configuration file is not changed.
A Greenplum Database utility uses the storage unit ID based on this order of precedence from highest to lowest:

- Storage unit ID specified with `--ddboost-storage-unit`
- Storage unit ID specified in the configuration file
- Default storage unit ID GPDB

Greenplum Database master and segment instances use a single storage unit ID when performing a backup, restore, or remote replication operation.

**Important:** The storage unit ID in the Greenplum Database master and segment host configuration files must be the same. The Data Domain storage unit is created by the `gpcrondump` utility from the Greenplum Database master host.

The following occurs if storage unit IDs are different in the master and segment host configuration files:

- If all the storage units have not been created, the operation fails.
- If all the storage units have been created, a backup operation completes. However, the backup files are in different storage units and a restore operation fails because a full set of backup files is not in a single storage unit.

When performing a full backup operation (not an incremental backup), the storage unit is created on the Data Domain system if it does not exist.

A storage unit is not created if these `gpcrondump` options are specified: `--incremental, --list-backup-file, --list-filter-tables, -o, or --ddboost-config-remove`.

Greenplum Database replication operations use the same storage unit ID on both systems. For example, if you specify the `--ddboost-storage-unit` option for `--replicate` or `--recover` through `gpmfr` or `--replicate` from `gpcrondump`, the storage unit ID applies to both local and remote Data Domain systems.

When performing a replicate or recover operation with `gpmfr`, the storage unit on the destination Data Domain system (where the backup is being copied) is created if it does not exist.

### Configuring Data Domain Boost for Greenplum Database

After you set up credentials for Data Domain Boost on the Greenplum Database, perform the following tasks in Data Domain to allow Data Domain Boost to work with Greenplum Database:

- Configuring Distributed Segment Processing in Data Domain
- Configuring Advanced Load Balancing and Link Failover in Data Domain
- Export the Data Domain Path to Greenplum Database Hosts

#### Configuring Distributed Segment Processing in Data Domain

Configure the distributed segment processing option on the Data Domain system. The configuration applies to all the Greenplum Database servers with the Data Domain Boost plug-in installed on them. This option is enabled by default, but verify that it is enabled before using Data Domain Boost backups:

```
# ddboost option show
```

To enable or disable distributed segment processing:

```
# ddboost option set distributed-segment-processing {enabled | disabled}
```

#### Configuring Advanced Load Balancing and Link Failover in Data Domain

If you have multiple network connections on a network subnet, you can create an interface group to provide load balancing and higher network throughput on your Data Domain system. When a Data
Domain system on an interface group receives data from the media server clients, the data transfer is load balanced and distributed as separate jobs on the private network. You can achieve optimal throughput with multiple 10 GbE connections.

**Note:** To ensure that interface groups function properly, use interface groups only when using multiple network connections on the same networking subnet.

To create an interface group on the Data Domain system, create interfaces with the `net` command. If interfaces do not already exist, add the interfaces to the group, and register the Data Domain system with the backup application.

1. Add the interfaces to the group:

```
# ddboost ifgroup add interface 192.0.2.1
# ddboost ifgroup add interface 192.0.2.2
# ddboost ifgroup add interface 192.0.2.3
# ddboost ifgroup add interface 192.0.2.4
```

**Note:** You can create only one interface group and this group cannot be named.

2. Select one interface on the Data Domain system to register with the backup application. Create a failover aggregated interface and register that interface with the backup application.

**Note:** You do not have to register one of the `ifgroup` interfaces with the backup application. You can use an interface that is not part of the `ifgroup` to register with the backup application.

3. Enable `ddboost` on the Data Domain system:

```
# ddboost ifgroup enable
```

4. Verify the Data Domain system configuration as follows:

```
# ddboost ifgroup show config
```

Results similar to the following are displayed.

```
Interface
---------
192.0.2.1
192.0.2.2
192.0.2.3
192.0.2.4
```

You can add or delete interfaces from the group at any time.

**Note:** Manage Advanced Load Balancing and Link Failover (an interface group) using the `ddboost ifgroup` command or from the Enterprise Manager Data Management > DD Boost view.

### Export the Data Domain Path to Greenplum Database Hosts

The commands and options in this topic apply to DDOS 5.0.x and 5.1.x. See the Data Domain documentation for details.

Use the following Data Domain commands to export the `/backup/ost` directory to a Greenplum Database host for Data Domain Boost backups.

```
# nfs add /backup/ost 192.0.2.0/24, 198.51.100.0/24 (insecure)
```

**Note:** The IP addresses refer to the Greenplum Database system working with the Data Domain Boost system.
Create the Data Domain Login Credentials for the Greenplum Database Host

Create a username and password for the host to access the DD Boost Storage Unit (SU) at the time of backup and restore:

```
# user add user [password password] [priv {admin | security | user}]
```

Backup Options for Data Domain Boost

Specify the `gpcrondump` options to match the setup.

Data Domain Boost backs up files to a storage unit in the Data Domain system. Status and report files remain on the local disk. If needed, specify the Data Domain system storage unit with the `--ddboost-storage-unit` option. This DD Boost command displays the names of all storage units on a Data Domain system.

```
ddboost storage-unit show
```

To configure Data Domain Boost to remove old backup directories before starting a backup operation, specify a `gpcrondump` backup expiration option:

- The `-c` option clears all backup directories.
- The `-o` option clears the oldest backup directory.

To remove the oldest dump directory, specify `gpcrondump --ddboost` with the `-o` option. For example, if your retention period is 30 days, use `gpcrondump --ddboost` with the `-o` option on day 31.

Use `gpcrondump --ddboost` with the `-c` option to clear out all the old dump directories in `db_dumps`. The `-c` option deletes all dump directories that are at least one day old.

Using CRON to Schedule a Data Domain Boost Backup

1. Ensure the One-Time Data Domain Boost Credential Setup is complete.
2. Add the option `--ddboost` to the `gpcrondump` option:

   ```
gpcrondump -x mydatabase -z -v --ddboost
   ```

   If needed, specify the Data Domain system storage unit with the `--ddboost-storage-unit` option.

   **Important:** Do not use compression with Data Domain Boost backups. The `-z` option turns backup compression off.

   Some of the options available in `gpcrondump` have different implications when using Data Domain Boost. For details, see `gpcrondump` in the Greenplum Database Utility Reference.

Restoring From a Data Domain System with Data Domain Boost

1. Ensure the One-Time Data Domain Boost Credential Setup is complete.
2. Add the option `--ddboost` to the `gpdbrestore` command:

   ```
   $ gpdbrestore -t backup_timestamp -v -ddboost
   ```

   If needed, specify the Data Domain system storage unit with the `--ddboost-storage-unit` option.

   **Note:** Some of the `gpdbrestore` options available have different implications when using Data Domain. For details, see `gpdbrestore` in the Greenplum Database Utility Reference.
**Backing Up Databases with Veritas NetBackup**

For Greenplum Database on Red Hat Enterprise Linux, you can configure Greenplum Database to perform backup and restore operations with Veritas NetBackup. You configure Greenplum Database and NetBackup and then run a Greenplum Database `gpcrondump` or `gpdbrestore` command. The following topics describe how to set up NetBackup and back up or restore Greenplum Databases.

- About NetBackup Software
- Limitations
- Configuring Greenplum Database Hosts for NetBackup
- Configuring NetBackup for Greenplum Database
- Performing a Back Up or Restore with NetBackup
- Example NetBackup Back Up and Restore Commands

**About NetBackup Software**

NetBackup includes the following server and client software:

- The NetBackup master server manages NetBackup backups, archives, and restores. The master server is responsible for media and device selection for NetBackup.
- NetBackup Media servers are the NetBackup device hosts that provide additional storage by allowing NetBackup to use the storage devices that are attached to them.
- NetBackup client software that resides on the Greenplum Database hosts that contain data to be backed up.

See the [Veritas NetBackup Getting Started Guide](#) for information about NetBackup.

See the Release Notes for information about compatible NetBackup versions for this release of Pivotal Greenplum Database.

**Limitations**

- NetBackup is not compatible with DDBoost. Both NetBackup and DDBoost cannot be used in a single back up or restore operation.
- For incremental back up sets, a full backup and associated incremental backups, the backup set must be on a single device. For example, a backup set must all be on a NetBackup system. The backup set cannot have some backups on a NetBackup system and others on the local file system or a Data Domain system.

**Configuring Greenplum Database Hosts for NetBackup**

You install and configure NetBackup client software on the Greenplum Database master host and all segment hosts. The NetBackup client software must be able to communicate with the NetBackup server software.

1. Install the NetBackup client software on Greenplum Database hosts. See the NetBackup installation documentation for information on installing NetBackup clients on UNIX systems.
2. Set parameters in the NetBackup configuration file `/usr/openv/netbackup/bp.conf` on the Greenplum Database master and segment hosts. Set the following parameters on each Greenplum Database host.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SERVER</td>
<td>Host name of the NetBackup Master Server</td>
</tr>
<tr>
<td>MEDIA_SERVER</td>
<td>Host name of the NetBackup Media Server</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>CLIENT_NAME</td>
<td>Host name of the Greenplum Database Host</td>
</tr>
</tbody>
</table>

See the *Veritas NetBackup Administrator's Guide* for information about the `bp.conf` file.

3. Set the `LD_LIBRARY_PATH` environment variable for Greenplum Database hosts to use NetBackup client. Greenplum Database installs NetBackup SDK library files that are used with the NetBackup client. To configure Greenplum Database to use the library files that correspond to the version of the NetBackup client that is installed on the hosts, add the following line to the file `$GPHOME/greenplum_path.sh`:

```bash
LD_LIBRARY_PATH=$GPHOME/lib/nbuNN/lib:$LD_LIBRARY_PATH
```

Replace the `NN` with the NetBackup client version that is installed on the host (for example, use 77 for NetBackup 7.7.x).

The `LD_LIBRARY_PATH` line should be added before this line in `$GPHOME/greenplum_path.sh`:

```bash
export LD_LIBRARY_PATH
```

4. Execute this command to remove the current `LD_LIBRARY_PATH` value:

```bash
unset LD_LIBRARY_PATH
```

5. Execute this command to update the environment variables for Greenplum Database:

```bash
source $GPHOME/greenplum_path.sh
```

See the *Veritas NetBackup Administrator's Guide* for information about configuring NetBackup servers.

1. Ensure that the Greenplum Database hosts are listed as NetBackup clients for the NetBackup server.

   In the NetBackup Administration Console, the information for the NetBackup clients, Media Server, and Master Server is in the *NetBackup Management* node within the *Host Properties* node.

2. Configure a NetBackup storage unit. The storage unit must be configured to point to a writable disk location.

   In the NetBackup Administration Console, the information for NetBackup storage units is in *NetBackup Management* node within the *Storage* node.

3. Configure a NetBackup backup policy and schedule within the policy.

   In the NetBackup Administration Console, the *Policy* node below the *Master Server* node is where you create a policy and a schedule for the policy.

   • In the *Policy Attributes* tab, these values are required for Greenplum Database:

     The value in the *Policy type* field must be DataStore

     The value in the *Policy storage* field is the storage unit created in the previous step.

     The value in *Limit jobs per policy* field must be at least 3.

   • In the *Policy Schedules* tab, create a NetBackup schedule for the policy.

### Configuring NetBackup for Greenplum Database

See the *Veritas NetBackup Administrator's Guide* for information about configuring NetBackup servers.

1. Ensure that the Greenplum Database hosts are listed as NetBackup clients for the NetBackup server.

   In the NetBackup Administration Console, the information for the NetBackup clients, Media Server, and Master Server is in *NetBackup Management* node within the *Host Properties* node.

2. Configure a NetBackup storage unit. The storage unit must be configured to point to a writable disk location.
In the NetBackup Administration Console, the information for NetBackup storage units is in `NetBackup Management` node within the `Storage` node.

3. Configure a NetBackup backup policy and schedule within the policy.

   In the NetBackup Administration Console, the `Policy` node below the `Master Server` node is where you create a policy and a schedule for the policy.
   
   - In the `Policy Attributes` tab, these values are required for Greenplum Database:
     
     The value in the `Policy type` field must be `DataStore`.

     The value in the `Policy storage` field is the storage unit created in the previous step.

     The value in `Limit jobs per policy` field must be at least 3.

   - In the `Policy Schedules` tab, create a NetBackup schedule for the policy.

**Performing a Back Up or Restore with NetBackup**

The Greenplum Database `gpcrondump` and `gpdbrestore` utilities support options to back up or restore data to a NetBackup storage unit. When performing a back up, Greenplum Database transfers data files directly to the NetBackup storage unit. No backup data files are created on the Greenplum Database hosts.

The backup metadata files are both stored on the hosts and backed up to the NetBackup storage unit. When performing a restore, the files are retrieved from the NetBackup server, and then restored.

Following are the `gpcrondump` utility options for NetBackup:

```
--netbackup-service-host netbackup_master_server
--netbackup-policy policy_name
--netbackup-schedule schedule_name
--netbackup-block-size size (optional)
--netbackup-keyword keyword (optional)
```

The `gpdbrestore` utility provides the following options for NetBackup:

```
--netbackup-service-host netbackup_master_server
--netbackup-block-size size (optional)
```

**Note:** When performing a restore operation from NetBackup, you must specify the backup timestamp with the `gpdbrestore` utility `-t` option.

The policy name and schedule name are defined on the NetBackup master server. See Configuring NetBackup for Greenplum Database for information about policy name and schedule name. See the Greenplum Database Utility Guide for information about the Greenplum Database utilities.

**Note:** You must run the `gpcrondump` or `gpdbrestore` command during a time window defined for the NetBackup schedule.

During a back up or restore operation, a separate NetBackup job is created for the following types of Greenplum Database data:

- Segment data for each segment instance
- C database data
- Metadata
- Post data for the master
- State files Global objects (`gpcrondump -G` option)
- Configuration files for master and segments (`gpcrondump -g` option)
- Report files (`gpcrondump -h` option)

In the NetBackup Administration Console, the Activity Monitor lists NetBackup jobs. For each job, the job detail displays Greenplum Database backup information.
**Note:** When backing up or restoring a large amount of data, set the NetBackup `CLIENT_READ_TIMEOUT` option to a value that is at least twice the expected duration of the operation (in seconds). The `CLIENT_READ_TIMEOUT` default value is 300 seconds (5 minutes).

For example, if a backup takes 3 hours, set the `CLIENT_READ_TIMEOUT` to 21600 (2 x 3 x 60 x 60). You can use the NetBackup `nbgetconfig` and `nbsetconfig` commands on the NetBackup server to view and change the option value.

For information about `CLIENT_READ_TIMEOUT` and the `nbgetconfig`, and `nbsetconfig` commands, see the NetBackup documentation.

**Example NetBackup Back Up and Restore Commands**

This `gpcrondump` command backs up the database `customer` and specifies a NetBackup policy and schedule that are defined on the NetBackup master server `nbu_server1`. A block size of 1024 bytes is used to transfer data to the NetBackup server.

```bash
sh
gpcrondump -x customer --netbackup-service-host=nbu_server1\ 
    --netbackup-policy=gpdb_cust --netbackup-schedule=gpdb_backup\ 
    --netbackup-block-size=1024
```

This `gpdbrestore` command restores Greenplum Database data from the data managed by NetBackup master server `nbu_server1`. The option `-t 20170530090000` specifies the timestamp generated by `gpcrondump` when the backup was created. The `-e` option specifies that the target database is dropped before it is restored.

```bash
sh
gpdbrestore -t 20170530090000 -e --netbackup-service-host=nbu_server1
```

**Restoring Greenplum Databases**

How you restore a database from parallel backup files depends on how you answer the following questions.

1. **Where are your backup files?** If your backup files are on the segment hosts where `gpcrondump` created them, you can restore the database with `gpdbrestore`. If you moved your backup files away from the Greenplum array, for example to an archive server with `gpcrondump`, use `gpdbrestore`.

2. **Are you recreating the Greenplum Database system, or just restoring your data?** If Greenplum Database is running and you are restoring your data, use `gpdbrestore`. If you lost your entire array and need to rebuild the entire system from backup, use `gpinitsystem`.

3. **Are you restoring to a system with the same number of segment instances as your backup set?** If you are restoring to an array with the same number of segment hosts and segment instances per host, use `gpdbrestore`. If you are migrating to a different array configuration, you must do a non-parallel restore. See **Restoring to a Different Greenplum System Configuration**.

**Restoring a Database Using gpdbrestore**

The `gpdbrestore` utility restores a database from backup files created by `gpcrondump`.

The `gpdbrestore` requires one of the following options to identify the backup set to restore:

- `-t timestamp` — restore the backup with the specified timestamp.
- `-b YYYYMMDD` — restore dump files for the specified date in the `db_dumps` subdirectories on the segment data directories.
- `-s database_name` — restore the latest dump files for the specified database found in the segment data directories.
- `-R hostname:path` — restore the backup set located in the specified directory of a remote host.
To restore an incremental backup, you need a complete set of backup files—a full backup and any required incremental backups. You can use the `--list-backups` option to list the full and incremental backup sets required for an incremental backup specified by timestamp. For example:

```
$ gpdbrestore -t 20151013195916 --list-backup
```

You can restore a backup to a different database using the `--redirect database` option. The database is created if it does not exist. The following example restores the most recent backup of the `mydb` database to a new database named `mydb_snapshot`:

```
$ gpdbrestore -s grants --redirect grants_snapshot
```

You can also restore a backup to a different Greenplum Database system. See `Restoring to a Different Greenplum System Configuration` for information about this option.

### To restore from an archive host using gpdbrestore

You can restore a backup saved on a host outside of the Greenplum cluster using the `-R` option. Although the Greenplum Database software does not have to be installed on the remote host, the remote host must have a `gpadmin` account configured with passwordless ssh access to all hosts in the Greenplum cluster. This is required because each segment host will use scp to copy its segment backup file from the archive host. See `gpssh-exkeys` in the `Greenplum Database Utility Guide` for help adding the remote host to the cluster.

This procedure assumes that the backup set was moved off the Greenplum array to another host in the network.

1. Ensure that the archive host is reachable from the Greenplum master host:

   ```
   $ ping archive_host
   ```

2. Ensure that you can ssh into the remote host with the `gpadmin` account and no password.

   ```
   $ ssh gpadmin@archive_host
   ```

3. Ensure that you can ping the master host from the archive host:

   ```
   $ ping mdw
   ```

4. Ensure that the restore's target database exists. For example:

   ```
   $ createdb database_name
   ```

5. From the master, run the `gpdbrestore` utility. The `-R` option specifies the host name and path to a complete backup set:

   ```
   $ gpdbrestore -R archive_host:/gpdb/backups/archive/20120714 -e dbname
   ```

   Omit the `-e dbname` option if the database has already been created.

### Restoring to a Different Greenplum System Configuration

To perform a parallel restore operation using `gpdbrestore`, the system you are restoring to must have the same configuration as the system that was backed up. To restore your database objects and data into a different system configuration, for example, to expand into a system with more segments, restore your parallel backup files by loading them through the Greenplum master. To perform a non-parallel restore, you must have:

- A full backup set created by a `gpcrondump` operation. The backup file of the master contains the DDL to recreate your database objects. The backup files of the segments contain the data.
A running Greenplum Database system.
The database you are restoring to exists in the system.

Segment dump files contain a `COPY` command for each table followed by the data in delimited text format. Collect all of the dump files for all of the segment instances and run them through the master to restore your data and redistribute it across the new system configuration.

### To restore a database to a different system configuration

1. Ensure that you have a complete backup set, including dump files of the master (`gp_dump_-1_1_timestamp, gp_dump_-1_1_timestamp_post_data`) and one for each segment instance (for example, `gp_dump_0_2_timestamp, gp_dump_1_3_timestamp, gp_dump_2_4_timestamp, and so on`). Each dump file must have the same timestamp key.

   `gpcrondump` creates the dump files in each segment instance’s data directory. You must collect all the dump files and move them to one location on the master host. You can copy each segment dump file to the master, load it, and then delete it after it loads successfully.

2. Ensure that the database you are restoring to is created in the system. For example:

   ```
   $ createdb database_name
   ```

3. Load the master dump file to restore the database objects. For example:

   ```
   $ psql database_name -f /gpdb/backups/gp_dump_-1_1_20160714
   ```

4. Load each segment dump file to restore the data. For example:

   ```
   $ psql database_name -f /gpdb/backups/gp_dump_0_2_20160714
   $ psql database_name -f /gpdb/backups/gp_dump_1_3_20160714
   $ psql database_name -f /gpdb/backups/gp_dump_2_4_20160714
   $ psql database_name -f /gpdb/backups/gp_dump_3_5_20160714
   ...
   ```

5. Load the post data file to restore database objects such as indexes, triggers, primary key constraints, etc.

   ```
   $ psql database_name -f /gpdb/backups/gp_dump_0_5_20160714_post_data
   ```

6. Update the database sequences based on the values from the original database.

   You can use the system utilities `gunzip` and `egrep` to extract the sequence value information from the original Greenplum Database master dump file `gp_dump_-1_1_timestamp.gz` into a text file. This command extracts the information into the file `schema_path_and_seq_next_val`.

   ```
   gunzip -c path_to_master_dump_directory/gp_dump_-1_1_timestamp.gz | egrep "SET search_path|SELECT pg_catalog.setval" > schema_path_and_seq_next_val
   ```

   This example command assumes the original Greenplum Database master dump file is in `/data/gpdb/master/gpseg-1/db_dumps/20150112`.

   ```
   gunzip -c /data/gpdb/master/gpseg-1/db_dumps/20150112/gp_dump_-1_1_20150112140316.gz | egrep "SET search_path|SELECT pg_catalog.setval" > schema_path_and_seq_next_val
   ```

   After extracting the information, use the Greenplum Database `psql` utility to update the sequences in the database. This example command updates the sequence information in the database `test_restore`.

   ```
   psql test_restore -f schema_path_and_seq_next_val
   ```
Parallel Backup with gpbackup and gprestore

gpbackup and gprestore are Greenplum Database utilities that create and restore backup sets for Greenplum Database. By default, gpbackup stores only the object metadata files and DDL files for a backup in the Greenplum Database master data directory. Greenplum Database segments use the COPY ... ON SEGMENT command to store their data for backed-up tables in compressed CSV data files, located in each segment's backups directory.

The backup metadata files contain all of the information that gprestore needs to restore a full backup set in parallel. Backup metadata also provides the framework for restoring only individual objects in the data set, along with any dependent objects, in future versions of gprestore. (See Understanding Backup Files for more information.) Storing the table data in CSV files also provides opportunities for using other restore utilities, such as gpload, to load the data either in the same cluster or another cluster. By default, one file is created for each table on the segment. You can specify the --leaf-partition-data option with gpbackup to create one data file per leaf partition of a partitioned table, instead of a single file. This option also enables you to filter backup sets by leaf partitions.

Each gpbackup task uses a single transaction in Greenplum Database. During this transaction, metadata is backed up on the master host, and data for each table on each segment host is written to CSV backup files using COPY ... ON SEGMENT commands in parallel. The backup process acquires an ACCESS SHARE lock on each table that is backed up.

For information about the gpbackup and gprestore utility options, see gpbackup and gprestore.

Requirements and Limitations

The gpbackup and gprestore utilities are available with Greenplum Database 5.5.0 and later.

gpbackup and gprestore have the following limitations:

• If you create an index on a parent partitioned table, gpbackup does not back up that same index on child partitioned tables of the parent, as creating the same index on a child would cause an error. However, if you exchange a partition, gpbackup does not detect that the index on the exchanged partition is inherited from the new parent table. In this case, gpbackup backs up conflicting CREATE INDEX statements, which causes an error when you restore the backup set.
• You can execute multiple instances of gpbackup, but each execution requires a distinct timestamp.
• Database object filtering is currently limited to schemas and tables.
• If you use the gpbackup --single-data-file option to combine table backups into a single file per segment, you cannot perform a parallel restore operation with gprestore (cannot set --jobs to a value higher than 1).
• You cannot use the --exclude-table-file with --leaf-partition-data. Although you can specify leaf partition names in a file specified with --exclude-table-file, gpbackup ignores the partition names.
• Incremental backups are not supported.

Objects Included in a Backup or Restore

The following table lists the objects that are backed up and restored with gpbackup and gprestore.

Database objects are backed up for the database you specify with the --dbname option. Global objects (Greenplum Database system objects) are also backed up by default, but they are restored only if you include the --with-globals option to gprestore.
Table 28: Objects that are backed up and restored

<table>
<thead>
<tr>
<th>Database (for database specified with <code>--dbname</code>)</th>
<th>Global (requires the <code>--with-globals</code> option to restore)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Session-level configuration parameter settings (GUCs)</td>
<td>• Tablespaces</td>
</tr>
<tr>
<td>• Schemas, see <em>Note</em></td>
<td>• Databases</td>
</tr>
<tr>
<td>• Procedural language extensions</td>
<td>• Database-wide configuration parameter settings (GUCs)</td>
</tr>
<tr>
<td>• Sequences</td>
<td>• Resource group definitions</td>
</tr>
<tr>
<td>• Comments</td>
<td>• Resource queue definitions</td>
</tr>
<tr>
<td>• Tables</td>
<td>• Roles</td>
</tr>
<tr>
<td>• Indexes</td>
<td>• <code>GRANT</code> assignments of roles to databases</td>
</tr>
<tr>
<td>• Owners</td>
<td></td>
</tr>
<tr>
<td>• Writable External Tables (DDL only)</td>
<td></td>
</tr>
<tr>
<td>• Readable External Tables (DDL only)</td>
<td></td>
</tr>
<tr>
<td>• Functions</td>
<td></td>
</tr>
<tr>
<td>• Aggregates</td>
<td></td>
</tr>
<tr>
<td>• Casts</td>
<td></td>
</tr>
<tr>
<td>• Types</td>
<td></td>
</tr>
<tr>
<td>• Views</td>
<td></td>
</tr>
<tr>
<td>• Protocols</td>
<td></td>
</tr>
<tr>
<td>• Triggers. (While Greenplum Database does not support triggers, any trigger definitions that are present are backed up and restored.)</td>
<td></td>
</tr>
<tr>
<td>• Rules</td>
<td></td>
</tr>
<tr>
<td>• Domains</td>
<td></td>
</tr>
<tr>
<td>• Operators, operator families, and operator classes</td>
<td></td>
</tr>
<tr>
<td>• Conversions</td>
<td></td>
</tr>
<tr>
<td>• Extensions</td>
<td></td>
</tr>
<tr>
<td>• Text search parsers, dictionaries, templates, and configurations</td>
<td></td>
</tr>
</tbody>
</table>

*Note:* These schemas are not included in a backup.

- `gp_toolkit`
- `information_schema`
- `pg_aoseg`
- `pg_bitmapindex`
- `pg_catalog`
- `pg_toast*`
- `pg_temp*`

When restoring to an existing database, `gprestore` assumes the `public` schema exists when restoring objects to the `public` schema. When restoring to a new database (with the `--create-db` option), `gprestore` creates the `public` schema automatically when creating a database with the `CREATE DATABASE` command. The command uses the `template0` database that contains the `public` schema.

See also *Understanding Backup Files.*
Performing Basic Backup and Restore Operations

To perform a complete backup of a database, as well as Greenplum Database system metadata, use the command:

```
$ gpbackup --dbname <database_name>
```

For example:

```
$ gpbackup --dbname demo
20180105:11:27:54 gpbackup:gpadmin:centos6.localdomain:002182-[INFO]:-Backup Type = Unfiltered Compressed Full Backup
20180105:11:27:54 gpbackup:gpadmin:centos6.localdomain:002182-[INFO]:-Acquiring ACCESS SHARE locks on tables
Locks acquired:  6 / 6
[================================================================] 100.00% 0s
20180105:11:27:54 gpbackup:gpadmin:centos6.localdomain:002182-[INFO]:-Writing data to file
Tables backed up:  3 / 3
[==============================================================] 100.00% 0s
```

The above command creates a file that contains global and database-specific metadata on the Greenplum Database master host in the default directory, `$MASTER_DATA_DIRECTORY/backups/<YYYYMMDD>/<YYYYMMDDHHMMSS>`. For example:

```
$ ls /gpmaster/gpsne-1/backups/20180105/20180105112754
gpbackup_20180105112754_config.yaml gpbackup_20180105112754_report
```
By default, each segment stores each table's data for the backup in a separate compressed CSV file in
<seg_dir>/backups/<YYYYMMDD>/<YYYYMMDDHHMMSS>/:

$ ls /gpdata1/gpsne0/backups/20180105/20180105112754/
gpbackup_0_20180105112754_17166.gz  gpbackup_0_20180105112754_26303.gz
gpbackup_0_20180105112754_21816.gz

To consolidate all backup files into a single directory, include the --backup-dir option. Note that you
must specify an absolute path with this option:

$ gpbackup --dbname demo --backup-dir /home/gpadmin/backups

When performing a backup operation, you can use the --single-data-file in situations where the
additional overhead of multiple files might be prohibitive. For example, if you use a third party storage
solution such as Data Domain with backups.

Restoring from Backup

To use gprestore to restore from a backup set, you must use the --timestamp option to specify the
exact timestamp value (YYYYMMDDHHMMSS) to restore. Include the --create-db option if the database
does not exist in the cluster. For example:

$ dropdb demo
$ gprestore --timestamp 20171103152558 --create-db

20171103:15:45:30 gprestore:gpadmin:0ee2f5fb02c9:017714-[INFO]:-Restore Key
= 20171103152558
20171103:15:45:31 gprestore:gpadmin:0ee2f5fb02c9:017714-[INFO]:-Creating
database
20171103:15:45:44 gprestore:gpadmin:0ee2f5fb02c9:017714-[INFO]:-Database
creation complete
20171103:15:45:44 gprestore:gpadmin:0ee2f5fb02c9:017714-[INFO]:-Restoring
pre-data metadata from /gpmaster/gpsne-1/backups/20171103/20171103152558/
gbackup_20171103152558_predata.sql
If you specified a custom `--backup-dir` to consolidate the backup files, include the same `--backup-dir` option when using `gprestore` to locate the backup files:

```bash
$ dropdb demo
$ gprestore --backup-dir /home/gpadmin/backups/ --timestamp 20171103153156 --create-db
20171103:15:51:02 gprestore:gpadmin:0ee2f5fb02c9:017819-[INFO]:-Restore Key = 20171103153156
...
20171103:15:51:17 gprestore:gpadmin:0ee2f5fb02c9:017819-[INFO]:-Post-data metadata restore complete
```

`gprestore` does not attempt to restore global metadata for the Greenplum System by default. If this is required, include the `--with-globals` argument.

By default, `gprestore` uses 1 connection to restore table data and metadata. If you have a large backup set, you can improve performance of the restore by increasing the number of parallel connections with the `--jobs` option. For example:

```bash
$ gprestore --backup-dir /home/gpadmin/backups/ --timestamp 20171103153156 --create-db --jobs 8
```

Test the number of parallel connections with your backup set to determine the ideal number for fast data recovery.

**Note:** You cannot perform a parallel restore operation with `gprestore` if the backup combined table backups into a single file per segment with the `gpbackup` option `--single-data-file`.

### Report Files

When performing a backup or restore operation, `gpbackup` and `gprestore` generate a report file. When email notification is configured, the email sent contains the contents of the report file. For information about email notification, see [Configuring Email Notifications](#).

The report file is placed in the Greenplum Database master backup directory. The report file name contains the timestamp of the operation. These are the formats of the `gpbackup` and `gprestore` report file names.

- `gpbackup_<backup_timestamp>_report`
- `gprestore_<backup_timestamp>_<restore_timestamp>_report`

For these example report file names, `20180213114446` is the timestamp of the backup and `20180213115426` is the timestamp of the restore operation.
This backup directory on a Greenplum Database master host contains both a `gpbackup` and `gprestore` report file.

```
$ ls -l /gpmaster/seg-1/backups/20180213/20180213114446
total 36
-r--r--r--. 1 gpadmin gpadmin 295 Feb 13 11:44
gpbackup_20180213114446_config.yaml
-r--r--r--. 1 gpadmin gpadmin 1855 Feb 13 11:44
gpbackup_20180213114446_metadata.sql
-r--r--r--. 1 gpadmin gpadmin 1402 Feb 13 11:44
gpbackup_20180213114446_report
-r--r--r--. 1 gpadmin gpadmin 2199 Feb 13 11:44
gpbackup_20180213114446_toc.yaml
-r--r--r--. 1 gpadmin gpadmin 404 Feb 13 11:54
gprestore_20180213114446_20180213115426_report
```

The contents of the report files are similar. This is an example of the contents of a `gprestore` report file.

```
Greenplum Database Restore Report

Timestamp Key: 20180213114446
GPDB Version: 5.4.1+dev.8.g9f83645 build
    commit:9f836456b00f855959d52749d5790ed1c6efc042
gprestore Version: 1.0.0-alpha.3+dev.73.g0406681

Database Name: test
Command Line: gprestore --timestamp 20180213114446 --with-globals --createdb

Start Time: 2018-02-13 11:54:26
End Time: 2018-02-13 11:54:31
Duration: 0:00:05

Restore Status: Success
```

### Return Codes

One of these codes is returned after `gpbackup` or `gprestore` completes.

- **0** – Backup or restore completed with no problems
- **1** – Backup or restore completed with non-fatal errors. See log file for more information.
- **2** – Backup or restore failed with a fatal error. See log file for more information.

### Filtering the Contents of a Backup or Restore

`gpbackup` backs up all schemas and tables in the specified database, unless you exclude or include individual schema or table objects with schema level or table level filter options.

The schema level options are `--include-schema` or `--exclude-schema` command-line options to `gpbackup`. For example, if the "demo" database includes only two schemas, "wikipedia" and "twitter," both of the following commands back up only the "wikipedia" schema:

```
$ gpbackup --dbname demo --include-schema wikipedia
$ gpbackup --dbname demo --exclude-schema twitter
```

You can include multiple `--include-schema` options in a `gpbackup` or multiple `--exclude-schema` options. For example:

```
$ gpbackup --dbname demo --include-schema wikipedia --include-schema twitter
```
To filter the individual tables that are included in a backup set, or excluded from a backup set, specify individual tables with the `--include-table` option or the `--exclude-table` option. The table must be schema qualified, `<schema-name>.<table-name>`. The individual table filtering options can be specified multiple times. However, `--include-table` and `--exclude-table` cannot both be used in the same command.

You can create a list of qualified table names in a text file. When listing tables in a file, each line in the text file must define a single table using the format `<schema-name>.<table-name>`. The file must not include trailing lines. For example:

```
  wikipedia.articles
  twitter.message
```

If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. For example:

```
  beer."IPA"
  "Wine".riesling
  "Wine"."sauvignon blanc"
  water.tonic
```

After creating the file, you can use it either to include or exclude tables with the `gpbackup` options `--include-table-file` or `--exclude-table-file`. For example:

```
  $ gpbackup --dbname demo --include-table-file /home/gpadmin/table-list.txt
```

You can combine `--include-schema` with `--exclude-table` or `--exclude-table-file` for a backup. This example uses `--include-schema` with `--exclude-table` to back up a schema except for a single table.

```
  $ gpbackup --dbname demo --include-schema mydata --exclude-table mydata.addresses
```

You cannot combine `--include-schema` with `--include-table` or `--include-table-file`, and you cannot combine `--exclude-schema` with any table filtering option such as `--exclude-table` or `--include-table`.

### Filtering by Leaf Partition

By default, `gpbackup` creates one file for each table on a segment. You can specify the `--leaf-partition-data` option to create one data file per leaf partition of a partitioned table, instead of a single file. You can also filter backups to specific leaf partitions by listing the leaf partition names in a text file to include. For example, consider a table that was created using the statement:

```
  demo=# CREATE TABLE sales (id int, date date, amt decimal(10,2))
  DISTRIBUTED BY (id)
  PARTITION BY RANGE (date)
    ( PARTITION Jan17 START (date '2017-01-01') INCLUSIVE ,
      PARTITION Feb17 START (date '2017-02-01') INCLUSIVE ,
      PARTITION Mar17 START (date '2017-03-01') INCLUSIVE ,
      PARTITION Apr17 START (date '2017-04-01') INCLUSIVE ,
      PARTITION May17 START (date '2017-05-01') INCLUSIVE ,
      PARTITION Jun17 START (date '2017-06-01') INCLUSIVE ,
      PARTITION Jul17 START (date '2017-07-01') INCLUSIVE ,
      PARTITION Aug17 START (date '2017-08-01') INCLUSIVE ,
      PARTITION Sep17 START (date '2017-09-01') INCLUSIVE ,
      PARTITION Oct17 START (date '2017-10-01') INCLUSIVE ,
      PARTITION Nov17 START (date '2017-11-01') INCLUSIVE ,
      PARTITION Dec17 START (date '2017-12-01') INCLUSIVE
    )
```
END (date '2018-01-01') EXCLUSIVE );

NOTICE: CREATE TABLE will create partition "sales_1_prt_jan17" for table "sales"
NOTICE: CREATE TABLE will create partition "sales_1_prt_feb17" for table "sales"
NOTICE: CREATE TABLE will create partition "sales_1_prt_mar17" for table "sales"
NOTICE: CREATE TABLE will create partition "sales_1_prt_apr17" for table "sales"
NOTICE: CREATE TABLE will create partition "sales_1_prt_may17" for table "sales"
NOTICE: CREATE TABLE will create partition "sales_1_prt_jun17" for table "sales"
NOTICE: CREATE TABLE will create partition "sales_1_prt_jul17" for table "sales"
NOTICE: CREATE TABLE will create partition "sales_1_prt_aug17" for table "sales"
NOTICE: CREATE TABLE will create partition "sales_1_prt_sep17" for table "sales"
NOTICE: CREATE TABLE will create partition "sales_1_prt_oct17" for table "sales"
NOTICE: CREATE TABLE will create partition "sales_1_prt_nov17" for table "sales"
NOTICE: CREATE TABLE will create partition "sales_1_prt_dec17" for table "sales"

CREATE TABLE

To back up only data for the last quarter of the year, first create a text file that lists those leaf partition names instead of the full table name:

```
public.sales_1_prt_oct17
public.sales_1_prt_nov17
public.sales_1_prt_dec17
```

Then specify the file with the `--include-table-file` option to generate one data file per leaf partition:

```
$ gpbackup --dbname demo --include-table-file last-quarter.txt --leaf-partition-data
```

When you specify `--leaf-partition-data`, `gpbackup` generates one data file per leaf partition when backing up a partitioned table. For example, this command generates one data file for each leaf partition:

```
$ gpbackup --dbname demo --include-table public.sales --leaf-partition-data
```

When leaf partitions are backed up, the leaf partition data is backed up along with the metadata for the entire partitioned table.

**Note:** You cannot use the `--exclude-table-file` option with `--leaf-partition-data`. Although you can specify leaf partition names in a file specified with `--exclude-table-file`, `gpbackup` ignores the partition names.

### Filtering with gprestore

After creating a backup set with `gpbackup`, you can filter the schemas and tables that you want to restore from the backup set using the `gprestore --include-schema` and `--include-table-file` options. These options work in the same way as their `gpbackup` counterparts, but have the following restrictions:

- The tables that you attempt to restore must not already exist in the database.
- If you attempt to restore a schema or table that does not exist in the backup set, the `gprestore` does not execute.
• If you use the `--include-schema` option, `gprestore` cannot restore objects that have dependencies on multiple schemas.

• If you use the `--include-table-file` option, `gprestore` does not create roles or set the owner of the tables. The utility restores table indexes and rules. Triggers are also restored but are not supported in Greenplum Database.

• The file that you specify with `--include-table-file` cannot include a leaf partition name, as it can when you specify this option with `gpbackup`. If you specified leaf partitions in the backup set, specify the partitioned table to restore the leaf partition data.

When restoring a backup set that contains data from some leaf partitions of a partitioned table, the partitioned table is restored along with the data for the leaf partitions. For example, you create a backup with the `gpbackup` option `--include-table-file` and the text file lists some leaf partitions of a partitioned table. Restoring the backup creates the partitioned table and restores the data only for the leaf partitions listed in the file.

### Configuring Email Notifications

`gpbackup` and `gprestore` can send email notifications after a backup or restore operation completes.

To have `gpbackup` or `gprestore` send out status email notifications, you must place a file named `gp_email_contacts.yaml` in the home directory of the user running `gpbackup` or `gpbackup` in the same directory as the utilities (`$GPHOME/bin`). A utility issues a message if it cannot locate a `gp_email_contacts.yaml` file in either location. If both locations contain a `.yaml` file, the utility uses the file in user `$HOME`.

The email subject line includes the utility name, timestamp, status, and the name of the Greenplum Database master. This is an example subject line for a `gpbackup` email.

```
gpbackup 20180202133601 on gp-master completed
```

The email contains summary information about the operation including options, duration, and number of objects backed up or restored. For information about the contents of a notification email, see [Report Files](#).

**Note:** The UNIX mail utility must be running on the Greenplum Database host and must be configured to allow the Greenplum superuser (`gpadmin`) to send email.

### gpbackup and gprestore Email File Format

The `gpbackup` and `gprestore` email notification YAML file `gp_email_contacts.yaml` uses indentation (spaces) to determine the document hierarchy and the relationships of the sections to one another. The use of white space is significant. White space should not be used simply for formatting purposes, and tabs should not be used at all.

**Note:** If the `status` parameters are not specified correctly, the utility does not issue a warning. For example, if the `success` parameter is misspelled and is set to `true`, a warning is not issued and an email is not sent to the email address after a successful operation. To ensure email notification is configured correctly, run tests with email notifications configured.

This is the format of the `gp_email_contacts.yaml` YAML file for `gpbackup` email notifications:

```yaml
contacts:
gpbackup:
  - address: user@domain
    status:
      success: [true | false]
      success_with_errors: [true | false]
      failure: [true | false]
gprestore:
  - address: user@domain
    status:
      success: [true | false]
```
success_with_errors: [true | false]
failure: [true | false]

### Email YAML File Sections

#### contacts
Required. The section that contains the `gpbackup` and `gprestore` sections. The YAML file can contain a `gpbackup` section, a `gprestore` section, or one of each.

#### gpbackup
Optional. Begins the `gpbackup` email section.

##### address
Required. At least one email address must be specified. Multiple email address parameters can be specified. Each `address` requires a `status` section.

`user@domain` is a single, valid email address.

##### status
Required. Specify when the utility sends an email to the specified email address. The default is to not send email notification.

You specify sending email notifications based on the completion status of a backup or restore operation. At least one of these parameters must be specified and each parameter can appear at most once.

- **success**
  Optional. Specify if an email is sent if the operation completes without errors. If the value is `true`, an email is sent if the operation completes without errors. If the value is `false` (the default), an email is not sent.

- **success_with_errors**
  Optional. Specify if an email is sent if the operation completes with errors. If the value is `true`, an email is sent if the operation completes with errors. If the value is `false` (the default), an email is not sent.

- **failure**
  Optional. Specify if an email is sent if the operation fails. If the value is `true`, an email is sent if the operation fails. If the value is `false` (the default), an email is not sent.

#### gprestore
Optional. Begins the `gprestore` email section. This section contains the `address` and `status` parameters that are used to send an email notification after a `gprestore` operation. The syntax is the same as the `gpbackup` section.

### Examples

This example YAML file specifies sending email to email addresses depending on the success or failure of an operation. For a backup operation, an email is sent to a different address depending on the success or failure of the backup operation. For a restore operation, an email is sent to `gpadmin@example.com` only when the operation succeeds or completes with errors.

```yaml
contacts
backup:
- address: gpadmin@example.com
  status:
    success: true
- address: my_dba@example.com
  status:
    success_with_errors: true
    failure: true
restore:
```
Understanding Backup Files

Warning: All gpbackup metadata files are created with read-only permissions. Never delete or modify the metadata files for a gpbackup backup set. Doing so will render the backup files non-functional.

A complete backup set for gpbackup includes multiple metadata files, supporting files, and CSV data files, each designated with the timestamp at which the backup was created.

By default, metadata and supporting files are stored on the Greenplum Database master host in the directory $MASTER_DATA_DIRECTORY/backups/YYYYMMDD/YYYYMMDDHHMMSS/. If you specify a custom backup directory, this same file path is created as a subdirectory of the backup directory. The following table describes the names and contents of the metadata and supporting files.
### Table 29: gpbackup Metadata Files (master)

<table>
<thead>
<tr>
<th>File name</th>
<th>Description</th>
</tr>
</thead>
</table>
| `gpbackup_<YYYYMMDDHHMMSS>_metadata.sql` | Contains global and database-specific metadata:  
  - DDL for objects that are global to the Greenplum Database cluster, and not owned by a specific database within the cluster.  
  - DDL for objects in the backed-up database (specified with `--dbname`) that must be created before to restoring the actual data, and DDL for objects that must be created after restoring the data.  
  
  Global objects include:  
  - Tables  
  - Databases  
  - Database-wide configuration parameter settings (GUCs)  
  - Resource group definitions  
  - Resource queue definitions  
  - Roles  
  - `GRANT` assignments of roles to databases  

  **Note:** Global metadata is not restored by default. You must include the `--with-globals` option to the `gprestore` command to restore global metadata.  

  Database-specific objects that must be created before to restoring the actual data include:  
  - Session-level configuration parameter settings (GUCs)  
  - Schemas  
  - Procedural language extensions  
  - Types  
  - Sequences  
  - Functions  
  - Tables  
  - Protocols  
  - Operators and operator classes  
  - Conversions  
  - Aggregates  
  - Casts  
  - Views  
  - Constraints  

  Database-specific objects that must be created after restoring the actual data include:  
  - Indexes  
  - Rules |
<table>
<thead>
<tr>
<th>File name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>gpbackup_&lt;YYYYMMDDHHMMSS&gt;_toc.yaml</td>
<td>Contains metadata for locating object DDL in the _predata.sql and _postdata.sql files. This file also contains the table names and OIDs used for locating the corresponding table data in CSV data files that are created on each segment. See Segment Data Files.</td>
</tr>
</tbody>
</table>
| gpbackup_<YYYYMMDDHHMMSS>_report | Contains information about the backup operation that is used to populate the email notice (if configured) that is sent after the backup completes. This file contains information such as:
- Command-line options that were provided
- Database that was backed up
- Database version
- Backup type
See Configuring Email Notifications. |
| gpbackup_<YYYYMMDDHHMMSS>_config.yaml | Contains metadata about the execution of the particular backup task, including:
- gpbackup version
- Database name
- Greenplum Database version
- Additional option settings such as --no-compression, --compression-level, --metadata-only, --data-only, and --with-stats. |

**Segment Data Files**

By default, each segment creates one compressed CSV file for each table that is backed up on the segment. You can optionally specify the --single-data-file option to create a single data file on each segment. The files are stored in <seg_dir>/backups/YYYYMMDD/YYYYMMDDHHMMSS/.

If you specify a custom backup directory, segment data files are copied to this same file path as a subdirectory of the backup directory. If you include the --leaf-partition-data option, gpbackup creates one data file for each leaf partition of a partitioned table, instead of just one file for file.

Each data file uses the file name format gpbackup_<content_id>_<YYYYMMDDHHMMSS>_<oid>.gz where:
- <content_id> is the content ID of the segment.
- <YYYYMMDDHHMMSS> is the timestamp of the gpbackup operation.
- <oid> is the object ID of the table. The metadata file gpbackup_<YYYYMMDDHHMMSS>_toc.yaml references this <oid> to locate the data for a specific table in a schema.

You can optionally specify the gzip compression level (from 1-9) using the --compression-level option, or disable compression entirely with --no-compression. If you do not specify a compression level, gpbackup uses compression level 1 by default.
Using gpbackup and gprestore with BoostFS

You can use the Greenplum Database gpbackup and gprestore utilities with the Data Domain DD Boost File System Plug-In (BoostFS) to access a Data Domain system. BoostFS leverages DD Boost technology and helps reduce bandwidth usage, can improve backup-times, offers load-balancing and in-flight encryption, and supports the Data Domain multi-tenancy feature set.

You install the BoostFS plug-in on the Greenplum Database host systems to provide access to a Data Domain system as a standard file system mount point. With direct access to a BoostFS mount point, gpbackup and gprestore can leverage the storage and network efficiencies of the DD Boost protocol for backup and recovery.

To back up or restore with BoostFS, you include the option --backup-dir with the gpbackup or gprestore command to access the Data Domain system.

Installing BoostFS

These steps install BoostFS and create a mounted directory that accesses a Data Domain system.

1. Download and install the BoostFS RPM. This `yum` command installs the RPM.

   ```shell
   sudo yum -y install DDBoostFS-1.1.0.1-565598.rhel.x86_64.rpm
   ```

   The RPM supports both RHEL and SuSE.

   After installation, the DDBoostFS package files are located under `/opt/emc/boostfs`.

2. Set up the BoostFS lockbox with the storage unit with the `boostfs` utility. Enter the Data Domain user password at the prompts.

   ```shell
   /opt/emc/boostfs/bin/boostfs lockbox set -d <Data_Domain_IP> -s <Storage_Unit> -u <Data_Domain_User>
   ```

   The `<Storage_Unit>` is the Data Domain storage unit ID. The `<Data_Domain_User>` is a Data Domain user with access to the storage unit.

3. Create the directory in the location you want to mount BoostFS.

   ```shell
   mkdir <path_to_mount_directory>
   ```

4. Mount the Data Domain storage unit with the `boostfs` utility. Use the mount option `--allow-others=true` to allow other users to write to the BoostFS mounted file system.

   ```shell
   /opt/emc/boostfs/bin/boostfs mount <path_to_mount_directory> -d $<Data_Domain_IP> -s <Storage_Unit> -o allow-others=true
   ```

5. Confirm that the mount was successful by running this command.

   ```shell
   mountpoint <mounted_directory>
   ```

   The command lists the directory as a mount point.

   `<mounted_directory>` is a mountpoint

You can now run gpbackup and gprestore with the `--backup-dir` option to back up a database to `<mounted_directory>` on the Data Domain system and restore data from the Data Domain system.
**Backing Up and Restoring with BoostFS**

These are required `gpbackup` options when backing up data to a Data Domain system with BoostFS.

- **--backup-dir** - Specify the mounted Data Domain storage unit.
- **--single-data-file** - Create a single data file on each segment host. A single data file avoids a BoostFS stream limitation.

When you use `gprestore` to restore a backup from a Data Domain system with BoostFS, you must specify the mounted Data Domain storage unit with the option **--backup-dir**.

When you use the `gpbackup` option **--single-data-file**, you cannot specify the **--jobs** option to perform a parallel restore operation with `gprestore`.

This example `gpbackup` command backs up the database `test`. The example assumes that the directory `/boostfs-test/` is the mounted Data Domain storage unit.

```bash
$ gpbackup --dbname test --backup-dir /boostfs-test/ --single-data-file --no-compression
```

These commands drop the database `test` and restore the database from the backup.

```bash
$ dropdb test
$ gprestore --backup-dir /boostfs-test/ --timestamp 20171103153156 --create-db
```

The value `20171103153156` is the timestamp of the `gpbackup` backup set to restore. For information about how `gpbackup` uses timestamps when creating backups, see Parallel Backup with `gpbackup` and `gprestore`. For information about the **--timestamp** option, see `gprestore`.

**Using the S3 Storage Plugin with gpbackup and gprestore**

**Warning:** The S3 storage plugin for `gpbackup` and `gprestore` is an experimental feature and is not intended for use in a production environment. Experimental features are subject to change without notice in future releases.

The S3 storage plugin application lets you use an Amazon Simple Storage Service (Amazon S3) location to store and retrieve backups when you run `gpbackup` and `gprestore`. Amazon S3 provides secure, durable, highly-scalable object storage.

To use the S3 storage plugin application, you specify the location of the plugin and the Amazon Web Services (AWS) login and backup location in a configuration file. When you run `gpbackup` or `gprestore`, you specify the configuration file with the option **--plugin-config**. For information about the configuration file, see *S3 Storage Plugin Configuration File Format*.

If you perform a backup operation with the `gpbackup` option **--plugin-config**, you must also specify the **--plugin-config** option when you restore the backup with `gprestore`.

**S3 Storage Plugin Configuration File Format**

The configuration file specifies the absolute path to the Greenplum Database S3 storage plugin executable, AWS connection credentials, and S3 location.

The S3 storage plugin configuration file uses the *YAML 1.1* document format and implements its own schema for specifying the location of the Greenplum Database S3 storage plugin, AWS connection credentials, and S3 location and login information.

The configuration file must be a valid YAML document. The `gpbackup` and `gprestore` utilities process the control file document in order and use indentation (spaces) to determine the document hierarchy and
the relationships of the sections to one another. The use of white space is significant. White space should not be used simply for formatting purposes, and tabs should not be used at all.

This is the structure of a S3 storage plugin configuration file.

```yaml
executablepath: <absolute-path-to-gpbackup_s3_plugin>
options:
  region: <aws-region>
  aws_access_key_id: <aws-user-id>
  aws_secret_access_key: <aws-user-id-key>
  bucket: <s3-bucket>
  backupdir: <s3-location>
```

**executablepath**

Required. Absolute path to the plugin executable. For example, the Pivotal Greenplum Database installation location is `$GPHOME/bin/gpbackup_s3_plugin`.

**options**

Required. Begins the S3 storage plugin options section.

**region**

Required. The AWS region.

**aws_access_key_id**

Required. The AWS S3 ID to access the S3 bucket location that stores backup files.

**aws_secret_access_key**

Required. AWS S3 passcode for the S3 ID to access the S3 bucket location.

**bucket**

Required. The name of the S3 bucket in the AWS region. The bucket must exist.

**backupdir**

Required. The S3 location for backups. During a backup operation, the plugin creates the S3 location if it does not exist in the S3 bucket.

**Example**

This is an example S3 storage plugin configuration file that is used in the next `gpbackup` example command. The name of the file is `s3-test-config.yaml`.

```yaml
executablepath: $GPHOME/bin/gpbackup_s3_plugin
options:
  region: us-west-2
  aws_access_key_id: test-s3-user
  aws_secret_access_key: asdf1234asdf
  bucket: gpdb-backup
  backupdir: test/backup3
```

This `gpbackup` example backs up the database demo using the S3 storage plugin. The absolute path to the S3 storage plugin configuration file is `/home/gpadmin/s3-test`.

```sh
gpbackup --dbname demo --single-data-file --plugin-config /home/gpadmin/s3-test-config.yaml
```

The S3 storage plugin writes the backup files to this S3 location in the AWS region us-west-2.

```sh
gpdb-backup/test/backup3/backups/YYYYMMDD/YYYYMMDDHHMMSS/
```
Notes

The S3 storage plugin application must be in the same location on every Greenplum Database host. The configuration file is required only on the master host.

When running gpbackup, the --plugin-config option is supported only with --single-data-file or --metadata-only.

When you perform a backup with the S3 storage plugin, the plugin stores the backup files in this location in the S3 bucket.

<backupdir>/backups/<datestamp>/<timestamp>

Where backupdir is the location you specified in the S3 configuration file, and datestamp and timestamp are the backup date and time stamps.

Using Amazon S3 to back up and restore data requires an Amazon AWS account with access to the Amazon S3 bucket. These are the Amazon S3 bucket permissions required for backing up and restoring data.

- Upload/Delete for the S3 user ID that uploads the files
- Open/Download and View for the S3 user ID that accesses the files

For information about Amazon S3, see Amazon S3.

- For information about Amazon S3 regions and endpoints, see http://docs.aws.amazon.com/general/latest/gr/rande.html#s3_region.
- For information about S3 buckets and folders, see the Amazon S3 documentation https://aws.amazon.com/documentation/s3/.

Backup/Restore Storage Plugin API

This topic describes how to develop a custom storage plugin with the Greenplum Database Backup/Restore Storage Plugin API.

**Warning:** The Greenplum Database Backup/Restore Storage Plugin API is an experimental feature and is not intended for use in a production environment. Experimental features are subject to change without notice in future releases.

The Backup/Restore Storage Plugin API provides a framework that you can use to develop and integrate a custom backup storage system with the Greenplum Database gpbackup and gprestore utilities.

The Backup/Restore Storage Plugin API defines a set of interfaces that a plugin must support. The API also specifies the format and content of a configuration file for a plugin.

When you use the Backup/Restore Storage Plugin API, you create a plugin that the Greenplum Database administrator deploys to the Greenplum Database cluster. Once deployed, the plugin is available for use in certain backup and restore operations.

**Note:** Greenplum Database supports using a custom storage plugin on a backup operation only when gpbackup is run with the --single-data-file or --metadata-only options.

This topic includes the following subtopics:

- Plugin Configuration File
- Plugin API
- Plugin Commands
- Implementing a Backup/Restore Storage Plugin
- Verifying a Backup/Restore Storage Plugin
- Packaging and Deploying a Backup/Restore Storage Plugin
Plugin Configuration File

Specifying the `--plugin-config` option to the `gpbackup` and `gprestore` commands instructs the utilities to use the plugin specified in the configuration file for the operation.

The plugin configuration file provides information for both Greenplum Database and the plugin. The Backup/Restore Storage Plugin API defines the format of, and certain keywords used in, the plugin configuration file.

A plugin configuration file is a YAML file in the following format:

```yaml
executablepath: path_to_plugin_executable
options:
  keyword1: value1
  keyword2: value2
  ...
  keywordN: valueN
```

gpbackup and gprestore use the `executablepath` value to determine the file system location of the plugin executable program.

The plugin configuration file may also include keywords and values specific to a plugin instance. A backup/restore storage plugin can use the `options` block specified in the file to obtain information from the user that may be required to perform its tasks. This information may include location, connection, or authentication information, for example. The plugin should both specify and consume the content of this information in `keyword: value` syntax.

A sample plugin configuration file for the Greenplum Database S3 backup/restore storage plugin follows:

```yaml
executablepath: $GPHOME/bin/gpbackup_s3_plugin
options:
  region: us-west-2
  aws_access_key_id: notarealID
  aws_secret_access_key: notarealkey
  bucket: gp_backup_bucket
  backupdir: greenplum_backups
```

Plugin API

The plugin that you implement when you use the Backup/Restore Storage Plugin API is an executable program that supports specific commands invoked by `gpbackup` and `gprestore` at defined points in their respective life cycle operations:

- The Greenplum Database Backup/Restore Storage Plugin API provides hooks into the `gpbackup` lifecycle at initialization, during backup, and at cleanup/exit time.
- The API provides hooks into the `gprestore` lifecycle at initialization, during restore, and at cleanup/exit time.

The Backup/Restore Storage Plugin API defines the following call syntax for a backup/restore storage plugin executable program:

```
plugin_executable command config_file arg
```

where:

- `plugin_executable` - The absolute path of the backup/restore storage plugin executable program. This path is determined by the `executablepath` property value configured in the plugin's configuration YAML file.
- `command` - The name of a Backup/Restore Storage Plugin API command that identifies a specific entry point to a `gpbackup` or `gprestore` lifecycle operation.
- `config_file` - The absolute path of the plugin's configuration YAML file.
- `arg` - The command argument; the actual argument differs depending upon the command specified.

**Plugin Commands**

The Greenplum Database Backup/Restore Storage Plugin API defines the following commands:

**Table 30: Backup/Restore Storage Plugin API Commands**

<table>
<thead>
<tr>
<th>Command Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>plugin_api_version</code></td>
<td>Return the version of the Backup/Restore Storage Plugin API supported by the plugin. The only supported version is 0.1.0.</td>
</tr>
<tr>
<td><code>setup_plugin_for_backup</code></td>
<td>Initialize the plugin for a backup operation.</td>
</tr>
<tr>
<td><code>backup_file</code></td>
<td>Move a backup file to the remote storage system.</td>
</tr>
<tr>
<td><code>backup_data</code></td>
<td>Move streaming data from stdin to a file on the remote storage system.</td>
</tr>
<tr>
<td><code>cleanup_plugin_for_backup</code></td>
<td>Clean up after a backup operation.</td>
</tr>
<tr>
<td><code>setup_plugin_for_restore</code></td>
<td>Initialize the plugin for a restore operation.</td>
</tr>
<tr>
<td><code>restore_file</code></td>
<td>Move a backup file from the remote storage system to a designated location on the local host.</td>
</tr>
<tr>
<td><code>restore_data</code></td>
<td>Move a backup file from the remote storage system, streaming the data to stdout.</td>
</tr>
<tr>
<td><code>cleanup_plugin_for_restore</code></td>
<td>Clean up after a restore operation.</td>
</tr>
</tbody>
</table>

A backup/restore storage plugin must support every command identified above, even if it is a no-op.

**Implementing a Backup/Restore Storage Plugin**

You can implement a backup/restore storage plugin executable in any programming or scripting language. The tasks performed by a backup/restore storage plugin will be very specific to the remote storage system. As you design the plugin implementation, you will want to:

- Examine the connection and data transfer interface to the remote storage system.
- Identify the storage path specifics of the remote system.
- Identify configuration information required from the user.
- Define the keywords and value syntax for information required in the plugin configuration file.
- Determine if, and how, the plugin will modify (compress, etc.) the data en route to/from the remote storage system.
- Define a mapping between a `gpbackup` file path and the remote storage system.
- Identify how `gpbackup` options affect the plugin, as well as which are required and/or not applicable. For example, if the plugin performs its own compression, `gpbackup` must be invoked with the `--no-compression` option to prevent the utility from compressing the data.

A backup/restore storage plugin that you implement must:

- Support all plugin commands identified in **Plugin Commands**. Each command must exit with the values identified on the command reference page.

Refer to the `gpbackup-s3-plugin` github repository for an example plugin implementation.
Verifying a Backup/Restore Storage Plugin

The Backup/Restore Storage Plugin API includes a test bench that you can run to ensure that a plugin is well integrated with gpbackup and gprestore.

The test bench is a bash script that you run in a Greenplum Database installation. The script generates a small (<1MB) data set in a Greenplum Database table, explicitly tests each command, and runs a backup and restore of the data (file and streaming). The test bench invokes gpbackup and gprestore, which in turn individually call/test each Backup/Restore Storage Plugin API command implemented in the plugin.

The test bench program calling syntax is:

```
plugin_test_bench.sh plugin_executable plugin_config
```

Procedure

To run the Backup/Restore Storage Plugin API test bench against a plugin:

1. Log in to the Greenplum Database master host and set up your environment. For example:

   ```
   $ ssh gpadmin@gpmaster
gadmin@gpmaster$ . /usr/local/greenplum-db/greenplum_path.sh
   ```

2. Obtain a copy of the test bench from the gpbackup github repository. For example:

   ```
   $ git clone git@github.com:greenplum-db/gpbackup.git
   ```
   The clone operation creates a directory named gpbackup/ in the current working directory.

3. Locate the test bench program in the gpbackup/master/plugins directory. For example:

   ```
   $ ls gpbackup/master/plugins/plugin_test_bench.sh
   ```

4. Copy the plugin executable program and the plugin configuration YAML file from your development system to the Greenplum Database master host. Note the file system location to which you copied the files.

5. Copy the plugin executable program from the Greenplum Database master host to the same file system location on each segment host.

6. If required, edit the plugin configuration YAML file to specify the absolute path of the plugin executable program that you just copied to the Greenplum segments.

7. Run the test bench program against the plugin. For example:

   ```
   $ gpbackup/master/plugins/plugin_test_bench.sh /path/to/pluginexec /path/to/plugincfg.yaml
   ```

8. Examine the test bench output. Your plugin passed the test bench if all output messages specify RUNNING and PASSED. For example:

   ```
   # ------------------------------
   # Starting gpbackup plugin tests
   # ------------------------------
   [RUNNING] plugin_api_version
   [PASSED] plugin_api_version
   [RUNNING] setup_plugin_for_backup
   [RUNNING] backup_file
   [RUNNING] setup_plugin_for_restore
   [RUNNING] restore_file
   [PASSED] setup_plugin_for_backup
   [PASSED] backup_file
   [PASSED] setup_plugin_for_restore
   [PASSED] restore_file
   ```
Packaging and Deploying a Backup/Restore Storage Plugin

Your backup/restore storage plugin is ready to be deployed to a Greenplum Database installation after the plugin passes your testing and the test bench verification. When you package the backup/restore storage plugin, consider the following:

- The backup/restore storage plugin must be installed in the same file system location on every host in the Greenplum Database cluster. Provide installation instructions for the plugin identifying the same.
- The `gpadmin` user must have permission to traverse the file system path to the backup/restore plugin executable program.
- Include a template configuration file with the plugin.
- Document the valid plugin configuration keywords, making sure to include the syntax of expected values.
- Document required `gpbackup` options and how they affect plugin processing.

backup_data

Plugin command to move streaming data from `stdin` to the remote storage system.

Synopsis

```
plugin_executable backup_data plugin_config_file data_filenamekey
```

Description

gpbackup invokes the `backup_data` plugin command on each segment host during a streaming backup. The `backup_data` implementation should read a potentially large stream of data from `stdin` and write the data to a single file on the remote storage system. The data is sent to the command as a single continuous stream per Greenplum Database segment. If `backup_data` modifies the data in any manner (i.e. compresses), `restore_data` must perform the reverse operation.

Name or maintain a mapping from the destination file to `data_filenamekey`. This will be the file key used for the restore operation.

Arguments

- `plugin_config_file` The absolute path to the plugin configuration YAML file.
- `data_filenamekey` The mapping key for a specially-named backup file for streamed data.
Exit Code

The `backup_data` command must exit with a value of 0 on success, non-zero if an error occurs. In the case of a non-zero exit code, `gpbackup` displays the contents of `stderr` to the user.

**backup_file**

Plugin command to move a backup file to the remote storage system.

**Synopsis**

```
plugin_executable backup_file plugin_config_file file_to_backup
```

**Description**

gpbackup invokes the `backup_file` plugin command on the master and each segment host for the file that `gpbackup` writes to a backup directory on local disk.

The `backup_file` implementation should process and move the file to the remote storage system. `gpbackup` does not remove the `file_to_backup` from the local system. Remove the file in the `backup_file` command, if appropriate.

**Arguments**

- `plugin_config_file`:
  The absolute path to the plugin configuration YAML file.

- `file_to_backup`:
  The absolute path to a local backup file generated by `gpbackup`.

Exit Code

The `backup_file` command must exit with a value of 0 on success, non-zero if an error occurs. In the case of a non-zero exit code, `gpbackup` displays the contents of `stderr` to the user.

**cleanup_plugin_for_backup**

Plugin command to clean up a storage plugin after backup.

**Synopsis**

```
plugin_executable cleanup_plugin_for_backup plugin_config_file local_backup_dir
```

**Description**

gpbackup invokes the `cleanup_plugin_for_backup` plugin command on the master and all segment hosts when a `gpbackup` operation completes, both in success and failure cases.

The `cleanup_plugin_for_backup` command should perform the actions necessary to clean up the remote storage system after a backup. Clean up activities may include removing remote directories or temporary files created during the backup, disconnecting from the backup service, etc.

**Arguments**

- `plugin_config_file`:
  The absolute path to the plugin configuration YAML file.

- `local_backup_dir`
The local directory on the Greenplum Database host (master and segments) to which gpbackup wrote backup files.

**Exit Code**

The cleanup_plugin_for_backup command must exit with a value of 0 on success, non-zero if an error occurs. In the case of a non-zero exit code, gpbackup displays the contents of stderr to the user.

**cleanup_plugin_for_restore**

Plugin command to clean up a storage plugin after restore.

**Synopsis**

```
plugin_executable cleanup_plugin_for_restore plugin_config_file local_backup_dir
```

**Description**

gprestore invokes the cleanup_plugin_for_restore plugin command on the master and all segment hosts when a gprestore operation completes, both in success and failure cases.

The cleanup_plugin_for_restore implementation should perform the actions necessary to clean up the remote storage system after a restore. Clean up activities may include removing remote directories or temporary files created during the restore, disconnecting from the backup service, etc.

**Arguments**

- **plugin_config_file**
  
The absolute path to the plugin configuration YAML file.

- **local_backup_dir**
  
The local directory on the Greenplum Database host (master and segments) from which gprestore reads backup files.

**Exit Code**

The cleanup_plugin_for_restore command must exit with a value of 0 on success, non-zero if an error occurs. In the case of a non-zero exit code, gprestore displays the contents of stderr to the user.

**plugin_api_version**

Plugin command to display the supported Backup Storage Plugin API version.

**Synopsis**

```
plugin_executable plugin_api_version
```

**Description**

gpbackup and gprestore invoke the plugin_api_version plugin command before a backup or restore operation to determine Backup Storage Plugin API version compatibility.

**Return Value**

The plugin_api_version command must return the Backup Storage Plugin API version number supported by the storage plugin, "0.1.0".
**restore_data**

Plugin command to stream data from the remote storage system to `stdout`.

** Synopsis **

```
plugin_executable restore_data plugin_config_file data_filenamekey
```

** Description **

`gprestore` invokes the `restore_data` plugin command on each segment host when a restoring a streaming backup.

The `restore_data` implementation should read a potentially large data file named or mapped to `data_filenamekey` from the remote storage system and write the contents to `stdout`. If the `backup_data` command modified the data in any way (i.e. compressed), `restore_data` should perform the reverse operation.

** Arguments **

- `plugin_config_file`
  - The absolute path to the plugin configuration YAML file.
- `data_filenamekey`
  - The mapping key to a backup file on the remote storage system. `data_filenamekey` is the same key provided to the `backup_data` command.

** Exit Code **

The `restore_data` command must exit with a value of 0 on success, non-zero if an error occurs. In the case of a non-zero exit code, `gprestore` displays the contents of `stderr` to the user.

** restore_file **

Plugin command to move a backup file from the remote storage system.

** Synopsis **

```
plugin_executable restore_file plugin_config_file file_to_restore
```

** Description **

`gprestore` invokes the `restore_file` plugin command on the master and each segment host for the file that `gprestore` will read from a backup directory on local disk.

The `restore_file` command should process and move the file from the remote storage system to `file_to_restore` on the local host.

** Arguments **

- `plugin_config_file`
  - The absolute path to the plugin configuration YAML file.
- `file_to_restore`
  - The absolute path to which to move a backup file from the remote storage system.
Exit Code

The `restore_file` command must exit with a value of 0 on success, non-zero if an error occurs. In the case of a non-zero exit code, gprestore displays the contents of `stderr` to the user.

`setup_plugin_for_backup`

Plugin command to initialize a storage plugin for the backup operation.

Synopsis

```
plugin_executable setup_plugin_for_backup plugin_config_file local_backup_dir
```

Description

gpbackup invokes the `setup_plugin_for_backup` plugin command on the master and all segment hosts during `gpbackup` initialization phase.

The `setup_plugin_for_backup` command should perform the activities necessary to initialize the remote storage system before backup begins. Set up activities may include creating remote directories, validating connectivity to the remote storage system, checking disks, and so forth.

Arguments

- `plugin_config_file`
  
The absolute path to the plugin configuration YAML file.
- `local_backup_dir`
  
The local directory on the Greenplum Database host (master and segments) to which `gpbackup` will write backup files. `gpbackup` creates this local directory.

Exit Code

The `setup_plugin_for_backup` command must exit with a value of 0 on success, non-zero if an error occurs. In the case of a non-zero exit code, `gpbackup` displays the contents of `stderr` to the user.

`setup_plugin_for_restore`

Plugin command to initialize a storage plugin for the restore operation.

Synopsis

```
plugin_executable setup_plugin_for_restore plugin_config_file local_backup_dir
```

Description

gprestore invokes the `setup_plugin_for_restore` plugin command on the master and all segment hosts during `gprestore` initialization phase.

The `setup_plugin_for_restore` command should perform the activities necessary to initialize the remote storage system before a restore operation begins. Set up activities may include creating remote directories, validating connectivity to the remote storage system, etc.

Arguments

- `plugin_config_file`
  
The absolute path to the plugin configuration YAML file.
- `local_backup_dir`
The local directory on the Greenplum Database host (master and segments) from which `gprestore` reads backup files. `setup_plugin_for_restore` must create this directory if it does not already exist.

**Exit Code**

The `setup_plugin_for_restore` command must exit with a value of 0 on success, non-zero if an error occurs. In the case of a non-zero exit code, `gprestore` displays the contents of `stderr` to the user.

**Expanding a Greenplum System**

To scale up performance and storage capacity, expand your Greenplum system by adding hosts to the array.

Data warehouses typically grow over time as additional data is gathered and the retention periods increase for existing data. At times, it is necessary to increase database capacity to consolidate different data warehouses into a single database. Additional computing capacity (CPU) may also be needed to accommodate newly added analytics projects. Although it is wise to provide capacity for growth when a system is initially specified, it is not generally possible to invest in resources long before they are required. Therefore, you should expect to execute a database expansion project periodically.

Because of the Greenplum MPP architecture, when you add resources to the system, the capacity and performance are the same as if the system had been originally implemented with the added resources. Unlike data warehouse systems that require substantial downtime in order to dump and restore the data, expanding a Greenplum Database system is a phased process with minimal downtime. Regular and ad hoc workloads can continue while data is redistributed and transactional consistency is maintained. The administrator can schedule the distribution activity to fit into ongoing operations and can pause and resume as needed. Tables can be ranked so that datasets are redistributed in a prioritized sequence, either to ensure that critical workloads benefit from the expanded capacity sooner, or to free disk space needed to redistribute very large tables.

The expansion process uses standard Greenplum Database operations so it is transparent and easy for administrators to troubleshoot. Segment mirroring and any replication mechanisms in place remain active, so fault-tolerance is uncompromised and disaster recovery measures remain effective.

**System Expansion Overview**

Data warehouses typically grow over time, often at a continuous pace, as additional data is gathered and the retention period increases for existing data. At times, it is necessary to increase database capacity to consolidate disparate data warehouses into a single database. The data warehouse may also require additional computing capacity (CPU) to accommodate added analytics projects. It is good to provide capacity for growth when a system is initially specified, but even if you anticipate high rates of growth, it is generally unwise to invest in capacity long before it is required. Database expansion, therefore, is a project that you should expect to have to execute periodically.

When you expand your database, you should expect the following qualities:

- Scalable capacity and performance. When you add resources to a Greenplum Database, the capacity and performance are the same as if the system had been originally implemented with the added resources.
- Uninterrupted service during expansion. Regular workloads, both scheduled and ad-hoc, are not interrupted. A short, scheduled downtime period is required to initialize the new servers, similar to downtime required to restart the system. The length of downtime is unrelated to the size of the system before or after expansion.
- Transactional consistency.
- Fault tolerance. During the expansion, standard fault-tolerance mechanisms—such as segment mirroring—remain active, consistent, and effective.
- Replication and disaster recovery. Any existing replication mechanisms continue to function during expansion. Restore mechanisms needed in case of a failure or catastrophic event remain effective.
• Transparency of process. The expansion process employs standard Greenplum Database mechanisms, so administrators can diagnose and troubleshoot any problems.
• Configurable process. Expansion can be a long running process, but it can be fit into a schedule of ongoing operations. The expansion schema's tables allow administrators to prioritize the order in which tables are redistributed, and the expansion activity can be paused and resumed.

The planning and physical aspects of an expansion project are a greater share of the work than expanding the database itself. It will take a multi-discipline team to plan and execute the project. For on-premise installations, space must be acquired and prepared for the new servers. The servers must be specified, acquired, installed, cabled, configured, and tested. For cloud deployments, similar plans should also be made. Planning New Hardware Platforms describes general considerations for deploying new hardware.

After you provision the new hardware platforms and set up their networks, configure the operating systems and run performance tests using Greenplum utilities. The Greenplum Database software distribution includes utilities that are helpful to test and burn-in the new servers before beginning the software phase of the expansion. See Preparing and Adding Nodes for steps to prepare the new hosts for Greenplum Database.

Once the new servers are installed and tested, the software phase of the Greenplum Database expansion process begins. The software phase is designed to be minimally disruptive, transactionally consistent, reliable, and flexible.

• There is a brief period of downtime while the new segment hosts are initialized and the system is prepared for the expansion process. This downtime can be scheduled to occur during a period of low activity to avoid disrupting ongoing business operations. During the initialization process, the following tasks are performed:
  • Greenplum Database software is installed.
  • Databases and database objects are created on the new segment hosts.
  • An expansion schema is created in the master database to control the expansion process.
  • The distribution policy for each table is changed to DISTRIBUTED RANDOMLY.
  • The system is restarted and applications resume.

  • New segments are immediately available and participate in new queries and data loads. The existing data, however, is skewed. It is concentrated on the original segments and must be redistributed across the new total number of primary segments.
  • Because tables now have a random distribution policy, the optimizer creates query plans that are not dependent on distribution keys. Some queries will be less efficient because more data motion operators are needed.
  • Using the expansion control tables as a guide, tables and partitions are redistributed. For each table:
    • An ALTER TABLE statement is issued to change the distribution policy back to the original policy. This causes an automatic data redistribution operation, which spreads data across all of the servers, old and new, according to the original distribution policy.
    • The table's status is updated in the expansion control tables.
    • The query optimizer creates more efficient execution plans by including the distribution key in the planning.
  • When all tables have been redistributed, the expansion is complete.

Redistributing data is a long-running process that creates a large volume of network and disk activity. It can take days to redistribute some very large databases. To minimize the effects of the increased activity on business operations, system administrators can pause and resume expansion activity on an ad hoc basis, or according to a predetermined schedule. Datasets can be prioritized so that critical applications benefit first from the expansion.

In a typical operation, you run the gpexpand utility four times with different options during the complete expansion process.
1. To *create an expansion input file*:
   
   ```
   gpexpand -f hosts_file
   ```

2. To *initialize segments and create the expansion schema*:
   
   ```
   gpexpand -i input_file -D database_name
   ```

   The `gpexpand` command creates a data directory, copies user tables from all existing databases on the new segments, and captures metadata for each table in an expansion schema for status tracking. After this process completes, the expansion operation is committed and irrevocable.

3. *To redistribute tables*:
   
   ```
   gpexpand -d duration
   ```

   At initialization, `gpexpand` nullifies hash distribution policies on tables in all existing databases, except for parent tables of a partitioned table, and sets the distribution policy for all tables to random distribution.

   To complete system expansion, you must run `gpexpand` to redistribute data tables across the newly added segments. Depending on the size and scale of your system, redistribution can be accomplished in a single session during low-use hours, or you can divide the process into batches over an extended period. Each table or partition is unavailable for read or write operations during redistribution. As each table is redistributed across the new segments, database performance should incrementally improve until it exceeds pre-expansion performance levels.

   You may need to run `gpexpand` several times to complete the expansion in large-scale systems that require multiple redistribution sessions. `gpexpand` can benefit from explicit table redistribution ranking; see *Planning Table Redistribution*.

   Users can access Greenplum Database after initialization completes and the system is back online, but they may experience performance degradation on systems that rely heavily on hash distribution of tables. Normal operations such as ETL jobs, user queries, and reporting can continue, though users might experience slower response times.

   When a table has a random distribution policy, Greenplum Database cannot enforce unique constraints (such as `PRIMARY KEY`). This can affect your ETL and loading processes until table redistribution completes because duplicate rows do not issue a constraint violation error.

4. To *remove the expansion schema*:
   
   ```
   gpexpand -c
   ```

   For information about the `gpexpand` utility and the other utilities that are used for system expansion, see the *Greenplum Database Utility Guide*.

---

**Planning Greenplum System Expansion**

Careful planning will help to ensure a successful Greenplum expansion project.

The topics in this section help to ensure that you are prepared to execute a system expansion.

- *System Expansion Checklist* is a checklist you can use to prepare for and execute the system expansion process.
- *Planning New Hardware Platforms* covers planning for acquiring and setting up the new hardware.
- *Planning New Segment Initialization* provides information about planning to initialize new segment hosts with `gpexpand`.
- *Planning Table Redistribution* provides information about planning the data redistribution after the new segment hosts have been initialized.
**System Expansion Checklist**
This checklist summarizes the tasks for a Greenplum Database system expansion.

**Table 31: Greenplum Database System Expansion Checklist**

<table>
<thead>
<tr>
<th>Online Pre-Expansion Tasks</th>
<th>* System is up and available</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Devise and execute a plan for ordering, building, and networking new hardware platforms, or provisioning cloud resources.</td>
</tr>
<tr>
<td></td>
<td>Devise a database expansion plan. Map the number of segments per host, schedule the downtime period for testing performance and creating the expansion schema, and schedule the intervals for table redistribution.</td>
</tr>
<tr>
<td></td>
<td>Perform a complete schema dump.</td>
</tr>
<tr>
<td></td>
<td>Install Greenplum Database binaries on new hosts.</td>
</tr>
<tr>
<td></td>
<td>Copy SSH keys to the new hosts (gpssh-exkeys).</td>
</tr>
<tr>
<td></td>
<td>Validate the operating system environment of the new hardware or cloud resources (gpcheck).</td>
</tr>
<tr>
<td></td>
<td>Validate disk I/O and memory bandwidth of the new hardware or cloud resources (gpcheckperf).</td>
</tr>
<tr>
<td></td>
<td>Validate that the master data directory has no extremely large files in the <em>pg_log</em> or <em>gpperfmon/data</em> directories.</td>
</tr>
<tr>
<td></td>
<td>Validate that there are no catalog issues (gpcheckcat).</td>
</tr>
<tr>
<td></td>
<td>Prepare an expansion input file (gpexpand).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Offline Expansion Tasks</th>
<th>* The system is locked and unavailable to all user activity during this process.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Validate the operating system environment of the combined existing and new hardware or cloud resources (gpcheck).</td>
</tr>
<tr>
<td></td>
<td>Validate disk I/O and memory bandwidth of the combined existing and new hardware or cloud resources (gpcheckperf).</td>
</tr>
<tr>
<td></td>
<td>Initialize new segments into the array and create an expansion schema (gpexpand-i <em>input_file</em>).</td>
</tr>
</tbody>
</table>
Online Expansion and Table Redistribution

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>* System is up and available</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Before you start table redistribution, stop any automated snapshot processes or other processes that consume disk space.</td>
</tr>
<tr>
<td></td>
<td>Redistribute tables through the expanded system (gpexpand).</td>
</tr>
<tr>
<td></td>
<td>Remove expansion schema (gpexpand -c).</td>
</tr>
<tr>
<td></td>
<td>Run analyze to update distribution statistics. During the expansion, use gpexpand -a, and post-expansion, use analyze.</td>
</tr>
</tbody>
</table>

**Planning New Hardware Platforms**

A deliberate, thorough approach to deploying compatible hardware greatly minimizes risk to the expansion process.

Hardware resources and configurations for new segment hosts should match those of the existing hosts. Work with *Greenplum Platform Engineering* before making a hardware purchase to expand Greenplum Database.

The steps to plan and set up new hardware platforms vary for each deployment. Some considerations include how to:

- Prepare the physical space for the new hardware; consider cooling, power supply, and other physical factors.
- Determine the physical networking and cabling required to connect the new and existing hardware.
- Map the existing IP address spaces and developing a networking plan for the expanded system.
- Capture the system configuration (users, profiles, NICs, and so on) from existing hardware to use as a detailed list for ordering new hardware.
- Create a custom build plan for deploying hardware with the desired configuration in the particular site and environment.

After selecting and adding new hardware to your network environment, ensure you perform the burn-in tasks described in *Verifying OS Settings*.

**Planning New Segment Initialization**

Expanding Greenplum Database requires a limited period of system downtime. During this period, run gpexpand to initialize new segments into the array and create an expansion schema.

The time required depends on the number of schema objects in the Greenplum system and other factors related to hardware performance. In most environments, the initialization of new segments requires less than thirty minutes offline.

*Note:* After you begin initializing new segments, you can no longer restore the system using backup files created for the pre-expansion system. When initialization successfully completes, the expansion is committed and cannot be rolled back.

**Planning Mirror Segments**

If your existing array has mirror segments, the new segments must have mirroring configured. If there are no mirrors configured for existing segments, you cannot add mirrors to new hosts with the gpexpand utility.
For Greenplum Database arrays with mirror segments, ensure you add enough new host machines to accommodate new mirror segments. The number of new hosts required depends on your mirroring strategy:

- **Spread Mirroring** — Add at least one more host to the array than the number of segments per host. The number of separate hosts must be greater than the number of segment instances per host to ensure even spreading.

- **Grouped Mirroring** — Add at least two new hosts so the mirrors for the first host can reside on the second host, and the mirrors for the second host can reside on the first. For more information, see About Segment Mirroring.

### Increasing Segments Per Host

By default, new hosts are initialized with as many primary segments as existing hosts have. You can increase the segments per host or add new segments to existing hosts.

For example, if existing hosts currently have two segments per host, you can use `gpexpand` to initialize two additional segments on existing hosts for a total of four segments and four new segments on new hosts.

The interactive process for creating an expansion input file prompts for this option; you can also specify new segment directories manually in the input configuration file. For more information, see Creating an Input File for System Expansion.

### About the Expansion Schema

At initialization, `gpexpand` creates an expansion schema. If you do not specify a database at initialization (`gpexpand -D`), the schema is created in the database indicated by the `PGDATABASE` environment variable.

The expansion schema stores metadata for each table in the system so its status can be tracked throughout the expansion process. The expansion schema consists of two tables and a view for tracking expansion operation progress:

- `gpexpand.status`
- `gpexpand.status_detail`
- `gpexpand.expansion_progress`

Control expansion process aspects by modifying `gpexpand.status_detail`. For example, removing a record from this table prevents the system from expanding the table across new segments. Control the order in which tables are processed for redistribution by updating the `rank` value for a record. For more information, see Ranking Tables for Redistribution.

### Planning Table Redistribution

Table redistribution is performed while the system is online. For many Greenplum systems, table redistribution completes in a single `gpexpand` session scheduled during a low-use period. Larger systems may require multiple sessions and setting the order of table redistribution to minimize performance impact. Complete the table redistribution in one session if possible.

**Important:** To perform table redistribution, your segment hosts must have enough disk space to temporarily hold a copy of your largest table. All tables are unavailable for read and write operations during redistribution.

The performance impact of table redistribution depends on the size, storage type, and partitioning design of a table. For any given table, redistributing it with `gpexpand` takes as much time as a `CREATE TABLE AS SELECT` operation would. When redistributing a terabyte-scale fact table, the expansion utility can use much of the available system resources, which could affect query performance or other database workloads.
Managing Redistribution in Large-Scale Greenplum Systems

You can manage the order in which tables are redistributed by adjusting their ranking. See Ranking Tables for Redistribution. Manipulating the redistribution order can help adjust for limited disk space and restore optimal query performance for high-priority queries sooner.

When planning the redistribution phase, consider the impact of the exclusive lock taken on each table during redistribution. User activity on a table can delay its redistribution, but also tables are unavailable for user activity during redistribution.

Systems with Abundant Free Disk Space

In systems with abundant free disk space (required to store a copy of the largest table), you can focus on restoring optimum query performance as soon as possible by first redistributing important tables that queries use heavily. Assign high ranking to these tables, and schedule redistribution operations for times of low system usage. Run one redistribution process at a time until large or critical tables have been redistributed.

Systems with Limited Free Disk Space

If your existing hosts have limited disk space, you may prefer to first redistribute smaller tables (such as dimension tables) to clear space to store a copy of the largest table. Available disk space on the original segments increases as each table is redistributed across the expanded array. When enough free space exists on all segments to store a copy of the largest table, you can redistribute large or critical tables. Redistribution of large tables requires exclusive locks; schedule this procedure for off-peak hours.

Also consider the following:

- Run multiple parallel redistribution processes during off-peak hours to maximize available system resources.
- When running multiple processes, operate within the connection limits for your Greenplum system. For information about limiting concurrent connections, see Limiting Concurrent Connections.

Redistributing Append-Optimized and Compressed Tables

gpexpand redistributes append-optimized and compressed append-optimized tables at different rates than heap tables. The CPU capacity required to compress and decompress data tends to increase the impact on system performance. For similar-sized tables with similar data, you may find overall performance differences like the following:

- Uncompressed append-optimized tables expand 10% faster than heap tables.
- zlib-compressed append-optimized tables expand at a significantly slower rate than uncompressed append-optimized tables, potentially up to 80% slower.
- Systems with data compression such as ZFS/LZJB take longer to redistribute.

**Important:** If your system nodes use data compression, use identical compression on new nodes to avoid disk space shortage.

Redistributing Tables with Primary Key Constraints

There is a time period during which primary key constraints cannot be enforced between the initialization of new segments and successful table redistribution. Duplicate data inserted into tables during this period prevents the expansion utility from redistributing the affected tables.

After a table is redistributed, the primary key constraint is properly enforced again. If an expansion process violates constraints, the expansion utility logs errors and displays warnings when it completes. To fix constraint violations, perform one of the following remedies:

- Clean up duplicate data in the primary key columns, and re-run gpexpand.
- Drop the primary key constraints, and re-run gpexpand.
**Redistributing Tables with User-Defined Data Types**

You cannot perform redistribution with the expansion utility on tables with dropped columns of user-defined data types. To redistribute tables with dropped columns of user-defined types, first re-create the table using `CREATE TABLE AS SELECT`. After this process removes the dropped columns, redistribute the table with `gpexpand`.

**Redistributing Partitioned Tables**

Because the expansion utility can process each individual partition on a large table, an efficient partition design reduces the performance impact of table redistribution. Only the child tables of a partitioned table are set to a random distribution policy. The read/write lock for redistribution applies to only one child table at a time.

**Redistributing Indexed Tables**

Because the `gpexpand` utility must re-index each indexed table after redistribution, a high level of indexing has a large performance impact. Systems with intensive indexing have significantly slower rates of table redistribution.

**Preparing and Adding Nodes**

Verify your new nodes are ready for integration into the existing Greenplum system.

To prepare new system nodes for expansion, install the Greenplum Database software binaries, exchange the required SSH keys, and run performance tests.

Run performance tests first on the new nodes and then all nodes. Run the tests on all nodes with the system offline so user activity does not distort results.

Generally, you should run performance tests when an administrator modifies node networking or other special conditions in the system. For example, if you will run the expanded system on two network clusters, run tests on each cluster.

**Adding New Nodes to the Trusted Host Environment**

New nodes must exchange SSH keys with the existing nodes to enable Greenplum administrative utilities to connect to all segments without a password prompt. Perform the key exchange process twice.

First perform the process as `root`, for administration convenience, and then as the user `gpadmin`, for management utilities. Perform the following tasks in order:

1. **To exchange SSH keys as root**
2. **To create the gpadmin user**
3. **To exchange SSH keys as the gpadmin user**

   **Note:** The Greenplum Database segment host naming convention is `sdwN` where `sdw` is a prefix and `N` is an integer (`sdw1`, `sdw2` and so on). For hosts with multiple interfaces, the convention is to append a dash (`-`) and number to the host name. For example, `sdw1-1` and `sdw1-2` are the two interface names for host `sdw1`.

**To exchange SSH keys as root**

1. Create a host file with the existing host names in your array and a separate host file with the new expansion host names. For existing hosts, you can use the same host file used to set up SSH keys in the system. In the files, list all hosts (master, backup master, and segment hosts) with one name per line and no extra lines or spaces. Exchange SSH keys using the configured host names for a given host.
if you use a multi-NIC configuration. In this example, mdw is configured with a single NIC, and sdw1, sdw2, and sdw3 are configured with 4 NICs:

```
mdw
sdw1-1
sdw1-2
sdw1-3
sdw1-4
sdw2-1
sdw2-2
sdw2-3
sdw2-4
sdw3-1
sdw3-2
sdw3-3
sdw3-4
```

2. Log in as root on the master host, and source the greenplum_path.sh file from your Greenplum installation.

```
$ su -
# source /usr/local/greenplum-db/greenplum_path.sh
```

3. Run the gpssh-exkeys utility referencing the host list files. For example:

```
# gpssh-exkeys -e /home/gpadmin/existing_hosts_file -x /home/gpadmin/new_hosts_file
```

4. gpssh-exkeys checks the remote hosts and performs the key exchange between all hosts. Enter the root user password when prompted. For example:

```
***Enter password for root@hostname: <root_password>
```

To create the gpadmin user

1. Use gpssh to create the gpadmin user on all the new segment hosts (if it does not exist already). Use the list of new hosts you created for the key exchange. For example:

```
# gpssh -f new_hosts_file '/usr/sbin/useradd gpadmin -d /home/gpadmin -s /bin/bash'
```

2. Set a password for the new gpadmin user. On Linux, you can do this on all segment hosts simultaneously using gpssh. For example:

```
# gpssh -f new_hosts_file 'echo gpadmin_password | passwd gpadmin --stdin'
```

3. Verify the gpadmin user has been created by looking for its home directory:

```
# gpssh -f new_hosts_file ls -l /home
```

To exchange SSH keys as the gpadmin user

1. Log in as gpadmin and run the gpssh-exkeys utility referencing the host list files. For example:

```
# gpssh-exkeys -e /home/gpadmin/existing_hosts_file -x /home/gpadmin/new_hosts_file
```
2. `gpssh-exkeys` will check the remote hosts and perform the key exchange between all hosts. Enter the `gpadmin` user password when prompted. For example:

```
***Enter password for gpadmin@hostname: <gpadmin_password>
```

### Verifying OS Settings

Use the `gpcheck` utility to verify all new hosts in your array have the correct OS settings to run Greenplum Database software.

#### To run gpcheck

1. Log in on the master host as the user who will run your Greenplum Database system (for example, `gpadmin`).

   ```sh
   $ su - gpadmin
   ```

2. Run the `gpcheck` utility using your host file for new hosts. For example:

   ```sh
   $ gpcheck -f new_hosts_file
   ```

### Validating Disk I/O and Memory Bandwidth

Use the `gpcheckperf` utility to test disk I/O and memory bandwidth.

#### To run gpcheckperf

1. Run the `gpcheckperf` utility using the host file for new hosts. Use the `-d` option to specify the file systems you want to test on each host. You must have write access to these directories. For example:

   ```sh
   $ gpcheckperf -f new_hosts_file -d /data1 -d /data2 -v
   ```

2. The utility may take a long time to perform the tests because it is copying very large files between the hosts. When it is finished, you will see the summary results for the Disk Write, Disk Read, and Stream tests.

   For a network divided into subnets, repeat this procedure with a separate host file for each subnet.

### Integrating New Hardware into the System

Before initializing the system with the new segments, shut down the system with `gpstop` to prevent user activity from skewing performance test results. Then, repeat the performance tests using host files that include all nodes, existing and new:

- Verifying OS Settings
- Validating Disk I/O and Memory Bandwidth

### Initializing New Segments

Use the `gpexpand` utility to initialize the new segments, create the expansion schema, and set a system-wide random distribution policy for the database.

The first time you run `gpexpand` with a valid input file it creates the expansion schema and sets the distribution policy for all tables to `DISTRIBUTED RANDOMLY`. After these steps are completed, running `gpexpand` detects if the expansion schema has been created and, if so, performs table redistribution.

- Creating an Input File for System Expansion
- Running `gpexpand` to Initialize New Segments
- Rolling Back a Failed Expansion Setup
Creating an Input File for System Expansion

To begin expansion, `gpexpand` requires an input file containing information about the new segments and hosts. If you run `gpexpand` without specifying an input file, the utility displays an interactive interview that collects the required information and automatically creates an input file.

If you create the input file using the interactive interview, you may specify a file with a list of expansion hosts in the interview prompt. If your platform or command shell limits the length of the host list, specifying the hosts with `-f` may be mandatory.

Creating an input file in Interactive Mode

Before you run `gpexpand` to create an input file in interactive mode, ensure you know:

• The number of new hosts (or a hosts file)
• The new hostnames (or a hosts file)
• The mirroring strategy used in existing hosts, if any
• The number of segments to add per host, if any

The utility automatically generates an input file based on this information, `dbid`, `content ID`, and data directory values stored in `gp_segment_configuration`, and saves the file in the current directory.

To create an input file in interactive mode

1. Log in on the master host as the user who will run your Greenplum Database system; for example, `gpadmin`.
2. Run `gpexpand`. The utility displays messages about how to prepare for an expansion operation, and it prompts you to quit or continue.
   
   Optionally, specify a hosts file using `-f`. For example:

   ```
   $ gpexpand -f /home/gpadmin/new_hosts_file
   ```

3. At the prompt, select `Y` to continue.
4. Unless you specified a hosts file using `-f`, you are prompted to enter hostnames. Enter a comma separated list of the hostnames of the new expansion hosts. Do not include interface hostnames. For example:

   ```
   > sdw4, sdw5, sdw6, sdw7
   ```

   To add segments to existing hosts only, enter a blank line at this prompt. Do not specify `localhost` or any existing host name.

5. Enter the mirroring strategy used in your system, if any. Options are `spread|grouped|none`. The default setting is `grouped`.

   Ensure you have enough hosts for the selected grouping strategy. For more information about mirroring, see Planning Mirror Segments.

6. Enter the number of new primary segments to add, if any. By default, new hosts are initialized with the same number of primary segments as existing hosts. Increase segments per host by entering a number greater than zero. The number you enter will be the number of additional segments initialized on all hosts. For example, if existing hosts currently have two segments each, entering a value of 2 initializes two more segments on existing hosts, and four segments on new hosts.

7. If you are adding new primary segments, enter the new primary data directory root for the new segments. Do not specify the actual data directory name, which is created automatically by `gpexpand` based on the existing data directory names.

   For example, if your existing data directories are as follows:

   ```
   /gpdata/primary/gp0
   ```
then enter the following (one at each prompt) to specify the data directories for two new primary segments:

```
/gpdata/primary
/gpdata/primary
```

When the initialization runs, the utility creates the new directories `gp2` and `gp3` under `/gpdata/primary`.

8. If you are adding new mirror segments, enter the new mirror data directory root for the new segments. Do not specify the data directory name; it is created automatically by `gpexpand` based on the existing data directory names.

For example, if your existing data directories are as follows:

```
/gpdata/mirror/gp0
/gpdata/mirror/gp1
```

enter the following (one at each prompt) to specify the data directories for two new mirror segments:

```
/gpdata/mirror
/gpdata/mirror
```

When the initialization runs, the utility will create the new directories `gp2` and `gp3` under `/gpdata/mirror`.

These primary and mirror root directories for new segments must exist on the hosts, and the user running `gpexpand` must have permissions to create directories in them.

After you have entered all required information, the utility generates an input file and saves it in the current directory. For example:

```
gpexpand_inputfile_yyyymmdd_145134
```

**Expansion Input File Format**

Use the interactive interview process to create your own input file unless your expansion scenario has atypical needs.

The format for expansion input files is:

```
hostname:address:port:fseolocation:dbid:content:preferred_role:replication_port
```

For example:

```
sdw5:sdw5-1:50011:/gpdata/primary/gp9:11:9:p:53011
sdw5:sdw5-2:50012:/gpdata/primary/gp10:12:10:p:53011
sdw5:sdw5-1:60012:/gpdata/mirror/gp10:14:10:m:63011
```

For each new segment, this format of expansion input file requires the following:

**Table 32: Data for the expansion configuration file**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Valid Values</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>hostname</td>
<td>Hostname</td>
<td>Hostname for the segment host.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Valid Values</td>
<td>Description</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>port</td>
<td>An available port number</td>
<td>Database listener port for the segment, incremented on the existing segment port base number.</td>
</tr>
<tr>
<td>fselocation</td>
<td>Directory name</td>
<td>The data directory (filesystem) location for a segment as per the pg_filespace_entry system catalog.</td>
</tr>
<tr>
<td>dbid</td>
<td>Integer. Must not conflict with existing dbid values.</td>
<td>Database ID for the segment. The values you enter should be incremented sequentially from existing dbid values shown in the system catalog gp_segment_configuration. For example, to add four nodes to an existing ten-segment array with dbid values of 1-10, list new dbid values of 11, 12, 13 and 14.</td>
</tr>
<tr>
<td>content</td>
<td>Integer. Must not conflict with existing content values.</td>
<td>The content ID of the segment. A primary segment and its mirror should have the same content ID, incremented sequentially from existing values. For more information, see content in the reference for gp_segment_configuration.</td>
</tr>
<tr>
<td>preferred_role</td>
<td>p</td>
<td>m</td>
</tr>
<tr>
<td>replication_port</td>
<td>An available port number</td>
<td>File replication port for the segment, incremented on the existing segment replication_port base number.</td>
</tr>
</tbody>
</table>

**Running gpexpand to Initialize New Segments**

After you have created an input file, run `gpexpand` to initialize new segments. The utility automatically stops Greenplum Database segment initialization and restarts the system when the process finishes.

**To run gpexpand with an input file**

1. Log in on the master host as the user who will run your Greenplum Database system; for example, `gpadmin`.
2. Run the `gpexpand` utility, specifying the input file with `-i`. Optionally, use `-D` to specify the database in which to create the expansion schema. For example:

   ```bash
   $ gpexpand -i input_file -D database1
   ```

   The utility detects if an expansion schema exists for the Greenplum Database system. If a schema exists, remove it with `gpexpand -c` before you start a new expansion operation. See *Removing the Expansion Schema*.  

---

**Parameter**

- **port**: An available port number. Database listener port for the segment, incremented on the existing segment port base number.

**Valid Values**

- **port**: An available port number.

**Description**

- **fselocation**: Directory name. The data directory (filesystem) location for a segment as per the pg_filespace_entry system catalog.

- **dbid**: Integer. Must not conflict with existing dbid values. Database ID for the segment. The values you enter should be incremented sequentially from existing dbid values shown in the system catalog gp_segment_configuration. For example, to add four nodes to an existing ten-segment array with dbid values of 1-10, list new dbid values of 11, 12, 13 and 14.

- **content**: Integer. Must not conflict with existing content values. The content ID of the segment. A primary segment and its mirror should have the same content ID, incremented sequentially from existing values. For more information, see content in the reference for gp_segment_configuration.

- **preferred_role**: p | m. Determines whether this segment is a primary or mirror. Specify p for primary and m for mirror.

- **replication_port**: An available port number. File replication port for the segment, incremented on the existing segment replication_port base number.
When the new segments are initialized and the expansion schema is created, the utility prints a success message and exits.

When the initialization process completes, you can connect to Greenplum Database and view the expansion schema. The schema resides in the database you specified with `-D` or in the database specified by the `PGDATABASE` environment variable. For more information, see *About the Expansion Schema*.

### Rolling Back a Failed Expansion Setup

You can roll back an expansion setup operation only if the operation fails.

If the expansion fails during the initialization step, while the database is down, you must first restart the database in master-only mode by running the `gpstart -m` command.

Roll back the failed expansion with the following command, specifying the database that contains the expansion schema:

```
gpexpand --rollback -D database_name
```

### Redistributing Tables

Redistribute tables to balance existing data over the newly expanded cluster.

After creating an expansion schema, you can bring Greenplum Database back online and redistribute tables across the entire array with `gpexpand`. Aim to run this during low-use hours when the utility's CPU usage and table locks have minimal impact on operations. Rank tables to redistribute the largest or most critical tables first.

**Note:** When redistributing data, Greenplum Database must be running in production mode. Greenplum Database cannot be restricted mode or in master mode. The `gpstart` options `-R` or `-m` cannot be specified to start Greenplum Database.

While table redistribution is underway, any new tables or partitions created are distributed across all segments exactly as they would be under normal operating conditions. Queries can access all segments, even before the relevant data is redistributed to tables on the new segments. The table or partition being redistributed is locked and unavailable for read or write operations. When its redistribution completes, normal operations resume.

- Ranking Tables for Redistribution
- Redistributing Tables Using `gpexpand`
- Monitoring Table Redistribution

### Ranking Tables for Redistribution

For large systems, you can control the table redistribution order. Adjust tables' `rank` values in the expansion schema to prioritize heavily-used tables and minimize performance impact. Available free disk space can affect table ranking; see *Managing Redistribution in Large-Scale Greenplum Systems*.

To rank tables for redistribution by updating `rank` values in `gpexpand.status_detail`, connect to Greenplum Database using `psql` or another supported client. Update `gpexpand.status_detail` with commands such as:

```
=> UPDATE gpexpand.status_detail SET rank=10;
=> UPDATE gpexpand.status_detail SET rank=1 WHERE fq_name = 'public.lineitem';
=> UPDATE gpexpand.status_detail SET rank=2 WHERE fq_name = 'public.orders';
```

These commands lower the priority of all tables to 10 and then assign a rank of 1 to `lineitem` and a rank of 2 to `orders`. When table redistribution begins, `lineitem` is redistributed first, followed by `orders` and
all other tables in \texttt{gpexpand.status\_detail}. To exclude a table from redistribution, remove the table from \texttt{gpexpand.status\_detail}.

\section*{Redistributing Tables Using \texttt{gpexpand}}

\textbf{To redistribute tables with \texttt{gpexpand}}

1. Log in on the master host as the user who will run your Greenplum Database system, for example, \texttt{gpadmin}.
2. Run the \texttt{gpexpand} utility. You can use the \texttt{-d} or \texttt{-e} option to define the expansion session time period. For example, to run the utility for up to 60 consecutive hours:

\begin{verbatim}
$ gpexpand -d 60:00:00
\end{verbatim}

The utility redistributes tables until the last table in the schema completes or it reaches the specified duration or end time. \texttt{gpexpand} updates the status and time in \texttt{gpexpand.status} when a session starts and finishes.

\section*{Monitoring Table Redistribution}

You can query the expansion schema during the table redistribution process. The view \texttt{gpexpand.expansion\_progress} provides a current progress summary, including the estimated rate of table redistribution and estimated time to completion. You can query the table \texttt{gpexpand.status\_detail} for per-table status information.

\subsection*{Viewing Expansion Status}

After the first table completes redistribution, \texttt{gpexpand.expansion\_progress} calculates its estimates and refreshes them based on all tables' redistribution rates. Calculations restart each time you start a table redistribution session with \texttt{gpexpand}. To monitor progress, connect to Greenplum Database using \texttt{psql} or another supported client; query \texttt{gpexpand.expansion\_progress} with a command like the following:

\begin{verbatim}
=# SELECT * FROM gpexpand.expansion\_progress;
 name             |         value
 ----------------------------------+-----------------------
 Bytes Left                   | 5534842880
 Bytes Done                   | 142475264
 Estimated Expansion Rate     | 680.75667095996092 MB/s
 Estimated Time to Completion | 00:01:01.008047
 Tables Expanded              | 4
 Tables Left                  | 4
(6 rows)
\end{verbatim}

\subsection*{Viewing Table Status}

The table \texttt{gpexpand.status\_detail} stores status, time of last update, and more facts about each table in the schema. To see a table's status, connect to Greenplum Database using \texttt{psql} or another supported client and query \texttt{gpexpand.status\_detail}:

\begin{verbatim}
=> SELECT status, expansion\_started, source\_bytes FROM gpexpand.status\_detail WHERE fq\_name = 'public.sales';
 status | expansion\_started | source\_bytes
--------+-------------------+-----------------
 COMPLETED | 2017-02-20 10:54:10.043869 | 4929748992
(1 row)
\end{verbatim}
Removing the Expansion Schema

To clean up after expanding the Greenplum cluster, remove the expansion schema. You can safely remove the expansion schema after the expansion operation is complete and verified. To run another expansion operation on a Greenplum system, first remove the existing expansion schema.

To remove the expansion schema

1. Log in on the master host as the user who will be running your Greenplum Database system (for example, gpadmin).
2. Run the gpexpand utility with the -c option. For example:

   ```
   $ gpexpand -c
   $ 
   ```

   Note: Some systems require you to press Enter twice.

Migrating Data with gptransfer

This topic describes how to use the gptransfer utility to transfer data between databases.

The gptransfer migration utility transfers Greenplum Database metadata and data from one Greenplum database to another Greenplum database, allowing you to migrate the entire contents of a database, or just selected tables, to another database. The source and destination databases may be in the same or a different cluster. Data is transferred in parallel across all the segments, using the gpfdist data loading utility to attain the highest transfer rates.

gptransfer handles the setup and execution of the data transfer. Participating clusters must already exist, have network access between all hosts in both clusters, and have certificate-authenticated ssh access between all hosts in both clusters.

The interface includes options to transfer one or more full databases, or one or more database tables. A full database transfer includes the database schema, table data, indexes, views, roles, user-defined functions, and resource queues. Configuration files, including postgres.conf and pg_hba.conf, must be transferred manually by an administrator. Extensions installed in the database with gppkg, such as MADlib, must be installed in the destination database by an administrator.

See the Greenplum Database Utility Guide for complete syntax and usage information for the gptransfer utility.

Prerequisites

- The gptransfer utility can only be used with Greenplum Database. Apache HAWQ is not supported as a source or destination.
- The source and destination Greenplum clusters must both be version 4.2 or higher.
- At least one Greenplum instance must include the gptransfer utility in its distribution. If neither the source or destination includes gptransfer, you must upgrade one of the clusters to use gptransfer.
- The gptransfer utility can be run from the cluster with the source or destination database.
- The number of segments in the destination cluster must be greater than or equal to the number of hosts in the source cluster. The number of segments in the destination may be smaller than the number of segments in the source, but the data will transfer at a slower rate.
- The segment hosts in both clusters must have network connectivity with each other.
- Every host in both clusters must be able to connect to every other host with certificate-authenticated SSH. You can use the gpssh_exkeys utility to exchange public keys between the hosts of both clusters.
What gpTransfer Does

`gptransfer` uses writable and readable external tables, the Greenplum `gpfdist` parallel data-loading utility, and named pipes to transfer data from the source database to the destination database. Segments on the source cluster select from the source database table and insert into a writable external table. Segments in the destination cluster select from a readable external table and insert into the destination database table. The writable and readable external tables are backed by named pipes on the source cluster's segment hosts, and each named pipe has a `gpfdist` process serving the pipe's output to the readable external table on the destination segments.

`gptransfer` orchestrates the process by processing the database objects to be transferred in batches. For each table to be transferred, it performs the following tasks:

- creates a writable external table in the source database
- creates a readable external table in the destination database
- creates named pipes and `gpfdist` processes on segment hosts in the source cluster
- executes a `SELECT INTO` statement in the source database to insert the source data into the writable external table
- executes a `SELECT INTO` statement in the destination database to insert the data from the readable external table into the destination table
- optionally validates the data by comparing row counts or MD5 hashes of the rows in the source and destination
- cleans up the external tables, named pipes, and `gpfdist` processes

Fast Mode and Slow Mode

`gptransfer` sets up data transfer using the `gpfdist` parallel file serving utility, which serves the data evenly to the destination segments. Running more `gpfdist` processes increases the parallelism and the data transfer rate. When the destination cluster has the same or a greater number of segments than the source cluster, `gptransfer` sets up one named pipe and one `gpfdist` process for each source segment. This is the configuration for optimal data transfer rates and is called **fast mode**. The following figure illustrates a setup on a segment host when the destination cluster has at least as many segments as the source cluster.
The configuration of the input end of the named pipes differs when there are fewer segments in the destination cluster than in the source cluster. `gptransfer` handles this alternative setup automatically. The difference in configuration means that transferring data into a destination cluster with fewer segments than the source cluster is not as fast as transferring into a destination cluster of the same or greater size. It is called slow mode because there are fewer `gpfdist` processes serving the data to the destination cluster, although the transfer is still quite fast with one `gpfdist` per segment host.

When the destination cluster is smaller than the source cluster, there is one named pipe per segment host and all segments on the host send their data through it. The segments on the source host write their data to a writable external web table connected to a `gpfdist` process on the input end of the named pipe. This consolidates the table data into a single named pipe. A `gpfdist` process on the output of the named pipe serves the consolidated data to the destination cluster. The following figure illustrates this configuration.
On the destination side, `gptransfer` defines a readable external table with the `gpfdist` server on the source host as input and selects from the readable external table into the destination table. The data is distributed evenly to all the segments in the destination cluster.

### Batch Size and Sub-batch Size

The degree of parallelism of a `gptransfer` execution is determined by two command-line options: `--batch-size` and `--sub-batch-size`. The `--batch-size` option specifies the number of tables to transfer in a batch. The default batch size is 2, which means that two table transfers are in process at any time. The minimum batch size is 1 and the maximum is 10. The `--sub-batch-size` parameter specifies the maximum number of parallel sub-processes to start to do the work of transferring a table. The default is 25 and the maximum is 50. The product of the batch size and sub-batch size is the amount of parallelism. If set to the defaults, for example, `gptransfer` can perform 50 concurrent tasks. Each thread is a Python process and consumes memory, so setting these values too high can cause a Python Out of Memory error. For this reason, the batch sizes should be tuned for your environment.

### Preparing Hosts for gptransfer

When you install a Greenplum Database cluster, you set up all the master and segment hosts so that the Greenplum Database administrative user (`gpadmin`) can connect with SSH from every host in the cluster to any other host in the cluster without providing a password. The `gptransfer` utility requires this capability between every host in the source and destination clusters. First, ensure that the clusters have network connectivity with each other. Then, prepare a hosts file containing a list of all the hosts in both clusters, and use the `gpssh-exkeys` utility to exchange keys. See the reference for `gpssh-exkeys` in the Greenplum Database Utility Guide.

The host map file is a text file that lists the segment hosts in the source cluster. It is used to enable communication between the hosts in Greenplum clusters. The file is specified on the `gptransfer` command line with the `--source-map-file=host_map_file` command option. It is a required option when using `gptransfer` to copy data between two separate Greenplum clusters.
The file contains a list in the following format:

```
host1_name,host1_ip_addr
host2_name,host2_ipaddr
...
```

The file uses IP addresses instead of host names to avoid any problems with name resolution between the clusters.

**Limitations**

`gptransfer` transfers data from user databases only; the `postgres`, `template0`, and `template1` databases cannot be transferred. Administrators must transfer configuration files manually and install extensions into the destination database with `gppkg`.

The destination cluster must have at least as many segments as the source cluster has segment hosts. Transferring data to a smaller cluster is not as fast as transferring data to a larger cluster.

Transferring small or empty tables can be unexpectedly slow. There is significant fixed overhead in setting up external tables and communications processes for parallel data loading between segments that occurs whether or not there is actual data to transfer. It can be more efficient to transfer the schema and smaller tables to the destination database using other methods, then use `gptransfer` with the `-t` option to transfer large tables.

When transferring data between databases, you can run only one instance of `gptransfer` at a time. Running multiple, concurrent instances of `gptransfer` is not supported.

**Full Mode and Table Mode**

When run with the `--full` option, `gptransfer` copies all user-created databases, tables, views, indexes, roles, user-defined functions, and resource queues in the source cluster to the destination cluster. The destination system cannot contain any user-defined databases, only the default databases `postgres`, `template0`, and `template1`. If `gptransfer` finds a database on the destination it fails with a message like the following:

```
[ERROR]:- gptransfer: error: --full option specified but tables exist on destination system
```

**Note:** The `--full` option cannot be specified with the `-t`, `-d`, `-f`, or `--partition-transfer` options.

To copy tables individually, specify the tables using either the `-t` command-line option (one option per table) or by using the `-f` command-line option to specify a file containing a list of tables to transfer. Tables are specified in the fully-qualified format `database.schema.table`. The table definition, indexes, and table data are copied. The database must already exist on the destination cluster.

By default, `gptransfer` fails if you attempt to transfer a table that already exists in the destination database:

```
[INFO]:-Validating transfer table set...
[CRITICAL]:- gptransfer failed. (Reason='Table database.schema.table exists in database database. ') exiting...
```

Override this behavior with the `--skip-existing`, `--truncate`, or `--drop` options.

The following table shows the objects that are copied in full mode and table mode.

<table>
<thead>
<tr>
<th>Object</th>
<th>Full Mode</th>
<th>Table Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### Object

<table>
<thead>
<tr>
<th>Object</th>
<th>Full Mode</th>
<th>Table Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indexes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Roles</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Functions</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Resource Queues</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>postgres.conf</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>pg_hba.conf</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>gppkg</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

The `--full` option and the `--schema-only` option can be used together if you want to copy databases in phases, for example, during scheduled periods of downtime or low activity. Run `gptransfer --full --schema-only ...` to create the databases on the destination cluster, but with no data. Then you can transfer the tables in stages during scheduled down times or periods of low activity. Be sure to include the `--truncate` or `--drop` option when you later transfer tables to prevent the transfer from failing because the table already exists at the destination.

### Locking

The `-x` option enables table locking. An exclusive lock is placed on the source table until the copy and validation, if requested, are complete.

### Validation

By default, `gptransfer` does not validate the data transferred. You can request validation using the `--validate=type` option. The validation type can be one of the following:

- **count** – Compares the row counts for the tables in the source and destination databases.
- **md5** – Sorts tables on both source and destination, and then performs a row-by-row comparison of the MD5 hashes of the sorted rows.

If the database is accessible during the transfer, be sure to add the `-x` option to lock the table. Otherwise, the table could be modified during the transfer, causing validation to fail.

### Failed Transfers

A failure on a table does not end the `gptransfer` job. When a transfer fails, `gptransfer` displays an error message and adds the table name to a failed transfers file. At the end of the `gptransfer` session, `gptransfer` writes a message telling you there were failures, and providing the name of the failed transfer file. For example:

```plaintext
[WARNING]:-Some tables failed to transfer. A list of these tables
[WARNING]:-has been written to the file
  failed_transfer_tables_20140808_101813.txt
[WARNING]:-This file can be used with the -f option to continue
```

The failed transfers file is in the format required by the `-f` option, so you can use it to start a new `gptransfer` session to retry the failed transfers.

### Best Practices

Be careful not to exceed host memory by specifying too much parallelism with the `--batch-size` and `--sub-batch-size` command line options. Too many sub-processes can exhaust memory, causing a Python Out of Memory error. Start with a smaller batch size and sub-batch size, and increase based on your experiences.
Transfer a database in stages. First, run `gptransfer` with the `--schema-only` and `--d database` options, then transfer the tables in phases. After running `gptransfer` with the `--schema-only` option, be sure to add the `--truncate` or `--drop` option to prevent a failure because a table already exists.

Be careful choosing `gpfdist` and external table parameters such as the delimiter for external table data and the maximum line length. For example, don't choose a delimiter that can appear within table data.

If you have many empty tables to transfer, consider a DDL script instead of `gptransfer`. The `gptransfer` overhead to set up each table for transfer is significant and not an efficient way to transfer empty tables.

`gptransfer` creates table indexes before transferring the data. This slows the data transfer since indexes are updated at the same time the data is inserted in the table. For large tables especially, consider dropping indexes before running `gptransfer` and recreating the indexes when the transfer is complete.

---

**Monitoring a Greenplum System**

You can monitor a Greenplum Database system using a variety of tools included with the system or available as add-ons. SNMP support allows Greenplum to be integrated with popular system management frameworks.

Observing the Greenplum Database system day-to-day performance helps administrators understand the system behavior, plan workflow, and troubleshoot problems. This chapter discusses tools for monitoring database performance and activity.

Also, be sure to review the *Recommended Monitoring and Maintenance Tasks* for monitoring activities you can script to quickly detect problems in the system.

**Monitoring Database Activity and Performance**

Greenplum Database includes an optional system monitoring and management database, `gpperfmon`, that administrators can enable. The `gpperfmon_install` command-line utility creates the `gpperfmon` database and enables data collection agents that collect and store query and system metrics in the database. Administrators can query metrics in the `gpperfmon` database. See the documentation for the `gpperfmon` database in the *Greenplum Database Reference Guide*.

Pivotal Greenplum Command Center, an optional web-based interface, graphically displays the metrics collected in the `gpperfmon` database and provides additional system management tools. Download the Greenplum Command Center package from Pivotal Network and view the documentation at the *Greenplum Command Center Documentation* website.

**Monitoring System State**

As a Greenplum Database administrator, you must monitor the system for problem events such as a segment going down or running out of disk space on a segment host. The following topics describe how to monitor the health of a Greenplum Database system and examine certain state information for a Greenplum Database system.

- Enabling System Alerts and Notifications
- Checking System State
- Checking Disk Space Usage
- Checking for Data Distribution Skew
- Viewing Metadata Information about Database Objects
- Viewing Session Memory Usage Information
- Viewing Query Workfile Usage Information
Enabling System Alerts and Notifications

You can configure a Greenplum Database system to trigger SNMP (Simple Network Management Protocol) alerts or send email notifications to system administrators if certain database events occur. These events include:

- All PANIC-level error conditions
- All FATAL-level error conditions
- ERROR-level conditions that are "internal errors" (for example, SIGSEGV errors)
- Database system shutdown and restart
- Segment failure and recovery
- Standby master out-of-sync conditions
- Master host manual shutdown or other software problem (in certain failure scenarios, Greenplum Database cannot send an alert or notification)

This topic includes the following sub-topics:

- Using SNMP with a Greenplum Database System
- Enabling Email Notifications

Note that SNMP alerts and email notifications report the same event information. There is no difference in the event information that either tool reports. For information about the SNMP event information, see Greenplum Database SNMP OIDs and Error Codes.

Using SNMP with a Greenplum Database System

Greenplum Database supports SNMP to monitor the state of a Greenplum Database system using MIBs (Management Information Bases). MIBs are collections of objects that describe an SNMP-manageable entity — in this case, a Greenplum Database system.

The Greenplum Database SNMP support allows a Network Management System to obtain information about the hardware, operating system, and Greenplum Database from the same port (161) and IP address. It also enables the auto-discovery of Greenplum Database instances.

Prerequisites

Before setting up SNMP support on Greenplum Database, ensure SNMP is installed on the master host. If the snmpd file is not present in the /usr/sbin directory, then SNMP is not installed on the system. Depending on the platform on which you are running Greenplum Database, install the following:

Table 33: SNMP Prerequisites

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Packages¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Hat Enterprise</td>
<td>net-snmp</td>
</tr>
<tr>
<td></td>
<td>net-snmp-libs</td>
</tr>
<tr>
<td></td>
<td>net-snmp-utils</td>
</tr>
<tr>
<td>CentOS</td>
<td>net-snmp</td>
</tr>
<tr>
<td>SUSE</td>
<td>N/A</td>
</tr>
</tbody>
</table>

1. SNMP is installed by default on SUSE platforms.

The snmp.conf configuration file is located in /etc/snmp/.
Pre-installation Tasks

After you establish that SNMP is on the master host, log in as root, open a text editor, and edit the path_to/snmp/snmpd.conf file. To use SNMP with Greenplum Database, the minimum configuration change required to the snmpd.conf file is specifying a community name. For example:

rocommunity public

Note: Replace public with the name of your SNMP community. You should also configure syslocation and syscontact. Configure other SNMP settings as required for your environment and save the file.

For more information about the snmpd.conf file, enter:

man snmpd.conf

Note: On SUSE Linux platforms, make sure to review and configure security settings in the snmp.conf file so snmpd accepts connections from sub-agents and returns all available Object IDs (OIDs).

After you finish configuring the snmpd.conf file, start the system snmpd daemon:

# /sbin/chkconfig snmpd on

Then, verify the system snmpd daemon is running. Enter:

# snmpwalk -v 1 -c community_name localhost .1.3.6.1.2.1.1.1.0

For example:

# snmpwalk -v 1 -c public localhost .1.3.6.1.2.1.1.1.0

If this command returns "Timeout: No Response from localhost", then the system snmpd daemon is not running. If the daemon is running, output similar to the following displays:

SNMPv2-MIB::sysDescr.0 = STRING: Linux hostname
2.6.18-92.el5 #1 SMP Tue Jun 10 18:51:06 EDT 2016 x86_64

Setting up SNMP Notifications

1. To configure a Greenplum Database system to send SNMP notifications when alerts occur, set the following parameters on the Greenplum Database master host with the gpconfig utility:

   - gp_snmp_community: Set this parameter to the community name you specified for your environment.
   - gp_snmp_monitor_address: Enter the hostname:port of your network monitor application. Typically, the port number is 162. If there are multiple monitor addresses, separate them with a comma.
   - gp_snmp_use_inform_or_trap: Enter either trap or inform. Trap notifications are SNMP messages sent from one application to another (for example, between Greenplum Database and a network monitoring application). These messages are unacknowledged by the monitoring application, but generate less network overhead.

   Inform notifications are the same as trap messages, except the application sends an acknowledgement to the application that generated the alert. In this case, the monitoring application sends acknowledgement messages to Greenplum Database-generated trap notifications. While inform messages create more overhead, they inform Greenplum Database the monitoring application has received the traps.
The following example commands set the server configuration parameters with the Greenplum Database gpconfig utility:

```
$ gpconfig -c gp_snmp_community -v public --masteronly
$ gpconfig -c gp_snmp_monitor_address -v mdw:162 --masteronly
$ gpconfig -c gp_snmp_use_inform_or_trap -v trap --masteronly
```

2. To test SNMP notifications, you can use the `snmptrapd` trap receiver. As root, enter:

```
# /usr/sbin/snmptrapd -m ALL -Lf ~/filename.log
```

- `-Lf` indicates that traps are logged to a file.
- `-Le` indicates that traps are logged to `stderr` instead.
- `-m ALL` loads all available MIBs (you can also specify individual MIBs if required).

### Enabling Email Notifications

Complete the following steps to enable Greenplum Database to send email notifications to system administrators whenever certain database events occur.

1. Open `$MASTER_DATA_DIRECTORY/postgresql.conf` in a text editor.
2. In the `EMAIL ALERTS` section, uncomment the following parameters and enter the appropriate values for your email server and domain. For example:

   ```
   gp_email_smtp_server='smtp.company.com:25'
gp_email_smtp_userid='gpadmin@example.com'
gp_email_smtp_password='mypassword'
gp_email_from='Greenplum Database <gpadmin@example.com>'
gp_email_to='dba@example.com;John Smith <jsmith@example.com>'
   ```

   You may create specific email accounts or groups in your email system that send and receive email alerts from the Greenplum Database system. For example:

   ```
   gp_email_from='GPDB Production Instance <gpdb@example.com>'
gp_email_to='gpdb_dba_group@example.com'
   ```

   You can also specify multiple email addresses for both `gp_email` parameters. Use a semi-colon (`;`) to separate each email address. For example:

   ```
   gp_email_to='gpdb_dba_group@example.com;admin@example.com'
   ```

3. Save and close the `postgresql.conf` file.
4. Reload the Greenplum Database `postgresql.conf` file:

   ```
   $ gpstop -u
   ```

### Testing Email Notifications

The Greenplum Database master host must be able to connect to the SMTP email server you specify for the `gp_email_smtp_server` parameter. To test connectivity, use the `ping` command:

```
$ ping my_email_server
```

If the master host can contact the SMTP server, log in to `psql` and test email notifications with the following command:

```
$ psql postgres
=# SELECT gp_elog('Test GPDB Email',true); gp_elog
```
The address you specified for the gp_email_to parameter should receive an email with Test GPDB Email in the subject line.

You can also test email notifications by using a public SMTP server, such as Google's Gmail SMTP server, and an external email address. For example:

```sql
gp_email_smtp_server='smtp.gmail.com:25'
#gp_email_smtp_userid=''
#gp_email_smtp_password=''
gp_email_from='gpadmin@example.com'
gp_email_to='test_account@example.com'
```

**Note:** If you have difficulty sending and receiving email notifications, verify the security settings for your organization's email server and firewall.

### Checking System State

A Greenplum Database system is comprised of multiple PostgreSQL instances (the master and segments) spanning multiple machines. To monitor a Greenplum Database system, you need to know information about the system as a whole, as well as status information of the individual instances. The `gpstate` utility provides status information about a Greenplum Database system.

#### Viewing Master and Segment Status and Configuration

The default `gpstate` action is to check segment instances and show a brief status of the valid and failed segments. For example, to see a quick status of your Greenplum Database system:

```bash
$ gpstate
```

To see more detailed information about your Greenplum Database array configuration, use `gpstate` with the `-s` option:

```bash
$ gpstate -s
```

#### Viewing Your Mirroring Configuration and Status

If you are using mirroring for data redundancy, you may want to see the list of mirror segment instances in the system, their current synchronization status, and the mirror to primary mapping. For example, to see the mirror segments in the system and their status:

```bash
$ gpstate -m
```

To see the primary to mirror segment mappings:

```bash
$ gpstate -c
```

To see the status of the standby master mirror:

```bash
$ gpstate -f
```

### Checking Disk Space Usage

A database administrator's most important monitoring task is to make sure the file systems where the master and segment data directories reside do not grow to more than 70 percent full. A filled data disk will not result in data corruption, but it may prevent normal database activity from continuing. If the disk grows too full, it can cause the database server to shut down.
You can use the `gp_disk_free` external table in the `gp_toolkit` administrative schema to check for remaining free space (in kilobytes) on the segment host file systems. For example:

```
=# SELECT * FROM gp_toolkit.gp_disk_free
   ORDER BY dfsegment;
```

### Checking Sizing of Distributed Databases and Tables

The `gp_toolkit` administrative schema contains several views that you can use to determine the disk space usage for a distributed Greenplum Database database, schema, table, or index.

For a list of the available sizing views for checking database object sizes and disk space, see the Greenplum Database Reference Guide.

### Viewing Disk Space Usage for a Database

To see the total size of a database (in bytes), use the `gp_size_of_database` view in the `gp_toolkit` administrative schema. For example:

```
=> SELECT * FROM gp_toolkit.gp_size_of_database
   ORDER BY sodddatname;
```

### Viewing Disk Space Usage for a Table

The `gp_toolkit` administrative schema contains several views for checking the size of a table. The table sizing views list the table by object ID (not by name). To check the size of a table by name, you must look up the relation name (`relname`) in the `pg_class` table. For example:

```
=> SELECT relname AS name, sotdsize AS size, sotdtoastsize AS toast, sotdadditionalsize AS other
   FROM gp_toolkit.gp_size_of_table_disk as sotd, pg_class
   WHERE sotd.sotdoid=pg_class.oid ORDER BY relname;
```

For a list of the available table sizing views, see the Greenplum Database Reference Guide.

### Viewing Disk Space Usage for Indexes

The `gp_toolkit` administrative schema contains a number of views for checking index sizes. To see the total size of all index(es) on a table, use the `gp_size_of_all_table_indexes` view. To see the size of a particular index, use the `gp_size_of_index` view. The index sizing views list tables and indexes by object ID (not by name). To check the size of an index by name, you must look up the relation name (`relname`) in the `pg_class` table. For example:

```
=> SELECT soisize, relname as indexname
   FROM pg_class, gp_toolkit.gp_size_of_index
   WHERE pg_class.oid=gp_size_of_index.soioid
   AND pg_class.relkind='i';
```

### Checking for Data Distribution Skew

All tables in Greenplum Database are distributed, meaning their data is divided evenly across all of the segments in the system. Unevenly distributed data may diminish query processing performance. A table's distribution policy is determined at table creation time. For information about choosing the table distribution policy, see the following topics:

- Viewing a Table's Distribution Key
- Viewing Data Distribution
- Checking for Query Processing Skew
The gp_toolkit administrative schema also contains a number of views for checking data distribution skew on a table. For information about how to check for uneven data distribution, see the Greenplum Database Reference Guide.

**Viewing a Table’s Distribution Key**

To see the columns used as the data distribution key for a table, you can use the \d+ meta-command in psql to examine the definition of a table. For example:

```
=# \d+ sales
+-----------------------+----------+------------+-------------------------+
| Column | Type  | Modifiers | Description           |
|--------+-------+-----------+-----------------------|
| sale_id | integer |           |                       |
| amt    | float  |           |                       |
| date   | date   |           |                       |
|---------|--------|-----------+-----------------------|
| Has OIDs: no
Distributed by: (sale_id)
```

**Viewing Data Distribution**

To see the data distribution of a table's rows (the number of rows on each segment), you can run a query such as:

```
=# SELECT gp_segment_id, count(*)
    FROM table_name
    GROUP BY gp_segment_id;
```

A table is considered to have a balanced distribution if all segments have roughly the same number of rows.

**Checking for Query Processing Skew**

When a query is being processed, all segments should have equal workloads to ensure the best possible performance. If you identify a poorly-performing query, you may need to investigate further using the EXPLAIN command. For information about using the EXPLAIN command and query profiling, see Query Profiling.

Query processing workload can be skewed if the table's data distribution policy and the query predicates are not well matched. To check for processing skew, you can run a query such as:

```
=# SELECT gp_segment_id, count(*) FROM table_name
    WHERE column='value'
    GROUP BY gp_segment_id;
```

This will show the number of rows returned by segment for the given WHERE predicate.

**Avoiding an Extreme Skew Warning**

You may receive the following warning message while executing a query that performs a hash join operation:

```
Extreme skew in the innerside of Hashjoin
```

This occurs when the input to a hash join operator is skewed. It does not prevent the query from completing successfully. You can follow these steps to avoid skew in the plan:

1. Ensure that all fact tables are analyzed.
2. Verify that any populated temporary table used by the query is analyzed.
3. View the EXPLAIN ANALYZE plan for the query and look for the following:
• If there are scans with multi-column filters that are producing more rows than estimated, then set the `gp_selectivity_damping_factor` server configuration parameter to 2 or higher and retest the query.
• If the skew occurs while joining a single fact table that is relatively small (less than 5000 rows), set the `gp_segments_for_planner` server configuration parameter to 1 and retest the query.

4. Check whether the filters applied in the query match distribution keys of the base tables. If the filters and distribution keys are the same, consider redistributing some of the base tables with different distribution keys.

5. Check the cardinality of the join keys. If they have low cardinality, try to rewrite the query with different joining columns or additional filters on the tables to reduce the number of rows. These changes could change the query semantics.

**Viewing Metadata Information about Database Objects**

Greenplum Database tracks various metadata information in its system catalogs about the objects stored in a database, such as tables, views, indexes, and so on, as well as global objects such as roles and tablespaces.

**Viewing the Last Operation Performed**

You can use the system views `pg_stat_operations` and `pg_stat_partition_operations` to look up actions performed on an object, such as a table. For example, to see the actions performed on a table, such as when it was created and when it was last vacuumed and analyzed:

```sql
=> SELECT schemaname as schema, objname as table, usename as role, actionname as action, subtype as type, statime as time
FROM pg_stat_operations
WHERE objname='cust';
```

```
schema | table | role | action  | type  | time
--------+-------+------+---------+-------+-------------------------------
sales | cust  | main | CREATE  | TABLE | 2016-02-09 18:10:07.867977-08
sales | cust  | main | VACUUM  |       | 2016-02-10 13:32:39.068219-08
sales | cust  | main | ANALYZE |       | 2016-02-25 16:07:01.157168-08
(3 rows)
```

**Viewing the Definition of an Object**

To see the definition of an object, such as a table or view, you can use the `\d+` meta-command when working in `psql`. For example, to see the definition of a table:

```sql
=> \d+ mytable
```

**Viewing Session Memory Usage Information**

You can create and use the `session_level_memory_consumption` view that provides information about the current memory utilization for sessions that are running queries on Greenplum Database. The view contains session information and information such as the database that the session is connected to, the query that the session is currently running, and memory consumed by the session processes.

**Creating the session_level_memory_consumption View**

To create the `session_level_memory_consumption` view in a Greenplum Database, run the script `$GPHOME/share/postgresql/contrib/gp_session_state.sql` once for each database. For example, to install the view in the database `testdb`, use this command:

```bash
$ psql -d testdb -f $GPHOME/share/postgresql/contrib/gp_session_state.sql
```
**The session_level_memory_consumption View**

The `session_level_memory_consumption` view provides information about memory consumption and idle time for sessions that are running SQL queries.

When resource queue-based resource management is active, the column `is_runaway` indicates whether Greenplum Database considers the session a runaway session based on the `vmem` memory consumption of the session's queries. Under the resource queue-based resource management scheme, Greenplum Database considers the session a runaway when the queries consume an excessive amount of memory. The Greenplum Database server configuration parameter `runaway_detector_activation_percent` governs the conditions under which Greenplum Database considers a session a runaway session.

The `is_runaway`, `runaway_vmem_mb`, and `runaway_command_cnt` columns are not applicable when resource group-based resource management is active.

**Table 34: session_level_memory_consumption**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>datname</td>
<td>name</td>
<td></td>
<td>Name of the database that the session is connected to.</td>
</tr>
<tr>
<td>sess_id</td>
<td>integer</td>
<td></td>
<td>Session ID.</td>
</tr>
<tr>
<td>usename</td>
<td>name</td>
<td></td>
<td>Name of the session user.</td>
</tr>
<tr>
<td>current_query</td>
<td>text</td>
<td></td>
<td>Current SQL query that the session is running.</td>
</tr>
<tr>
<td>segid</td>
<td>integer</td>
<td></td>
<td>Segment ID.</td>
</tr>
<tr>
<td>vmem_mb</td>
<td>integer</td>
<td></td>
<td>Total vmem memory usage for the session in MB.</td>
</tr>
<tr>
<td>is_runaway</td>
<td>boolean</td>
<td></td>
<td>Session is marked as runaway on the segment.</td>
</tr>
<tr>
<td>qe_count</td>
<td>integer</td>
<td></td>
<td>Number of query processes for the session.</td>
</tr>
<tr>
<td>active_qe_count</td>
<td>integer</td>
<td></td>
<td>Number of active query processes for the session.</td>
</tr>
<tr>
<td>dirty_qe_count</td>
<td>integer</td>
<td></td>
<td>Number of query processes that have not yet released their memory.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The value is –1 for sessions that are not running.</td>
</tr>
</tbody>
</table>
### Viewing Query Workfile Usage Information

The Greenplum Database administrative schema `gp_toolkit` contains views that display information about Greenplum Database workfiles. Greenplum Database creates workfiles on disk if it does not have sufficient memory to execute the query in memory. This information can be used for troubleshooting and tuning queries. The information in the views can also be used to specify the values for the Greenplum Database configuration parameters `gp_workfile_limit_per_query` and `gp_workfile_limit_per_segment`.

These are the views in the schema `gp_toolkit`:

- The `gp_workfile_entries` view contains one row for each operator using disk space for workfiles on a segment at the current time.
- The `gp_workfile_usage_per_query` view contains one row for each query using disk space for workfiles on a segment at the current time.
- The `gp_workfile_usage_per_segment` view contains one row for each segment. Each row displays the total amount of disk space used for workfiles on the segment at the current time.

For information about using `gp_toolkit`, see [Using gp_toolkit](#).

### Viewing the Database Server Log Files

Every database instance in Greenplum Database (master and segments) runs a PostgreSQL database server with its own server log file. Daily log files are created in the `pg_log` directory of the master and each segment data directory.

#### Log File Format

The server log files are written in comma-separated values (CSV) format. Some log entries will not have values for all log fields. For example, only log entries associated with a query worker process will have the `slice_id` populated. You can identify related log entries of a particular query by the query’s session identifier (`gp_session_id`) and command identifier (`gp_command_count`).

The following fields are written to the log:

**Table 35: Greenplum Database Server Log Format**

<table>
<thead>
<tr>
<th>#</th>
<th>Field Name</th>
<th>Data Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>event_time</td>
<td>timestamp with time zone</td>
<td>Time that the log entry was written to the log</td>
</tr>
<tr>
<td>2</td>
<td>user_name</td>
<td>varchar(100)</td>
<td>The database user name</td>
</tr>
<tr>
<td>#</td>
<td>Field Name</td>
<td>Data Type</td>
<td>Description</td>
</tr>
<tr>
<td>----</td>
<td>----------------------</td>
<td>-------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>3</td>
<td>database_name</td>
<td>varchar(100)</td>
<td>The database name</td>
</tr>
<tr>
<td>4</td>
<td>process_id</td>
<td>varchar(10)</td>
<td>The system process ID (prefixed with &quot;p&quot;)</td>
</tr>
<tr>
<td>5</td>
<td>thread_id</td>
<td>varchar(50)</td>
<td>The thread count (prefixed with &quot;th&quot;)</td>
</tr>
<tr>
<td>6</td>
<td>remote_host</td>
<td>varchar(100)</td>
<td>On the master, the hostname/address of the client machine. On the segment, the hostname/address of the master.</td>
</tr>
<tr>
<td>7</td>
<td>remote_port</td>
<td>varchar(10)</td>
<td>The segment or master port number</td>
</tr>
<tr>
<td>8</td>
<td>session_start_time</td>
<td>timestamp with time zone</td>
<td>Time session connection was opened</td>
</tr>
<tr>
<td>9</td>
<td>transaction_id</td>
<td>int</td>
<td>Top-level transaction ID on the master. This ID is the parent of any subtransactions.</td>
</tr>
<tr>
<td>10</td>
<td>gp_session_id</td>
<td>text</td>
<td>Session identifier number (prefixed with &quot;con&quot;)</td>
</tr>
<tr>
<td>11</td>
<td>gp_command_count</td>
<td>text</td>
<td>The command number within a session (prefixed with &quot;cmd&quot;)</td>
</tr>
<tr>
<td>12</td>
<td>gp_segment</td>
<td>text</td>
<td>The segment content identifier (prefixed with &quot;seg&quot; for primaries or &quot;mir&quot; for mirrors). The master always has a content ID of -1.</td>
</tr>
<tr>
<td>13</td>
<td>slice_id</td>
<td>text</td>
<td>The slice ID (portion of the query plan being executed)</td>
</tr>
<tr>
<td>14</td>
<td>distr_tranx_id</td>
<td>text</td>
<td>Distributed transaction ID</td>
</tr>
<tr>
<td>15</td>
<td>local_tranx_id</td>
<td>text</td>
<td>Local transaction ID</td>
</tr>
<tr>
<td>16</td>
<td>sub_tranx_id</td>
<td>text</td>
<td>Subtransaction ID</td>
</tr>
<tr>
<td>17</td>
<td>event_severity</td>
<td>varchar(10)</td>
<td>Values include: LOG, ERROR, FATAL, PANIC, DEBUG1, DEBUG2</td>
</tr>
<tr>
<td>18</td>
<td>sql_state_code</td>
<td>varchar(10)</td>
<td>SQL state code associated with the log message</td>
</tr>
<tr>
<td>19</td>
<td>event_message</td>
<td>text</td>
<td>Log or error message text</td>
</tr>
<tr>
<td>20</td>
<td>event_detail</td>
<td>text</td>
<td>Detail message text associated with an error or warning message</td>
</tr>
<tr>
<td>21</td>
<td>event_hint</td>
<td>text</td>
<td>Hint message text associated with an error or warning message</td>
</tr>
<tr>
<td>22</td>
<td>internal_query</td>
<td>text</td>
<td>The internally-generated query text</td>
</tr>
<tr>
<td>23</td>
<td>internal_query_pos</td>
<td>int</td>
<td>The cursor index into the internally-generated query text</td>
</tr>
<tr>
<td>24</td>
<td>event_context</td>
<td>text</td>
<td>The context in which this message gets generated</td>
</tr>
<tr>
<td>25</td>
<td>debug_query_string</td>
<td>text</td>
<td>User-supplied query string with full detail for debugging. This string can be modified for internal use.</td>
</tr>
<tr>
<td>26</td>
<td>error_cursor_pos</td>
<td>int</td>
<td>The cursor index into the query string</td>
</tr>
<tr>
<td>27</td>
<td>func_name</td>
<td>text</td>
<td>The function in which this message is generated</td>
</tr>
<tr>
<td>28</td>
<td>file_name</td>
<td>text</td>
<td>The internal code file where the message originated</td>
</tr>
<tr>
<td>29</td>
<td>file_line</td>
<td>int</td>
<td>The line of the code file where the message originated</td>
</tr>
<tr>
<td>#</td>
<td>Field Name</td>
<td>Data Type</td>
<td>Description</td>
</tr>
<tr>
<td>----</td>
<td>------------</td>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td>30</td>
<td>stack_trace</td>
<td>text</td>
<td>Stack trace text associated with this message</td>
</tr>
</tbody>
</table>

### Searching the Greenplum Server Log Files

Greenplum Database provides a utility called `gplogfilter` can search through a Greenplum Database log file for entries matching the specified criteria. By default, this utility searches through the Greenplum Database master log file in the default logging location. For example, to display the last three lines of the master log file:

```
$ gplogfilter -n 3
```

To search through all segment log files simultaneously, run `gplogfilter` through the `gpssh` utility. For example, to display the last three lines of each segment log file:

```
$ gpssh -f seg_host_file
=> source /usr/local/greenplum-db/greenplum_path.sh
=> gplogfilter -n 3 /gpdata/gp*/pg_log/gpdb*.log
```

### Using `gp_toolkit`

Use the Greenplum Database administrative schema `gp_toolkit` to query the system catalogs, log files, and operating environment for system status information. The `gp_toolkit` schema contains several views you can access using SQL commands. The `gp_toolkit` schema is accessible to all database users. Some objects require superuser permissions. Use a command similar to the following to add the `gp_toolkit` schema to your schema search path:

```
=> ALTER ROLE myrole SET search_path TO myschema,gp_toolkit;
```

For a description of the available administrative schema views and their usages, see the *Greenplum Database Reference Guide*.

### Greenplum Database SNMP OIDs and Error Codes

When a Greenplum Database system is configured to trigger SNMP alerts or send email notifications to system administrators if certain database events occur, the alerts and notifications contain Object IDs (OIDs) and SQL error codes.

- Greenplum Database SNMP OIDs
- SQL Standard Error Codes

For information about enabling Greenplum Database to use SNMP, see *Enabling System Alerts and Notifications*.

### Greenplum Database SNMP OIDs

This is the Greenplum Database OID hierarchy structure:

```plaintext
iso(1) identified-organization(3) dod(6) internet(1) private(4) enterprises(1) gpdbMIB(31327) gpdbObjects(1)
```
gpdbAlertMsg

1.3.6.1.4.1.31327.1.1: STRING: alert message text

gpdbAlertSeverity

1.3.6.1.4.1.31327.1.2: INTEGER: severity level

gpdbAlertSeverity can have one of the following values:

- gpdbSevUnknown(0)
- gpdbSevOk(1)
- gpdbSevWarning(2)
- gpdbSevError(3)
- gpdbSevFatal(4)
- gpdbSevPanic(5)
- gpdbSevSystemDegraded(6)
- gpdbSevSystemDown(7)

gpdbAlertSqlstate

1.3.6.1.4.1.31327.1.3: STRING: SQL standard error codes

For a list of codes, see SQL Standard Error Codes.

gpdbAlertDetail

1.3.6.1.4.1.31327.1.4: STRING: detailed alert message text

gpdbAlertSqlStmt

1.3.6.1.4.1.31327.1.5: STRING: SQL statement generating this alert if applicable

gpdbAlertSystemName

1.3.6.1.4.1.31327.1.6: STRING: hostname

**SQL Standard Error Codes**

The following table lists all the defined error codes. Some are not used, but are defined by the SQL standard. The error classes are also shown. For each error class there is a standard error code having the last three characters 000. This code is used only for error conditions that fall within the class but do not have any more-specific code assigned.

The PL/pgSQL condition name for each error code is the same as the phrase shown in the table, with underscores substituted for spaces. For example, code 22012, DIVISION BY ZERO, has condition name DIVISION_BY_ZERO. Condition names can be written in either upper or lower case.

**Note:** PL/pgSQL does not recognize warning, as opposed to error, condition names; those are classes 00, 01, and 02.

**Table 36: SQL Codes**

<table>
<thead>
<tr>
<th>Error Code</th>
<th>Meaning</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 00</td>
<td>Successful Completion</td>
<td></td>
</tr>
<tr>
<td>Error Code</td>
<td>Meaning</td>
<td>Constant</td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
<td>----------</td>
</tr>
<tr>
<td>00000</td>
<td>SUCCESSFUL COMPLETION</td>
<td>successful_completion</td>
</tr>
<tr>
<td></td>
<td>Class 01 — Warning</td>
<td></td>
</tr>
<tr>
<td>01000</td>
<td>WARNING</td>
<td>warning</td>
</tr>
<tr>
<td>0100c</td>
<td>DYNAMIC RESULT SETS RETURNED</td>
<td>dynamic_result_sets_returned</td>
</tr>
<tr>
<td>01008</td>
<td>IMPLICIT ZERO BIT Padding</td>
<td>implicit_zero_bit_padding</td>
</tr>
<tr>
<td>01003</td>
<td>NULL VALUE ELIMINATED IN SET FUNCTION</td>
<td>null_value_eliminated_in_set_function</td>
</tr>
<tr>
<td>01007</td>
<td>PRIVILEGE NOT GRANTED</td>
<td>privilege_not_granted</td>
</tr>
<tr>
<td>01006</td>
<td>PRIVILEGE NOT REVOKED</td>
<td>privilege_not_revoked</td>
</tr>
<tr>
<td>01004</td>
<td>STRING DATA RIGHT TRUNCATION</td>
<td>string_data_right_truncation</td>
</tr>
<tr>
<td>01P01</td>
<td>DEPRECATED FEATURE</td>
<td>deprecated_feature</td>
</tr>
<tr>
<td></td>
<td>Class 02 — No Data (this is also a warning class per the SQL standard)</td>
<td></td>
</tr>
<tr>
<td>02000</td>
<td>NO DATA</td>
<td>no_data</td>
</tr>
<tr>
<td>02001</td>
<td>NO ADDITIONAL DYNAMIC RESULT SETS RETURNED</td>
<td>no_additional_dynamic_result_sets_returned</td>
</tr>
<tr>
<td></td>
<td>Class 03 — SQL Statement Not Yet Complete</td>
<td></td>
</tr>
<tr>
<td>03000</td>
<td>SQL STATEMENT NOT YET COMPLETE</td>
<td>sql_statement_not_yet_complete</td>
</tr>
<tr>
<td></td>
<td>Class 08 — Connection Exception</td>
<td></td>
</tr>
<tr>
<td>08000</td>
<td>CONNECTION EXCEPTION</td>
<td>connection_exception</td>
</tr>
<tr>
<td>08003</td>
<td>CONNECTION DOES NOT EXIST</td>
<td>connection_does_not_exist</td>
</tr>
<tr>
<td>08006</td>
<td>CONNECTION FAILURE</td>
<td>connection_failure</td>
</tr>
<tr>
<td>08001</td>
<td>SQLCLIENT UNABLE TO ESTABLISH SQLCONNECTION</td>
<td>sqlclient_unable_to_establish_sqlconnection</td>
</tr>
<tr>
<td>08004</td>
<td>SQLSERVER REJECTED ESTABLISHMENT OF SQLCONNECTION</td>
<td>sqlserver_rejected_establishment_of_sqlconnection</td>
</tr>
<tr>
<td>08007</td>
<td>TRANSACTION RESOLUTION UNKNOWN</td>
<td>transaction_resolution_unknown</td>
</tr>
<tr>
<td>08P01</td>
<td>PROTOCOL VIOLATION</td>
<td>protocol_violation</td>
</tr>
<tr>
<td></td>
<td>Class 09 — Triggered Action Exception</td>
<td></td>
</tr>
<tr>
<td>09000</td>
<td>TRIGGERED ACTION EXCEPTION</td>
<td>triggered_action_exception</td>
</tr>
<tr>
<td></td>
<td>Class 0A — Feature Not Supported</td>
<td></td>
</tr>
<tr>
<td>0A000</td>
<td>FEATURE NOT SUPPORTED</td>
<td>feature_not_supported</td>
</tr>
<tr>
<td></td>
<td>Class 0B — Invalid Transaction Initiation</td>
<td></td>
</tr>
<tr>
<td>0B000</td>
<td>INVALID TRANSACTION INITIATION</td>
<td>invalid_transaction_initiation</td>
</tr>
<tr>
<td></td>
<td>Class 0F — Locator Exception</td>
<td></td>
</tr>
<tr>
<td>Error Code</td>
<td>Meaning</td>
<td>Constant</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>0F000</td>
<td>LOCATOR EXCEPTION</td>
<td>locator_exception</td>
</tr>
<tr>
<td>0F001</td>
<td>INVALID LOCATOR SPECIFICATION</td>
<td>invalid_locator_specification</td>
</tr>
<tr>
<td><strong>Class 0L</strong> — Invalid Grantor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0L000</td>
<td>INVALID GRANTOR</td>
<td>invalid_grantor</td>
</tr>
<tr>
<td>0LP01</td>
<td>INVALID GRANT OPERATION</td>
<td>invalid_grant_operation</td>
</tr>
<tr>
<td><strong>Class 0P</strong> — Invalid Role Specification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0P000</td>
<td>INVALID ROLE SPECIFICATION</td>
<td>invalid_role_specification</td>
</tr>
<tr>
<td><strong>Class 21</strong> — Cardinality Violation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21000</td>
<td>CARDINALITY VIOLATION</td>
<td>cardinality_violation</td>
</tr>
<tr>
<td><strong>Class 22</strong> — Data Exception</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22000</td>
<td>DATA EXCEPTION</td>
<td>data_exception</td>
</tr>
<tr>
<td>2202E</td>
<td>ARRAY SUBSCRIPT ERROR</td>
<td>array_subscript_error</td>
</tr>
<tr>
<td>22021</td>
<td>CHARACTER NOT IN REPERTOIRE</td>
<td>character_not_in_repertoire</td>
</tr>
<tr>
<td>22008</td>
<td>DATETIME FIELD OVERFLOW</td>
<td>datetime_field_overflow</td>
</tr>
<tr>
<td>22012</td>
<td>DIVISION BY ZERO</td>
<td>division_by_zero</td>
</tr>
<tr>
<td>22005</td>
<td>ERROR IN ASSIGNMENT</td>
<td>error_in_assignment</td>
</tr>
<tr>
<td>2200B</td>
<td>ESCAPE CHARACTER CONFLICT</td>
<td>escape_character_conflict</td>
</tr>
<tr>
<td>22022</td>
<td>INDICATOR OVERFLOW</td>
<td>indicator_overflow</td>
</tr>
<tr>
<td>22015</td>
<td>INTERVAL FIELD OVERFLOW</td>
<td>interval_field_overflow</td>
</tr>
<tr>
<td>2201E</td>
<td>INVALID ARGUMENT FOR LOGARITHM</td>
<td>invalid_argument_for_logarithm</td>
</tr>
<tr>
<td>2201F</td>
<td>INVALID ARGUMENT FOR POWER FUNCTION</td>
<td>invalid_argument_for_power_function</td>
</tr>
<tr>
<td>2201G</td>
<td>INVALID ARGUMENT FOR WIDTH BUCKET FUNCTION</td>
<td>invalid_argument_for_width_bucket_function</td>
</tr>
<tr>
<td>22018</td>
<td>INVALID CHARACTER VALUE FOR CAST</td>
<td>invalid_character_value_for_cast</td>
</tr>
<tr>
<td>22007</td>
<td>INVALID DATETIME FORMAT</td>
<td>invalid_datetime_format</td>
</tr>
<tr>
<td>22019</td>
<td>INVALID ESCAPE CHARACTER</td>
<td>invalid_escape_character</td>
</tr>
<tr>
<td>2200D</td>
<td>INVALID ESCAPE OCTET</td>
<td>invalid_escape_octet</td>
</tr>
<tr>
<td>22025</td>
<td>INVALID ESCAPE SEQUENCE</td>
<td>invalid_escape_sequence</td>
</tr>
<tr>
<td>22P06</td>
<td>NONSTANDARD USE OF ESCAPE CHARACTER</td>
<td>nonstandard_use_of_escape_character</td>
</tr>
<tr>
<td>22010</td>
<td>INVALID INDICATOR PARAMETER VALUE</td>
<td>invalid_indicator_parameter_value</td>
</tr>
<tr>
<td>22020</td>
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**Class 23 — Integrity Constraint Violation**

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**Class 24 — Invalid Cursor State**

| 24000 | INVALID CURSOR STATE           | invalid_cursor_state                 |

**Class 25 — Invalid Transaction State**

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Routine System Maintenance Tasks

To keep a Greenplum Database system running efficiently, the database must be regularly cleared of expired data and the table statistics must be updated so that the query optimizer has accurate information.

Greenplum Database requires that certain tasks be performed regularly to achieve optimal performance. The tasks discussed here are required, but database administrators can automate them using standard UNIX tools such as `cron` scripts. An administrator sets up the appropriate scripts and checks that they execute successfully. See "Recommended Monitoring and Maintenance Tasks" for additional suggested maintenance activities you can implement to keep your Greenplum system running optimally.

Routine Vacuum and Analyze

The design of the MVCC transaction concurrency model used in Greenplum Database means that deleted or updated data rows still occupy physical space on disk even though they are not visible to new transactions. If your database has many updates and deletes, many expired rows exist and the space they use must be reclaimed with the `VACUUM` command. The `VACUUM` command also collects table-level statistics, such as numbers of rows and pages, so it is also necessary to vacuum append-optimized tables, even when there is no space to reclaim from updated or deleted rows.

Vacuuming an append-optimized table follows a different process than vacuuming heap tables. On each segment, a new segment file is created and visible rows are copied into it from the current segment. When the segment file has been copied, the original is scheduled to be dropped and the new segment file is made available. This requires sufficient available disk space for a copy of the visible rows until the original segment file is dropped.

If the ratio of hidden rows to total rows in a segment file is less than a threshold value (10, by default), the segment file is not compacted. The threshold value can be configured with the `gp_appendonly_compaction_threshold` server configuration parameter. `VACUUM FULL` ignores the value of `gp_appendonly_compaction_threshold` and rewrites the segment file regardless of the ratio.

You can use the `__gp_aovisimap_compaction_info()` function in the `gp_toolkit` schema to investigate the effectiveness of a `VACUUM` operation on append-optimized tables.

For information about the `__gp_aovisimap_compaction_info()` function see, "Checking Append-Optimized Tables" in the Greenplum Database Reference Guide.

`VACUUM` can be disabled for append-optimized tables using the `gp_appendonly_compaction` server configuration parameter.

For details about vacuuming a database, see "Vacuuming the Database".

For information about the `gp_appendonly_compaction_threshold` server configuration parameter and the `VACUUM` command, see the Greenplum Database Reference Guide.
Transaction ID Management

Greenplum’s MVCC transaction semantics depend on comparing transaction ID (XID) numbers to determine visibility to other transactions. Transaction ID numbers are compared using modulo $2^{32}$ arithmetic, so a Greenplum system that runs more than about two billion transactions can experience transaction ID wraparound, where past transactions appear to be in the future. This means past transactions' outputs become invisible. Therefore, it is necessary to `VACUUM` every table in every database at least once per two billion transactions.

Greenplum Database assigns XID values only to transactions that involve DDL or DML operations, which are typically the only transactions that require an XID.

**Important:** Greenplum Database monitors transaction IDs. If you do not vacuum the database regularly, Greenplum Database will generate a warning and error.

Greenplum Database issues the following warning when a significant portion of the transaction IDs are no longer available and before transaction ID wraparound occurs:

```
WARNING: database "database_name" must be vacuumed within number_of_transactions transactions
```

When the warning is issued, a `VACUUM` operation is required. If a `VACUUM` operation is not performed, Greenplum Database stops creating transactions when it reaches a limit prior to when transaction ID wraparound occurs. Greenplum Database issues this error when it stops creating transactions to avoid possible data loss:

```
FATAL: database is not accepting commands to avoid wraparound data loss in database "database_name"
```

The Greenplum Database configuration parameter `xid_warn_limit` controls when the warning is displayed. The parameter `xid_stop_limit` controls when Greenplum Database stops creating transactions.

Recovering from a Transaction ID Limit Error

When Greenplum Database reaches the `xid_stop_limit` transaction ID limit due to infrequent `VACUUM` maintenance, it becomes unresponsive. To recover from this situation, perform the following steps as database administrator:

1. Shut down Greenplum Database.
2. Temporarily lower the `xid_stop_limit` by 10,000,000.
3. Start Greenplum Database.
4. Run `VACUUM FREEZE` on all affected databases.
5. Reset the `xid_stop_limit` to its original value.
6. Restart Greenplum Database.

For information about the configuration parameters, see the Greenplum Database Reference Guide.

For information about transaction ID wraparound see the PostgreSQL documentation.

System Catalog Maintenance

Numerous database updates with `CREATE` and `DROP` commands increase the system catalog size and affect system performance. For example, running many `DROP TABLE` statements degrades the overall system performance due to excessive data scanning during metadata operations on catalog tables. The performance loss occurs between thousands to tens of thousands of `DROP TABLE` statements, depending on the system.
You should run a system catalog maintenance procedure regularly to reclaim the space occupied by deleted objects. If a regular procedure has not been run for a long time, you may need to run a more intensive procedure to clear the system catalog. This topic describes both procedures.

**Regular System Catalog Maintenance**

It is recommended that you periodically run `VACUUM` and `REINDEX` on the system catalog to clear the space that deleted objects occupy in the system tables and indexes. If regular database operations include numerous `DROP` statements, it is safe and appropriate to run a system catalog maintenance procedure with `VACUUM` daily at off-peak hours. You can do this while the system is available.

The following example script performs a `VACUUM`, `REINDEX`, and `ANALYZE` of the Greenplum Database system catalog:

```bash
#!/bin/bash

DBNAME="<database-name>"

SYSTABLES='"pg_catalog." || relname || "'; from pg_class a, pg_namespace b
where a.relnamespace=b.oid and b.nspname='pg_catalog' and a.relkind='r'"

psql -tc "SELECT 'VACUUM' || $SYSTABLES" $DBNAME | psql -a $DBNAME

reindexdb --system -d $DBNAME

analyzedb -s pg_catalog -d $DBNAME
```

**Intensive System Catalog Maintenance**

If a system catalog maintenance procedure has not been performed in a long time, the catalog can become bloated with dead space; this causes excessively long wait times for simple metadata operations. A wait of more than two seconds to list user tables, such as with the `\d` metacommand from within `psql`, is an indication of catalog bloat.

If you see indications of system catalog bloat, you must perform an intensive system catalog maintenance procedure with `VACUUM FULL` during a scheduled downtime period. During this period, stop all catalog activity on the system; the `FULL` system catalog maintenance procedure takes exclusive locks against the system catalog.

Running regular system catalog maintenance procedures can prevent the need for this more costly procedure.

**Vacuum and Analyze for Query Optimization**

Greenplum Database uses a cost-based query optimizer that relies on database statistics. Accurate statistics allow the query optimizer to better estimate selectivity and the number of rows that a query operation retrieves. These estimates help it choose the most efficient query plan. The `ANALYZE` command collects column-level statistics for the query optimizer.

You can run both `VACUUM` and `ANALYZE` operations in the same command. For example:

```bash
=# VACUUM ANALYZE mytable;
```

Running the `VACUUM ANALYZE` command might produce incorrect statistics when the command is run on a table with a significant amount of bloat (a significant amount of table disk space is occupied by deleted or obsolete rows). For large tables, the `ANALYZE` command calculates statistics from a random sample of rows. It estimates the number rows in the table by multiplying the average number of rows per page in the sample by the number of actual pages in the table. If the sample contains many empty pages, the estimated row count can be inaccurate.

For a table, you can view information about the amount of unused disk space (space that is occupied by deleted or obsolete rows) in the `gp_toolkit` view `gp_bloat_diag`. If the `bdidiag` column for a table contains the value `significant amount of bloat suspected`, a significant amount of table disk space consists of unused space. Entries are added to the `gp_bloat_diag` view after a table has been vacuumed.
To remove unused disk space from the table, you can run the command `VACUUM FULL` on the table. Due to table lock requirements, `VACUUM FULL` might not be possible until a maintenance period.

As a temporary workaround, run `ANALYZE` to compute column statistics and then run `VACUUM` on the table to generate an accurate row count. This example runs `ANALYZE` and then `VACUUM` on the `cust_info` table.

```sql
ANALYZE cust_info;
VACUUM cust_info;
```

**Important:** If you intend to execute queries on partitioned tables with GPORCA enabled (the default), you must collect statistics on the partitioned table root partition with the `ANALYZE ROOTPARTITION` command. For information about GPORCA, see [Overview of GPORCA](#).

**Note:** You can use the Greenplum Database utility `analyzedb` to update table statistics. Tables can be analyzed concurrently. For append optimized tables, `analyzedb` updates statistics only if the statistics are not current. For information about the `analyzedb` utility, see the [Greenplum Database Utility Guide](#).

### Routine Reindexing

For B-tree indexes, a freshly-constructed index is slightly faster to access than one that has been updated many times because logically adjacent pages are usually also physically adjacent in a newly built index. Reindexing older indexes periodically can improve access speed. If all but a few index keys on a page have been deleted, there will be wasted space on the index page. A reindex will reclaim that wasted space. In Greenplum Database it is often faster to drop an index (`DROP INDEX`) and then recreate it (`CREATE INDEX`) than it is to use the `REINDEX` command.

For table columns with indexes, some operations such as bulk updates or inserts to the table might perform more slowly because of the updates to the indexes. To enhance performance of bulk operations on tables with indexes, you can drop the indexes, perform the bulk operation, and then re-create the index.

### Managing Greenplum Database Log Files

- **Database Server Log Files**
- **Management Utility Log Files**

#### Database Server Log Files

Greenplum Database log output tends to be voluminous, especially at higher debug levels, and you do not need to save it indefinitely. Administrators rotate the log files periodically so new log files are started and old ones are removed.

Greenplum Database has log file rotation enabled on the master and all segment instances. Daily log files are created in the `pg_log` subdirectory of the master and each segment data directory using the following naming convention: `gpdb-YYYY-MM-DD_hhmmss.csv`. Although log files are rolled over daily, they are not automatically truncated or deleted. Administrators need to implement scripts or programs to periodically clean up old log files in the `pg_log` directory of the master and each segment instance.

For information about viewing the database server log files, see [Viewing the Database Server Log Files](#).

#### Management Utility Log Files

Log files for the Greenplum Database management utilities are written to `~/gpAdminLogs` by default. The naming convention for management log files is:

```
script_name_date.log
```
The log entry format is:

```
timestamp:utility:host:user:[INFO|WARN|FATAL]:message
```

The log file for a particular utility execution is appended to its daily log file each time that utility is run.

**Recommended Monitoring and Maintenance Tasks**

This section lists monitoring and maintenance activities recommended to ensure high availability and consistent performance of your Greenplum Database cluster.

The tables in the following sections suggest activities that a Greenplum System Administrator can perform periodically to ensure that all components of the system are operating optimally. Monitoring activities help you to detect and diagnose problems early. Maintenance activities help you to keep the system up-to-date and avoid deteriorating performance, for example, from bloated system tables or diminishing free disk space.

It is not necessary to implement all of these suggestions in every cluster; use the frequency and severity recommendations as a guide to implement measures according to your service requirements.

**Database State Monitoring Activities**

**Table 37: Database State Monitoring Activities**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
</table>
| List segments that are currently down. If any rows are returned, this should generate a warning or alert. Recommended frequency: run every 5 to 10 minutes Severity: IMPORTANT | Run the following query in the postgres database: `SELECT * FROM gp_segment_configuration WHERE status <> 'u';` | If the query returns any rows, follow these steps to correct the problem:  
1. Verify that the hosts with down segments are responsive.  
2. If hosts are OK, check the pg_log files for the primaries and mirrors of the down segments to discover the root cause of the segments going down.  
3. If no unexpected errors are found, run the gprecoverseg utility to bring the segments back online. |
| Check for segments that are currently in change tracking mode. If any rows are returned, this should generate a warning or alert. Recommended frequency: run every 5 to 10 minutes Severity: IMPORTANT | Execute the following query in the postgres database: `SELECT * FROM gp_segment_configuration WHERE mode = 'c';` | If the query returns any rows, follow these steps to correct the problem:  
1. Verify that hosts with down segments are responsive.  
2. If hosts are OK, check the pg_log files for the primaries and mirrors of the down segments to determine the root cause of the segments going down.  
3. If no unexpected errors are found, run the gprecoverseg utility to bring the segments back online. |
<table>
<thead>
<tr>
<th>Activity</th>
<th>Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check for segments that are currently re-syncing. If rows are returned, this should generate a warning or alert. Recommended frequency: run every 5 to 10 minutes Severity: IMPORTANT</td>
<td>Execute the following query in the postgres database: <code>SELECT * FROM gp_segment_configuration WHERE mode = 'r';</code></td>
<td>When this query returns rows, it implies that the segments are in the process of being re-synched. If the state does not change from 'r' to 's', then check the pg_log files from the primaries and mirrors of the affected segments for errors.</td>
</tr>
<tr>
<td>Check for segments that are not operating in their optimal role. If any segments are found, the cluster may not be balanced. If any rows are returned this should generate a warning or alert. Recommended frequency: run every 5 to 10 minutes Severity: IMPORTANT</td>
<td>Execute the following query in the postgres database: <code>SELECT * FROM gp_segment_configuration WHERE preferred_role &lt;&gt; role;</code></td>
<td>When the segments are not running in their preferred role, hosts have uneven numbers of primary segments on each host, implying that processing is skewed. Wait for a potential window and restart the database to bring the segments into their preferred roles.</td>
</tr>
<tr>
<td>Run a distributed query to test that it runs on all segments. One row should be returned for each primary segment. Recommended frequency: run every 5 to 10 minutes Severity: CRITICAL</td>
<td>Execute the following query in the postgres database: <code>SELECT gp_segment_id, count(*) FROM gp_dist_random('pg_class') GROUP BY 1;</code></td>
<td>If this query fails, there is an issue dispatching to some segments in the cluster. This is a rare event. Check the hosts that are not able to be dispatched to ensure there is no hardware or networking issue.</td>
</tr>
<tr>
<td>Test the state of master mirroring on a Greenplum Database 4.2 or earlier cluster. If the value is &quot;Not Synchronized&quot;, raise an alert or warning. Recommended frequency: run every 5 to 10 minutes Severity: IMPORTANT</td>
<td>Execute the following query in the postgres database: <code>SELECT summary_state FROM gp_master_mirroring;</code></td>
<td>Check the pg_log from the master and standby master for errors. If there are no unexpected errors and the machines are up, run the gpinitstandby utility to bring the standby online. This requires a database restart on GPDB 4.2 and earlier.</td>
</tr>
<tr>
<td>Test the state of master mirroring on Greenplum Database. If the value is not &quot;STREAMING&quot;, raise an alert or warning. Recommended frequency: run every 5 to 10 minutes Severity: IMPORTANT</td>
<td>Run the following psql command: <code>psql dbname -c 'SELECT procpid, state FROM pg_stat_replication;';</code></td>
<td>Check the pg_log file from the master and standby master for errors. If there are no unexpected errors and the machines are up, run the gpinitstandby utility to bring the standby online.</td>
</tr>
</tbody>
</table>
Perform a basic check to see if the master is up and functioning.
Recommended frequency: run every 5 to 10 minutes
Severity: CRITICAL

<table>
<thead>
<tr>
<th>Activity</th>
<th>Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run the following query in the <code>postgres</code> database:</td>
<td>If this query fails the active master may be down. Try again several times and then inspect the active master manually. If the active master is down, reboot or power cycle the active master to ensure no processes remain on the active master and then trigger the activation of the standby master.</td>
<td></td>
</tr>
<tr>
<td><code>SELECT count(*) FROM gp_segment_configuration;</code></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Database Alert Log Monitoring**

**Table 38: Database Alert Log Monitoring Activities**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check for FATAL and ERROR log messages from the system. Recommended frequency: run every 15 minutes Severity: WARNING</td>
<td>Run the following query in the <code>gpperfmon</code> database:</td>
<td>Send an alert to the DBA to analyze the alert. You may want to add additional filters to the query to ignore certain messages of low interest.</td>
</tr>
<tr>
<td><code>SELECT * FROM log_alert_history WHERE logseverity in ('FATAL', 'ERROR') AND logtime &gt; (now() - interval '15 minutes');</code></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This activity and the next are two methods for monitoring messages in the log_alert_history table. It is only necessary to set up one or the other.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activity</th>
<th>Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set up server configuration parameters to send SNMP or email alerts. Recommended frequency: N/A. Alerts are generated by the system. Severity: WARNING</td>
<td>Enable server configuration parameters to send alerts via SNMP or email:</td>
<td>DBA takes action based on the nature of the alert.</td>
</tr>
<tr>
<td><code>• gp_email_smtp_server</code></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>• gp_email_smtp_userid</code></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>• gp_email_smtp_password</code></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>• gp_snmp_monitor_address</code></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>• gp_snmp_community</code></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>• gp_snmp_use_inform_or_trap</code></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This activity and the previous are two methods for monitoring messages in the log_alert_history table. It is only necessary to set up one or the other.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Hardware and Operating System Monitoring

## Table 39: Hardware and Operating System Monitoring Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underlying platform check for maintenance required or system down of the hardware.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended frequency: real-time, if possible, or every 15 minutes</td>
<td>Set up SNMP or other system check for hardware and OS errors.</td>
<td>If required, remove a machine from the Greenplum cluster to resolve hardware and OS issues, then, after add it back to the cluster and run <code>gprecoverseg</code>.</td>
</tr>
<tr>
<td>Severity: CRITICAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check disk space usage on volumes used for Greenplum Database data storage and the OS.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended frequency: every 5 to 30 minutes</td>
<td>Set up a disk space check.</td>
<td>Free space on the system by removing some data or files.</td>
</tr>
<tr>
<td>Severity: CRITICAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check for errors or dropped packets on the network interfaces.</td>
<td>Set up a network interface checks.</td>
<td>Work with network and OS teams to resolve errors.</td>
</tr>
<tr>
<td>Recommended frequency: hourly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severity: IMPORTANT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check for RAID errors or degraded RAID performance.</td>
<td>Set up a RAID check.</td>
<td>• Replace failed disks as soon as possible.</td>
</tr>
<tr>
<td>Recommended frequency: every 5 minutes</td>
<td></td>
<td>• Work with system administration team to resolve other RAID or controller errors as soon as possible.</td>
</tr>
<tr>
<td>Severity: CRITICAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run the Greenplum gpcheck utility to test that the configuration of the cluster complies with current recommendations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended frequency: when creating a cluster or adding new machines to the cluster</td>
<td>Run gpcheck.</td>
<td>Work with system administration team to update configuration according to the recommendations made by the gpcheck utility.</td>
</tr>
</tbody>
</table>
Check for adequate I/O bandwidth and I/O skew.
Recommended frequency: when create a cluster or when hardware issues are suspected.

Run the Greenplum gpcheckperf utility.

The cluster may be under-specified if data transfer rates are not similar to the following:
- 2GB per second disk read
- 1 GB per second disk write
- 10 Gigabit per second network read and write

If transfer rates are lower than expected, consult with your data architect regarding performance expectations.
If the machines on the cluster display an uneven performance profile, work with the system administration team to fix faulty machines.

---

### Catalog Monitoring

Table 40: Catalog Monitoring Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run catalog consistency checks to ensure the catalog on each host in the cluster is consistent and in a good state. Recommended frequency: weekly Severity: IMPORTANT</td>
<td>Run the Greenplum gpcheckcat utility in each database: <code>gpcheckcat -O</code></td>
<td>Run repair scripts for any issues detected.</td>
</tr>
<tr>
<td>Run a persistent table catalog check. Recommended frequency: monthly Severity: CRITICAL</td>
<td>During a downtime, with no users on the system, run the Greenplum gpcheckcat utility in each database: <code>gpcheckcat -R persistent</code></td>
<td>Run repair scripts for any issues detected.</td>
</tr>
<tr>
<td>Check for <code>pg_class</code> entries that have no corresponding <code>pg_attribute</code> entry. Recommended frequency: monthly Severity: IMPORTANT</td>
<td>During a downtime, with no users on the system, run the Greenplum gpcheckcat utility in each database: <code>gpcheckcat -R pgclass</code></td>
<td>Run the repair scripts for any issues identified.</td>
</tr>
</tbody>
</table>
### Corrective Actions

- Run the repair scripts for any issues identified.

### Table 41: Data Maintenance Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
</table>
| Check for leaked temporary schema and missing schema definition. Recommended frequency: monthly Severity: IMPORTANT | During a downtime, with no users on the system, run the Greenplum `gpcheckcat` utility in each database:  
```
gpcheckcat -R namespace
``` | Run the repair scripts for any issues identified. |
| Check constraints on randomly distributed tables. Recommended frequency: monthly Severity: IMPORTANT | During a downtime, with no users on the system, run the Greenplum `gpcheckcat` utility in each database:  
```
gpcheckcat -R distribution_policy
``` | Run the repair scripts for any issues identified. |
| Check for dependencies on nonexistent objects. Recommended frequency: monthly Severity: IMPORTANT | During a downtime, with no users on the system, run the Greenplum `gpcheckcat` utility in each database:  
```
gpcheckcat -R dependency
``` | Run the repair scripts for any issues identified. |
| Check for missing statistics on tables. | Check the `gp_stats_missing` view in each database:  
```
SELECT * FROM gp_toolkit.gp_stats_missing;
``` | Run `ANALYZE` on tables that are missing statistics. |
| Check for tables that have bloat (dead space) in data files that cannot be recovered by a regular `VACUUM` command. Recommended frequency: weekly or monthly Severity: WARNING | Check the `gp_bloat_diag` view in each database:  
```
SELECT * FROM gp_toolkit.gp_bloat_diag;
``` | Execute a `VACUUM FULL` statement at a time when users are not accessing the table to remove bloat and compact the data. |
# Database Maintenance

## Table 42: Database Maintenance Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mark deleted rows in heap tables so that the space they occupy can be</td>
<td>Vacuum user tables: VACUUM &lt;table&gt;;</td>
<td>Vacuum updated tables regularly to prevent bloating.</td>
</tr>
<tr>
<td>reused. Recommended frequency: daily</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severity: CRITICAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Update table statistics.</td>
<td>Analyze user tables. You can use the <code>analyzedb</code> management utility:</td>
<td>Analyze updated tables regularly so that the optimizer can produce efficient query</td>
</tr>
<tr>
<td>Recommended frequency: after loading data and before executing queries</td>
<td><code>analyzedb -d &amp;lt;database&amp;gt; -a</code></td>
<td>execution plans.</td>
</tr>
<tr>
<td>Severity: CRITICAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backup the database data.</td>
<td>Run the <code>gpcrondump</code> utility to create a backup of the master and segment</td>
<td>Best practice is to have a current backup ready in case the database must be</td>
</tr>
<tr>
<td>Recommended frequency: daily, or as required by your backup plan</td>
<td>databases in parallel.</td>
<td>restored.</td>
</tr>
<tr>
<td>Severity: CRITICAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vacuum, reindex, and analyze system catalogs to maintain an efficient</td>
<td>1. VACUUM the system tables in each database.</td>
<td>The optimizer retrieves information from the system tables to create query plans. If</td>
</tr>
<tr>
<td>catalog. Recommended frequency: weekly, or more often if database objects</td>
<td>2. Run REINDEX SYSTEM in each database, or use the <code>reindexdb</code> command-line</td>
<td>system tables and indexes are allowed to become bloated over time, scanning the</td>
</tr>
<tr>
<td>are created and dropped frequently</td>
<td>utility with the <code>-s</code> option:</td>
<td>system tables increases query execution time. It is important to run <code>ANALYZE</code> after</td>
</tr>
<tr>
<td></td>
<td><code>reindexdb -s &amp;lt;database&amp;gt;</code></td>
<td>reindexing, because <code>REINDEX</code> leaves indexes with no statistics.</td>
</tr>
<tr>
<td></td>
<td>3. ANALYZE each of the system tables:</td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>analyzedb -s pg_catalog -d &amp;lt;database&amp;gt;</code></td>
<td></td>
</tr>
</tbody>
</table>
## Patching and Upgrading

### Table 43: Patch and Upgrade Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Procedure</th>
<th>Corrective Actions</th>
</tr>
</thead>
</table>
| Ensure any bug fixes or enhancements are applied to the kernel.  
Recommended frequency: at least every 6 months  
Severity: IMPORTANT | Follow the vendor's instructions to update the Linux kernel.             | Keep the kernel current to include bug fixes and security fixes, and to avoid difficult future upgrades. |
| Install Greenplum Database minor releases, for example 5.0.x.  
Recommended frequency: quarterly  
Managing Greenplum Database Access

Securing Greenplum Database includes protecting access to the database through network configuration, database user authentication, and encryption.

This section contains the following topics:

- Configuring Client Authentication
  - Using LDAP Authentication with TLS/SSL
  - Using Kerberos Authentication
- Managing Roles and Privileges

Configuring Client Authentication

This topic explains how to configure client connections and authentication for Greenplum Database.

When a Greenplum Database system is first initialized, the system contains one predefined superuser role. This role will have the same name as the operating system user who initialized the Greenplum Database system. This role is referred to as gpadmin. By default, the system is configured to only allow local connections to the database from the gpadmin role. If you want to allow any other roles to connect, or if you want to allow connections from remote hosts, you have to configure Greenplum Database to allow such connections. This section explains how to configure client connections and authentication to Greenplum Database.

Note: The PgBouncer connection pooler is bundled with Greenplum Database. PgBouncer can be configured to support LDAP or Active Directory authentication for users connecting to Greenplum Database through the connection pooler client connections to Greenplum Database. See Using the PgBouncer Connection Pooler.

Allowing Connections to Greenplum Database

Client access and authentication is controlled by the standard PostgreSQL host-based authentication file, pg_hba.conf. For detailed information about this file, see The pg_hba.conf File in the PostgreSQL documentation.

In Greenplum Database, the pg_hba.conf file of the master instance controls client access and authentication to your Greenplum Database system. The Greenplum Database segments also have pg_hba.conf files, but these are already correctly configured to allow only client connections from the master host. The segments never accept outside client connections, so there is no need to alter the pg_hba.conf file on segments.

The general format of the pg_hba.conf file is a set of records, one per line. Greenplum Database ignores blank lines and any text after the # comment character. A record consists of a number of fields that are separated by spaces or tabs. Fields can contain white space if the field value is quoted. Records cannot be continued across lines. Each remote client access record has the following format:

```
host  database  role     CIDR-address  authentication-method
```

Each UNIX-domain socket access record is in this format:

```
local  database  role  authentication-method
```

The following table describes meaning of each field.
### Table 44: pg_hba.conf Fields

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>local</td>
<td>Matches connection attempts using UNIX-domain sockets. Without a record of this type, UNIX-domain socket connections are disallowed.</td>
</tr>
<tr>
<td>host</td>
<td>Matches connection attempts made using TCP/IP. Remote TCP/IP connections will not be possible unless the server is started with an appropriate value for the <code>listen_addresses</code> server configuration parameter.</td>
</tr>
<tr>
<td>hostssl</td>
<td>Matches connection attempts made using TCP/IP, but only when the connection is made with SSL encryption. SSL must be enabled at server start time by setting the <code>ssl</code> server configuration parameter.</td>
</tr>
<tr>
<td>hostnossl</td>
<td>Matches connection attempts made over TCP/IP that do not use SSL.</td>
</tr>
<tr>
<td>database</td>
<td>Specifies which database names this record matches. The value <code>all</code> specifies that it matches all databases. Multiple database names can be supplied by separating them with commas. A separate file containing database names can be specified by preceding the file name with <code>@</code>.</td>
</tr>
<tr>
<td>role</td>
<td>Specifies which database role names this record matches. The value <code>all</code> specifies that it matches all roles. If the specified role is a group and you want all members of that group to be included, precede the role name with a <code>+</code>. Multiple role names can be supplied by separating them with commas. A separate file containing role names can be specified by preceding the file name with <code>@</code>.</td>
</tr>
<tr>
<td>CIDR-address</td>
<td>Specifies the client machine IP address range that this record matches. It contains an IP address in standard dotted decimal notation and a CIDR mask length. IP addresses can only be specified numerically, not as domain or host names. The mask length indicates the number of high-order bits of the client IP address that must match. Bits to the right of this must be zero in the given IP address. There must not be any white space between the IP address, the <code>/</code>, and the CIDR mask length. Typical examples of a CIDR-address are 172.20.143.89/32 for a single host, or 172.20.143.0/24 for a small network, or 10.6.0.0/16 for a larger one. To specify a single host, use a CIDR mask of 32 for IPv4 or 128 for IPv6. In a network address, do not omit trailing zeroes.</td>
</tr>
<tr>
<td>IP-address</td>
<td>These fields can be used as an alternative to the CIDR-address notation. Instead of specifying the mask length, the actual mask is specified in a separate column. For example, 255.0.0.0 represents an IPv4 CIDR mask length of 8, and 255.255.255.255 represents a CIDR mask length of 32. These fields only apply to and 255.255.255.255 represents a CIDR mask length of 32. These fields only apply to host, hostssl, and hostnossl records.</td>
</tr>
<tr>
<td>IP-mask</td>
<td></td>
</tr>
<tr>
<td>authentication-method</td>
<td>Specifies the authentication method to use when connecting. Greenplum supports the <code>authentication methods</code> supported by PostgreSQL 9.0.</td>
</tr>
</tbody>
</table>

**Caution:** For a more secure system, consider removing records for remote connections that use trust authentication from the `pg_hba.conf` file. Trust authentication grants any user who can connect to the server access to the database using any role they specify. You can safely replace trust authentication with `ident` authentication for local UNIX-socket connections. You can also use `ident` authentication for local and remote TCP clients, but the client host must be running an `ident` service and you must trust the integrity of that machine.
Editing the pg_hba.conf File

Initially, the pg_hba.conf file is set up with generous permissions for the gpadmin user and no database access for other Greenplum Database roles. You will need to edit the pg_hba.conf file to enable users' access to databases and to secure the gpadmin user. Consider removing entries that have trust authentication, since they allow anyone with access to the server to connect with any role they choose. For local (UNIX socket) connections, use ident authentication, which requires the operating system user to match the role specified. For local and remote TCP connections, ident authentication requires the client's host to run an indent service. You can install an indent service on the master host and then use ident authentication for local TCP connections, for example 127.0.0.1/28. Using ident authentication for remote TCP connections is less secure because it requires you to trust the integrity of the indent service on the client's host.

This example shows how to edit the pg_hba.conf file of the master to allow remote client access to all databases from all roles using encrypted password authentication.

Editing pg_hba.conf

1. Open the file $MASTER_DATA_DIRECTORY/pg_hba.conf in a text editor.
2. Add a line to the file for each type of connection you want to allow. Records are read sequentially, so the order of the records is significant. Typically, earlier records will have tight connection match parameters and weaker authentication methods, while later records will have looser match parameters and stronger authentication methods. For example:

```
# allow the gpadmin user local access to all databases
# using ident authentication
local   all   gpadmin   ident         sameuser
host    all   gpadmin   127.0.0.1/32  ident
host    all   gpadmin   ::1/128       ident
# allow the 'dba' role access to any database from any
# host with IP address 192.168.x.x and use md5 encrypted
# passwords to authenticate the user
# Note that to use SHA-256 encryption, replace md5 with
# in the line below
host    all   dba   192.168.0.0/32  md5
# allow all roles access to any database from any
# host and use ldap to authenticate the user. Greenplum role
# names must match the LDAP common name.
host    all   all   192.168.0.0/32  ldap
ldapport=1389 ldapprefix="cn="
ldapsuffix=",ou=People,dc=company,dc=com"
```

3. Save and close the file.
4. Reload the pg_hba.conf configuration file for your changes to take effect:

```
$ gpstop -u
```

Note: Note that you can also control database access by setting object privileges as described in Managing Object Privileges. The pg_hba.conf file just controls who can initiate a database session and how those connections are authenticated.

Limiting Concurrent Connections

Greenplum Database allocates some resources on a per-connection basis, so setting the maximum number of connections allowed is recommended.

To limit the number of active concurrent sessions to your Greenplum Database system, you can configure the max_connections server configuration parameter. This is a local parameter, meaning that you must set it in the postgresql.conf file of the master, the standby master, and each segment instance.
(primary and mirror). The recommended value of `max_connections` on segments is 5-10 times the value on the master.

When you set `max_connections`, you must also set the dependent parameter `max_prepared_transactions`. This value must be at least as large as the value of `max_connections` on the master, and segment instances should be set to the same value as the master.

For example:

- In `$MASTER_DATA_DIRECTORY/postgresql.conf` (including standby master):
  ```
  max_connections=100
  max_prepared_transactions=100
  ```

- In `$SEGMENT_DATA_DIRECTORY/postgresql.conf` for all segment instances:
  ```
  max_connections=500
  max_prepared_transactions=100
  ```

The following steps set the parameter values with the Greenplum Database utility `gpconfig`.

For information about `gpconfig`, see the *Greenplum Database Utility Guide*.

**To change the number of allowed connections**

1. Log into the Greenplum Database master host as the Greenplum Database administrator and source the file `$GPHOME/greenplum_path.sh`.

2. Set the value of the `max_connections` parameter. This `gpconfig` command sets the value on the segments to 1000 and the value on the master to 200.
   ```
   $ gpconfig -c max_connections -v 1000 -m 200
   ```

   The value on the segments must be greater than the value on the master. The recommended value of `max_connections` on segments is 5-10 times the value on the master.

3. Set the value of the `max_prepared_transactions` parameter. This `gpconfig` command sets the value to 200 on the master and all segments.
   ```
   $ gpconfig -c max_prepared_transactions -v 200
   ```

   The value of `max_prepared_transactions` must be greater than or equal to `max_connections` on the master.

4. Stop and restart your Greenplum Database system.
   ```
   $ gpstop -r
   ```

5. You can check the value of parameters on the master and segments with the `gpconfig -s` option. This `gpconfig` command displays the values of the `max_connections` parameter.
   ```
   $ gpconfig -s max_connections
   ```

**Note:**

Raising the values of these parameters may cause Greenplum Database to request more shared memory. To mitigate this effect, consider decreasing other memory-related parameters such as `gp_cached_segworkers_threshold`. 
Encrypting Client/Server Connections

Enable SSL for client connections to Greenplum Database to encrypt the data passed over the network between the client and the database.

Greenplum Database has native support for SSL connections between the client and the master server. SSL connections prevent third parties from snooping on the packets, and also prevent man-in-the-middle attacks. SSL should be used whenever the client connection goes through an insecure link, and must be used whenever client certificate authentication is used.

To enable SSL requires that OpenSSL be installed on both the client and the master server systems. Greenplum Database can be started with SSL enabled by setting the server configuration parameter `ssl=on` in the master `postgresql.conf`. When starting in SSL mode, the server will look for the files `server.key` (server private key) and `server.crt` (server certificate) in the master data directory. These files must be set up correctly before an SSL-enabled Greenplum Database system can start.

**Important:** Do not protect the private key with a passphrase. The server does not prompt for a passphrase for the private key, and the database startup fails with an error if one is required.

A self-signed certificate can be used for testing, but a certificate signed by a certificate authority (CA) should be used in production, so the client can verify the identity of the server. Either a global or local CA can be used. If all the clients are local to the organization, a local CA is recommended.

Creating a Self-signed Certificate without a Passphrase for Testing Only

To create a quick self-signed certificate for the server for testing, use the following OpenSSL command:

```bash
# openssl req -new -text -out server.req
```

Enter the information requested by the prompts. Be sure to enter the local host name as **Common Name**. The challenge password can be left blank.

The program will generate a key that is passphrase protected, and does not accept a passphrase that is less than four characters long.

To use this certificate with Greenplum Database, remove the passphrase with the following commands:

```bash
# openssl rsa -in privkey.pem -out server.key
# rm privkey.pem
```

Enter the old passphrase when prompted to unlock the existing key.

Then, enter the following command to turn the certificate into a self-signed certificate and to copy the key and certificate to a location where the server will look for them.

```bash
# openssl req -x509 -in server.req -text -key server.key -out server.crt
```

Finally, change the permissions on the key with the following command. The server will reject the file if the permissions are less restrictive than these.

```bash
# chmod og-rwx server.key
```

For more details on how to create your server private key and certificate, refer to the OpenSSL documentation.
Using LDAP Authentication with TLS/SSL

You can control access to Greenplum Database with an LDAP server and, optionally, secure the connection with encryption by adding parameters to pg_hba.conf file entries.

Greenplum Database supports LDAP authentication with the TLS/SSL protocol to encrypt communication with an LDAP server:

- LDAP authentication with STARTTLS and TLS protocol – STARTTLS starts with a clear text connection (no encryption) and upgrades it to a secure connection (with encryption).
- LDAP authentication with a secure connection and TLS/SSL (LDAPS) – Greenplum Database uses the TLS or SSL protocol based on the protocol that is used by the LDAP server.

If no protocol is specified, Greenplum Database communicates with the LDAP server with a clear text connection.

To use LDAP authentication, the Greenplum Database master host must be configured as an LDAP client. See your LDAP documentation for information about configuring LDAP clients.

*Note:* The PgBouncer connection pooler bundled with Greenplum Database is modified to support LDAP or Active Directory authentication for users connecting to Greenplum Database through the connection pooler. See *Setting up LDAP Authentication with PgBouncer* for instructions.

Enabling LDAP Authentication with STARTTLS and TLS

To enable STARTTLS with the TLS protocol, in the pg_hba.conf file, add an `ldap` line and specify the `ldaptls` parameter with the value 1. The default port is 389. In this example, the authentication method parameters include the `ldaptls` parameter.

```
ldap ldapsuffix="ou=People,dc=example,dc=com"
```

Specify a non-default port with the `ldapport` parameter. In this example, the authentication method includes the `ldaptls` parameter and the `ldapport` parameter to specify the port 550.

```
ldap ldapsuffix="ou=People,dc=example,dc=com"
```

Enabling LDAP Authentication with a Secure Connection and TLS/SSL

To enable a secure connection with TLS/SSL, add `ldaps://` as the prefix to the LDAP server name specified in the `ldapserver` parameter. The default port is 636.

This example `ldapserver` parameter specifies a secure connection and the TLS/SSL protocol for the LDAP server `myldap.com`.

```
ldapserver=ldaps://myldap.com
```

To specify a non-default port, add a colon (:) and the port number after the LDAP server name. This example `ldapserver` parameter includes the `ldaps://` prefix and the non-default port 550.

```
ldapserver=ldaps://myldap.com:550
```
Configuring Authentication with a System-wide OpenLDAP System

If you have a system-wide OpenLDAP system and logins are configured to use LDAP with TLS or SSL in the pg_hba.conf file, logins may fail with the following message:

```
could not start LDAP TLS session: error code '-11'
```

To use an existing OpenLDAP system for authentication, Greenplum Database must be set up to use the LDAP server’s CA certificate to validate user certificates. Follow these steps on both the master and standby hosts to configure Greenplum Database:

1. Copy the base64-encoded root CA chain file from the Active Directory or LDAP server to the Greenplum Database master and standby master hosts. This example uses the directory `/etc/pki/tls/certs`.

2. Change to the directory where you copied the CA certificate file and, as the root user, generate the hash for OpenLDAP:

   ```
   # cd /etc/pki/tls/certs
   # openssl x509 -noout -hash -in <ca-certificate-file>
   # ln -s <ca-certificate-file> <ca-certificate-file>.0
   ```

3. Configure an OpenLDAP configuration file for Greenplum Database with the CA certificate directory and certificate file specified.

   As the root user, edit the OpenLDAP configuration file `/etc/openldap/ldap.conf`:

   ```
   SASL_NOCANON on
   URI ldaps://ldapA.example.priv ldaps://ldapB.example.priv ldaps://ldapC.example.priv
   BASE dc=example,dc=priv
   TLS_CACERTDIR /etc/pki/tls/certs
   TLS_CACERT /etc/pki/tls/certs/<ca-certificate-file>
   ```

   **Note:** For certificate validation to succeed, the hostname in the certificate must match a hostname in the URI property. Otherwise, you must also add `TLS_REQCERT allow` to the file.

4. As the `gpadmin` user, edit `/usr/local/greenplum-db/greenplum_path.sh` and add the following line.

   ```
   export LDAPCONF=/etc/openldap/ldap.conf
   ```

**Notes**

Greenplum Database logs an error if the following are specified in an `pg_hba.conf` file entry:

- If both the `ldaps://` prefix and the `ldapTLS=1` parameter are specified.
- If both the `ldaps://` prefix and the `ldapport` parameter are specified.

Enabling encrypted communication for LDAP authentication only encrypts the communication between Greenplum Database and the LDAP server.

See *Encrypting Client/Server Connections* for information about encrypting client connections.

**Examples**

These are example entries from an `pg_hba.conf` file.

This example specifies LDAP authentication with no encryption between Greenplum Database and the LDAP server.

```
host all plainuser 0.0.0.0/0 ldap ldapserver=myldap.com ldapprefix="uid=" ldapsuffix="",ou=People,dc=example,dc=com"
```
This example specifies LDAP authentication with the STARTTLS and TLS protocol between Greenplum Database and the LDAP server.

```
host all tlsuser 0.0.0.0/0 ldap ldapsuser=myldap.com ldaptls=1
ldapprefix="uid=" ldapsuffix="ou=People,dc=example,dc=com"
```

This example specifies LDAP authentication with a secure connection and TLS/SSL protocol between Greenplum Database and the LDAP server.

```
host all ldapsuser 0.0.0.0/0 ldap ldapsuser=ldaps://myldap.com
ldapprefix="uid=" ldapsuffix="ou=People,dc=example,dc=com"
```

### Using Kerberos Authentication

You can control access to Greenplum Database with a Kerberos authentication server.

Greenplum Database supports the Generic Security Service Application Program Interface (GSSAPI) with Kerberos authentication. GSSAPI provides automatic authentication (single sign-on) for systems that support it. You specify the Greenplum Database users (roles) that require Kerberos authentication in the Greenplum Database configuration file `pg_hba.conf`. The login fails if Kerberos authentication is not available when a role attempts to log in to Greenplum Database.

Kerberos provides a secure, encrypted authentication service. It does not encrypt data exchanged between the client and database and provides no authorization services. To encrypt data exchanged over the network, you must use an SSL connection. To manage authorization for access to Greenplum databases and objects such as schemas and tables, you use settings in the `pg_hba.conf` file and privileges given to Greenplum Database users and roles within the database. For information about managing authorization privileges, see [Managing Roles and Privileges](#).

For more information about Kerberos, see [http://web.mit.edu/kerberos/](http://web.mit.edu/kerberos/).

### Requirements for Using Kerberos with Greenplum Database

The following items are required for using Kerberos with Greenplum Database:

- Kerberos Key Distribution Center (KDC) server using the `krb5-server` library
- Kerberos version 5 `krb5-libs` and `krb5-workstation` packages installed on the Greenplum Database master host
- Greenplum Database version with support for Kerberos
- System time on the Kerberos server and Greenplum Database master host must be synchronized. (Install Linux `ntp` package on both servers.)
- Network connectivity between the Kerberos server and the Greenplum Database master
- Java 1.7.0_17 or later is required to use Kerberos-authenticated JDBC on Red Hat Enterprise Linux 6.x

### Enabling Kerberos Authentication for Greenplum Database

Complete the following tasks to set up Kerberos authentication with Greenplum Database:

1. Verify your system satisfies the prerequisites for using Kerberos with Greenplum Database. See [Requirements for Using Kerberos with Greenplum Database](#).
2. Set up, or identify, a Kerberos Key Distribution Center (KDC) server to use for authentication. See [Install and Configure a Kerberos KDC Server](#).
3. In a Kerberos database on the KDC server, set up a Kerberos realm and principals on the server. For Greenplum Database, a principal is a Greenplum Database role that uses Kerberos authentication. In the Kerberos database, a realm groups together Kerberos principals that are Greenplum Database roles.
4. Create Kerberos keytab files for Greenplum Database. To access Greenplum Database, you create a service key known only by Kerberos and Greenplum Database. On the Kerberos server, the service key is stored in the Kerberos database.

On the Greenplum Database master, the service key is stored in key tables, which are files known as keytabs. The service keys are usually stored in the keytab file /etc/krb5.keytab. This service key is the equivalent of the service's password, and must be kept secure. Data that is meant to be read-only by the service is encrypted using this key.

5. Install the Kerberos client packages and the keytab file on Greenplum Database master.

6. Create a Kerberos ticket for gpadmin on the Greenplum Database master node using the keytab file. The ticket contains the Kerberos authentication credentials that grant access to the Greenplum Database.

With Kerberos authentication configured on the Greenplum Database, you can use Kerberos for PSQL and JDBC.

- Set up Greenplum Database with Kerberos for PSQL
- Set up Greenplum Database with Kerberos for JDBC

You can also configure external authentication for clients running on a Microsoft Windows system.

- Configure Kerberos authentication for the Greenplum Database client utilities gpload and psql on a Microsoft Windows system. See Configure Kerberos on Windows for Greenplum Database Clients.
- Configure a Microsoft Windows user with a Microsoft Active Directory (AD) account for single sign-on to a Greenplum Database system. See Configure Client Authentication with Active Directory.

Install and Configure a Kerberos KDC Server
Steps to set up a Kerberos Key Distribution Center (KDC) server on a Red Hat Enterprise Linux host for use with Greenplum Database.

Follow these steps to install and configure a Kerberos Key Distribution Center (KDC) server on a Red Hat Enterprise Linux host.

1. Install the Kerberos server packages:

   ```bash
   sudo yum install krb5-libs krb5-server krb5-workstation
   ```

2. Edit the /etc/krb5.conf configuration file. The following example shows a Kerberos server with a default KRB.GREENTPUL.COM realm.

   ```ini
   [logging]
   default = FILE:/var/log/krb5libs.log
   kdc = FILE:/var/log/krb5kdc.log
   admin_server = FILE:/var/log/kadmind.log

   [libdefaults]
   default_realm = KRB.GREENTPUL.COM
   dns_lookup_realm = false
   dns_lookup_kdc = false
   ticket_lifetime = 24h
   renew_lifetime = 7d
   forwardable = true
   default_tgs_enctypes = aes128-cts des3-hmac-shal des-cbc-crc des-cbc-md5
   default_tkt_enctypes = aes128-cts des3-hmac-shal des-cbc-crc des-cbc-md5
   permitted_enctypes = aes128-cts des3-hmac-shal des-cbc-crc des-cbc-md5

   [realms]
   KRB.GREENTPUL.COM = {
     kdc = kerberos-gpdb:88
     admin_server = kerberos-gpdb:749
     default_domain = kerberos-gpdb
   }
   ```
The `kdc` and `admin_server` keys in the `[realms]` section specify the host (`kerberos-gpdb`) and port where the Kerberos server is running. IP numbers can be used in place of host names.

If your Kerberos server manages authentication for other realms, you would instead add the `KRB.GREENPLUM.COM` realm in the `[realms]` and `[domain_realm]` section of the `kdc.conf` file. See the Kerberos documentation for information about the `kdc.conf` file.

3. To create a Kerberos KDC database, run the `kdb5_util`.

    kdb5_util create -s

The `kdb5_util` `create` option creates the database to store keys for the Kerberos realms that are managed by this KDC server. The `-s` option creates a stash file. Without the stash file, every time the KDC server starts it requests a password.

4. Add an administrative user to the KDC database with the `kadmin.local` utility. Because it does not itself depend on Kerberos authentication, the `kadmin.local` utility allows you to add an initial administrative user to the local Kerberos server. To add the user `gpadmin` as an administrative user to the KDC database, run the following command:

    kadmin.local -q "addprinc gpadmin/admin"

Most users do not need administrative access to the Kerberos server. They can use `kadmin` to manage their own principals (for example, to change their own password). For information about `kadmin`, see the Kerberos documentation.

5. If needed, edit the `/var/kerberos/krb5kdc/kadm5.acl` file to grant the appropriate permissions to `gpadmin`.

6. Start the Kerberos daemons:

    /sbin/service krb5kdc start
    /sbin/service kadmin start

7. To start Kerberos automatically upon restart:

    /sbin/chkconfig krb5kdc on
    /sbin/chkconfig kadmin on

---

**Create Greenplum Database Roles in the KDC Database**

Add principals to the Kerberos realm for Greenplum Database.

Start `kadmin.local` in interactive mode, then add two principals to the Greenplum Database Realm.

1. Start `kadmin.local` in interactive mode:

    kadmin.local

2. Add principals:
The `adprinc` commands prompt for passwords for each principal. The first `adprinc` creates a Greenplum Database user as a principal, `gpadmin/kerberos-gpdb`. The second `adprinc` command creates the `postgres` process on the Greenplum Database master host as a principal in the Kerberos KDC. This principal is required when using Kerberos authentication with Greenplum Database.

3. Create a Kerberos keytab file with `kadmin.local`. The following example creates a keytab file `gpdb-kerberos.keytab` in the current directory with authentication information for the two principals.

   ```bash
   kadmin.local: xst -k gpdb-kerberos.keytab
gpadmin/kerberos-gpdb@KRB.EXAMPLE.COM
   postgres/master.test.com@KRB.EXAMPLE.COM
   ```

   You will copy this file to the Greenplum Database master host.

4. Exit `kadmin.local` interactive mode with the `quit` command:

   ```bash
   kadmin.local: quit
   ```

### Install and Configure the Kerberos Client

Steps to install the Kerberos client on the Greenplum Database master host.

1. Install the Kerberos packages on the Greenplum Database master.

   ```bash
   sudo yum install krb5-libs krb5-workstation
   ```

2. Ensure that the `/etc/krb5.conf` file is the same as the one that is on the Kerberos server.

3. Copy the `gpdb-kerberos.keytab` file that was generated on the Kerberos server to the Greenplum Database master host.

4. Remove any existing tickets with the Kerberos utility `kdestroy`. Run the utility as root.

   ```bash
   sudo kdestroy
   ```

5. Use the Kerberos utility `kinit` to request a ticket using the keytab file on the Greenplum Database master for `gpadmin/kerberos-gpdb@KRB.EXAMPLE.COM`. The `-t` option specifies the keytab file on the Greenplum Database master.

   ```bash
   # kinit -k -t gpdb-kerberos.keytab gpadmin/kerberos-gpdb@KRB.EXAMPLE.COM
   ```

6. Use the Kerberos utility `klist` to display the contents of the Kerberos ticket cache on the Greenplum Database master. The following is an example:

   ```bash
   # klist
   Ticket cache: FILE:/tmp/krb5cc_108061
   Default principal: gpadmin/kerberos-gpdb@KRB.EXAMPLE.COM
   Valid starting            Expires            Service principal
   03/28/13 14:50:26  03/29/13 14:50:26  krbtgt/KRB.GREENPLUM.COM
   renewable                   until 03/28/13 14:50:26
   ```

### Set up Greenplum Database with Kerberos for PSQL

Configure a Greenplum Database to use Kerberos.

After you have set up Kerberos on the Greenplum Database master, you can configure Greenplum Database to use Kerberos. For information on setting up the Greenplum Database master, see [Install and Configure the Kerberos Client](#).
1. Create a Greenplum Database administrator role in the database postgres for the Kerberos principal that is used as the database administrator. The following example uses gpamin/kerberos-gpdb.

   

   ```
   psql postgres -c 'create role "gpadmin/kerberos-gpdb" login superuser;'
   ```

   The role you create in the database postgres will be available in any new Greenplum Database that you create.

2. Modify postgresql.conf to specify the location of the keytab file. For example, adding this line to the postgresql.conf specifies the folder /home/gpadmin as the location of the keytab file gpdb-kerberos.keytab.

   ```
   krb_server_keyfile = '/home/gpadmin/gpdb-kerberos.keytab'
   ```

3. Modify the Greenplum Database file pg_hba.conf to enable Kerberos support. Then restart Greenplum Database (gpstop -ar). For example, adding the following line to pg_hba.conf adds GSSAPI and Kerberos support. The value for krb_realm is the Kerberos realm that is used for authentication to Greenplum Database.

   ```
   host all all 0.0.0.0/0 gss include_realm=0 krb_realm=KRB.GREENPLUM.COM
   ```

   For information about the pg_hba.conf file, see The pg_hba.conf file in the Postgres documentation.

4. Create a ticket using kinit and show the tickets in the Kerberos ticket cache with klist.

5. As a test, log in to the database as the gpadmin role with the Kerberos credentials gpadmin/kerberos-gpdb:

   ```
   psql -U "gpadmin/kerberos-gpdb" -h master.test postgres
   ```

   A username map can be defined in the pg_ident.conf file and specified in the pg_hba.conf file to simplify logging into Greenplum Database. For example, this psql command logs into the default Greenplum Database on mdw.proddb as the Kerberos principal adminuser/mdw.proddb:

   ```
   $ psql -U "adminuser/mdw.proddb" -h mdw.proddb
   ```

   If the default user is adminuser, the pg_ident.conf file and the pg_hba.conf file can be configured so that the adminuser can log in to the database as the Kerberos principal adminuser/mdw.proddb without specifying the -U option:

   ```
   $ psql -h mdw.proddb
   ```

   The following username map is defined in the Greenplum Database file $MASTER_DATA_DIRECTORY/pg_ident.conf:

<table>
<thead>
<tr>
<th>MAPNAME</th>
<th>SYSTEM-USERNAME</th>
<th>GP-USERNAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>mymap</td>
<td>/^(.*)mdw.proddb$</td>
<td>adminuser</td>
</tr>
</tbody>
</table>

   The map can be specified in the pg_hba.conf file as part of the line that enables Kerberos support:

   ```
   host all all 0.0.0.0/0 krb5 include_realm=0 krb_realm=proddb map=mymap
   ```

   For more information about specifying username maps see Username maps in the Postgres documentation.

6. If a Kerberos principal is not a Greenplum Database user, a message similar to the following is displayed from the psql command line when the user attempts to log in to the database:

   ```
   psql: krb5_sendauth: Bad response
   ```

   The principal must be added as a Greenplum Database user.
**Set up Greenplum Database with Kerberos for JDBC**

Enable Kerberos-authenticated JDBC access to Greenplum Database.

You can configure Greenplum Database to use Kerberos to run user-defined Java functions.

1. Ensure that Kerberos is installed and configured on the Greenplum Database master. See Install and Configure the Kerberos Client.
2. Create the file `.java.login.config` in the folder `/home/gpadmin` and add the following text to the file:

   ```
   pgjdbc {
   com.sun.security.auth.module.Krb5LoginModule required
   doNotPrompt=true
   useTicketCache=true
   debug=true
   client=true;
   };
   ```

3. Create a Java application that connects to Greenplum Database using Kerberos authentication. The following example database connection URL uses a PostgreSQL JDBC driver and specifies parameters for Kerberos authentication:

   ```
   jdbc:postgresql://mdw:5432/mytest?kerberosServerName=postgres
   &jaasApplicationName=pgjdbc&user=gpadmin/kerberos-gpdb
   ```

   The parameter names and values specified depend on how the Java application performs Kerberos authentication.

4. Test the Kerberos login by running a sample Java application from Greenplum Database.

**Configuring Kerberos for Linux Clients**

You can configure Linux client applications to connect to a Greenplum Database system that is configured to authenticate with Kerberos.

If your JDBC application on RedHat Enterprise Linux uses Kerberos authentication when it connects to your Greenplum Database, your client system must be configured to use Kerberos authentication. If you are not using Kerberos authentication to connect to a Greenplum Database, Kerberos is not needed on your client system.

- **Requirements**
- Setting Up Client System with Kerberos Authentication
- Running a Java Application

For information about enabling Kerberos authentication with Greenplum Database, see the chapter “Setting Up Kerberos Authentication” in the Greenplum Database Administrator Guide.

**Requirements**

The following are requirements to connect to a Greenplum Database that is enabled with Kerberos authentication from a client system with a JDBC application.

- **Prerequisites**
- Required Software on the Client Machine

**Prerequisites**

- Kerberos must be installed and configured on the Greenplum Database master host.

  **Important:** Greenplum Database must be configured so that a remote user can connect to Greenplum Database with Kerberos authentication. Authorization to access Greenplum
Database is controlled by the `pg_hba.conf` file. For details, see "Editing the `pg_hba.conf` File" in the Greenplum Database Administration Guide, and also see the Greenplum Database Security Configuration Guide.

- The client system requires the Kerberos configuration file `krb5.conf` from the Greenplum Database master.
- The client system requires a Kerberos keytab file that contains the authentication credentials for the Greenplum Database user that is used to log into the database.
- The client machine must be able to connect to Greenplum Database master host.

If necessary, add the Greenplum Database master host name and IP address to the system `hosts` file. On Linux systems, the `hosts` file is in `/etc`.

**Required Software on the Client Machine**

- The Kerberos `kinit` utility is required on the client machine. The `kinit` utility is available when you install the Kerberos packages:
  - krb5-libs
  - krb5-workstation

  Note: When you install the Kerberos packages, you can use other Kerberos utilities such as `klist` to display Kerberos ticket information.

Java applications require this additional software:

- Java JDK
  - Java JDK 1.7.0_17 is supported on Red Hat Enterprise Linux 6.x.
  - Ensure that `JAVA_HOME` is set to the installation directory of the supported Java JDK.

**Setting Up Client System with Kerberos Authentication**

To connect to Greenplum Database with Kerberos authentication requires a Kerberos ticket. On client systems, tickets are generated from Kerberos keytab files with the `kinit` utility and are stored in a cache file.

1. Install a copy of the Kerberos configuration file `krb5.conf` from the Greenplum Database master. The file is used by the Greenplum Database client software and the Kerberos utilities.

   Install `krb5.conf` in the directory `/etc`.

   If needed, add the parameter `default_ccache_name` to the `[libdefaults]` section of the `krb5.ini` file and specify location of the Kerberos ticket cache file on the client system.

2. Obtain a Kerberos keytab file that contains the authentication credentials for the Greenplum Database user.

3. Run `kinit` specifying the keytab file to create a ticket on the client machine. For this example, the `keytab` file `gpdb-kerberos.keytab` is in the current directory. The ticket cache file is in the `gpadmin` user home directory.

   ```
   > kinit -k -t gpdb-kerberos.keytab -c /home/gpadmin/cache.txt
   gpadmin/kerberos-gpdb@KRB.EXAMPLE.COM
   ```

**Running psql**

From a remote system, you can access a Greenplum Database that has Kerberos authentication enabled.

**To connect to Greenplum Database with psql**

1. As the `gpadmin` user, open a command window.

2. Start `psql` from the command window and specify a connection to the Greenplum Database specifying the user that is configured with Kerberos authentication.
The following example logs into the Greenplum Database on the machine kerberos-gpdb as the gpadmin user with the Kerberos credentials gpadmin/kerberos-gpdb:

```
$ psql -U "gpadmin/kerberos-gpdb" -h kerberos-gpdb postgres
```

### Running a Java Application

Accessing Greenplum Database from a Java application with Kerberos authentication uses the Java Authentication and Authorization Service (JAAS)

1. Create the file .java.login.config in the user home folder.
   For example, on a Linux system, the home folder is similar to /home/gpadmin.
   Add the following text to the file:

   ```
   pgjdbc {
   com.sun.security.auth.module.Krb5LoginModule required
   doNotPrompt=true
   useTicketCache=true
   ticketCache = "/home/gpadmin/cache.txt"
   debug=true
   client=true;
   }
   ```

2. Create a Java application that connects to Greenplum Database using Kerberos authentication and run the application as the user.

   This example database connection URL uses a PostgreSQL JDBC driver and specifies parameters for Kerberos authentication.

   ```
   jdbc:postgresql://kerberos-gpdb:5432/mytest?
   kerberosServerName=postgres&jaasApplicationName=pgjdbc&
   user=gpadmin/kerberos-gpdb
   ```

   The parameter names and values specified depend on how the Java application performs Kerberos authentication.

### Configuring Kerberos For Windows Clients

You can configure Microsoft Windows client applications to connect to a Greenplum Database system that is configured to authenticate with Kerberos.

- Configure Kerberos on Windows for Greenplum Database Clients
- Configure Client Authentication with Active Directory

For information about configuring Greenplum Database with Kerberos authentication, see Using Kerberos Authentication.

#### Configure Kerberos on Windows for Greenplum Database Clients

When a Greenplum Database system is configured to authenticate with Kerberos, you can configure Kerberos authentication for the Greenplum Database client utilities `gpload` and `psql` on a Microsoft Windows system. The Greenplum Database clients authenticate with Kerberos directly, not with Microsoft Active Directory (AD).

This section contains the following information.

- Installing Kerberos on a Windows System.
- Running the psql Utility
- Example gpload YAML File
Creating a Kerberos Keytab File

These topics assume that the Greenplum Database system is configured to authenticate with Kerberos and Microsoft Active Directory. See Configure Client Authentication with Active Directory.

Installing Kerberos on a Windows System

To use Kerberos authentication with the Greenplum Database clients on a Windows system, the MIT Kerberos Windows client must be installed on the system. For the clients, you can install MIT Kerberos for Windows 4.0.1 (for krb5) that is available at http://web.mit.edu/kerberos/dist/index.html.

On the Windows system, you manage Kerberos tickets with the Kerberos kinit utility

The automatic start up of the Kerberos service is not enabled. The service cannot be used to authenticate with Greenplum Database.

Create a copy of the Kerberos configuration file /etc/krb5.conf from the Greenplum Database master and place it in the default Kerberos location on the Windows system C:\ProgramData\MIT\Kerberos5\krb5.ini. In the file section [libdefaults], remove the location of the Kerberos ticket cache default_ccache_name.

On the Windows system, use the environment variable KRB5CCNAME to specify the location of the Kerberos ticket. The value for the environment variable is a file, not a directory and should be unique to each login on the server.

This is an example configuration file with default_ccache_name removed. Also, the section [logging] is removed.

```
[libdefaults]
default_realm = EXAMPLE.LOCAL
dns_lookup_realm = false
dns_lookup_kdc = false
ticket_lifetime = 24h
renew_lifetime = 7d
forwardable = true

[realms]
EXAMPLE.LOCAL = {
kdc = bocdc.example.local
admin_server = bocdc.example.local
}

[domain_realm]
.example.local = EXAMPLE.LOCAL
e.example.local = EXAMPLE.LOCAL
```

When specifying a Kerberos ticket with KRB5CCNAME, you can specify the value in either a local user environment or within a session. These commands set KRB5CCNAME, runs kinit, and runs the batch file to set the environment variables for the Greenplum Database clients.

```
set KRB5CCNAME=%USERPROFILE%\krb5cache
kinit
"c:\Program Files (x86)\Greenplum\greenplum-clients-<version>\greenplum_clients_path.bat"
```
Running the \textit{psql} Utility

After installing and configuring Kerberos and the Kerberos ticket on a Windows system, you can run the Greenplum Database command line client \textit{psql}.

If you get warnings indicating that the Console code page differs from Windows code page, you can run the Windows utility \textit{chcp} to change the code page. This is an example of the warning and fix.

\begin{verbatim}
psql -h prod1.example.local warehouse
psql (8.3.23)
WARNING: Console code page (850) differs from Windows code page (1252)
  8-bit characters might not work correctly. See psql reference
  page "Notes for Windows users" for details.
Type "help" for help.

warehouse=# \q
chcp 1252
Active code page: 1252
psql -h prod1.example.local warehouse
psql (8.3.23)
Type "help" for help.
\end{verbatim}

Creating a Kerberos Keytab File

You can create and use a Kerberos \texttt{keytab} file to avoid entering a password at the command line or the listing a password in a script file when connecting to a Greenplum Database system. You can create a keyab file with these utilities:

- Windows Kerberos utility \texttt{ktpass}
- Java JRE keytab utility \texttt{ktab}

If you use AES256-CTS-HMAC-SHA1-96 encryption, you need to download and install the Java extension \textit{Java Cryptography Extension (JCE) Unlimited Strength Jurisdiction Policy Files for JDK/JRE} from Oracle. This command creates the keyab file \texttt{svcPostgresProd1.keytab}.

You run the \texttt{ktpass} utility as an AD Domain Administrator. The utility expects a user account to have a Service Principal Name (SPN) defined as an AD user attribute, however, it does not appear to be required. You can specify it as a parameter to \texttt{ktpass} and ignore the warning that it cannot be set.

The Java JRE \texttt{ktab} utility does not require an AD Domain Administrator and does not require an SPN.

\textbf{Note:} When you enter the password to create the keytab file, the password is visible on screen.

This example runs the \texttt{ktpass} utility to create the keytab \texttt{dev1.keytab}.

\begin{verbatim}
ktpass -out dev1.keytab -princ dev1@EXAMPLE.LOCAL -mapUser dev1 -pass your_password -crypto all -ptype KRB5_NT_PRINCIPAL

It works despite the warning message Unable to set SPN mapping data.

This example runs the Java \texttt{ktab.exe} to create a keytab file (-a option) and list the keytab name and entries (-1 -e -t options).

C:\Users\dev1>"\Program Files\Java\jre1.8.0_77\bin"\ktab -a dev1
Password for dev1@EXAMPLE.LOCAL:your_password
Done!
Service key for dev1 is saved in C:\Users\dev1\krb5.keytab

C:\Users\dev1>"\Program Files\Java\jre1.8.0_77\bin"\ktab -1 -e -t
Keytab name: C:\Users\dev1\krb5.keytab
KVNO Timestamp Principal
\end{verbatim}
You can then use a keytab with the following:

```bash
kinit -kt dev1.keytab dev1
or
kinit -kt %USERPROFILE%\krb5.keytab dev1
```

**Example gpload YAML File**

This is an example of running a gpload job with the user dev1 logged onto a Windows desktop with the AD domain.

In the example test.yaml control file, the USER: line has been removed. Kerberos authentication is used.

```yaml
---
VERSION: 1.0.0.1
DATABASE: warehouse
HOST: prod1.example.local
PORT: 5432

GPLOAD:
  INPUT:
    - SOURCE:
    PORT_RANGE: [18080,18080]
  FILE:
    - /Users/dev1/Downloads/test.csv
    - FORMAT: text
    - DELIMITER: ','
    - QUOTE: '"'
    - ERROR_LIMIT: 25
    - LOG_ERRORS: true
  OUTPUT:
    - TABLE: public.test
    - MODE: INSERT
  PRELOAD:
    - REUSE_TABLES: true
```

These commands run kinit and then gpload with the test.yaml file and displays successful gpload output.

```bash
kinit -kt %USERPROFILE%\krb5.keytab dev1
gpload.py -f test.yaml
2016-04-10 16:54:12|INFO|gpload session started 2016-04-10 16:54:12
2016-04-10 16:54:12|INFO|started gpfdist -p 18080 -P 18080 -f "/Users/dev1/
Downloads/test.csv" -t 30
2016-04-10 16:54:13|INFO|running time: 0.23 seconds
2016-04-10 16:54:13|INFO|rows Inserted = 3
2016-04-10 16:54:13|INFO|rows Updated = 0
2016-04-10 16:54:13|INFO|data formatting errors = 0
2016-04-10 16:54:13|INFO|gpload succeeded
```
Issues and Possible Solutions

- This message indicates that Kerberos cannot find your cache file:

  Credentials cache I/O operation failed XXX
  (Kerberos error 193)
  krb5_cc_default() failed

  To ensure that Kerberos can find the file set the environment variable `KRB5CCNAME` and run `kinit`.

  ```
  set KRB5CCNAME=%USERPROFILE%\krb5cache
  kinit
  ```

- This `kinit` message indicates that the `kinit -k -t` command could not find the keytab.

  ```
  kinit: Generic preauthentication failure while getting initial credentials
  ```

  Confirm the full path and filename for the Kerberos keytab file is correct.

Configure Client Authentication with Active Directory

You can configure a Microsoft Windows user with a Microsoft Active Directory (AD) account for single sign-on to a Greenplum Database system.

You configure an AD user account to support logging in with Kerberos authentication.

With AD single sign-on, a Windows user can use Active Directory credentials with a Windows client application to log into a Greenplum Database system. For Windows applications that use ODBC, the ODBC driver can use Active Directory credentials to connect to a Greenplum Database system.

**Note:** Greenplum Database clients that run on Windows, like `gpload`, connect with Greenplum Database directly and do not use Active Directory. For information about connecting Greenplum Database clients on Windows to a Greenplum Database system with Kerberos authentication, see Configure Kerberos on Windows for Greenplum Database Clients.

This section contains the following information.

- Prerequisites
- Active Directory Setup
- Greenplum Database Setup for Active Directory
- Single Sign-On Examples
- Issues and Possible Solutions for Active Directory

Prerequisites

These items are required enable AD single sign-on to a Greenplum Database system.

- The Greenplum Database system must be configured to support Kerberos authentication. For information about configuring Greenplum Database with Kerberos authentication, see Configuring Kerberos For Windows Clients.
- You must know the fully-qualified domain name (FQDN) of the Greenplum Database master host. Also, the Greenplum Database master host name must have a domain portion. If the system does not have a domain, you must configure the system to use a domain.

  This Linux `hostname` command displays the FQDN.

  ```
  hostname --fqdn
  ```

- You must confirm that the Greenplum Database system has the same date and time as the Active Directory domain. For example, you could set the Greenplum Database system NTP time source to be an AD Domain Controller, or configure the master host to use the same external time source as the AD Domain Controller.
• To support single sign-on, you configure an AD user account as a Managed Service Account in AD. These are requirements for Kerberos authentication.

• You need to add the Service Principal Name (SPN) attribute to the user account information because the Kerberos utilities require the information during Kerberos authentication.

• Also, as Greenplum database has unattended startups, you must also provide the account login details in a Kerberos keytab file.

  **Note:** Setting the SPN and creating the keytab requires AD administrative permissions.

**Active Directory Setup**

The AD naming convention should support multiple Greenplum Database systems. In this example, we create a new AD Managed Service Account *svcPostgresProd1* for our *prod1* Greenplum Database system master host.

The Active Directory domain is *example.local*.

The fully qualified domain name for the Greenplum Database master host is *prod1.example.local*. We will add the SPN *postgres/prod1.example.local* to this account. Service accounts for other Greenplum Database systems will all be in the form *postgres/fully.qualified.hostname*.

In this example, the AD password is set to never expire and cannot be changed by the user. The AD account password is only used when creating the Kerberos keytab file. There is no requirement to provide it to a database administrator.
An AD administrator must add the Service Principal Name attribute to the account from the command line with the Windows `setspn` command. This example command set the SPN attribute value to `postgres/prod1.example.local` for the AD user `svcPostgresProd1`:

```
setspn -A postgres/prod1.example.local svcPostgresProd1
```

You can see the SPN if Advanced Features are set in the Active Directory Users and Computers view. Find `servicePrincipalName` in the Attribute Editor tab and edit it if necessary.
The next step is to create a Kerberos keytab file.

You can select a specific cryptography method if your security requirements require it, but in the absence of that, it is best to get it to work first and then remove any cryptography methods you do not want.

As an AD Domain Administrator, you can list the types of encryption that your AD domain controller supports with this `ktpass` command:

```
ktpass /?
```

As an AD Domain Administrator, you can run the `ktpass` command to create a keytab file. This example command creates the file `svcPostgresProd1.keytab` with this information:

- **ServicePrincipalName (SPN):** `postgres/prod1.example.local@EXAMPLE.LOCAL`
- **AD user:** `svcPostgresProd1`
- **Encryption methods:** ALL available on AD
- **Principal Type:** `KR5_NT_PRINCIPAL`

```
ktpass -out svcPostgresProd1.keytab -princ postgres/prod1.example.local@EXAMPLE.LOCAL -mapUser svcPostgresProd1 -pass your_password -crypto all -ptype KRB5_NT_PRINCIPAL
```

**Note:** The AD domain `@EXAMPLE.LOCAL` is appended to the SPN.
You copy the keytab file `svcPostgresProd1.keytab` to the Greenplum Database master host.

As an alternative to running `ktpass` as an AD Domain Administrator, you can run the Java `ktab.exe` utility to generate a keytab file if you have the Java JRE installed on your desktop. When you enter the password using either `ktpass` or `ktab.exe`, the password will be visible on the screen as a command line argument.

This example command creates the keytab file `svcPostgresProd1.keytab`.

```
"c:\Program Files\Java\jre1.8.0_77\bin\ktab.exe" -a svcPostgresprod1 -k svcPostgresProd1.keytab
Password for svcPostgresprod1@EXAMPLE.LOCAL: your_password
Done!
Service key for svcPostgresprod1 is saved in svcPostgresProd1.keytab
```

**Note**: If you use AES256-CTS-HMAC-SHA1-96 encryption, you must download and install the Java extension *Java Cryptography Extension (JCE) Unlimited Strength Jurisdiction Policy Files for JDK/JRE* from Oracle.

### Greenplum Database Setup for Active Directory

These instructions assume that the Kerberos workstation utilities `krb5-workstation` are installed on the Greenplum Database master host.

Update `/etc/krb5.conf` with the AD domain name details and the location of an AD domain controller. This is an example configuration.

```ini
[logging]
default = FILE:/var/log/krb5libs.log
disable = FILE:/var/log/krb5kdc.log
admin_server = FILE:/var/log/kadmind.log

[libdefaults]
default_realm = EXAMPLE.LOCAL
disable = false
dns_lookup_kdc = false
ticket_lifetime = 24h
renew_lifetime = 7d
forwardable = true

[realms]
EXAMPLE.LOCAL = {
kdc = bocdc.example.local
admin_server = bocdc.example.local
}

[domain_realm]
.example.local = EXAMPLE.LOCAL
example.com = EXAMPLE.LOCAL
```

Copy the Kerberos keytab file that contains the AD user information to the Greenplum Database master directory. This example copies the `svcPostgresProd1.keytab` that was created in Active Directory Setup.

```bash
my_svcPostgresProd1.keytab $MASTER_DATA_DIRECTORY
chown gpadmin:gpadmin $MASTER_DATA_DIRECTORY/svcPostgresProd1.keytab
chmod 600 $MASTER_DATA_DIRECTORY/svcPostgresProd1.keytab
```
Add this line as the last line in the Greenplum Database pg_hba.conf file. This line configures Greenplum Database authentication to use Active Directory for authentication for connection any attempt that is not matched by a previous line.

```plaintext
host all all 0.0.0.0/0 gss include_realm=0
```

Update the Greenplum Database postgresql.conf file with the location details for the keytab file and the principal name to use. The fully qualified host name and the default realm from /etc/krb5.conf forms the full service principal name.

```plaintext
krb_server_keyfile = '/data/master/gpseg-1/svcPostgresProd1.keytab'
krb_srvname = 'postgres'
```

Create a database role for the AD user. This example logs into the default database and runs the `CREATE ROLE` command. The user `dev1` was the user specified when creating the keytab file in Active Directory Setup.

```plaintext
psql create role dev1 with login superuser;
```

Restart the database to use the updated authentication information:

```plaintext
gpstop -a
gpstart
```

**Note:** The Greenplum Database libraries might conflict with the Kerberos workstation utilities such as `kinit`. If you are using these utilities on the Greenplum Database master, you can either run a `gpadmin` shell that does not source the `$GPHOME/greenplum_path.sh` script, or unset the `LD_LIBRARY_PATH` environment variable similar to this example:

```plaintext
unset LD_LIBRARY_PATH
kinit
source $GPHOME/greenplum_path.sh
```

Confirm Greenplum Database access with Kerberos authentication:

```plaintext
kinit dev1
psql -h prod1.example.local -U dev1
```

**Single Sign-On Examples**

These single sign-on examples that use AD and Kerberos assume that the AD user `dev1` configured for single sign-on is logged into the Windows desktop.

This example configures Aginity Workbench for Greenplum Database. When using single sign-on, you enable Use Integrated Security.
This example configures an ODBC source. When setting up the ODBC source, do not enter a User Name or Password. This DSN can then be used by applications as an ODBC data source.
You can use the DSN `testdata` with an R client. This example configures R to access the DSN.

```r
library("RODBC")
conn <- odbcDriverConnect("testdata")
sql <- "select * from public.data1"
my_data <- sqlQuery(conn, sql)
print(my_data)
```

Issues and Possible Solutions for Active Directory

- Kerberos tickets contain a version number that must match the version number for AD.
  To display the version number in your keytab file, use the `klist -ket` command. For example:

```bash
klist -ket svcPostgresProd1.keytab
```

To get the corresponding value from AD domain controller, run this command as an AD Administrator:

```bash
kvno postgres/prod1.example.local@EXAMPLE.LOCAL
```

- This login error can occur when there is a mismatch between the Windows ID and the Greenplum Database user role ID. This log file entry shows the login error. A user `dev22` is attempting to login from a Windows desktop where the user is logged in as a different Windows user.

```
PDT,1917,con32,,seg-1,,,x1917,sx1, "FATAL","28000","authentication failed for user ""dev22"": valid
```
The error can also occur when the user can be authenticated, but does not have a Greenplum Database user role.

Ensure that the user is using the correct Windows ID and that a Greenplum Database user role is configured for the user ID.

- This error can occur when the Kerberos keytab does not contain a matching cryptographic type to a client attempting to connect.

```bash
code
psql -h 'hostname' postgres
psql: GSSAPI continuation error: Unspecified GSS failure. Minor code may provide more information
GSSAPI continuation error: Key version is not available
```

The resolution is to add the additional encryption types to the keytab using `ktutil` or recreating the postgres keytab with all crypto systems from AD.

## Managing Roles and Privileges

The Greenplum Database authorization mechanism stores roles and permissions to access database objects in the database and is administered using SQL statements or command-line utilities.

Greenplum Database manages database access permissions using **roles**. The concept of roles subsumes the concepts of **users** and **groups**. A role can be a database user, a group, or both. Roles can own database objects (for example, tables) and can assign privileges on those objects to other roles to control access to the objects. Roles can be members of other roles, thus a member role can inherit the object privileges of its parent role.

Every Greenplum Database system contains a set of database roles (users and groups). Those roles are separate from the users and groups managed by the operating system on which the server runs. However, for convenience you may want to maintain a relationship between operating system user names and Greenplum Database role names, since many of the client applications use the current operating system user name as the default.

In Greenplum Database, users log in and connect through the master instance, which then verifies their role and access privileges. The master then issues commands to the segment instances behind the scenes as the currently logged in role.

Roles are defined at the system level, meaning they are valid for all databases in the system.

In order to bootstrap the Greenplum Database system, a freshly initialized system always contains one predefined **superuser** role (also referred to as the system user). This role will have the same name as the operating system user that initialized the Greenplum Database system. Customarily, this role is named `gpadmin`. In order to create more roles you first have to connect as this initial role.

### Security Best Practices for Roles and Privileges

- **Secure the gpadmin system user.** Greenplum requires a UNIX user id to install and initialize the Greenplum Database system. This system user is referred to as `gpadmin` in the Greenplum documentation. This `gpadmin` user is the default database superuser in Greenplum Database, as well as the file system owner of the Greenplum installation and its underlying data files. This default administrator account is fundamental to the design of Greenplum Database. The system cannot run without it, and there is no way to limit the access of this `gpadmin` user id. Use roles to manage who has access to the database for specific purposes. You should only use the `gpadmin` account for system maintenance tasks such as expansion and upgrade. Anyone who logs on to a Greenplum host as this user id can read, alter or delete any data; including system catalog data and database access rights. Therefore, it is very important to secure the `gpadmin` user id and only provide access to essential system administrators. Administrators should only log in to Greenplum as `gpadmin` when performing...
certain system maintenance tasks (such as upgrade or expansion). Database users should never log on as gpadmin, and ETL or production workloads should never run as gpadmin.

- **Assign a distinct role to each user that logs in.** For logging and auditing purposes, each user that is allowed to log in to Greenplum Database should be given their own database role. For applications or web services, consider creating a distinct role for each application or service. See *Creating New Roles (Users)*.

- **Use groups to manage access privileges.** See *Role Membership*.

- **Limit users who have the SUPERUSER role attribute.** Roles that are superusers bypass all access privilege checks in Greenplum Database, as well as resource queuing. Only system administrators should be given superuser rights. See *Altering Role Attributes*.

### Creating New Roles (Users)

A user-level role is considered to be a database role that can log in to the database and initiate a database session. Therefore, when you create a new user-level role using the `CREATE ROLE` command, you must specify the `LOGIN` privilege. For example:

```sql
=# CREATE ROLE jsmith WITH LOGIN;
```

A database role may have a number of attributes that define what sort of tasks that role can perform in the database. You can set these attributes when you create the role, or later using the `ALTER ROLE` command. See *Table 45: Role Attributes* for a description of the role attributes you can set.

### Altering Role Attributes

A database role may have a number of attributes that define what sort of tasks that role can perform in the database.

#### Table 45: Role Attributes

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUPERUSER</td>
<td>NOSUPERUSER</td>
</tr>
<tr>
<td>CREATEDB</td>
<td>NOCREATEDB</td>
</tr>
<tr>
<td>CREATEROLE</td>
<td>NOCREATEROLE</td>
</tr>
<tr>
<td>INHERIT</td>
<td>NOINHERIT</td>
</tr>
<tr>
<td>LOGIN</td>
<td>NOLOGIN</td>
</tr>
<tr>
<td>CONNECTION LIMIT connlimit</td>
<td>If role can log in, this specifies how many concurrent connections the role can make. -1 (the default) means no limit.</td>
</tr>
<tr>
<td>Attributes</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>CREATEEXTTABLE</td>
<td>NOCREATEEXTTABLE</td>
</tr>
<tr>
<td>PASSWORD 'password'</td>
<td>Sets the role's password. If you do not plan to use password authentication you can omit this option. If no password is specified, the password will be set to null and password authentication will always fail for that user. A null password can optionally be written explicitly as PASSWORD NULL.</td>
</tr>
<tr>
<td>ENCRYPTED</td>
<td>UNENCRIPTED</td>
</tr>
<tr>
<td>VALID UNTIL 'timestamp'</td>
<td>Sets a date and time after which the role's password is no longer valid. If omitted the password will be valid for all time.</td>
</tr>
<tr>
<td>RESOURCE QUEUE queue_name</td>
<td>Assigns the role to the named resource queue for workload management. Any statement that role issues is then subject to the resource queue's limits. Note that the RESOURCE QUEUE attribute is not inherited; it must be set on each user-level (LOGIN) role.</td>
</tr>
<tr>
<td>DENY {deny_interval</td>
<td>deny_point}</td>
</tr>
</tbody>
</table>

You can set these attributes when you create the role, or later using the ALTER ROLE command. For example:

```
=# ALTER ROLE jsmith WITH PASSWORD 'passwd123';
=# ALTER ROLE admin VALID UNTIL 'infinity';
=# ALTER ROLE jsmith LOGIN;
=# ALTER ROLE jsmith RESOURCE QUEUE adhoc;
=# ALTER ROLE jsmith DENY DAY 'Sunday';
```

A role can also have role-specific defaults for many of the server configuration settings. For example, to set the default schema search path for a role:

```
=# ALTER ROLE admin SET search_path TO myschema, public;
```

**Role Membership**

It is frequently convenient to group users together to ease management of object privileges: that way, privileges can be granted to, or revoked from, a group as a whole. In Greenplum Database this is done by creating a role that represents the group, and then granting membership in the group role to individual user roles.
Use the `CREATE ROLE` SQL command to create a new group role. For example:

```sql
=# CREATE ROLE admin CREATEROLE CREATEDB;
```

Once the group role exists, you can add and remove members (user roles) using the `GRANT` and `REVOKE` commands. For example:

```sql
=# GRANT admin TO john, sally;
=# REVOKE admin FROM bob;
```

For managing object privileges, you would then grant the appropriate permissions to the group-level role only (see Table 46: Object Privileges). The member user roles then inherit the object privileges of the group role. For example:

```sql
=# GRANT ALL ON TABLE mytable TO admin;
=# GRANT ALL ON SCHEMA myschema TO admin;
=# GRANT ALL ON DATABASE mydb TO admin;
```

The role attributes `LOGIN`, `SUPERUSER`, `CREATEDB`, `CREATEROLE`, `CREATEEXTTABLE`, and `RESOURCE QUEUE` are never inherited as ordinary privileges on database objects are. User members must actually `SET ROLE` to a specific role having one of these attributes in order to make use of the attribute. In the above example, we gave `CREATEDB` and `CREATEROLE` to the `admin` role. If `sally` is a member of `admin`, she could issue the following command to assume the role attributes of the parent role:

```sql
=> SET ROLE admin;
```

### Managing Object Privileges

When an object (table, view, sequence, database, function, language, schema, or tablespace) is created, it is assigned an owner. The owner is normally the role that executed the creation statement. For most kinds of objects, the initial state is that only the owner (or a superuser) can do anything with the object. To allow other roles to use it, privileges must be granted. Greenplum Database supports the following privileges for each object type:

#### Table 46: Object Privileges

<table>
<thead>
<tr>
<th>Object Type</th>
<th>Privileges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tables, Views, Sequences</td>
<td>SELECT, INSERT, UPDATE, DELETE, RULE, ALL</td>
</tr>
<tr>
<td>External Tables</td>
<td>SELECT, RULE, ALL</td>
</tr>
</tbody>
</table>
Object Type | Privileges
---|---
Databases | CONNECT
| CREATE
| TEMPORARY | TEMP
| ALL

Functions | EXECUTE

Procedural Languages | USAGE

Schemas | CREATE
| USAGE
| ALL

Custom Protocol | SELECT
| INSERT
| UPDATE
| DELETE
| RULE
| ALL

**Note:** Privileges must be granted for each object individually. For example, granting ALL on a database does not grant full access to the objects within that database. It only grants all of the database-level privileges (CONNECT, CREATE, TEMPORARY) to the database itself.

Use the `GRANT` SQL command to give a specified role privileges on an object. For example:

```sql
=# GRANT INSERT ON mytable TO jsmith;
```

To revoke privileges, use the `REVOKE` command. For example:

```sql
=# REVOKE ALL PRIVILEGES ON mytable FROM jsmith;
```

You can also use the `DROP OWNED` and `REASSIGN OWNED` commands for managing objects owned by deprecated roles (Note: only an object's owner or a superuser can drop an object or reassign ownership). For example:

```sql
=# REASSIGN OWNED BY sally TO bob;
=# DROP OWNED BY visitor;
```

**Simulating Row and Column Level Access Control**

Row-level or column-level access is not supported, nor is labeled security. Row-level and column-level access can be simulated using views to restrict the columns and/or rows that are selected. Row-level labels can be simulated by adding an extra column to the table to store sensitivity information, and then using views to control row-level access based on this column. Roles can then be granted access to the views rather than the base table.

**Encrypting Data**

Greenplum Database is installed with an optional module of encryption/decryption functions called `pgcrypto`. The `pgcrypto` functions allow database administrators to store certain columns of data in
encrypted form. This adds an extra layer of protection for sensitive data, as data stored in Greenplum Database in encrypted form cannot be read by anyone who does not have the encryption key, nor can it be read directly from the disks.

**Note:** The pgcrypto functions run inside the database server, which means that all the data and passwords move between pgcrypto and the client application in clear-text. For optimal security, consider also using SSL connections between the client and the Greenplum master server.

To use pgcrypto functions, run the installation script
\$GPHOME/share/postgresql/contrib/pgcrypto.sql in each database where you want the ability to query other databases:

```
$ psql -d testdb -f $GPHOME/share/postgresql/contrib/pgcrypto.sql
```

See pgcrypto in the PostgreSQL documentation for more information about individual functions.

### Protecting Passwords in Greenplum Database

In its default configuration, Greenplum Database saves MD5 hashes of login users' passwords in the pg_authid system catalog rather than saving clear text passwords. Anyone who is able to view the pg_authid table can see hash strings, but no passwords. This also ensures that passwords are obscured when the database is dumped to backup files.

The hash function executes when the password is set by using any of the following commands:

- create user name with encrypted password 'password'
- create role name with login encrypted password 'password'
- alter user name with encrypted password 'password'
- alter role name with encrypted password 'password'

The ENCRYPTED keyword may be omitted when the password_encryption system configuration parameter is on, which is the default value. The password_encryption configuration parameter determines whether clear text or hashed passwords are saved when the ENCRYPTED or UNENCRYPTED keyword is not present in the command.

**Note:** The SQL command syntax and password_encryption configuration variable include the term encrypt, but the passwords are not technically encrypted. They are hashed and therefore cannot be decrypted.

The hash is calculated on the concatenated clear text password and role name. The MD5 hash produces a 32-byte hexadecimal string prefixed with the characters md5. The hashed password is saved in the rolpassword column of the pg_authid system table.

Although it is not recommended, passwords may be saved in clear text in the database by including the UNENCRYPTED keyword in the command or by setting the password_encryption configuration variable to off. Note that changing the configuration value has no effect on existing passwords, only newly created or updated passwords.

To set password_encryption globally, execute these commands in a shell as the gpadmin user:

```
$ gpconfig -c password_encryption -v 'off'
$ gpstop -u
```

To set password_encryption in a session, use the SQL SET command:

```
=# SET password_encryption = 'on';
```

Passwords may be hashed using the SHA-256 hash algorithm instead of the default MD5 hash algorithm. The algorithm produces a 64-byte hexadecimal string prefixed with the characters sha256.

**Note:**
Although SHA-256 uses a stronger cryptographic algorithm and produces a longer hash string, it cannot be used with the MD5 authentication method. To use SHA-256 password hashing the authentication method must be set to `password` in the `pg_hba.conf` configuration file so that clear text passwords are sent to Greenplum Database. Because clear text passwords are sent over the network, it is very important to use SSL for client connections when you use SHA-256. The default `md5` authentication method, on the other hand, hashes the password twice before sending it to Greenplum Database, once on the password and role name and then again with a salt value shared between the client and server, so the clear text password is never sent on the network.

To enable SHA-256 hashing, change the `password_hash_algorithm` configuration parameter from its default value, `md5`, to `sha-256`. The parameter can be set either globally or at the session level. To set `password_hash_algorithm` globally, execute these commands in a shell as the `gpadmin` user:

```bash
$ gpconfig -c password_hash_algorithm -v 'sha-256'
$ gpstop -u
```

To set `password_hash_algorithm` in a session, use the SQL `SET` command:

```sql
=# SET password_hash_algorithm = 'sha-256';
```

### Time-based Authentication

Greenplum Database enables the administrator to restrict access to certain times by role. Use the `CREATE ROLE` or `ALTER ROLE` commands to specify time-based constraints.

For details, refer to the *Greenplum Database Security Configuration Guide*. 

"
Defining Database Objects

This section covers data definition language (DDL) in Greenplum Database and how to create and manage database objects.

Creating objects in a Greenplum Database includes making up-front choices about data distribution, storage options, data loading, and other Greenplum features that will affect the ongoing performance of your database system. Understanding the options that are available and how the database will be used will help you make the right decisions.

Most of the advanced Greenplum features are enabled with extensions to the SQL CREATE DDL statements.

Creating and Managing Databases

A Greenplum Database system is a single instance of Greenplum Database. There can be several separate Greenplum Database systems installed, but usually just one is selected by environment variable settings. See your Greenplum administrator for details.

There can be multiple databases in a Greenplum Database system. This is different from some database management systems (such as Oracle) where the database instance is the database. Although you can create many databases in a Greenplum system, client programs can connect to and access only one database at a time — you cannot cross-query between databases.

About Template Databases

Each new database you create is based on a template. Greenplum provides a default database, template1. Use postgres to connect to Greenplum Database for the first time. Greenplum Database uses template1 to create databases unless you specify another template. Do not create any objects in template1 unless you want those objects to be in every database you create.

Greenplum Database uses another database templates, template0, internally. Do not drop or modify template0. You can use template0 to create a completely clean database containing only the standard objects predefined by Greenplum Database at initialization, especially if you modified template1.

Creating a Database

The CREATE DATABASE command creates a new database. For example:

```
=> CREATE DATABASE new_dbname;
```

To create a database, you must have privileges to create a database or be a Greenplum Database superuser. If you do not have the correct privileges, you cannot create a database. Contact your Greenplum Database administrator to either give you the necessary privilege or to create a database for you.

You can also use the client program createdb to create a database. For example, running the following command in a command line terminal connects to Greenplum Database using the provided host name and port and creates a database named mydatabase:

```
$ createdb -h masterhost -p 5432 mydatabase
```

The host name and port must match the host name and port of the installed Greenplum Database system.

Some objects, such as roles, are shared by all the databases in a Greenplum Database system. Other objects, such as tables that you create, are known only in the database in which you create them.

Warning: The CREATE DATABASE command is not transactional.
**Cloning a Database**

By default, a new database is created by cloning the standard system database template, `template1`. Any database can be used as a template when creating a new database, thereby providing the capability to 'clone' or copy an existing database and all objects and data within that database. For example:

```sql
=> CREATE DATABASE new_dbname TEMPLATE old_dbname;
```

**Creating a Database with a Different Owner**

Another database owner can be assigned when a database is created:

```sql
=> CREATE DATABASE new_dbname WITH owner=new_user;
```

**Viewing the List of Databases**

If you are working in the `psql` client program, you can use the `\l` meta-command to show the list of databases and templates in your Greenplum Database system. If using another client program and you are a superuser, you can query the list of databases from the `pg_database` system catalog table. For example:

```sql
=> SELECT datname from pg_database;
```

**Altering a Database**

The `ALTER DATABASE` command changes database attributes such as owner, name, or default configuration attributes. For example, the following command alters a database by setting its default schema search path (the `search_path` configuration parameter):

```sql
=> ALTER DATABASE mydatabase SET search_path TO myschema, public, pg_catalog;
```

To alter a database, you must be the owner of the database or a superuser.

**Dropping a Database**

The `DROP DATABASE` command drops (or deletes) a database. It removes the system catalog entries for the database and deletes the database directory on disk that contains the data. You must be the database owner or a superuser to drop a database, and you cannot drop a database while you or anyone else is connected to it. Connect to `postgres` (or another database) before dropping a database. For example:

```sql
=> \c postgres
=> DROP DATABASE mydatabase;
```

You can also use the client program `dropdb` to drop a database. For example, the following command connects to Greenplum Database using the provided host name and port and drops the database `mydatabase`:

```bash
$ dropdb -h masterhost -p 5432 mydatabase
```

**Warning:** Dropping a database cannot be undone.

The `DROP DATABASE` command is not transactional.
Creating and Managing Tablespaces

Tablespaces allow database administrators to have multiple file systems per machine and decide how to best use physical storage to store database objects. They are named locations within a filespace in which you can create objects. Tablespaces allow you to assign different storage for frequently and infrequently used database objects or to control the I/O performance on certain database objects. For example, place frequently-used tables on file systems that use high performance solid-state drives (SSD), and place other tables on standard hard drives.

A tablespace requires a file system location to store its database files. In Greenplum Database, the master and each segment (primary and mirror) require a distinct storage location. The collection of file system locations for all components in a Greenplum system is a filespace. Filespaces can be used by one or more tablespaces.

Creating a Filespace

A filespace sets aside storage for your Greenplum system. A filespace is a symbolic storage identifier that maps onto a set of locations in your Greenplum hosts’ file systems. To create a filespace, prepare the logical file systems on all of your Greenplum hosts, then use the gpfilespace utility to define the filespace. You must be a database superuser to create a filespace.

**Note:** Greenplum Database is not directly aware of the file system boundaries on your underlying systems. It stores files in the directories that you tell it to use. You cannot control the location on disk of individual files within a logical file system.

To create a filespace using gpfilespace

1. Log in to the Greenplum Database master as the gpadmin user.

   ```
   $ su - gpadmin
   ```

2. Create a filespace configuration file:

   ```
   $ gpfilespace -o gpfilespace_config
   ```

3. At the prompt, enter a name for the filespace, the primary segment file system locations, the mirror segment file system locations, and a master file system location. Primary and mirror locations refer to directories on segment hosts; the master location refers to a directory on the master host and standby master, if configured. For example, if your configuration has 2 primary and 2 mirror segments per host:

   ```
   Enter a name for this filespace> fastdisk
   primary location 1> /gpfs1/seg1
   primary location 2> /gpfs1/seg2
   mirror location 1> /gpfs2/mir1
   mirror location 2> /gpfs2/mir2
   master location> /gpfs1/master
   ```

4. gpfilespace creates a configuration file. Examine the file to verify that the gpfilespace configuration is correct.

5. Run gpfilespace again to create the filespace based on the configuration file:

   ```
   $ gpfilespace -c gpfilespace_config
   ```

Moving the Location of Temporary or Transaction Files

You can move temporary or transaction files to a specific filespace to improve database performance when running queries, creating backups, and to store data more sequentially.
The dedicated filespace for temporary and transaction files is tracked in two separate flat files called `gp_temporary_files_filespace` and `gp_transaction_files_filespace`. These are located in the `pg_system` directory on each primary and mirror segment, and on master and standby. You must be a superuser to move temporary or transaction files. Only the `gpfilespace` utility can write to this file.

### About Temporary and Transaction Files

Unless otherwise specified, temporary and transaction files are stored together with all user data. The default location of temporary files, `<filespace_directory>/<tablespace_oid>/<database_oid>/pgsql_tmp` is changed when you use `gpfilespace --movetempfiles` for the first time.

Also note the following information about temporary or transaction files:

- You can dedicate only one filespace for temporary or transaction files, although you can use the same filespace to store other types of files.
- You cannot drop a filespace if it used by temporary files.
- You must create the filespace in advance. See [Creating a Filespace](#).

### To move temporary files using gpfilespace

1. Check that the filespace exists and is different from the filespace used to store all other user data.
2. Issue smart shutdown to bring the Greenplum Database offline.
   
   If any connections are still in progress, the `gpfilespace --movetempfiles` utility will fail.
3. Bring Greenplum Database online with no active session and run the following command:

   ```
   gpfilespace --movetempfilespace filespace_name
   ```

   The location of the temporary files is stored in the segment configuration shared memory (PMModuleState) and used whenever temporary files are created, opened, or dropped.

### To move transaction files using gpfilespace

1. Check that the filespace exists and is different from the filespace used to store all other user data.
2. Issue smart shutdown to bring the Greenplum Database offline.
   
   If any connections are still in progress, the `gpfilespace --movetransfiles` utility will fail.
3. Bring Greenplum Database online with no active session and run the following command:

   ```
   gpfilespace --movetransfilespace filespace_name
   ```

   The location of the transaction files is stored in the segment configuration shared memory (PMModuleState) and used whenever transaction files are created, opened, or dropped.

### Creating a Tablespace

After you create a filespace, use the `CREATE TABLESPACE` command to define a tablespace that uses that filespace. For example:

```
=# CREATE TABLESPACE fastspace FILESPACE fastdisk;
```

Database superusers define tablespaces and grant access to database users with the `GRANT CREATE` command. For example:

```
=# GRANT CREATE ON TABLESPACE fastspace TO admin;
```
Using a Tablespace to Store Database Objects

Users with the CREATE privilege on a tablespace can create database objects in that tablespace, such as tables, indexes, and databases. The command is:

```
CREATE TABLE tablename(options) TABLESPACE spacename
```

For example, the following command creates a table in the tablespace `space1`:

```
CREATE TABLE foo(i int) TABLESPACE space1;
```

You can also use the default_tablespace parameter to specify the default tablespace for CREATE TABLE and CREATE INDEX commands that do not specify a tablespace:

```
SET default_tablespace = spacel;
CREATE TABLE foo(i int);
```

The tablespace associated with a database stores that database's system catalogs, temporary files created by server processes using that database, and is the default tablespace selected for tables and indexes created within the database, if no TABLESPACE is specified when the objects are created. If you do not specify a tablesad when you create a database, the database uses the same tablespace used by its template database.

You can use a tablespace from any database if you have appropriate privileges.

Viewing Existing Tablespaces and Filespaces

Every Greenplum Database system has the following default tablespaces.
- `pg_global` for shared system catalogs.
- `pg_default`, the default tablespace. Used by the `template1` and `template0` databases.

These tablespaces use the system default filespace, `pg_system`, the data directory location created at system initialization.

To see filespace information, look in the `pg_filespace` and `pg_filespace_entry` catalog tables. You can join these tables with `pg_tablespace` to see the full definition of a tablespace. For example:

```
=# SELECT spcname as tblspc, fsname as filespc, 
    fsedbid as seg_dbid, fselocation as datadir 
FROM   pg_tablespace pgts, pg_filespace pgfs, 
    pg_filespace_entry pgfse 
WHERE  pgts.spcfsoid=pgfse.fsefsoid 
    AND pgfse.fsefsoid=pgfs.oid 
ORDER BY tblspc, seg_dbid;
```

Dropping Tablespaces and Filespaces

To drop a tablespace, you must be the tablespace owner or a superuser. You cannot drop a tablespace until all objects in all databases using the tablespace are removed.

Only a superuser can drop a filespace. A filespace cannot be dropped until all tablespaces using that filespace are removed.

The DROP TABLESPACE command removes an empty tablespace.

The DROP FILESPACE command removes an empty filespace.

Note: You cannot drop a filespace if it stores temporary or transaction files.
Creating and Managing Schemas

Schemas logically organize objects and data in a database. Schemas allow you to have more than one object (such as tables) with the same name in the database without conflict if the objects are in different schemas.

The Default "Public" Schema

Every database has a default schema named public. If you do not create any schemas, objects are created in the public schema. All database roles (users) have CREATE and USAGE privileges in the public schema. When you create a schema, you grant privileges to your users to allow access to the schema.

Creating a Schema

Use the CREATE SCHEMA command to create a new schema. For example:

```
=> CREATE SCHEMA myschema;
```

To create or access objects in a schema, write a qualified name consisting of the schema name and table name separated by a period. For example:

```
myschema.table
```

See Schema Search Paths for information about accessing a schema.

You can create a schema owned by someone else, for example, to restrict the activities of your users to well-defined namespaces. The syntax is:

```
=> CREATE SCHEMA schemaname AUTHORIZATION username;
```

Schema Search Paths

To specify an object’s location in a database, use the schema-qualified name. For example:

```
=> SELECT * FROM myschema.mytable;
```

You can set the search_path configuration parameter to specify the order in which to search the available schemas for objects. The schema listed first in the search path becomes the default schema. If a schema is not specified, objects are created in the default schema.

Setting the Schema Search Path

The search_path configuration parameter sets the schema search order. The ALTER DATABASE command sets the search path. For example:

```
=> ALTER DATABASE mydatabase SET search_path TO myschema, public, pg_catalog;
```

You can also set search_path for a particular role (user) using the ALTER ROLE command. For example:

```
=> ALTER ROLE sally SET search_path TO myschema, public, pg_catalog;
```
**Viewing the Current Schema**

Use the `current_schema()` function to view the current schema. For example:

```sql
=> SELECT current_schema();
```

Use the `SHOW` command to view the current search path. For example:

```sql
=> SHOW search_path;
```

**Dropping a Schema**

Use the `DROP SCHEMA` command to drop (delete) a schema. For example:

```sql
=> DROP SCHEMA myschema;
```

By default, the schema must be empty before you can drop it. To drop a schema and all of its objects (tables, data, functions, and so on) use:

```sql
=> DROP SCHEMA myschema CASCADE;
```

**System Schemas**

The following system-level schemas exist in every database:

- `pg_catalog` contains the system catalog tables, built-in data types, functions, and operators. It is always part of the schema search path, even if it is not explicitly named in the search path.
- `information_schema` consists of a standardized set of views that contain information about the objects in the database. These views get system information from the system catalog tables in a standardized way.
- `pg_toast` stores large objects such as records that exceed the page size. This schema is used internally by the Greenplum Database system.
- `pg_bitmapindex` stores bitmap index objects such as lists of values. This schema is used internally by the Greenplum Database system.
- `pg_aoseg` stores append-optimized table objects. This schema is used internally by the Greenplum Database system.
- `gp_toolkit` is an administrative schema that contains external tables, views, and functions that you can access with SQL commands. All database users can access `gp_toolkit` to view and query the system log files and other system metrics.

**Creating and Managing Tables**

Greenplum Database tables are similar to tables in any relational database, except that table rows are distributed across the different segments in the system. When you create a table, you specify the table’s distribution policy.

**Creating a Table**

The `CREATE TABLE` command creates a table and defines its structure. When you create a table, you define:

- The columns of the table and their associated data types. See *Choosing Column Data Types*.
- Any table or column constraints to limit the data that a column or table can contain. See *Setting Table and Column Constraints*.  

• The distribution policy of the table, which determines how Greenplum Database divides data is across the segments. See Choosing the Table Distribution Policy.
• The way the table is stored on disk. See Choosing the Table Storage Model.
• The table partitioning strategy for large tables. See Creating and Managing Databases.

Choosing Column Data Types

The data type of a column determines the types of data values the column can contain. Choose the data type that uses the least possible space but can still accommodate your data and that best constrains the data. For example, use character data types for strings, date or timestamp data types for dates, and numeric data types for numbers.

For table columns that contain textual data, specify the data type VARCHAR or TEXT. Specifying the data type CHAR is not recommended. In Greenplum Database, the data types VARCHAR or TEXT handles padding added to the data (space characters added after the last non-space character) as significant characters, the data type CHAR does not. For information on the character data types, see the CREATE TABLE command in the Greenplum Database Reference Guide.

Use the smallest numeric data type that will accommodate your numeric data and allow for future expansion. For example, using BIGINT for data that fits in INT or SMALLINT wastes storage space. If you expect that your data values will expand over time, consider that changing from a smaller datatypeto a larger datatypet after loading large amounts of data is costly. For example, if your current data values fit in a SMALLINT but it is likely that the values will expand, INT is the better long-term choice.

Use the same data types for columns that you plan to use in cross-table joins. Cross-table joins usually use the primary key in one table and a foreign key in the other table. When the data types are different, the database must convert one of them so that the data values can be compared correctly, which adds unnecessary overhead.

Greenplum Database has a rich set of native data types available to users. See the Greenplum Database Reference Guide for information about the built-in data types.

Setting Table and Column Constraints

You can define constraints on columns and tables to restrict the data in your tables. Greenplum Database support for constraints is the same as PostgreSQL with some limitations, including:

• CHECK constraints can refer only to the table on which they are defined.
• UNIQUE and PRIMARY KEY constraints must be compatible with their table#s distribution key and partitioning key, if any.

  Note: UNIQUE and PRIMARY KEY constraints are not allowed on append-optimized tables because the UNIQUE indexes that are created by the constraints are not allowed on append-optimized tables.
• FOREIGN KEY constraints are allowed, but not enforced.
• Constraints that you define on partitioned tables apply to the partitioned table as a whole. You cannot define constraints on the individual parts of the table.

Check Constraints

Check constraints allow you to specify that the value in a certain column must satisfy a Boolean (truth-value) expression. For example, to require positive product prices:

```sql
=> CREATE TABLE products
   ( product_no integer,
     name text,
     price numeric CHECK (price > 0) );
```
**Not-Null Constraints**

Not-null constraints specify that a column must not assume the null value. A not-null constraint is always written as a column constraint. For example:

```sql
=> CREATE TABLE products
   ( product_no integer NOT NULL,
     name text NOT NULL,
     price numeric );
```

**Unique Constraints**

Unique constraints ensure that the data contained in a column or a group of columns is unique with respect to all the rows in the table. The table must be hash-distributed (not DISTRIBUTED RANDOMLY), and the constraint columns must be the same as (or a superset of) the table's distribution key columns. For example:

```sql
=> CREATE TABLE products
   ( product_no integer UNIQUE,
     name text,
     price numeric)
   DISTRIBUTED BY (product_no);
```

**Primary Keys**

A primary key constraint is a combination of a UNIQUE constraint and a NOT NULL constraint. The table must be hash-distributed (not DISTRIBUTED RANDOMLY), and the primary key columns must be the same as (or a superset of) the table's distribution key columns. If a table has a primary key, this column (or group of columns) is chosen as the distribution key for the table by default. For example:

```sql
=> CREATE TABLE products
   ( product_no integer PRIMARY KEY,
     name text,
     price numeric)
   DISTRIBUTED BY (product_no);
```

**Foreign Keys**

Foreign keys are not supported. You can declare them, but referential integrity is not enforced. Foreign key constraints specify that the values in a column or a group of columns must match the values appearing in some row of another table to maintain referential integrity between two related tables. Referential integrity checks cannot be enforced between the distributed table segments of a Greenplum database.

**Choosing the Table Distribution Policy**

All Greenplum Database tables are distributed. When you create or alter a table, you optionally specify DISTRIBUTED BY (hash distribution) or DISTRIBUTED RANDOMLY (round-robin distribution) to determine the table row distribution.

**Note:** The Greenplum Database server configuration parameter `gp_create_table_random_default_distribution` controls the table distribution policy if the DISTRIBUTED BY clause is not specified when you create a table.

For information about the parameter, see "Server Configuration Parameters" of the *Greenplum Database Reference Guide*.

Consider the following points when deciding on a table distribution policy.
• **Even Data Distribution** — For the best possible performance, all segments should contain equal portions of data. If the data is unbalanced or skewed, the segments with more data must work harder to perform their portion of the query processing. Choose a distribution key that is unique for each record, such as the primary key.

• **Local and Distributed Operations** — Local operations are faster than distributed operations. Query processing is fastest if the work associated with join, sort, or aggregation operations is done locally, at the segment level. Work done at the system level requires distributing tuples across the segments, which is less efficient. When tables share a common distribution key, the work of joining or sorting on their shared distribution key columns is done locally. With a random distribution policy, local join operations are not an option.

• **Even Query Processing** — For best performance, all segments should handle an equal share of the query workload. Query workload can be skewed if a table's data distribution policy and the query predicates are not well matched. For example, suppose that a sales transactions table is distributed on the customer ID column (the distribution key). If a predicate in a query references a single customer ID, the query processing work is concentrated on just one segment.

### Declaring Distribution Keys

CREATE TABLE's optional clauses DISTRIBUTED BY and DISTRIBUTED RANDOMLY specify the distribution policy for a table. The default is a hash distribution policy that uses either the PRIMARY KEY (if the table has one) or the first column of the table as the distribution key. Columns with geometric or user-defined data types are not eligible as Greenplum distribution key columns. If a table does not have an eligible column, Greenplum distributes the rows randomly or in round-robin fashion.

To ensure even distribution of data, choose a distribution key that is unique for each record. If that is not possible, choose DISTRIBUTED RANDOMLY. For example:

```sql
=> CREATE TABLE products
    (name varchar(40),
     prod_id integer,
     supplier_id integer)
    DISTRIBUTED BY (prod_id);

=> CREATE TABLE random_stuff
    (things text,
     doodads text,
     etc text)
    DISTRIBUTED RANDOMLY;
```

**Important:** A Primary Key is always the Distribution Key for a table. If no Primary Key exists, but a Unique Key exists, this is the Distribution Key for the table.

### Choosing the Table Storage Model

Greenplum Database supports several storage models and a mix of storage models. When you create a table, you choose how to store its data. This topic explains the options for table storage and how to choose the best storage model for your workload.

• **Heap Storage**
• **Append-Optimized Storage**
• **Choosing Row or Column-Oriented Storage**
• **Using Compression (Append-Optimized Tables Only)**
• **Checking the Compression and Distribution of an Append-Optimized Table**
• **Altering a Table**
• **Dropping a Table**
**Note:** To simplify the creation of database tables, you can specify the default values for some table storage options with the Greenplum Database server configuration parameter `gp_default_storage_options`.

For information about the parameter, see "Server Configuration Parameters" in the *Greenplum Database Reference Guide*.

### Heap Storage

By default, Greenplum Database uses the same heap storage model as PostgreSQL. Heap table storage works best with OLTP-type workloads where the data is often modified after it is initially loaded. **UPDATE** and **DELETE** operations require storing row-level versioning information to ensure reliable database transaction processing. Heap tables are best suited for smaller tables, such as dimension tables, that are often updated after they are initially loaded.

### Append-Optimized Storage

Append-optimized table storage works best with denormalized fact tables in a data warehouse environment. Denormalized fact tables are typically the largest tables in the system. Fact tables are usually loaded in batches and accessed by read-only queries. Moving large fact tables to an append-optimized storage model eliminates the storage overhead of the per-row update visibility information, saving about 20 bytes per row. This allows for a leaner and easier-to-optimize page structure. The storage model of append-optimized tables is optimized for bulk data loading. Single row **INSERT** statements are not recommended.

### To create a heap table

Row-oriented heap tables are the default storage type.

```sql
=> CREATE TABLE foo (a int, b text) DISTRIBUTED BY (a);
```

### To create an append-optimized table

Use the **WITH** clause of the **CREATE TABLE** command to declare the table storage options. The default is to create the table as a regular row-oriented heap-storage table. For example, to create an append-optimized table with no compression:

```sql
=> CREATE TABLE bar (a int, b text)
    WITH (appendonly=true)
    DISTRIBUTED BY (a);
```

**UPDATE** and **DELETE** are not allowed on append-optimized tables in a serializable transaction and will cause the transaction to abort. **CLUSTER, DECLARE...FOR UPDATE, and triggers** are not supported with append-optimized tables.

### Choosing Row or Column-Oriented Storage

Greenplum provides a choice of storage orientation models: row, column, or a combination of both. This topic provides general guidelines for choosing the optimum storage orientation for a table. Evaluate performance using your own data and query workloads.

- **Row-oriented storage:** good for OLTP types of workloads with many iterative transactions and many columns of a single row needed all at once, so retrieving is efficient.
- **Column-oriented storage:** good for data warehouse workloads with aggregations of data computed over a small number of columns, or for single columns that require regular updates without modifying other column data.
For most general purpose or mixed workloads, row-oriented storage offers the best combination of flexibility and performance. However, there are use cases where a column-oriented storage model provides more efficient I/O and storage. Consider the following requirements when deciding on the storage orientation model for a table:

- **Updates of table data.** If you load and update the table data frequently, choose a row-oriented heap table. Column-oriented table storage is only available on append-optimized tables. See [Heap Storage](#) for more information.

- **Frequent INSERTs.** If rows are frequently inserted into the table, consider a row-oriented model. Column-oriented tables are not optimized for write operations, as column values for a row must be written to different places on disk.

- **Number of columns requested in queries.** If you typically request all or the majority of columns in the `SELECT` list or `WHERE` clause of your queries, consider a row-oriented model. Column-oriented tables are best suited to queries that aggregate many values of a single column where the `WHERE` or `HAVING` predicate is also on the aggregate column. For example:

  ```sql
  SELECT SUM(salary)...
  ```

  ```sql
  SELECT AVG(salary) WHERE salary > 10000
  ```

  Or where the `WHERE` predicate is on a single column and returns a relatively small number of rows. For example:

  ```sql
  SELECT salary, dept WHERE state='CA'
  ```

- **Number of columns in the table.** Row-oriented storage is more efficient when many columns are required at the same time, or when the row-size of a table is relatively small. Column-oriented tables can offer better query performance on tables with many columns where you access a small subset of columns in your queries.

- **Compression.** Column data has the same data type, so storage size optimizations are available in column-oriented data that are not available in row-oriented data. For example, many compression schemes use the similarity of adjacent data to compress. However, the greater adjacent compression achieved, the more difficult random access can become, as data must be uncompressed to be read.

### To create a column-oriented table

The `WITH` clause of the `CREATE TABLE` command specifies the table's storage options. The default is a row-oriented heap table. Tables that use column-oriented storage must be append-optimized tables. For example, to create a column-oriented table:

```sql
=> CREATE TABLE bar (a int, b text)
  WITH (appendonly=true, orientation=column)
  DISTRIBUTED BY (a);
```

### Using Compression (Append-Optimized Tables Only)

There are two types of in-database compression available in the Greenplum Database for append-optimized tables:

- **Table-level compression** is applied to an entire table.
- **Column-level compression** is applied to a specific column. You can apply different column-level compression algorithms to different columns.

The following table summarizes the available compression algorithms.
Table 47: Compression Algorithms for Append-Optimized Tables

<table>
<thead>
<tr>
<th>Table Orientation</th>
<th>Available Compression Types</th>
<th>Supported Algorithms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row</td>
<td>Table</td>
<td>ZLIB and QUICKLZ&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Column</td>
<td>Column and Table</td>
<td>RLE_TYPE, ZLIB, and QUICKLZ&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup>QuickLZ compression is not available in the open source version of Greenplum Database.

When choosing a compression type and level for append-optimized tables, consider these factors:

- **CPU usage.** Your segment systems must have the available CPU power to compress and uncompress the data.
- **Compression ratio/disk size.** Minimizing disk size is one factor, but also consider the time and CPU capacity required to compress and scan data. Find the optimal settings for efficiently compressing data without causing excessively long compression times or slow scan rates.
- **Speed of compression.** QuickLZ compression generally uses less CPU capacity and compresses data faster at a lower compression ratio than zlib. zlib provides higher compression ratios at lower speeds.

For example, at compression level 1 (compresslevel=1), QuickLZ and zlib have comparable compression ratios, though at different speeds. Using zlib with compresslevel=6 can significantly increase the compression ratio compared to QuickLZ, though with lower compression speed.

- **Speed of decompression/scan rate.** Performance with compressed append-optimized tables depends on hardware, query tuning settings, and other factors. Perform comparison testing to determine the actual performance in your environment.

<sup>Note:</sup> Do not create compressed append-optimized tables on file systems that use compression. If the file system on which your segment data directory resides is a compressed file system, your append-optimized table must not use compression.

Performance with compressed append-optimized tables depends on hardware, query tuning settings, and other factors. You should perform comparison testing to determine the actual performance in your environment.

<sup>Note:</sup> QuickLZ compression level can only be set to level 1; no other options are available. Compression level with zlib can be set at values from 1 - 9. Compression level with RLE can be set at values from 1 - 4.

An **ENCODING** clause specifies compression type and level for individual columns. When an **ENCODING** clause conflicts with a **WITH** clause, the **ENCODING** clause has higher precedence than the **WITH** clause.

### To create a compressed table

The **WITH** clause of the **CREATE TABLE** command declares the table storage options. Tables that use compression must be append-optimized tables. For example, to create an append-optimized table with zlib compression at a compression level of 5:

```sql
=> CREATE TABLE foo (a int, b text)
   WITH (appendonly=true, compressstype=zlib, compresslevel=5);
```

### Checking the Compression and Distribution of an Append-Optimized Table

Greenplum provides built-in functions to check the compression ratio and the distribution of an append-optimized table. The functions take either the object ID or a table name. You can qualify the table name with a schema name.
### Table 48: Functions for compressed append-optimized table metadata

<table>
<thead>
<tr>
<th>Function</th>
<th>Return Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>get_ao_distribution(name)</td>
<td>Set of (dbid, tuplecount) rows</td>
<td>Shows the distribution of an append-optimized table’s rows across the array. Returns a set of rows, each of which includes a segment dbid and the number of tuples stored on the segment.</td>
</tr>
<tr>
<td>get_ao_distribution(oid)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>get_ao_compression_ratio(name)</td>
<td>float8</td>
<td>Calculates the compression ratio for a compressed append-optimized table. If information is not available, this function returns a value of -1.</td>
</tr>
<tr>
<td>get_ao_compression_ratio(oid)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The compression ratio is returned as a common ratio. For example, a returned value of 3.19, or 3.19:1, means that the uncompressed table is slightly larger than three times the size of the compressed table.

The distribution of the table is returned as a set of rows that indicate how many tuples are stored on each segment. For example, in a system with four primary segments with dbid values ranging from 0 - 3, the function returns four rows similar to the following:

```sql
=# SELECT get_ao_distribution('lineitem_comp');
get_ao_distribution
---------------------
(0,7500721)
(1,7501365)
(2,7499978)
(3,7497731)
(4 rows)
```

### Support for Run-length Encoding

Greenplum Database supports Run-length Encoding (RLE) for column-level compression. RLE data compression stores repeated data as a single data value and a count. For example, in a table with two columns, a date and a description, that contains 200,000 entries containing the value `date1` and 400,000 entries containing the value `date2`, RLE compression for the date field is similar to `date1 200000 date2 400000`. RLE is not useful with files that do not have large sets of repeated data as it can greatly increase the file size.

There are four levels of RLE compression available. The levels progressively increase the compression ratio, but decrease the compression speed.

Greenplum Database versions 4.2.1 and later support column-oriented RLE compression. To backup a table with RLE compression that you intend to restore to an earlier version of Greenplum Database, alter the table to have no compression or a compression type supported in the earlier version (ZLIB or QUICKLZ) before you start the backup operation.

Greenplum Database combines delta compression with RLE compression for data in columns of type `BIGINT`, `INTEGER`, `DATE`, `TIME`, or `TIMESTAMP`. The delta compression algorithm is based on the change between consecutive column values and is designed to improve compression when data is loaded in sorted order or when the compression is applied to data in sorted order.

### Adding Column-level Compression

You can add the following storage directives to a column for append-optimized tables with column orientation:
- Compression type
- Compression level
- Block size for a column

Add storage directives using the `CREATE TABLE`, `ALTER TABLE`, and `CREATE TYPE` commands.

The following table details the types of storage directives and possible values for each.

**Table 49: Storage Directives for Column-level Compression**

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Values</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPRESSTYPE</td>
<td>Type of compression.</td>
<td>zlib: deflate algorithm, quicklz: fast compression, RLE_TYPE: run-length encoding, none: no compression</td>
<td>Values are not case-sensitive.</td>
</tr>
<tr>
<td>COMPRESSLEVEL</td>
<td>Compression level.</td>
<td>zlib compression: 1-9, QuickLZ compression: 1 - use compression, RLE_TYPE compression: 1 - 4, 1 - apply RLE only, 2 - apply RLE then apply zlib compression level 1, 3 - apply RLE then apply zlib compression level 5, 4 - apply RLE then apply zlib compression level 9</td>
<td>1 is the fastest method with the least compression. 1 is the default. 9 is the slowest method with the most compression. 1 is the default. 4 is the slowest method with the most compression. 1 is the default.</td>
</tr>
<tr>
<td>BLOCKSIZE</td>
<td>The size in bytes for each block in the table</td>
<td>8192 - 2097152</td>
<td>The value must be a multiple of 8192.</td>
</tr>
</tbody>
</table>

The following is the format for adding storage directives.

```
[ ENCODING ( storage_directive [,...] ) ]
```

where the word `ENCODING` is required and the storage directive has three parts:

- The name of the directive
- An equals sign
- The specification
Separate multiple storage directives with a comma. Apply a storage directive to a single column or designate it as the default for all columns, as shown in the following CREATE TABLE clauses.

**General Usage:**

- `column_name data_type ENCODING (storage_directive [, ... ] ), ...`
- `COLUMN column_name ENCODING (storage_directive [, ... ] ), ...`
- `DEFAULT COLUMN ENCODING (storage_directive [, ... ] )`

**Example:**

- `C1 char ENCODING (compressstype=quicklz, blocksize=65536)`
- `COLUMN C1 ENCODING (compressstype=zlib, compresslevel=6, blocksize=65536)`
- `DEFAULT COLUMN ENCODING (compressstype=quicklz)`

**Default Compression Values**

If the compression type, compression level and block size are not defined, the default is no compression, and the block size is set to the Server Configuration Parameter `block_size`.

**Precedence of Compression Settings**

Column compression settings are inherited from the table level to the partition level to the subpartition level. The lowest-level settings have priority.

- Column compression settings specified at the table level override any compression settings for the entire table.
- Column compression settings specified for partitions override any compression settings at the column or table levels.
- Column compression settings specified for subpartitions override any compression settings at the partition, column or table levels.
- When an `ENCODING` clause conflicts with a `WITH` clause, the `ENCODING` clause has higher precedence than the `WITH` clause.

**Note:** The `INHERITS` clause is not allowed in a table that contains a storage directive or a column reference storage directive.

Tables created using the `LIKE` clause ignore storage directive and column reference storage directives.

**Optimal Location for Column Compression Settings**

The best practice is to set the column compression settings at the level where the data resides. See **Example 5**, which shows a table with a partition depth of 2. `RLE_TYPE` compression is added to a column at the subpartition level.

**Storage Directives Examples**

The following examples show the use of storage directives in `CREATE TABLE` statements.
**Example 1**

In this example, column `c1` is compressed using `zlib` and uses the block size defined by the system. Column `c2` is compressed with `quicklz`, and uses a block size of 65536. Column `c3` is not compressed and uses the block size defined by the system.

```sql
CREATE TABLE T1 (c1 int ENCODING (compresstype=zlib),
    c2 char ENCODING (compresstype=quicklz, blocksize=65536),
    c3 char WITH (appendonly=true, orientation=column);
```

**Example 2**

In this example, column `c1` is compressed using `zlib` and uses the block size defined by the system. Column `c2` is compressed with `quicklz`, and uses a block size of 65536. Column `c3` is compressed using `RLE_TYPE` and uses the block size defined by the system.

```sql
CREATE TABLE T2 (c1 int ENCODING (compresstype=zlib),
    c2 char ENCODING (compresstype=quicklz, blocksize=65536),
    c3 char,
    COLUMN c3 ENCODING (compresstype=RLE_TYPE)
) WITH (appendonly=true, orientation=column)
```

**Example 3**

In this example, column `c1` is compressed using `zlib` and uses the block size defined by the system. Column `c2` is compressed with `quicklz`, and uses a block size of 65536. Column `c3` is compressed using `zlib` and uses the block size defined by the system. Note that column `c3` uses `zlib (not RLE_TYPE)` in the partitions, because the column storage in the partition clause has precedence over the storage directive in the column definition for the table.

```sql
CREATE TABLE T3 (c1 int ENCODING (compresstype=zlib),
    c2 char ENCODING (compresstype=quicklz, blocksize=65536),
    c3 char,
    COLUMN c3 ENCODING (compresstype=RLE_TYPE) )
WITH (appendonly=true, orientation=column)
PARTITION BY RANGE (c3) (START ('1900-01-01'::DATE)
    END ('2100-12-31'::DATE),
    COLUMN c3 ENCODING (zlib));
```

**Example 4**

In this example, `CREATE TABLE` assigns the zlib compressstype storage directive to `c1`. Column `c2` has no storage directive and inherits the compression type (`quicklz`) and block size (65536) from the `DEFAULT COLUMN ENCODING` clause.

Column `c3`'s `ENCODING` clause defines its compression type, `RLE_TYPE`. The `DEFAULT COLUMN ENCODING` clause defines `c3`'s block size, 65536.

The `ENCODING` clause defined for a specific column overrides the `DEFAULT ENCODING` clause, so column `c4` has a compress type of `none` and the default block size.

```sql
CREATE TABLE T4 (c1 int ENCODING (compresstype=zlib),
    c2 char,
    c4 smallint ENCODING (compresstype=none),
    DEFAULT COLUMN ENCODING (compresstype=quicklz,
    blocksize=65536),
    COLUMN c3 ENCODING (compresstype=RLE_TYPE)
)
WITH (appendonly=true, orientation=column);

**Example 5**

This example creates an append-optimized, column-oriented table, T5. T5 has two partitions, p1 and p2, each of which has subpartitions. Each subpartition has `ENCODING` clauses:

- The `ENCODING` clause for partition p1’s subpartition sp1 defines column i’s compression type as `zlib` and block size as 65536.
- The `ENCODING` clauses for partition p2’s subpartition sp1 defines column i’s compression type as `rle_type` and block size is the default value. Column k uses the default compression and its block size is 8192.

```sql
CREATE TABLE T5(i int, j int, k int, l int)
WITH (appendonly=true, orientation=column)
PARTITION BY range(i) SUBPARTITION BY range(j)
(
    p1 start(1) end(2)
    ( subpartition sp1 start(1) end(2)
        column i encoding(compresstype=zlib, blocksize=65536)
    ),
    partition p2 start(2) end(3)
    ( subpartition sp1 start(1) end(2)
        column i encoding(compresstype=rle_type)
        column k encoding(blocksize=8192)
    )
);```

For an example showing how to add a compressed column to an existing table with the `ALTER TABLE` command, see the section on [Adding a Compressed Column to Table](#).

**Adding Compression in a TYPE Command**

You can define a compression type to simplify column compression statements. For example, the following `CREATE TYPE` command defines a compression type, `comptype`, that specifies `quicklz` compression.

```sql
CREATE TYPE comptype (  
    internallength = 4,
    input = comptype_in,
    output = comptype_out,
    alignment = int4,
    default = 123,
    passedbyvalue,
    compressstype="quicklz",
    blocksize=65536,
    compresslevel=1
);```

You can then use `comptype` in a `CREATE TABLE` command to specify `quicklz` compression for a column:

```sql
CREATE TABLE t2 (c1 comptype)
    WITH (APPENDONLY=true, ORIENTATION=column);
```

For information about creating and adding compression parameters to a type, see `CREATE TYPE`. For information about changing compression specifications in a type, see `ALTER TYPE`. 
Choosing Block Size

The blocksize is the size, in bytes, for each block in a table. Block sizes must be between 8192 and 2097152 bytes, and be a multiple of 8192. The default is 32768.

Specifying large block sizes can consume large amounts of memory. Block size determines buffering in the storage layer. Greenplum maintains a buffer per partition, and per column in column-oriented tables. Tables with many partitions or columns consume large amounts of memory.

Altering a Table

The `ALTER TABLE` command changes the definition of a table. Use `ALTER TABLE` to change table attributes such as column definitions, distribution policy, storage model, and partition structure (see also *Maintaining Partitioned Tables*). For example, to add a not-null constraint to a table column:

```sql
=> ALTER TABLE address ALTER COLUMN street SET NOT NULL;
```

Altering Table Distribution

`ALTER TABLE` provides options to change a table's distribution policy. When the table distribution options change, the table data is redistributed on disk, which can be resource intensive. You can also redistribute table data using the existing distribution policy.

Changing the Distribution Policy

For partitioned tables, changes to the distribution policy apply recursively to the child partitions. This operation preserves the ownership and all other attributes of the table. For example, the following command redistributes the table sales across all segments using the customer_id column as the distribution key:

```sql
ALTER TABLE sales SET DISTRIBUTED BY (customer_id);
```

When you change the hash distribution of a table, table data is automatically redistributed. Changing the distribution policy to a random distribution does not cause the data to be redistributed. For example, the following `ALTER TABLE` command has no immediate effect:

```sql
ALTER TABLE sales SET DISTRIBUTED RANDOMLY;
```

Redistributing Table Data

To redistribute table data for tables with a random distribution policy (or when the hash distribution policy has not changed) use `REORGANIZE=TRUE`. Reorganizing data may be necessary to correct a data skew problem, or when segment resources are added to the system. For example, the following command redistributes table data across all segments using the current distribution policy, including random distribution.

```sql
ALTER TABLE sales SET WITH (REORGANIZE=TRUE);
```

Altering the Table Storage Model

Table storage, compression, and orientation can be declared only at creation. To change the storage model, you must create a table with the correct storage options, load the original table data into the new table, drop the original table, and rename the new table with the original table’s name. You must also regrant any table permissions. For example:

```sql
CREATE TABLE sales2 (LIKE sales)
```
WITH (appendonly=true, compressstype=quicklz, compresslevel=1, orientation=column);
INSERT INTO sales2 SELECT * FROM sales;
DROP TABLE sales;
ALTER TABLE sales2 RENAME TO sales;
GRANT ALL PRIVILEGES ON sales TO admin;
GRANT SELECT ON sales TO guest;

See Splitting a Partition to learn how to change the storage model of a partitioned table.

**Adding a Compressed Column to Table**

Use the ALTER TABLE command to add a compressed column to a table. All of the options and constraints for compressed columns described in Adding Column-level Compression apply to columns added with the ALTER TABLE command.

The following example shows how to add a column with zlib compression to a table, T1.

```
ALTER TABLE T1
  ADD COLUMN c4 int DEFAULT 0
  ENCODING (COMPRESSTYPE=zlib);
```

**Inheritance of Compression Settings**

A partition that is added to a table that has subpartitions with compression settings inherits the compression settings from the subpartition. The following example shows how to create a table with subpartition encodings, then alter it to add a partition.

```
CREATE TABLE ccddl (i int, j int, k int, l int)
  WITH
    (APPENDONLY = TRUE, ORIENTATION=COLUMN)
  PARTITION BY range(j)
  SUBPARTITION BY list (k)
  SUBPARTITION template{
    SUBPARTITION sp1 values(1, 2, 3, 4, 5),
    COLUMN i ENCODING(COMPRESSTYPE=ZLIB),
    COLUMN j ENCODING(COMPRESSTYPE=QUICKLZ),
    COLUMN k ENCODING(COMPRESSTYPE=ZLIB),
    COLUMN l ENCODING(COMPRESSTYPE=ZLIB))
    (PARTITION p1 START(1) END(10),
     PARTITION p2 START(10) END(20))
  };

ALTER TABLE ccddl
  ADD PARTITION p3 START(20) END(30)
  ;
```

Running the ALTER TABLE command creates partitions of table ccddl named ccddl_1_prt_p3 and ccddl_1_prt_p3_2_prt_sp1. Partition ccddl_1_prt_p3 inherites the different compression encodings of subpartition sp1.

**Dropping a Table**

The DROP TABLE command removes tables from the database. For example:

```
DROP TABLE mytable;
```

To empty a table of rows without removing the table definition, use DELETE or TRUNCATE. For example:

```
DELETE FROM mytable;
```
TRUNCATE mytable;

DROP TABLE always removes any indexes, rules, triggers, and constraints that exist for the target table. Specify CASCADE to drop a table that is referenced by a view. CASCADE removes dependent views.

**Partitioning Large Tables**

Table partitioning enables supporting very large tables, such as fact tables, by logically dividing them into smaller, more manageable pieces. Partitioned tables can improve query performance by allowing the Greenplum Database query optimizer to scan only the data needed to satisfy a given query instead of scanning all the contents of a large table.

- About Table Partitioning
- Deciding on a Table Partitioning Strategy
- Creating Partitioned Tables
- Loading Partitioned Tables
- Verifying Your Partition Strategy
- Viewing Your Partition Design
- Maintaining Partitioned Tables

**About Table Partitioning**

Partitioning does not change the physical distribution of table data across the segments. Table distribution is physical: Greenplum Database physically divides partitioned tables and non-partitioned tables across segments to enable parallel query processing. Table **partitioning** is logical: Greenplum Database logically divides big tables to improve query performance and facilitate data warehouse maintenance tasks, such as rolling old data out of the data warehouse.

Greenplum Database supports:

- **range partitioning**: division of data based on a numerical range, such as date or price.
- **list partitioning**: division of data based on a list of values, such as sales territory or product line.
- A combination of both types.

![Figure 22: Example Multi-level Partition Design](image)

**Table Partitioning in Greenplum Database**

Greenplum Database divides tables into parts (also known as partitions) to enable massively parallel processing. Tables are partitioned during `CREATE TABLE` using the `PARTITION BY` (and optionally the


SUBPARTITION BY) clause. Partitioning creates a top-level (or parent) table with one or more levels of sub-tables (or child tables). Internally, Greenplum Database creates an inheritance relationship between the top-level table and its underlying partitions, similar to the functionality of the INHERITS clause of PostgreSQL.

Greenplum uses the partition criteria defined during table creation to create each partition with a distinct CHECK constraint, which limits the data that table can contain. The query optimizer uses CHECK constraints to determine which table partitions to scan to satisfy a given query predicate.

The Greenplum system catalog stores partition hierarchy information so that rows inserted into the top-level parent table propagate correctly to the child table partitions. To change the partition design or table structure, alter the parent table using ALTER TABLE with the PARTITION clause.

To insert data into a partitioned table, you specify the root partitioned table, the table created with the CREATE TABLE command. You also can specify a leaf child table of the partitioned table in an INSERT command. An error is returned if the data is not valid for the specified leaf child table. Specifying a non-leaf or a non-root partition table in the DML command is not supported.

Deciding on a Table Partitioning Strategy

Not all tables are good candidates for partitioning. If the answer is yes to all or most of the following questions, table partitioning is a viable database design strategy for improving query performance. If the answer is no to most of the following questions, table partitioning is not the right solution for that table. Test your design strategy to ensure that query performance improves as expected.

- **Is the table large enough?** Large fact tables are good candidates for table partitioning. If you have millions or billions of records in a table, you may see performance benefits from logically breaking that data up into smaller chunks. For smaller tables with only a few thousand rows or less, the administrative overhead of maintaining the partitions will outweigh any performance benefits you might see.

- **Are you experiencing unsatisfactory performance?** As with any performance tuning initiative, a table should be partitioned only if queries against that table are producing slower response times than desired.

- **Do your query predicates have identifiable access patterns?** Examine the WHERE clauses of your query workload and look for table columns that are consistently used to access data. For example, if most of your queries tend to look up records by date, then a monthly or weekly date-partitioning design might be beneficial. Or if you tend to access records by region, consider a list-partitioning design to divide the table by region.

- **Does your data warehouse maintain a window of historical data?** Another consideration for partition design is your organization's business requirements for maintaining historical data. For example, your data warehouse may require that you keep data for the past twelve months. If the data is partitioned by month, you can easily drop the oldest monthly partition from the warehouse and load current data into the most recent monthly partition.

- **Can the data be divided into somewhat equal parts based on some defining criteria?** Choose partitioning criteria that will divide your data as evenly as possible. If the partitions contain a relatively equal number of records, query performance improves based on the number of partitions created. For example, by dividing a large table into 10 partitions, a query will execute 10 times faster than it would against the unpartitioned table, provided that the partitions are designed to support the query's criteria.

Do not create more partitions than are needed. Creating too many partitions can slow down management and maintenance jobs, such as vacuuming, recovering segments, expanding the cluster, checking disk usage, and others.

Partitioning does not improve query performance unless the query optimizer can eliminate partitions based on the query predicates. Queries that scan every partition run slower than if the table were not partitioned, so avoid partitioning if few of your queries achieve partition elimination. Check the explain plan for queries to make sure that partitions are eliminated. See Query Profiling for more about partition elimination.

**Warning:** Be very careful with multi-level partitioning because the number of partition files can grow very quickly. For example, if a table is partitioned by both day and city, and there are 1,000
days of data and 1,000 cities, the total number of partitions is one million. Column-oriented tables store each column in a physical table, so if this table has 100 columns, the system would be required to manage 100 million files for the table.

Before settling on a multi-level partitioning strategy, consider a single level partition with bitmap indexes. Indexes slow down data loads, so performance testing with your data and schema is recommended to decide on the best strategy.

Creating Partitioned Tables

You partition tables when you create them with `CREATE TABLE`. This topic provides examples of SQL syntax for creating a table with various partition designs.

To partition a table:

1. Decide on the partition design: date range, numeric range, or list of values.
2. Choose the column(s) on which to partition the table.
3. Decide how many levels of partitions you want. For example, you can create a date range partition table by month and then subpartition the monthly partitions by sales region.

- Defining Date Range Table Partitions
- Defining Numeric Range Table Partitions
- Defining List Table Partitions
- Defining Multi-level Partitions
- Partitioning an Existing Table

Defining Date Range Table Partitions

A date range partitioned table uses a single `date` or `timestamp` column as the partition key column. You can use the same partition key column to create subpartitions if necessary, for example, to partition by month and then subpartition by day. Consider partitioning by the most granular level. For example, for a table partitioned by date, you can partition by day and have 365 daily partitions, rather than partition by year then subpartition by month then subpartition by day. A multi-level design can reduce query planning time, but a flat partition design runs faster.

You can have Greenplum Database automatically generate partitions by giving a `START` value, an `END` value, and an `EVERY` clause that defines the partition increment value. By default, `START` values are always inclusive and `END` values are always exclusive. For example:

```sql
CREATE TABLE sales (id int, date date, amt decimal(10,2))
DISTRIBUTED BY (id)
PARTITION BY RANGE (date)
( START (date '2016-01-01') INCLUSIVE
  END (date '2017-01-01') EXCLUSIVE
  EVERY (INTERVAL '1 day') );
```

You can also declare and name each partition individually. For example:

```sql
CREATE TABLE sales (id int, date date, amt decimal(10,2))
DISTRIBUTED BY (id)
PARTITION BY RANGE (date)
( PARTITION Jan16 START (date '2016-01-01') INCLUSIVE ,
  PARTITION Feb16 START (date '2016-02-01') INCLUSIVE ,
  PARTITION Mar16 START (date '2016-03-01') INCLUSIVE ,
  PARTITION Apr16 START (date '2016-04-01') INCLUSIVE ,
  PARTITION May16 START (date '2016-05-01') INCLUSIVE ,
  PARTITION Jun16 START (date '2016-06-01') INCLUSIVE ,
  PARTITION Jul16 START (date '2016-07-01') INCLUSIVE ,
  PARTITION Aug16 START (date '2016-08-01') INCLUSIVE ,
  PARTITION Sep16 START (date '2016-09-01') INCLUSIVE ,
  PARTITION Oct16 START (date '2016-10-01') INCLUSIVE ,
  PARTITION Nov16 START (date '2016-11-01') INCLUSIVE ,
  PARTITION Dec16 START (date '2016-12-01') INCLUSIVE );
```
PARTITION Oct16 START (date '2016-10-01') INCLUSIVE,
PARTITION Nov16 START (date '2016-11-01') INCLUSIVE,
PARTITION Dec16 START (date '2016-12-01') INCLUSIVE
END (date '2017-01-01') EXCLUSIVE );

You do not have to declare an END value for each partition, only the last one. In this example, Jan16 ends where Feb16 starts.

**Defining Numeric Range Table Partitions**

A numeric range partitioned table uses a single numeric data type column as the partition key column. For example:

```
CREATE TABLE rank (id int, rank int, year int, gender char(1), count int)
DISTRIBUTED BY (id)
PARTITION BY RANGE (year)
  DEFAULT PARTITION extra );
```

For more information about default partitions, see [Adding a Default Partition](#).

**Defining List Table Partitions**

A list partitioned table can use any data type column that allows equality comparisons as its partition key column. A list partition can also have a multi-column (composite) partition key, whereas a range partition only allows a single column as the partition key. For list partitions, you must declare a partition specification for every partition (list value) you want to create. For example:

```
CREATE TABLE rank (id int, rank int, year int, gender char(1), count int )
DISTRIBUTED BY (id)
PARTITION BY LIST (gender)
( PARTITION girls VALUES ('F'),
  PARTITION boys VALUES ('M'),
  DEFAULT PARTITION other );
```

**Note:** The current Greenplum Database legacy optimizer allows list partitions with multi-column (composite) partition keys. A range partition only allows a single column as the partition key. The Greenplum Query Optimizer does not support composite keys, so you should not use composite partition keys.

For more information about default partitions, see [Adding a Default Partition](#).

**Defining Multi-level Partitions**

You can create a multi-level partition design with subpartitions of partitions. Using a subpartition template ensures that every partition has the same subpartition design, including partitions that you add later. For example, the following SQL creates the two-level partition design shown in [Figure 22: Example Multi-level Partition Design](#):
The following example shows a three-level partition design where the sales table is partitioned by year, then month, then region. The SUBPARTITION TEMPLATE clauses ensure that each yearly partition has the same subpartition structure. The example declares a DEFAULT partition at each level of the hierarchy.

```
CREATE TABLE p3_sales (id int, year int, month int, day int, region text)
DISTRIBUTED BY (id)
PARTITION BY RANGE (year)
  SUBPARTITION BY RANGE (month)
    SUBPARTITION TEMPLATE (START (1) END (13) EVERY (1),
  DEFAULT SUBPARTITION other_months )
    SUBPARTITION BY LIST (region)
    SUBPARTITION TEMPLATE (SUBPARTITION usa VALUES ('usa'),
  SUBPARTITION europe VALUES ('europe'),
  SUBPARTITION asia VALUES ('asia'),
   DEFAULT SUBPARTITION other_regions )
 DEFAULT PARTITION outlying_years );
```

Caution: When you create multi-level partitions on ranges, it is easy to create a large number of subpartitions, some containing little or no data. This can add many entries to the system tables, which increases the time and memory required to optimize and execute queries. Increase the range interval or choose a different partitioning strategy to reduce the number of subpartitions created.

**Partitioning an Existing Table**

Tables can be partitioned only at creation. If you have a table that you want to partition, you must create a partitioned table, load the data from the original table into the new table, drop the original table, and rename the partitioned table with the original table’s name. You must also re-grant any table permissions. For example:

```
CREATE TABLE sales2 (LIKE sales)
PARTITION BY RANGE (date)
  (START (date '2016-01-01') INCLUSIVE
   END (date '2017-01-01') EXCLUSIVE
   EVERY (INTERVAL '1 month')) ;
INSERT INTO sales2 SELECT * FROM sales;
DROP TABLE sales;
ALTER TABLE sales2 RENAME TO sales;
GRANT ALL PRIVILEGES ON sales TO admin;
GRANT SELECT ON sales TO guest;
```

**Limitations of Partitioned Tables**

For each partition level, a partitioned table can have a maximum of 32,767 partitions.

A primary key or unique constraint on a partitioned table must contain all the partitioning columns. A unique index can omit the partitioning columns; however, it is enforced only on the parts of the partitioned table, not on the partitioned table as a whole.

GPORCA, the Greenplum next generation query optimizer, supports uniform multi-level partitioned tables. If GPORCA is enabled (the default) and the multi-level partitioned table is not uniform, Greenplum Database executes queries against the table with the legacy query optimizer. For information about uniform multi-level partitioned tables, see About Uniform Multi-level Partitioned Tables.
For information about exchanging a leaf child partition with an external table, see *Exchanging a Leaf Child Partition with an External Table*.

These are limitations for partitioned tables when a leaf child partition of the table is an external table:

- Queries that run against partitioned tables that contain external table partitions are executed with the legacy query optimizer.
- The external table partition is a read only external table. Commands that attempt to access or modify data in the external table partition return an error. For example:
  - `INSERT`, `DELETE`, and `UPDATE` commands that attempt to change data in the external table partition return an error.
  - `TRUNCATE` commands return an error.
  - `COPY` commands cannot copy data to a partitioned table that updates an external table partition.
  - `COPY` commands that attempt to copy from an external table partition return an error unless you specify the `IGNORE EXTERNAL PARTITIONS` clause with `COPY` command. If you specify the clause, data is not copied from external table partitions.

To use the `COPY` command against a partitioned table with a leaf child table that is an external table, use an SQL query to copy the data. For example, if the table `my_sales` contains a with a leaf child table that is an external table, this command sends the data to `stdout`:

```
COPY (SELECT * FROM my_sales) TO stdout;
```

- `VACUUM` commands skip external table partitions.
- The following operations are supported if no data is changed on the external table partition. Otherwise, an error is returned.
  - Adding or dropping a column.
  - Changing the data type of column.
- *These `ALTER PARTITION` operations are not supported if the partitioned table contains an external table partition:*
  - Setting a subpartition template.
  - Altering the partition properties.
  - Creating a default partition.
  - Setting a distribution policy.
  - Setting or dropping a `NOT NULL` constraint of column.
  - Adding or dropping constraints.
  - Splitting an external partition.
- The Greenplum Database utility `gpcrondump` does not back up data from a leaf child partition of a partitioned table if the leaf child partition is a readable external table.

### Loading Partitioned Tables

After you create the partitioned table structure, top-level parent tables are empty. Data is routed to the bottom-level child table partitions. In a multi-level partition design, only the subpartitions at the bottom of the hierarchy can contain data.

Rows that cannot be mapped to a child table partition are rejected and the load fails. To avoid unmapped rows being rejected at load time, define your partition hierarchy with a `DEFAULT` partition. Any rows that do not match a partition's `CHECK` constraints load into the `DEFAULT` partition. See *Adding a Default Partition*.

At runtime, the query optimizer scans the entire table inheritance hierarchy and uses the `CHECK` table constraints to determine which of the child table partitions to scan to satisfy the query's conditions. The `DEFAULT` partition (if your hierarchy has one) is always scanned. `DEFAULT` partitions that contain data slow down the overall scan time.
When you use `COPY` or `INSERT` to load data into a parent table, the data is automatically rerouted to the correct partition, just like a regular table.

Best practice for loading data into partitioned tables is to create an intermediate staging table, load it, and then exchange it into your partition design. See `Exchanging a Partition`.

### Verifying Your Partition Strategy

When a table is partitioned based on the query predicate, you can use `EXPLAIN` to verify that the query optimizer scans only the relevant data to examine the query plan.

For example, suppose a `sales` table is date-range partitioned by month and subpartitioned by region as shown in Figure 22: Example Multi-level Partition Design. For the following query:

```sql
EXPLAIN SELECT * FROM sales WHERE date='01-07-12' AND region='usa';
```

The query plan for this query should show a table scan of only the following tables:

- the default partition returning 0-1 rows (if your partition design has one)
- the January 2012 partition (`sales_1_prt_1`) returning 0-1 rows
- the USA region subpartition (`sales_1_2_prt_usa`) returning some number of rows.

The following example shows the relevant portion of the query plan.

```sql
->  Seq Scan on sales_1_prt_1 sales (cost=0.00..0.00 rows=0 width=0)
    Filter: "date"=01-07-12::date AND region='USA'::text
->  Seq Scan on sales_1_2_prt_usa sales (cost=0.00..9.87 rows=20 width=40)
```

Ensure that the query optimizer does not scan unnecessary partitions or subpartitions (for example, scans of months or regions not specified in the query predicate), and that scans of the top-level tables return 0-1 rows.

### Troubleshooting Selective Partition Scanning

The following limitations can result in a query plan that shows a non-selective scan of your partition hierarchy.

- The query optimizer can selectively scan partitioned tables only when the query contains a direct and simple restriction of the table using immutable operators such as:
  ```
  =, <, <=, >, >=, and <>
  ```
- Selective scanning recognizes `STABLE` and `IMMUTABLE` functions, but does not recognize `VOLATILE` functions within a query. For example, `WHERE` clauses such as `date > CURRENT_DATE` cause the query optimizer to selectively scan partitioned tables, but `time > TIMEOFDAY` does not.

### Viewing Your Partition Design

You can look up information about your partition design using the `pg_partitions` view. For example, to see the partition design of the `sales` table:

```sql
SELECT partitionboundary, partitontablename, partitionname, partitionlevel, partitionrank
FROM pg_partitions
WHERE tablename='sales';
```

The following table and views show information about partitioned tables.
• **pg_partition** - Tracks partitioned tables and their inheritance level relationships.
• **pg_partition_templates** - Shows the subpartitions created using a subpartition template.
• **pg_partition_columns** - Shows the partition key columns used in a partition design.

For information about Greenplum Database system catalog tables and views, see the Greenplum Database Reference Guide.

### Maintaining Partitioned Tables

To maintain a partitioned table, use the `ALTER TABLE` command against the top-level parent table. The most common scenario is to drop old partitions and add new ones to maintain a rolling window of data in a range partition design. You can convert (exchange) older partitions to the append-optimized compressed storage format to save space. If you have a default partition in your partition design, you add a partition by splitting the default partition.

- **Adding a Partition**
- **Renaming a Partition**
- **Adding a Default Partition**
- **Dropping a Partition**
- **Truncating a Partition**
- **Exchanging a Partition**
- **Splitting a Partition**
- **Modifying a Subpartition Template**
- **Exchanging a Leaf Child Partition with an External Table**

**Important:** When defining and altering partition designs, use the given partition name, not the table object name. Although you can query and load any table (including partitioned tables) directly using SQL commands, you can only modify the structure of a partitioned table using the `ALTER TABLE...PARTITION` clauses.

Partitions are not required to have names. If a partition does not have a name, use one of the following expressions to specify a part: `PARTITION FOR (value)` or `PARTITION FOR(RANK(number)).`

### Adding a Partition

You can add a partition to a partition design with the `ALTER TABLE` command. If the original partition design included subpartitions defined by a `subpartition template`, the newly added partition is subpartitioned according to that template. For example:

```sql
ALTER TABLE sales ADD PARTITION
    START (date '2017-02-01') INCLUSIVE
    END (date '2017-03-01') EXCLUSIVE;
```

If you did not use a subpartition template when you created the table, you define subpartitions when adding a partition:

```sql
ALTER TABLE sales ADD PARTITION
    START (date '2017-02-01') INCLUSIVE
    END (date '2017-03-01') EXCLUSIVE
    ( SUBPARTITION usa VALUES ('usa'),
      SUBPARTITION asia VALUES ('asia'),
      SUBPARTITION europe VALUES ('europe') );
```

When you add a subpartition to an existing partition, you can specify the partition to alter. For example:

```sql
ALTER TABLE sales ALTER PARTITION FOR (RANK(12))
    ADD PARTITION africa VALUES ('africa');
```
**Note:** You cannot add a partition to a partition design that has a default partition. You must split the default partition to add a partition. See *Splitting a Partition.*

**Renaming a Partition**

Partitioned tables use the following naming convention. Partitioned subtable names are subject to uniqueness requirements and length limitations.

\[
\text{<parentname>_<level> prt_<partition_name>}
\]

For example:

\[
\text{sales_1 prt jan16}
\]

For auto-generated range partitions, where a number is assigned when no name is given):

\[
\text{sales_1 prt 1}
\]

To rename a partitioned child table, rename the top-level parent table. The \text{<parentname>} changes in the table names of all associated child table partitions. For example, the following command:

```
ALTER TABLE sales RENAME TO globalsales;
```

Changes the associated table names:

```
globalsales_1 prt 1
```

You can change the name of a partition to make it easier to identify. For example:

```
ALTER TABLE sales RENAME PARTITION FOR ('2016-01-01') TO jan16;
```

Changes the associated table name as follows:

```
sales_1 prt jan16
```

When altering partitioned tables with the `ALTER TABLE` command, always refer to the tables by their partition name (\textit{jan16}) and not their full table name (\textit{sales_1 prt jan16}).

**Note:** The table name cannot be a partition name in an `ALTER TABLE` statement. For example, `ALTER TABLE sales...` is correct, `ALTER TABLE sales_1 part jan16...` is not allowed.

**Adding a Default Partition**

You can add a default partition to a partition design with the `ALTER TABLE` command.

```
ALTER TABLE sales ADD DEFAULT PARTITION other;
```

If your partition design is multi-level, each level in the hierarchy must have a default partition. For example:

```
ALTER TABLE sales ALTER PARTITION FOR (RANK(1)) ADD DEFAULT PARTITION other;
```

```
ALTER TABLE sales ALTER PARTITION FOR (RANK(2)) ADD DEFAULT PARTITION other;
```

```
ALTER TABLE sales ALTER PARTITION FOR (RANK(3)) ADD DEFAULT PARTITION other;
```
If incoming data does not match a partition's `CHECK` constraint and there is no default partition, the data is rejected. Default partitions ensure that incoming data that does not match a partition is inserted into the default partition.

**Dropping a Partition**

You can drop a partition from your partition design using the `ALTER TABLE` command. When you drop a partition that has subpartitions, the subpartitions (and all data in them) are automatically dropped as well. For range partitions, it is common to drop the older partitions from the range as old data is rolled out of the data warehouse. For example:

```sql
ALTER TABLE sales DROP PARTITION FOR (RANK(1));
```

**Truncating a Partition**

You can truncate a partition using the `ALTER TABLE` command. When you truncate a partition that has subpartitions, the subpartitions are automatically truncated as well.

```sql
ALTER TABLE sales TRUNCATE PARTITION FOR (RANK(1));
```

**Exchanging a Partition**

You can exchange a partition using the `ALTER TABLE` command. Exchanging a partition swaps one table in place of an existing partition. You can exchange partitions only at the lowest level of your partition hierarchy (only partitions that contain data can be exchanged).

Partition exchange can be useful for data loading. For example, load a staging table and swap the loaded table into your partition design. You can use partition exchange to change the storage type of older partitions to append-optimized tables. For example:

```sql
CREATE TABLE jan12 (LIKE sales) WITH (appendonly=true);
INSERT INTO jan12 SELECT * FROM sales_1_prt_1 ;
ALTER TABLE sales EXCHANGE PARTITION FOR (DATE '2012-01-01')
WITH TABLE jan12;
```

**Note:** This example refers to the single-level definition of the table `sales`, before partitions were added and altered in the previous examples.

**Warning:** If you specify the `WITHOUT VALIDATION` clause, you must ensure that the data in table that you are exchanging for an existing partition is valid against the constraints on the partition. Otherwise, queries against the partitioned table might return incorrect results.

The Greenplum Database server configuration parameter `gp_enable_exchange_default_partition` controls availability of the `EXCHANGE DEFAULT PARTITION` clause. The default value for the parameter is `off`, the clause is not available and Greenplum Database returns an error if the clause is specified in an `ALTER TABLE` command.

For information about the parameter, see "Server Configuration Parameters" in the *Greenplum Database Reference Guide*.

**Warning:** Before you exchange the default partition, you must ensure the data in the table to be exchanged, the new default partition, is valid for the default partition. For example, the data in the new default partition must not contain data that would be valid in other leaf child partitions of the partitioned table. Otherwise, queries against the partitioned table with the exchanged default partition that are executed by GPORCA might return incorrect results.
**Splitting a Partition**

Splitting a partition divides a partition into two partitions. You can split a partition using the `ALTER TABLE` command. You can split partitions only at the lowest level of your partition hierarchy (partitions that contain data). For a multi-level partition, only range partitions can be split, not list partitions. The split value you specify goes into the latter partition.

For example, to split a monthly partition into two with the first partition containing dates January 1-15 and the second partition containing dates January 16-31:

```sql
ALTER TABLE sales SPLIT PARTITION FOR ('2017-01-01')
AT ('2017-01-16')
INTO (PARTITION jan171to15, PARTITION jan1716to31);
```

If your partition design has a default partition, you must split the default partition to add a partition.

When using the `INTO` clause, specify the current default partition as the second partition name. For example, to split a default range partition to add a new monthly partition for January 2017:

```sql
ALTER TABLE sales SPLIT DEFAULT PARTITION
START ('2017-01-01') INCLUSIVE
END ('2017-02-01') EXCLUSIVE
INTO (PARTITION jan17, default partition);
```

**Modifying a Subpartition Template**

Use `ALTER TABLE` `SET SUBPARTITION TEMPLATE` to modify the subpartition template of a partitioned table. Partitions added after you set a new subpartition template have the new partition design. Existing partitions are not modified.

The following example alters the subpartition template of this partitioned table:

```sql
CREATE TABLE sales (trans_id int, date date, amount decimal(9,2), region text)
    DISTRIBUTED BY (trans_id)
    PARTITION BY RANGE (date)
    SUBPARTITION BY LIST (region)
    SUBPARTITION TEMPLATE
    ( SUBPARTITION usa VALUES ('usa'),
      SUBPARTITION asia VALUES ('asia'),
      SUBPARTITION europe VALUES ('europe'),
      DEFAULT SUBPARTITION other_regions )
    ( START (date '2014-01-01') INCLUSIVE
      END (date '2014-04-01') EXCLUSIVE
      EVERY (INTERVAL '1 month') );

This `ALTER TABLE` command, modifies the subpartition template.

```sql
ALTER TABLE sales SET SUBPARTITION TEMPLATE
( SUBPARTITION usa VALUES ('usa'),
  SUBPARTITION asia VALUES ('asia'),
  SUBPARTITION europe VALUES ('europe'),
  SUBPARTITION africa VALUES ('africa'),
  DEFAULT SUBPARTITION regions );
```

When you add a date-range partition of the table sales, it includes the new regional list subpartition for Africa. For example, the following command creates the subpartitions `usa, asia, europe, africa`, and a default partition named `other`:

```sql
ALTER TABLE sales ADD PARTITION "4"
```
START ('2014-04-01') INCLUSIVE
END ('2014-05-01') EXCLUSIVE;

To view the tables created for the partitioned table `sales`, you can use the command `\dt sales*` from the `psql` command line.

To remove a subpartition template, use `SET SUBPARTITION TEMPLATE` with empty parentheses. For example, to clear the `sales` table subpartition template:

```
ALTER TABLE sales SET SUBPARTITION TEMPLATE ();
```

**Exchanging a Leaf Child Partition with an External Table**

You can exchange a leaf child partition of a partitioned table with a readable external table. The external table data can reside on a host file system, an NFS mount, or a Hadoop file system (HDFS).

For example, if you have a partitioned table that is created with monthly partitions and most of the queries against the table only access the newer data, you can copy the older, less accessed data to external tables and exchange older partitions with the external tables. For queries that only access the newer data, you could create queries that use partition elimination to prevent scanning the older, unneeded partitions.

Exchanging a leaf child partition with an external table is not supported if the partitioned table contains a column with a check constraint or a `NOT NULL` constraint.

For information about exchanging and altering a leaf child partition, see the `ALTER TABLE` command in the Greenplum Database Command Reference.

For information about limitations of partitioned tables that contain a external table partition, see Limitations of Partitioned Tables.

**Example Exchanging a Partition with an External Table**

This is a simple example that exchanges a leaf child partition of this partitioned table for an external table. The partitioned table contains data for the years 2010 through 2013.

```
CREATE TABLE sales (id int, year int, qtr int, day int, region text)
DISTRIBUTED BY (id)
PARTITION BY RANGE (year)
( PARTITION yr START (2010) END (2014) EVERY (1) ) ;
```

There are four leaf child partitions for the partitioned table. Each leaf child partition contains the data for a single year. The leaf child partition table `sales_1_prt_yr_1` contains the data for the year 2010. These steps exchange the table `sales_1_prt_yr_1` with an external table the uses the `gpfdist` protocol:

1. Ensure that the external table protocol is enabled for the Greenplum Database system.

   This example uses the `gpfdist` protocol. This command starts the `gpfdist` protocol.

   `$ gpfdist`

2. Create a writable external table.

   This `CREATE WRITABLE EXTERNAL TABLE` command creates a writable external table with the same columns as the partitioned table.

   ```
   CREATE WRITABLE EXTERNAL TABLE my_sales_ext ( LIKE sales_1_prt_yr_1 )
   LOCATION ( 'gpfdist://gpdb_test/sales_2010' )
   FORMAT 'csv'
   DISTRIBUTED BY (id) ;
   ```

3. Create a readable external table that reads the data from that destination of the writable external table created in the previous step.
This `CREATE EXTERNAL TABLE` create a readable external that uses the same external data as the writable external data.

```sql
CREATE EXTERNAL TABLE sales_2010_ext ( LIKE sales_1_prt_yr_1 )
    LOCATION ( 'gpfdist://gpdb_test/sales_2010' )
    FORMAT 'csv';
```

4. Copy the data from the leaf child partition into the writable external table.

This `INSERT` command copies the data from the child leaf partition table of the partitioned table into the external table.

```sql
INSERT INTO my_sales_ext SELECT * FROM sales_1_prt_yr_1 ;
```

5. Exchange the existing leaf child partition with the external table.

This `ALTER TABLE` command specifies the `EXCHANGE PARTITION` clause to switch the readable external table and the leaf child partition.

```sql
ALTER TABLE sales ALTER PARTITION yr_1
    EXCHANGE PARTITION yr_1
    WITH TABLE sales_2010_ext WITHOUT VALIDATION;
```

The external table becomes the leaf child partition with the table name `sales_1_prt_yr_1` and the old leaf child partition becomes the table `sales_2010_ext`.

**Warning:** In order to ensure queries against the partitioned table return the correct results, the external table data must be valid against the `CHECK` constraints on the leaf child partition. In this case, the data was taken from the child leaf partition table on which the `CHECK` constraints were defined.

6. Drop the table that was rolled out of the partitioned table.

```sql
DROP TABLE sales_2010_ext ;
```

You can rename the name of the leaf child partition to indicate that `sales_1_prt_yr_1` is an external table.

This example command changes the `partitionname` to `yr_1_ext` and the name of the child leaf partition table to `sales_1_prt_yr_1_ext`.

```sql
ALTER TABLE sales RENAME PARTITION yr_1 TO yr_1_ext ;
```

---

**Creating and Using Sequences**

A Greenplum Database sequence object is a special single row table that functions as a number generator. You can use a sequence to generate unique integer identifiers for a row that you add to a table. Declaring a column of type `SERIAL` implicitly creates a sequence counter for use in that table column.

Greenplum Database provides commands to create, alter, and drop a sequence. Greenplum Database also provides built-in functions to return the next value in the sequence (`nextval()`) or to set the sequence to a specific start value (`setval()`).

**Note:** The PostgreSQL `currval()` and `lastval()` sequence functions are not supported in Greenplum Database.

Attributes of a sequence object include the name of the sequence, its increment value, and the last, minimum, and maximum values of the sequence counter. Sequences also have a special boolean attribute named `is-called` that governs the auto-increment behavior of a `nextval()` operation on the sequence counter. When a sequence's `is-called` attribute is `true`, `nextval()` increments the sequence counter.
before returning the value. When the is_called attribute value of a sequence is false, nextval() does not increment the counter before returning the value.

Creating a Sequence

The CREATE SEQUENCE command creates and initializes a sequence with the given sequence name and optional start value. The sequence name must be distinct from the name of any other sequence, table, index, or view in the same schema. For example:

```
CREATE SEQUENCE myserial START 101;
```

When you create a new sequence, Greenplum Database sets the sequence is_called attribute to false. Invoking nextval() on a newly-created sequence does not increment the sequence counter, but returns the sequence start value and sets is_called to true.

Using a Sequence

After you create a sequence with the CREATE SEQUENCE command, you can examine the sequence and use the sequence built-in functions.

Examining Sequence Attributes

To examine the current attributes of a sequence, query the sequence directly. For example, to examine a sequence named myserial:

```
SELECT * FROM myserial;
```

Returning the Next Sequence Counter Value

You can invoke the nextval() built-in function to return and use the next value in a sequence. The following command inserts the next value of the sequence named myserial into the first column of a table named vendors:

```
INSERT INTO vendors VALUES (nextval('myserial'), 'acme');
```

nextval() uses the sequence's is_called attribute value to determine whether or not to increment the sequence counter before returning the value. nextval() advances the counter when is_called is true. nextval() sets the sequence is_called attribute to true before returning.

A nextval() operation is never rolled back. A fetched value is considered used, even if the transaction that performed the nextval() fails. This means that failed transactions can leave unused holes in the sequence of assigned values.

**Note:** You cannot use the nextval() function in UPDATE or DELETE statements if mirroring is enabled in Greenplum Database.

Setting the Sequence Counter Value

You can use the Greenplum Database setval() built-in function to set the counter value for a sequence. For example, the following command sets the counter value of the sequence named myserial to 201:

```
SELECT setval('myserial', 201);
```

setval() has two function signatures: setval(sequence, start_val) and setval(sequence, start_val, is_called). The default behaviour of setval( sequence, start_val) sets the sequence is_called attribute value to true.
If you do not want the sequence counter advanced on the next `nextval()` call, use the `setval( sequence, start_val, is_called)` function signature, passing a `false` argument:

```sql
SELECT setval('myserial', 201, false);
```

`setval()` operations are never rolled back.

### Altering a Sequence

The `ALTER SEQUENCE` command changes the attributes of an existing sequence. You can alter the sequence minimum, maximum, and increment values. You can also restart the sequence at a specific value.

Any parameters not set in the `ALTER SEQUENCE` command retain their prior settings.

The following command restarts the sequence named `myserial` at value 105:

```sql
ALTER SEQUENCE myserial RESTART WITH 105;
```

When you alter a sequence start value with the `ALTER SEQUENCE` command, Greenplum Database sets the sequence's `is_called` attribute to `false`. The first `nextval()` invoked after restarting a sequence does not advance the sequence counter, but returns the sequence restart value and sets `is_called` to `true`.

### Dropping a Sequence

The `DROP SEQUENCE` command removes a sequence. For example, the following command removes the sequence named `myserial`:

```sql
DROP SEQUENCE myserial;
```

### Specifying a Sequence as the Default Value for a Column

You can reference a sequence directly in the `CREATE TABLE` command in addition to using the `SERIAL` or `BIGSERIAL` types. For example:

```sql
CREATE TABLE tablename ( id INT4 DEFAULT nextval('myserial'), name text );
```

You can also alter a table column to set its default value to a sequence counter:

```sql
ALTER TABLE tablename ALTER COLUMN id SET DEFAULT nextval('myserial');
```

### Sequence Wraparound

By default, a sequence does not wrap around. That is, when a sequence reaches the max value (`+32767` for `SMALLSERIAL`, `+2147483647` for `SERIAL`, `+9223372036854775807` for `BIGSERIAL`), every subsequent `nextval()` call produces an error. You can alter a sequence to make it cycle around and start at 1 again:

```sql
ALTER SEQUENCE myserial CYCLE;
```

You can also specify the wraparound behaviour when you create the sequence:

```sql
CREATE SEQUENCE myserial CYCLE;
```
Using Indexes in Greenplum Database

In most traditional databases, indexes can greatly improve data access times. However, in a distributed database such as Greenplum, indexes should be used more sparingly. Greenplum Database performs very fast sequential scans; indexes use a random seek pattern to locate records on disk. Greenplum data is distributed across the segments, so each segment scans a smaller portion of the overall data to get the result. With table partitioning, the total data to scan may be even smaller. Because business intelligence (BI) query workloads generally return very large data sets, using indexes is not efficient.

First try your query workload without adding indexes. Indexes are more likely to improve performance for OLTP workloads, where the query is returning a single record or a small subset of data. Indexes can also improve performance on compressed append-optimized tables for queries that return a targeted set of rows, as the optimizer can use an index access method rather than a full table scan when appropriate. For compressed data, an index access method means only the necessary rows are uncompressed.

Greenplum Database automatically creates PRIMARY KEY constraints for tables with primary keys. To create an index on a partitioned table, create an index on the partitioned table that you created. The index is propagated to all the child tables created by Greenplum Database. Creating an index on a table that is created by Greenplum Database for use by a partitioned table is not supported.

Note that a UNIQUE CONSTRAINT (such as a PRIMARY KEY CONSTRAINT) implicitly creates a UNIQUE INDEX that must include all the columns of the distribution key and any partitioning key. The UNIQUE CONSTRAINT is enforced across the entire table, including all table partitions (if any).

Indexes add some database overhead — they use storage space and must be maintained when the table is updated. Ensure that the query workload uses the indexes that you create, and check that the indexes you add improve query performance (as compared to a sequential scan of the table). To determine whether indexes are being used, examine the query EXPLAIN plans. See Query Profiling.

Consider the following points when you create indexes.

- **Your Query Workload.** Indexes improve performance for workloads where queries return a single record or a very small data set, such as OLTP workloads.

- **Compressed Tables.** Indexes can improve performance on compressed append-optimized tables for queries that return a targeted set of rows. For compressed data, an index access method means only the necessary rows are uncompressed.

- **Avoid indexes on frequently updated columns.** Creating an index on a column that is frequently updated increases the number of writes required when the column is updated.

- **Create selective B-tree indexes.** Index selectivity is a ratio of the number of distinct values a column has divided by the number of rows in a table. For example, if a table has 1000 rows and a column has 800 distinct values, the selectivity of the index is 0.8, which is considered good. Unique indexes always have a selectivity ratio of 1.0, which is the best possible. Greenplum Database allows unique indexes only on distribution key columns.

- **Use Bitmap indexes for low selectivity columns.** The Greenplum Database Bitmap index type is not available in regular PostgreSQL. See About Bitmap Indexes.

- **Index columns used in joins.** An index on a column used for frequent joins (such as a foreign key column) can improve join performance by enabling more join methods for the query optimizer to use.

- **Index columns frequently used in predicates.** Columns that are frequently referenced in WHERE clauses are good candidates for indexes.

- **Avoid overlapping indexes.** Indexes that have the same leading column are redundant.

- **Drop indexes for bulk loads.** For mass loads of data into a table, consider dropping the indexes and re-creating them after the load completes. This is often faster than updating the indexes.

- **Consider a clustered index.** Clustering an index means that the records are physically ordered on disk according to the index. If the records you need are distributed randomly on disk, the database has to seek across the disk to fetch the records requested. If the records are stored close together, the fetching operation is more efficient. For example, a clustered index on a date column where the data is
ordered sequentially by date. A query against a specific date range results in an ordered fetch from the disk, which leverages fast sequential access.

To cluster an index in Greenplum Database

Using the `CLUSTER` command to physically reorder a table based on an index can take a long time with very large tables. To achieve the same results much faster, you can manually reorder the data on disk by creating an intermediate table and loading the data in the desired order. For example:

```sql
CREATE TABLE new_table (LIKE old_table)
    AS SELECT * FROM old_table ORDER BY myixcolumn;
DROP old_table;
ALTER TABLE new_table RENAME TO old_table;
CREATE INDEX myixcolumn_ix ON old_table;
VACUUM ANALYZE old_table;
```

**Index Types**

Greenplum Database supports the Postgres index types B-tree and GiST. Hash and GIN indexes are not supported. Each index type uses a different algorithm that is best suited to different types of queries. B-tree indexes fit the most common situations and are the default index type. See Index Types in the PostgreSQL documentation for a description of these types.

**Note:** Greenplum Database allows unique indexes only if the columns of the index key are the same as (or a superset of) the Greenplum distribution key. Unique indexes are not supported on append-optimized tables. On partitioned tables, a unique index cannot be enforced across all child table partitions of a partitioned table. A unique index is supported only within a partition.

**About Bitmap Indexes**

Greenplum Database provides the Bitmap index type. Bitmap indexes are best suited to data warehousing applications and decision support systems with large amounts of data, many ad hoc queries, and few data modification (DML) transactions.

An index provides pointers to the rows in a table that contain a given key value. A regular index stores a list of tuple IDs for each key corresponding to the rows with that key value. Bitmap indexes store a bitmap for each key value. Regular indexes can be several times larger than the data in the table, but bitmap indexes provide the same functionality as a regular index and use a fraction of the size of the indexed data.

Each bit in the bitmap corresponds to a possible tuple ID. If the bit is set, the row with the corresponding tuple ID contains the key value. A mapping function converts the bit position to a tuple ID. Bitmaps are compressed for storage. If the number of distinct key values is small, bitmap indexes are much smaller, compress better, and save considerable space compared with a regular index. The size of a bitmap index is proportional to the number of rows in the table times the number of distinct values in the indexed column.

Bitmap indexes are most effective for queries that contain multiple conditions in the `WHERE` clause. Rows that satisfy some, but not all, conditions are filtered out before the table is accessed. This improves response time, often dramatically.

**When to Use Bitmap Indexes**

Bitmap indexes are best suited to data warehousing applications where users query the data rather than update it. Bitmap indexes perform best for columns that have between 100 and 100,000 distinct values and when the indexed column is often queried in conjunction with other indexed columns. Columns with fewer than 100 distinct values, such as a gender column with two distinct values (male and female), usually do not benefit much from any type of index. On a column with more than 100,000 distinct values, the performance and space efficiency of a bitmap index decline.

Bitmap indexes can improve query performance for ad hoc queries. AND and OR conditions in the `WHERE` clause of a query can be resolved quickly by performing the corresponding Boolean operations directly on
the bitmaps before converting the resulting bitmap to tuple ids. If the resulting number of rows is small, the query can be answered quickly without resorting to a full table scan.

**When Not to Use Bitmap Indexes**

Do not use bitmap indexes for unique columns or columns with high cardinality data, such as customer names or phone numbers. The performance gains and disk space advantages of bitmap indexes start to diminish on columns with 100,000 or more unique values, regardless of the number of rows in the table.

Bitmap indexes are not suitable for OLTP applications with large numbers of concurrent transactions modifying the data.

Use bitmap indexes sparingly. Test and compare query performance with and without an index. Add an index only if query performance improves with indexed columns.

**Creating an Index**

The `CREATE INDEX` command defines an index on a table. A B-tree index is the default index type. For example, to create a B-tree index on the column `gender` in the table `employee`:

```
CREATE INDEX gender_idx ON employee (gender);
```

To create a bitmap index on the column `title` in the table `films`:

```
CREATE INDEX title_bmp_idx ON films USING bitmap (title);
```

**Examining Index Usage**

Greenplum Database indexes do not require maintenance and tuning. You can check which indexes are used by the real-life query workload. Use the `EXPLAIN` command to examine index usage for a query.

The query plan shows the steps or **plan nodes** that the database will take to answer a query and time estimates for each plan node. To examine the use of indexes, look for the following query plan node types in your `EXPLAIN` output:

- **Index Scan** - A scan of an index.
- **Bitmap Heap Scan** - Retrieves all
  from the bitmap generated by BitmapAnd, BitmapOr, or BitmapIndexScan and accesses the heap to retrieve the relevant rows.
- **Bitmap Index Scan** - Compute a bitmap by OR-ing all bitmaps that satisfy the query predicates from the underlying index.
- **BitmapAnd** or **BitmapOr** - Takes the bitmaps generated from multiple BitmapIndexScan nodes, ANDs or ORs them together, and generates a new bitmap as its output.

You have to experiment to determine the indexes to create. Consider the following points.

- Run `ANALYZE` after you create or update an index. `ANALYZE` collects table statistics. The query optimizer uses table statistics to estimate the number of rows returned by a query and to assign realistic costs to each possible query plan.
- Use real data for experimentation. Using test data for setting up indexes tells you what indexes you need for the test data, but that is all.
- Do not use very small test data sets as the results can be unrealistic or skewed.
- Be careful when developing test data. Values that are similar, completely random, or inserted in sorted order will skew the statistics away from the distribution that real data would have.
- You can force the use of indexes for testing purposes by using run-time parameters to turn off specific plan types. For example, turn off sequential scans (`enable_seqscan`) and nested-loop joins (`enable_nestloop`), the most basic plans, to force the system to use a different plan. Time your query with and without indexes and use the `EXPLAIN ANALYZE` command to compare the results.
Managing Indexes

Use the REINDEX command to rebuild a poorly-performing index. REINDEX rebuilds an index using the data stored in the index's table, replacing the old copy of the index.

To rebuild all indexes on a table

REINDEX my_table;

To rebuild a particular index

REINDEX my_index;

Dropping an Index

The DROP INDEX command removes an index. For example:

DROP INDEX title_idx;

When loading data, it can be faster to drop all indexes, load, then recreate the indexes.

Creating and Managing Views

Views enable you to save frequently used or complex queries, then access them in a SELECT statement as if they were a table. A view is not physically materialized on disk: the query runs as a subquery when you access the view.

If a subquery is associated with a single query, consider using the WITH clause of the SELECT command instead of creating a seldom-used view.

Creating Views

The CREATE VIEW command defines a view of a query. For example:

CREATE VIEW comedies AS SELECT * FROM films WHERE kind = 'comedy';

Views ignore ORDER BY and SORT operations stored in the view.

Dropping Views

The DROP VIEW command removes a view. For example:

DROP VIEW topten;

The DROP VIEW ... CASCADE command also removes all dependent objects. As example, if another view depends on the view which is about to be dropped, the other view will be dropped as well. Without the CASCADE option, the DROP VIEW command will fail.
Distribution and Skew

Greenplum Database relies on even distribution of data across segments.

In an MPP shared nothing environment, overall response time for a query is measured by the completion time for all segments. The system is only as fast as the slowest segment. If the data is skewed, segments with more data will take more time to complete, so every segment must have an approximately equal number of rows and perform approximately the same amount of processing. Poor performance and out of memory conditions may result if one segment has significantly more data to process than other segments.

Optimal distributions are critical when joining large tables together. To perform a join, matching rows must be located together on the same segment. If data is not distributed on the same join column, the rows needed from one of the tables are dynamically redistributed to the other segments. In some cases a broadcast motion, in which each segment sends its individual rows to all other segments, is performed rather than a redistribution motion, where each segment rehashes the data and sends the rows to the appropriate segments according to the hash key.

Local (Co-located) Joins

Using a hash distribution that evenly distributes table rows across all segments and results in local joins can provide substantial performance gains. When joined rows are on the same segment, much of the processing can be accomplished within the segment instance. These are called local or co-located joins. Local joins minimize data movement; each segment operates independently of the other segments, without network traffic or communications between segments.

To achieve local joins for large tables commonly joined together, distribute the tables on the same column. Local joins require that both sides of a join be distributed on the same columns (and in the same order) and that all columns in the distribution clause are used when joining tables. The distribution columns must also be the same data type—although some values with different data types may appear to have the same representation, they are stored differently and hash to different values, so they are stored on different segments.

Data Skew

Data skew may be caused by uneven data distribution due to the wrong choice of distribution keys or single tuple table insert or copy operations. Present at the table level, data skew, is often the root cause of poor query performance and out of memory conditions. Skewed data affects scan (read) performance, but it also affects all other query execution operations, for instance, joins and group by operations.

It is very important to validate distributions to ensure that data is evenly distributed after the initial load. It is equally important to continue to validate distributions after incremental loads.

The following query shows the number of rows per segment as well as the variance from the minimum and maximum numbers of rows:

```sql
SELECT 'Example Table' AS "Table Name",
       max(c) AS "Max Seg Rows", min(c) AS "Min Seg Rows",
       (max(c)-min(c))*100.0/max(c) AS "Percentage Difference Between Max & Min"
FROM (SELECT count(*) c, gp_segment_id FROM facts GROUP BY 2) AS a;
```

The gp_toolkit schema has two views that you can use to check for skew.

- The gp_toolkit.gp_skew_coefficients view shows data distribution skew by calculating the coefficient of variation (CV) for the data stored on each segment. The skccoeff column shows the coefficient of variation (CV), which is calculated as the standard deviation divided by the average. It
takes into account both the average and variability around the average of a data series. The lower the value, the better. Higher values indicate greater data skew.

- The `gp_toolkit.gp_skew_idle_fractions` view shows data distribution skew by calculating the percentage of the system that is idle during a table scan, which is an indicator of computational skew. The `siffraction` column shows the percentage of the system that is idle during a table scan. This is an indicator of uneven data distribution or query processing skew. For example, a value of 0.1 indicates 10% skew, a value of 0.5 indicates 50% skew, and so on. Tables that have more than 10% skew should have their distribution policies evaluated.

**Considerations for Randomly Distributed Tables**

When you create a table with random distribution (`DISTRIBUTED RANDOMLY`), Greenplum Database distributes the data you insert or copy into the table in a round-robin fashion. Greenplum Database starts a new instance of a round-robin cycle for each insert or copy operation. As such, single tuple inserts into a randomly distributed table are assigned to the first segment and will result in data skew. Greenplum Database more evenly distributes data from bulk inserts.

**Processing Skew**

Processing skew results when a disproportionate amount of data flows to, and is processed by, one or a few segments. It is often the culprit behind Greenplum Database performance and stability issues. It can happen with operations such join, sort, aggregation, and various OLAP operations. Processing skew happens in flight while a query is executing and is not as easy to detect as data skew.

If single segments are failing, that is, not all segments on a host, it may be a processing skew issue. Identifying processing skew is currently a manual process. First look for spill files. If there is skew, but not enough to cause spill, it will not become a performance issue. If you determine skew exists, then find the query responsible for the skew. Following are the steps and commands to use. (Change names like the host file name passed to gpssh accordingly):

1. Find the OID for the database that is to be monitored for skew processing:

   ```sql
   SELECT oid, datname FROM pg_database;
   ```

   **Example output:**

<table>
<thead>
<tr>
<th>oid</th>
<th>datname</th>
</tr>
</thead>
<tbody>
<tr>
<td>17088</td>
<td>gpadmin</td>
</tr>
<tr>
<td>10899</td>
<td>postgres</td>
</tr>
<tr>
<td>1</td>
<td>templatel</td>
</tr>
<tr>
<td>10898</td>
<td>template0</td>
</tr>
<tr>
<td>38817</td>
<td>pws</td>
</tr>
<tr>
<td>39682</td>
<td>gpperfmon</td>
</tr>
</tbody>
</table>
   (6 rows)

2. Run a `gpssh` command to check file sizes across all of the segment nodes in the system. Replace `<OID>` with the OID of the database from the prior command:

   ```bash
   [gpadmin@mdw kend]$ gpssh -f ~/hosts -e "du -b /data[1-2]/primary/gpseg*/base/<OID>/pgsql_tmp/*" | \ 
   grep -v "du -b" | sort | awk -F" " '{ arr[$1] = arr[$1] + $2 ; tot = tot + $2 ; } END \ 
   { for (i in arr) print "Segment node" i, arr[i], "bytes (" arr[i]/(1024**3) " GB):"; \ 
     print "Total", tot, "bytes (" tot/(1024**3) " GB)" }' -
   ```

   **Example output:**

   Segment node[sdw1] 2443370457 bytes (2.27557 GB)
If there is a **significant and sustained** difference in disk usage, then the queries being executed should be investigated for possible skew (the example output above does not reveal significant skew). In monitoring systems, there will always be some skew, but often it is **transient** and will be **short in duration**.

3. If significant and sustained skew appears, the next task is to identify the offending query.

The command in the previous step sums up the entire node. This time, find the actual segment directory. You can do this from the master or by logging into the specific node identified in the previous step. Following is an example run from the master.

This example looks specifically for sort files. Not all spill files or skew situations are caused by sort files, so you will need to customize the command:

```
$ gpssh -f ~/hosts -e
   "ls -l /data[1-2]/primary/gpseg*/base/19979/pgsql_tmp/*
    | grep -i sort | awk '{sub(/base.*tmp\//, ".../", $10); print $1,$6, $10}' | sort -k2 -n
```

Here is output from this command:

```
[sdw1] 288718848
   /data1/primary/gpseg2/.../pgsql_tmp_slice0_sort_17758_0001.0
291176448
   /data2/primary/gpseg5/.../pgsql_tmp_slice0_sort_17764_0001.0
924581888
   /data2/primary/gpseg45/.../pgsql_tmp_slice10_sort_15673_0010.9
980582400
   /data1/primary/gpseg18/.../pgsql_tmp_slice10_sort_29425_0001.0
986447872
   /data2/primary/gpseg35/.../pgsql_tmp_slice10_sort_29602_0001.0...
[sdw5] 999620608
   /data1/primary/gpseg26/.../pgsql_tmp_slice10_sort_28637_0001.0
999751680
   /data2/primary/gpseg9/.../pgsql_tmp_slice10_sort_3969_0001.0
1000112128
   /data1/primary/gpseg13/.../pgsql_tmp_slice10_sort_24723_0001.0
1000898560
   /data2/primary/gpseg28/.../pgsql_tmp_slice10_sort_28641_0001.0...
[sdw8] 1008009216
   /data1/primary/gpseg44/.../pgsql_tmp_slice10_sort_15671_0001.0
1008566272
   /data1/primary/gpseg24/.../pgsql_tmp_slice10_sort_28633_0001.0
1009451008
   /data1/primary/gpseg19/.../pgsql_tmp_slice10_sort_29427_0001.0
1011187712
   /data1/primary/gpseg37/.../pgsql_tmp_slice10_sort_18526_0001.0
1573741824
   /data2/primary/gpseg45/.../pgsql_tmp_slice10_sort_15673_0010.0
1573741824
   /data2/primary/gpseg45/.../pgsql_tmp_slice10_sort_15673_0002.1
1573741824
   /data2/primary/gpseg45/.../pgsql_tmp_slice10_sort_15673_0003.2
```
Scanning this output reveals that segment gpseg45 on host sdw8 is the culprit, as its sort files are larger than the others in the output.

4. Log in to the offending node with ssh and become root. Use the lsof command to find the PID for the process that owns one of the sort files:

```
[root@sdw8 ~]# lsof /data2/primary/gpseg45/base/19979/pgsql_tmp/
pgsql_tmp_slice10_sort_15673_0002.1
COMMAND  PID    USER    FD   TYPE DEVICE  SIZE        NODE        NAME
postgres 15673  gpadmin 11u  REG  8,48    1073741824  64424546751 /data2/
primary/gpseg45/base/19979/pgsql_tmp/pgsql_tmp_slice10_sort_15673_0002.1
```

The PID, 15673, is also part of the file name, but this may not always be the case.

5. Use the ps command with the PID to identify the database and connection information:

```
[root@sdw8 ~]# ps -eaf | grep 15673
gpadmin 15673 27471 28 12:05 ?        00:12:59 postgres: port 40003,
sbaskin bdw
172.28.12.250(21813) con699238 seg45 cmd32 slice10 MPPEXEC SELECT
root     29622 29566  0 12:50 pts/16   00:00:00 grep 15673
```

6. On the master, check the pg_log log file for the user in the previous command (sbaskin), connection (con699238, and command (cmd32). The line in the log file with these three values should be the line that contains the query, but occasionally, the command number may differ slightly. For example, the ps output may show cmd32, but in the log file it is cmd34. If the query is still running, the last query for the user and connection is the offending query.

The remedy for processing skew in almost all cases is to rewrite the query. Creating temporary tables can eliminate skew. Temporary tables can be randomly distributed to force a two-stage aggregation.
Inserting, Updating, and Deleting Data

This section provides information about manipulating data and concurrent access in Greenplum Database.

This topic includes the following subtopics:

- About Concurrency Control in Greenplum Database
- Inserting Rows
- Updating Existing Rows
- Deleting Rows
- Working With Transactions
- Vacuuming the Database

About Concurrency Control in Greenplum Database

Greenplum Database and PostgreSQL do not use locks for concurrency control. They maintain data consistency using a multiversion model, Multiversion Concurrency Control (MVCC). MVCC achieves transaction isolation for each database session, and each query transaction sees a snapshot of data. This ensures the transaction sees consistent data that is not affected by other concurrent transactions.

Because MVCC does not use explicit locks for concurrency control, lock contention is minimized and Greenplum Database maintains reasonable performance in multiuser environments. Locks acquired for querying (reading) data do not conflict with locks acquired for writing data.

Greenplum Database provides multiple lock modes to control concurrent access to data in tables. Most Greenplum Database SQL commands automatically acquire the appropriate locks to ensure that referenced tables are not dropped or modified in incompatible ways while a command executes. For applications that cannot adapt easily to MVCC behavior, you can use the `LOCK` command to acquire explicit locks. However, proper use of MVCC generally provides better performance.

Table 50: Lock Modes in Greenplum Database

<table>
<thead>
<tr>
<th>Lock Mode</th>
<th>Associated SQL Commands</th>
<th>Conflicts With</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCESS SHARE</td>
<td>SELECT</td>
<td>ACCESS EXCLUSIVE</td>
</tr>
<tr>
<td>ROW SHARE</td>
<td>SELECT FOR SHARE, SELECT FOR UPDATE</td>
<td>EXCLUSIVE, ACCESS EXCLUSIVE</td>
</tr>
<tr>
<td>ROW EXCLUSIVE</td>
<td>INSERT, COPY</td>
<td>SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, ACCESS EXCLUSIVE</td>
</tr>
<tr>
<td>SHARE UPDATE EXCLUSIVE</td>
<td>VACUUM (without FULL), ANALYZE</td>
<td>SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, ACCESS EXCLUSIVE</td>
</tr>
<tr>
<td>SHARE</td>
<td>CREATE INDEX</td>
<td>ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE ROW EXCLUSIVE, EXCLUSIVE, ACCESS EXCLUSIVE</td>
</tr>
<tr>
<td>SHARE ROW EXCLUSIVE</td>
<td></td>
<td>ROW EXCLUSIVE, SHARE UPDATE EXCLUSIVE, SHARE ROW EXCLUSIVE, EXCLUSIVE, ACCESS EXCLUSIVE</td>
</tr>
</tbody>
</table>
Inserting Rows

Use the `INSERT` command to create rows in a table. This command requires the table name and a value for each column in the table; you may optionally specify the column names in any order. If you do not specify column names, list the data values in the order of the columns in the table, separated by commas.

For example, to specify the column names and the values to insert:

```
INSERT INTO products (name, price, product_no) VALUES ('Cheese', 9.99, 1);
```

To specify only the values to insert:

```
INSERT INTO products VALUES (1, 'Cheese', 9.99);
```

Usually, the data values are literals (constants), but you can also use scalar expressions. For example:

```
INSERT INTO films SELECT * FROM tmp_films WHERE date_prod < '2016-05-07';
```

You can insert multiple rows in a single command. For example:

```
INSERT INTO products (product_no, name, price) VALUES
    (1, 'Cheese', 9.99),
    (2, 'Bread', 1.99),
    (3, 'Milk', 2.99);
```

To insert data into a partitioned table, you specify the root partitioned table, the table created with the `CREATE TABLE` command. You also can specify a leaf child table of the partitioned table in an `INSERT` command. An error is returned if the data is not valid for the specified leaf child table. Specifying a child table that is not a leaf child table in the `INSERT` command is not supported.

To insert large amounts of data, use external tables or the `COPY` command. These load mechanisms are more efficient than `INSERT` for inserting large quantities of rows. See `Loading and Unloading Data` for more information about bulk data loading.

The storage model of append-optimized tables is optimized for bulk data loading. Greenplum does not recommend single row `INSERT` statements for append-optimized tables. For append-optimized tables, Greenplum Database supports a maximum of 127 concurrent `INSERT` transactions into a single append-optimized table.
Updating Existing Rows

The UPDATE command updates rows in a table. You can update all rows, a subset of all rows, or individual rows in a table. You can update each column separately without affecting other columns.

To perform an update, you need:

• The name of the table and columns to update
• The new values of the columns
• One or more conditions specifying the row or rows to be updated.

For example, the following command updates all products that have a price of 5 to have a price of 10:

```
UPDATE products SET price = 10 WHERE price = 5;
```

Using UPDATE in Greenplum Database has the following restrictions:

• The Greenplum distribution key columns may not be updated.
• If mirrors are enabled, you cannot use STABLE or VOLATILE functions in an UPDATE statement.
• Greenplum Database does not support the RETURNING clause.
• Greenplum Database partitioning columns cannot be updated.

Deleting Rows

The DELETE command deletes rows from a table. Specify a WHERE clause to delete rows that match certain criteria. If you do not specify a WHERE clause, all rows in the table are deleted. The result is a valid, but empty, table. For example, to remove all rows from the products table that have a price of 10:

```
DELETE FROM products WHERE price = 10;
```

To delete all rows from a table:

```
DELETE FROM products;
```

Using DELETE in Greenplum Database has similar restrictions to using UPDATE:

• If mirrors are enabled, you cannot use STABLE or VOLATILE functions in an UPDATE statement.
• The RETURNING clause is not supported in Greenplum Database.

Truncating a Table

Use the TRUNCATE command to quickly remove all rows in a table. For example:

```
TRUNCATE mytable;
```

This command empties a table of all rows in one operation. Note that TRUNCATE does not scan the table, therefore it does not process inherited child tables or ON DELETE rewrite rules. The command truncates only rows in the named table.

Working With Transactions

Transactions allow you to bundle multiple SQL statements in one all-or-nothing operation.

The following are the Greenplum Database SQL transaction commands:

• BEGIN or START TRANSACTION starts a transaction block.
• END or COMMIT commits the results of a transaction.
• ROLLBACK abandons a transaction without making any changes.
- **SAVEPOINT** marks a place in a transaction and enables partial rollback. You can roll back commands executed after a savepoint while maintaining commands executed before the savepoint.
- **ROLLBACK TO SAVEPOINT** rolls back a transaction to a savepoint.
- **RELEASE SAVEPOINT** destroys a savepoint within a transaction.

## Transaction Isolation Levels

Greenplum Database accepts the standard SQL transaction levels as follows:

- **read uncommitted** and **read committed** behave like the standard **read committed**
- **repeatable read** is disallowed. If the behavior of **repeatable read** is required, use **serializable**.
- **serializable** behaves in a manner similar to SQL standard **serializable**

The following information describes the behavior of the Greenplum transaction levels:

### read committed/read uncommitted
- Provides fast, simple, partial transaction isolation. With read committed and read uncommitted transaction isolation, **SELECT**, **UPDATE**, and **DELETE** transactions operate on a snapshot of the database taken when the query started.

#### A SELECT query:
- Sees data committed before the query starts.
- Sees updates executed within the transaction.
- Does not see uncommitted data outside the transaction.
- Can possibly see changes that concurrent transactions made if the concurrent transaction is committed after the initial read in its own transaction.

Successive **SELECT** queries in the same transaction can see different data if other concurrent transactions commit changes before the queries start. **UPDATE** and **DELETE** commands find only rows committed before the commands started.

Read committed or read uncommitted transaction isolation allows concurrent transactions to modify or lock a row before **UPDATE** or **DELETE** finds the row. Read committed or read uncommitted transaction isolation may be inadequate for applications that perform complex queries and updates and require a consistent view of the database.

### serializable
- Provides strict transaction isolation in which transactions execute as if they run one after another rather than concurrently. Applications on the serializable level must be designed to retry transactions in case of serialization failures. In Greenplum Database, **SERIALIZABLE** prevents dirty reads, non-repeatable reads, and phantom reads without expensive locking, but there are other interactions that can occur between some **SERIALIZABLE** transactions in Greenplum Database that prevent them from being truly serializable. Transactions that run concurrently should be examined to identify interactions that are not prevented by disallowing concurrent updates of the same data. Problems identified can be prevented by using explicit table locks or by requiring the conflicting transactions to update a dummy row introduced to represent the conflict.

#### A SELECT query:
- Sees a snapshot of the data as of the start of the transaction (not as of the start of the current query within the transaction).
- Sees only data committed before the query starts.
- Sees updates executed within the transaction.
- Does not see uncommitted data outside the transaction.
- Does not see changes that concurrent transactions made.

Successive **SELECT** commands within a single transaction always see the same data. **UPDATE**, **DELETE**, **SELECT FOR UPDATE**, and **SELECT FOR SHARE** commands find only rows committed before the command started. If a concurrent transaction has already updated, deleted, or locked a target row when the row is found, the serializable or repeatable read transaction waits for the concurrent transaction to update the row, delete the row, or roll back.
If the concurrent transaction updates or deletes the row, the serializable or repeatable read transaction rolls back. If the concurrent transaction rolls back, then the serializable or repeatable read transaction updates or deletes the row.

The default transaction isolation level in Greenplum Database is *read committed*. To change the isolation level for a transaction, declare the isolation level when you `BEGIN` the transaction or use the `SET TRANSACTION` command after the transaction starts.

**Vacuuming the Database**

Deleted or updated data rows occupy physical space on disk even though new transactions cannot see them. Periodically running the `VACUUM` command removes these expired rows. For example:

```bash
VACUUM mytable;
```

The `VACUUM` command collects table-level statistics such as the number of rows and pages. Vacuum all tables after loading data, including append-optimized tables. For information about recommended routine vacuum operations, see *Routine Vacuum and Analyze*.

**Important:** The `VACUUM`, `VACUUM FULL`, and `VACUUM ANALYZE` commands should be used to maintain the data in a Greenplum database especially if updates and deletes are frequently performed on your database data. See the `VACUUM` command in the *Greenplum Database Reference Guide* for information about using the command.

**Configuring the Free Space Map**

Expired rows are held in the *free space map*. The free space map must be sized large enough to hold all expired rows in your database. If not, a regular `VACUUM` command cannot reclaim space occupied by expired rows that overflow the free space map.

`VACUUM FULL` reclaims all expired row space, but it is an expensive operation and can take an unacceptably long time to finish on large, distributed Greenplum Database tables. If the free space map overflows, you can recreate the table with a `CREATE TABLE AS` statement and drop the old table. Using `VACUUM FULL` is discouraged.

Size the free space map with the following server configuration parameters:

- `max_fsm_pages`
- `max_fsm_relations`
Querying Data

This topic provides information about using SQL in Greenplum databases. You enter SQL statements called queries to view, change, and analyze data in a database using the psql interactive SQL client and other client tools.

About Greenplum Query Processing

This topic provides an overview of how Greenplum Database processes queries. Understanding this process can be useful when writing and tuning queries.

Users issue queries to Greenplum Database as they would to any database management system. They connect to the database instance on the Greenplum master host using a client application such as psql and submit SQL statements.

Understanding Query Planning and Dispatch

The master receives, parses, and optimizes the query. The resulting query plan is either parallel or targeted. The master dispatches parallel query plans to all segments, as shown in Figure 23: Dispatching the Parallel Query Plan. The master dispatches targeted query plans to a single segment, as shown in Figure 24: Dispatching a Targeted Query Plan. Each segment is responsible for executing local database operations on its own set of data.

Most database operations—such as table scans, joins, aggregations, and sorts—execute across all segments in parallel. Each operation is performed on a segment database independent of the data stored in the other segment databases.

Figure 23: Dispatching the Parallel Query Plan
Certain queries may access only data on a single segment, such as single-row INSERT, UPDATE, DELETE, or SELECT operations or queries that filter on the table distribution key column(s). In queries such as these, the query plan is not dispatched to all segments, but is targeted at the segment that contains the affected or relevant row(s).

Figure 24: Dispatching a Targeted Query Plan

Understanding Greenplum Query Plans

A query plan is the set of operations Greenplum Database will perform to produce the answer to a query. Each node or step in the plan represents a database operation such as a table scan, join, aggregation, or sort. Plans are read and executed from bottom to top.

In addition to common database operations such as tables scans, joins, and so on, Greenplum Database has an additional operation type called motion. A motion operation involves moving tuples between the segments during query processing. Note that not every query requires a motion. For example, a targeted query plan does not require data to move across the interconnect.

To achieve maximum parallelism during query execution, Greenplum divides the work of the query plan into slices. A slice is a portion of the plan that segments can work on independently. A query plan is sliced wherever a motion operation occurs in the plan, with one slice on each side of the motion.

For example, consider the following simple query involving a join between two tables:

```sql
SELECT customer, amount
FROM sales JOIN customer USING (cust_id)
WHERE dateCol = '04-30-2016';
```

Figure 25: Query Slice Plan shows the query plan. Each segment receives a copy of the query plan and works on it in parallel.

The query plan for this example has a redistribute motion that moves tuples between the segments to complete the join. The redistribute motion is necessary because the customer table is distributed across the segments by cust_id, but the sales table is distributed across the segments by sale_id. To perform
the join, the sales tuples must be redistributed by cust_id. The plan is sliced on either side of the redistribute motion, creating slice 1 and slice 2.

This query plan has another type of motion operation called a gather motion. A gather motion is when the segments send results back up to the master for presentation to the client. Because a query plan is always sliced wherever a motion occurs, this plan also has an implicit slice at the very top of the plan (slice 3). Not all query plans involve a gather motion. For example, a CREATE TABLE x AS SELECT... statement would not have a gather motion because tuples are sent to the newly created table, not to the master.

![Figure 25: Query Slice Plan](image)

**Understanding Parallel Query Execution**

Greenplum creates a number of database processes to handle the work of a query. On the master, the query worker process is called the query dispatcher (QD). The QD is responsible for creating and dispatching the query plan. It also accumulates and presents the final results. On the segments, a query worker process is called a query executor (QE). A QE is responsible for completing its portion of work and communicating its intermediate results to the other worker processes.

There is at least one worker process assigned to each slice of the query plan. A worker process works on its assigned portion of the query plan independently. During query execution, each segment will have a number of processes working on the query in parallel.

Related processes that are working on the same slice of the query plan but on different segments are called gangs. As a portion of work is completed, tuples flow up the query plan from one gang of processes...
to the next. This inter-process communication between the segments is referred to as the *interconnect* component of Greenplum Database.

*Figure 26: Query Worker Processes* shows the query worker processes on the master and two segment instances for the query plan illustrated in *Figure 25: Query Slice Plan.*

---

**About GPORCA**

In Greenplum Database, the default GPORCA optimizer co-exists with the legacy query optimizer. These sections describe GPORCA functionality and usage:

- **Overview of GPORCA**
- **Enabling and Disabling GPORCA**
- **Considerations when Using GPORCA**
- **GPORCA Features and Enhancements**
- **Changed Behavior with the GPORCA**
- **GPORCA Limitations**
- **Determining the Query Optimizer that is Used**
- **About Uniform Multi-level Partitioned Tables**

**Overview of GPORCA**

GPORCA extends the planning and optimization capabilities of the Greenplum Database legacy optimizer. GPORCA is extensible and achieves better optimization in multi-core architecture environments. Greenplum Database uses GPORCA by default to generate an execution plan for a query when possible.

GPORCA also enhances Greenplum Database query performance tuning in the following areas:

- Queries against partitioned tables
- Queries that contain a common table expression (CTE)
- Queries that contain subqueries
In Greenplum Database, GPORCA co-exists with the legacy query optimizer. By default, Greenplum Database uses GPORCA. If GPORCA cannot be used, then the legacy query optimizer is used.

The following figure shows how GPORCA fits into the query planning architecture.

![Query Plan Generation Diagram](image)

**Note:** All legacy query optimizer (planner) server configuration parameters are ignored by GPORCA. However, if Greenplum Database falls back to the legacy optimizer, the planner server configuration parameters will impact the query plan generation. For a list of legacy query optimizer (planner) server configuration parameters, see *Query Tuning Parameters*.

### Enabling and Disabling GPORCA

By default, Greenplum Database uses GPORCA instead of the legacy query planner. Server configuration parameters enable or disable GPORCA.

Although GPORCA is on by default, you can configure GPORCA usage at the system, database, session, or query level using the `optimizer` parameter. Refer to one of the following sections if you want to change the default behavior:

- *Enabling GPORCA for a System*
- *Enabling GPORCA for a Database*
- *Enabling GPORCA for a Session or a Query*

  **Note:** You can disable the ability to enable or disable GPORCA with the server configuration parameter `optimizer_control`. For information about the server configuration parameters, see the *Greenplum Database Reference Guide*.

### Enabling GPORCA for a System

Set the server configuration parameter `optimizer` for the Greenplum Database system.

1. Log into the Greenplum Database master host as `gpadmin`, the Greenplum Database administrator.
2. Set the values of the server configuration parameters. These Greenplum Database `gpconfig` utility commands sets the value of the parameters to `on`:

```
$ gpconfig -c optimizer -v on --masteronly
```
3. Restart Greenplum Database. This Greenplum Database gpstop utility command reloads the postgresql.conf files of the master and segments without shutting down Greenplum Database.

```
$ gpstop -u
```

**Enabling GPORCA for a Database**

Set the server configuration parameter `optimizer` for individual Greenplum databases with the `ALTER DATABASE` command. For example, this command enables GPORCA for the database `test_db`.

```
> ALTER DATABASE test_db SET OPTIMIZER = ON ;
```

**Enabling GPORCA for a Session or a Query**

You can use the `SET` command to set `optimizer` server configuration parameter for a session. For example, after you use the `psql` utility to connect to Greenplum Database, this `SET` command enables GPORCA:

```
> set optimizer = on ;
```

To set the parameter for a specific query, include the `SET` command prior to running the query.

**Collecting Root Partition Statistics**

For a partitioned table, GPORCA uses statistics of the table root partition to generate query plans. These statistics are used for determining the join order, for splitting and joining aggregate nodes, and for costing the query steps. This is in contrast to the legacy planner, which uses the statistics of each leaf partition. If you execute queries on partitioned tables, you must collect statistics on the root partition and periodically update those statistics to ensure that GPORCA can generate optimal query plans.

**Setting the `optimizer_analyze_root_partition` Parameter**

A primary way to ensure that you collect root partition statistics is to set the `optimizer_analyze_root_partition` configuration parameter to on. When the parameter is enabled, Greenplum Database collects root partition statistics (ANALYZE_ROOTPARTITION operation) any time you run an ANALYZE command against a partitioned table.

1. Log into the Greenplum Database master host as `gpadmin`, the Greenplum Database administrator.
2. Set the values of the server configuration parameters. These Greenplum Database `gpconfig` utility commands sets the value of the parameters to on:

```
$ gpconfig -c optimizer_analyze_root_partition -v on --masteronly
```
3. Restart Greenplum Database. This Greenplum Database gpstop utility command reloads the postgresql.conf files of the master and segments without shutting down Greenplum Database.

```
$ gpstop -u
```

**Running ANALYZE_ROOTPARTITION**

The `ANALYZE_ROOTPARTITION` command samples the leaf partition data in a table, and stores the statistics in the root partition. The leaf partition data is only sampled, but statistics are not collected on the leaf partitions. Keep in mind that `ANALYZE_ROOTPARTITION` always scans the entire table before updating the root partition statistics. If your table is very large, this operation can take a significant amount of time. `ANALYZE_ROOTPARTITION` also uses an ACCESS_SHARE lock that prevents certain operations, such as `TRUNCATE` and `VACUUM` operations, during execution. For these reason, you should schedule `ANALYZE_ROOTPARTITION` operations periodically, or when there are significant changes to leaf partition data.
Keep in mind that even if the root partition statistics are not up-to-date or do not exist, GPORCA will still perform dynamic partition elimination for queries against the table.

Follow these best practices for running `ANALYZE ROOTPARTITION` in your system:

- **Always run** `ANALYZE ROOTPARTITION` **at least once for each newly-created partitioned table, after adding initial data.** If you execute a query on a root partition that has no statistics but has tuples, you receive the notice:

```sql
NOTICE: One or more columns in the following table(s) do not have statistics: <table_name>
HINT: For non-partitioned tables, run analyze <table_name>(<column_list>).
For partitioned tables, run analyze rootpartition <table_name>(<column_list>). See log for columns missing statistics.
```

- **Update root partition statistics when you observe query performance regression in EXPLAIN plans against the table, or after significant changes to leaf partition data.** For example, if you add a new leaf partition at some point after generating root partition statistics, consider running `ANALYZE ROOTPARTITION` to update root partition statistics with the new tuples inserted from the new leaf partition.

- **For very large tables, run `ANALYZE ROOTPARTITION` only weekly, or at some interval longer than daily.**

- **Avoid running `ANALYZE` with no arguments, because doing so executes the command on all database tables including partitioned tables.** With large databases, these global `ANALYZE` operations are difficult to monitor, and it can be difficult to predict the time needed for completion.

- **Consider running multiple `ANALYZE ROOTPARTITION <table_name>` operations in parallel to speed the operation of statistics collection, if your I/O throughput can support the load.**

- **You can also use the Greenplum Database utility `analyzedb` to update table statistics.** Using `analyzedb` ensures that tables that were previously analyzed are not re-analyzed if no modifications were made to the leaf partition.

**GPORCA and Leaf Partition Statistics**

Although creating and maintaining root partition statistics is crucial for GPORCA query performance with partitioned tables, maintaining leaf partition statistics is also important. If GPORCA cannot generate a plan for a query against a partitioned table, then the legacy planner is used and leaf partition statistics are needed to produce the optimal plan for that query.

GPORCA itself also uses leaf partition statistics for any queries that access leaf partitions directly, instead of using the root partition with predicates to eliminate partitions. For example, if you know which partitions hold necessary tuples for a query, you can directly query the leaf partition table itself; in this case GPORCA uses the leaf partition statistics.

**Considerations when Using GPORCA**

To execute queries optimally with GPORCA, query criteria to consider.

Ensure the following criteria are met:

- The table does not contain multi-column partition keys.
- The multi-level partitioned table is a uniform multi-level partitioned table. See *About Uniform Multi-level Partitioned Tables*.
- The server configuration parameter `optimizer_enable_master_only_queries` is set to `on` when running against master only tables such as the system table `pg_attribute`. For information about the parameter, see the *Greenplum Database Reference Guide*.

  **Note:** Enabling this parameter decreases performance of short running catalog queries. To avoid this issue, set this parameter only for a session or a query.

- Statistics have been collected on the root partition of a partitioned table.
If the partitioned table contains more than 20,000 partitions, consider a redesign of the table schema.

These server configuration parameters affect GPORCA query processing.

- `optimizer_cte_inlining_bound` controls the amount of inlining performed for common table expression (CTE) queries (queries that contain a `WHERE` clause).
- `optimizer_force_multistage_agg` forces GPORCA to choose a 3 stage aggregate plan for a scalar distinct qualified aggregate.
- `optimizer_force_three_stage_scalar_dqa` forces GPORCA to choose a plan with multistage aggregates when such a plan alternative is generated.
- `optimizer_join_order` sets the query optimization level for join ordering by specifying which types of join ordering alternatives to evaluate.
- `optimizer_join_order_threshold` specifies the maximum number of join children for which GPORCA uses the dynamic programming-based join ordering algorithm.
- `optimizer_nestloop_factor` controls nested loop join cost factor to apply to during query optimization.
- `optimizer_parallel_union` controls the amount of parallelization that occurs for queries that contain a `UNION` or `UNION ALL` clause. When the value is on, GPORCA can generate a query plan the child operations of a `UNION` or `UNION ALL` operation execute in parallel on segment instances.
- `optimizer_sort_factor` controls the cost factor that GPORCA applies to sorting operations during query optimization. The cost factor can be adjusted for queries when data skew is present.

These server configuration parameters control the display and logging of information.

- `optimizer_print_missing_stats` controls the display of column information about columns with missing statistics for a query (default is `true`)
- `optimizer_print_optimization_stats` controls the logging of GPORCA query optimization metrics for a query (default is `off`)

For information about the parameters, see the `Greenplum Database Reference Guide`.

GPORCA generates minidumps to describe the optimization context for a given query. The minidump files are used by Pivotal support to analyze Greenplum Database issues. The information in the file is not in a format that can be easily used for debugging or troubleshooting. The minidump file is located under the master data directory and uses the following naming format:

Minidump_{date}_{time}.mdp

For information about the minidump file, see the server configuration parameter `optimizer_minidump` in the `Greenplum Database Reference Guide`.

When the `EXPLAIN ANALYZE` command uses GPORCA, the `EXPLAIN` plan shows only the number of partitions that are being eliminated. The scanned partitions are not shown. To show the name of the scanned partitions in the segment logs set the server configuration parameter `gp_log_dynamic_partition_pruning` to `on`. This example `SET` command enables the parameter.

```
SET gp_log_dynamic_partition_pruning = on;
```

**GPORCA Features and Enhancements**

GPORCA, the Greenplum next generation query optimizer, includes enhancements for specific types of queries and operations:

- Queries Against Partitioned Tables
- Queries that Contain Subqueries
- Queries that Contain Common Table Expressions
- DML Operation Enhancements with GPORCA

GPORCA also includes these optimization enhancements:

- Improved join ordering
• Join-Aggregate reordering
• Sort order optimization
• Data skew estimates included in query optimization

**Queries Against Partitioned Tables**

GPORCA includes these enhancements for queries against partitioned tables:

• Partition elimination is improved.
• Uniform multi-level partitioned tables are supported. For information about uniform multi-level partitioned tables, see [About Uniform Multi-level Partitioned Tables](#).
• Query plan can contain the Partition selector operator.
• Partitions are not enumerated in EXPLAIN plans.

For queries that involve static partition selection where the partitioning key is compared to a constant, GPORCA lists the number of partitions to be scanned in the EXPLAIN output under the Partition Selector operator. This example Partition Selector operator shows the filter and number of partitions selected:

```
Partition Selector for Part_Table (dynamic scan id: 1)
  Filter: a > 10
  Partitions selected: 1 (out of 3)
```

For queries that involve dynamic partition selection where the partitioning key is compared to a variable, the number of partitions that are scanned will be known only during query execution. The partitions selected are not shown in the EXPLAIN output.

• Plan size is independent of number of partitions.
• Out of memory errors caused by number of partitions are reduced.

This example `CREATE TABLE` command creates a range partitioned table.

```
CREATE TABLE sales(order_id int, item_id int, amount numeric(15,2),
  date date, yr_qtr int)
  range partitioned by yr_qtr;
```

GPORCA improves on these types of queries against partitioned tables:

• Full table scan. Partitions are not enumerated in plans.

```
SELECT * FROM sales;
```

• Query with a constant filter predicate. Partition elimination is performed.

```
SELECT * FROM sales WHERE yr_qtr = 201501;
```

• Range selection. Partition elimination is performed.

```
SELECT * FROM sales WHERE yr_qtr BETWEEN 201601 AND 201704 ;
```

• Joins involving partitioned tables. In this example, the partitioned dimension table `date_dim` is joined with fact table `catalog_sales`:

```
SELECT * FROM catalog_sales
  WHERE date_id IN (SELECT id FROM date_dim WHERE month=12);
```
Queries that Contain Subqueries

GPORCA handles subqueries more efficiently. A subquery is query that is nested inside an outer query block. In the following query, the SELECT in the WHERE clause is a subquery.

```sql
SELECT * FROM part
WHERE price > (SELECT avg(price) FROM part);
```

GPORCA also handles queries that contain a correlated subquery (CSQ) more efficiently. A correlated subquery is a subquery that uses values from the outer query. In the following query, the price column is used in both the outer query and the subquery.

```sql
SELECT * FROM part p1
WHERE price > (SELECT avg(price) FROM part p2
              WHERE p2.brand = p1.brand);
```

GPORCA generates more efficient plans for the following types of subqueries:

- CSQ in the SELECT list.

```sql
SELECT *
  (SELECT min(price) FROM part p2 WHERE p1.brand = p2.brand)
AS foo
FROM part p1;
```

- CSQ in disjunctive (OR) filters.

```sql
SELECT FROM part p1 WHERE p_size > 40 OR
  p_retailprice >
  (SELECT avg(p_retailprice)
    FROM part p2
    WHERE p2.p_brand = p1.p_brand)
```

- Nested CSQ with skip level correlations

```sql
SELECT * FROM part p1 WHERE p1.p_partkey
    IN (SELECT p_partkey FROM part p2 WHERE p2.p_retailprice =
       (SELECT min(p_retailprice)
         FROM part p3
         WHERE p3.p_brand = p1.p_brand)
    )
```

**Note:** Nested CSQ with skip level correlations are not supported by the legacy query optimizer.

- CSQ with aggregate and inequality. This example contains a CSQ with an inequality.

```sql
SELECT * FROM part p1 WHERE p1.p_retailprice =
  (SELECT min(p_retailprice) FROM part p2 WHERE p2.p_brand <> p1.p_brand);
```

- CSQ that must return one row.

```sql
SELECT p_partkey,
  (SELECT p_retailprice FROM part p2 WHERE p2.p_brand = p1.p_brand )
FROM part p1;
```
**Queries that Contain Common Table Expressions**

GPORCA handles queries that contain the `WITH` clause. The `WITH` clause, also known as a common table expression (CTE), generates temporary tables that exist only for the query. This example query contains a CTE.

```
WITH v AS (SELECT a, sum(b) as s FROM T where c < 10 GROUP BY a)
SELECT * FROM  v AS v1 ,  v AS v2
WHERE v1.a <> v2.a AND v1.s < v2.s;
```

As part of query optimization, GPORCA can push down predicates into a CTE. For example query, GPORCA pushes the equality predicates to the CTE.

```
WITH v AS (SELECT a, sum(b) as s FROM T GROUP BY a)
SELECT *
FROM v as v1, v as v2, v as v3
WHERE v1.a < v2.a
  AND v1.s < v3.s
  AND v1.a = 10
  AND v2.a = 20
  AND v3.a = 30;
```

GPORCA can handle these types of CTEs:

- CTE that defines one or multiple tables. In this query, the CTE defines two tables.
  
  ```
  WITH cte1 AS (SELECT a, sum(b) as s FROM T
               where c < 10 GROUP BY a),
  cte2 AS (SELECT a, s FROM cte1 where s > 1000)
  SELECT *
  FROM cte1 as v1, cte2 as v2, cte2 as v3
  WHERE v1.a < v2.a AND v1.s < v3.s;
  ```

- Nested CTEs.

  ```
  WITH v AS (WITH w AS (SELECT a, b FROM foo
                 WHERE b < 5)
               SELECT w1.a, w2.b
               FROM w AS w1, w AS w2
               WHERE w1.a = w2.a AND w1.a > 2)
  SELECT v1.a, v2.a, v2.b
  FROM v AS v1, v AS v2
  WHERE v1.a < v2.a;
  ```

**DML Operation Enhancements with GPORCA**

GPORCA contains enhancements for DML operations such as `INSERT`, `UPDATE`, and `DELETE`.

- A DML node in a query plan is a query plan operator.
  - Can appear anywhere in the plan, as a regular node (top slice only for now)
  - Can have consumers
- `UPDATE` operations use the query plan operator `Split` and supports these operations:
  - `UPDATE` operations on the table distribution key columns.
  - `UPDATE` operations on the table on the partition key column.

This example plan shows the `Split` operator.

```
QUERY PLAN
---------------------------------------------------------------------
```
Update (cost=0.00..5.46 rows=1 width=1)
  -> Distribute Motion 2:2 (slice1; segments: 2)
      Hash Key: a
  -> Result (cost=0.00..3.23 rows=1 width=48)
     -> Split (cost=0.00..2.13 rows=1 width=40)
        -> Result (cost=0.00..1.05 rows=1 width=40)
        -> Table Scan on dmltest

• New query plan operator Assert is used for constraints checking.

This example plan shows the Assert operator.

QUERY PLAN
------------------------------------------------------------
Insert (cost=0.00..4.61 rows=3 width=8)
  -> Assert (cost=0.00..3.37 rows=3 width=24)
      Assert Cond: (dmlsource.a > 2) IS DISTINCT FROM false
  -> Assert (cost=0.00..2.25 rows=3 width=24)
      Assert Cond: NOT dmlsource.b IS NULL
  -> Result (cost=0.00..1.14 rows=3 width=24)
  -> Table Scan on dmlsource

Changed Behavior with the GPORCA
There are changes to Greenplum Database behavior with the GPORCA optimizer enabled (the default) as compared to the legacy planner.

• UPDATE operations on distribution keys are allowed.
• UPDATE operations on partitioned keys are allowed.
• Queries against uniform partitioned tables are supported.
• Queries against partitioned tables that are altered to use an external table as a leaf child partition fall back to the legacy query optimizer.
• Except for INSERT, DML operations directly on partition (child table) of a partitioned table are not supported.

For the INSERT command, you can specify a leaf child table of the partitioned table to insert data into a partitioned table. An error is returned if the data is not valid for the specified leaf child table. Specifying a child table that is not a leaf child table is not supported.

• The command CREATE TABLE AS distributes table data randomly if the DISTRIBUTED BY clause is not specified and no primary or unique keys are specified.
• Non-deterministic updates not allowed. The following UPDATE command returns an error.

  update r set b = r.b + 1 from s where r.a in (select a from s);

• Statistics are required on the root table of a partitioned table. The ANALYZE command generates statistics on both root and individual partition tables (leaf child tables). See the ROOTPARTITION clause for ANALYZE command.
• Additional Result nodes in the query plan:
  • Query plan Assert operator.
  • Query plan Partition selector operator.
  • Query plan Split operator.
• When running EXPLAIN, the query plan generated by GPORCA is different than the plan generated by the legacy query optimizer.
• Greenplum Database adds the log file message Planner produced plan when GPORCA is enabled and Greenplum Database falls back to the legacy query optimizer to generate the query plan.
• Greenplum Database issues a warning when statistics are missing from one or more table columns. When executing an SQL command with GPORCA, Greenplum Database issues a warning if the
command performance could be improved by collecting statistics on a column or set of columns referenced by the command. The warning is issued on the command line and information is added to the Greenplum Database log file. For information about collecting statistics on table columns, see the \texttt{ANALYZE} command in the Greenplum Database Reference Guide.

\section*{GPORCA Limitations}

There are limitations in Greenplum Database when using the default GPORCA optimizer. GPORCA and the legacy query optimizer currently coexist in Greenplum Database because GPORCA does not support all Greenplum Database features.

This section describes the limitations.

- \textit{Unsupported SQL Query Features}
- \textit{Performance Regressions}

\subsection*{Unsupported SQL Query Features}

These are unsupported features when GPORCA is enabled (the default):

- Indexed expressions (an index defined as expression based on one or more columns of the table)
- GIST indexing method. GPORCA supports only B-tree and bitmap indexes. GPORCA ignores indexes created with unsupported methods.
- \texttt{PERCENTILE} window function
- External parameters
- These types of partitioned tables:
  - Non-uniform partitioned tables.
  - Partitioned tables that have been altered to use an external table as a leaf child partition.
- SortMergeJoin (SMJ)
- Ordered aggregations
- These analytics extensions:
  - \texttt{CUBE}
  - Multiple grouping sets
- These scalar operators:
  - \texttt{ROW}
  - \texttt{ROWCOMPARE}
  - \texttt{FIELDSELECT}
- Aggregate functions that take set operators as input arguments
- Inverse distribution functions
- Queries that contain UNICODE characters in metadata names, such as table names, and the characters are not compatible with the host system locale
- \texttt{SELECT}, \texttt{UPDATE}, and \texttt{DELETE} commands where a table name is qualified by the \texttt{ONLY} keyword

\subsection*{Performance Regressions}

The following features are known performance regressions that occur with GPORCA enabled:

- Short running queries - For GPORCA, short running queries might encounter additional overhead due to GPORCA enhancements for determining an optimal query execution plan.
- \texttt{ANALYZE} - For GPORCA, the \texttt{ANALYZE} command generates root partition statistics for partitioned tables. For the legacy optimizer, these statistics are not generated.
- DML operations - For GPORCA, DML enhancements including the support of updates on partition and distribution keys might require additional overhead.

Also, enhanced functionality of the features from previous versions could result in additional time required when GPORCA executes SQL statements with the features.
Determining the Query Optimizer that is Used

When GPORCA is enabled (the default), you can determine if Greenplum Database is using GPORCA or is falling back to the legacy query optimizer.

You can examine the \texttt{EXPLAIN} query plan for the query determine which query optimizer was used by Greenplum Database to execute the query:

- When GPORCA generates the query plan, the setting \texttt{optimizer=on} and GPORCA version are displayed at the end of the query plan. For example.

  ```
  Settings: optimizer=on
  Optimizer status: PQO version 1.584
  ```

  When Greenplum Database falls back to the legacy optimizer to generate the plan, the setting \texttt{optimizer=on} and \texttt{legacy query optimizer} are displayed at the end of the query plan. For example.

  ```
  Settings: optimizer=on
  Optimizer status: legacy query optimizer
  ```

  When the server configuration parameter \texttt{OPTIMIZER} is \texttt{off}, these lines are displayed at the end of a query plan.

  ```
  Settings: optimizer=off
  Optimizer status: legacy query optimizer
  ```

- These plan items appear only in the \texttt{EXPLAIN} plan output generated by GPORCA. The items are not supported in a legacy optimizer query plan.
  - Assert operator
  - Sequence operator
  - DynamicIndexScan
  - DynamicTableScan
  - Table Scan

- When a query against a partitioned table is generated by GPORCA, the \texttt{EXPLAIN} plan displays only the number of partitions that are being eliminated is listed. The scanned partitions are not shown. The \texttt{EXPLAIN} plan generated by the legacy optimizer lists the scanned partitions.

The log file contains messages that indicate which query optimizer was used. If Greenplum Database falls back to the legacy optimizer, a message with \texttt{NOTICE} information is added to the log file that indicates the unsupported feature. Also, the label \texttt{Planner produced plan:} appears before the query in the query execution log message when Greenplum Database falls back to the legacy optimizer.

Note: You can configure Greenplum Database to display log messages on the \texttt{psql} command line by setting the Greenplum Database server configuration parameter \texttt{client_min_messages} to \texttt{LOG}. See the \textit{Greenplum Database Reference Guide} for information about the parameter.

Examples

This example shows the differences for a query that is run against partitioned tables when GPORCA is enabled.

This \texttt{CREATE TABLE} statement creates a table with single level partitions:

```sql
CREATE TABLE sales (trans_id int, date date, amount decimal(9,2), region text)
DISTRIBUTED BY (trans_id)
PARTITION BY RANGE (date)
(START (date '20160101')
```
This query against the table is supported by GPORCA and does not generate errors in the log file:

```sql
select * from sales;
```

The EXPLAIN plan output lists only the number of selected partitions.

```
-> Partition Selector for sales (dynamic scan id: 1)  (cost=10.00..100.00 rows=50 width=4)
     Partitions selected: 13 (out of 13)
```

If a query against a partitioned table is not supported by GPORCA, Greenplum Database falls back to the legacy optimizer. The EXPLAIN plan generated by the legacy optimizer lists the selected partitions. This example shows a part of the explain plan that lists some selected partitions.

```
-> Append  (cost=0.00..0.00 rows=26 width=53)
    -> Seq Scan on sales2_1_prt_7_2_prt_usa sales2  (cost=0.00..0.00 rows=1 width=53)
    -> Seq Scan on sales2_1_prt_7_2_prt_asia sales2  (cost=0.00..0.00 rows=1 width=53)
```

This example shows the log output when the Greenplum Database falls back to the legacy query optimizer from GPORCA.

When this query is run, Greenplum Database falls back to the legacy query optimizer.

```sql
explain select * from pg_class;
```

A message is added to the log file. The message contains this NOTICE information that indicates the reason GPORCA did not execute the query:

```
NOTICE,""Feature not supported by the Pivotal Query Optimizer: Queries on master-only tables"
```

### About Uniform Multi-level Partitioned Tables

GPORCA supports queries on a multi-level partitioned (MLP) table if the MLP table is a uniform partitioned table. A multi-level partitioned table is a partitioned table that was created with the SUBPARTITION clause. A uniform partitioned table must meet these requirements.

- The partitioned table structure is uniform. Each partition node at the same level must have the same hierarchical structure.
- The partition key constraints must be consistent and uniform. At each subpartition level, the sets of constraints on the child tables created for each branch must match.

You can display information about partitioned tables in several ways, including displaying information from these sources:

- The `pg_partitions` system view contains information on the structure of a partitioned table.
- The `pg_constraint` system catalog table contains information on table constraints.
- The `psql` meta command `\d+ `tablename` displays the table constraints for child leaf tables of a partitioned table.
Example

This CREATE TABLE command creates a uniform partitioned table.

```sql
CREATE TABLE mlp (id int, year int, month int, day int, region text)
    DISTRIBUTED BY (id)
    PARTITION BY RANGE (year)
        SUBPARTITION BY LIST (region)
            SUBPARTITION TEMPLATE (SUBPARTITION usa VALUES ('usa'),
                            SUBPARTITION europe VALUES ('europe'),
                            SUBPARTITION asia VALUES ('asia'))
            (START (2006) END (2016) EVERY (5));
```

These are child tables and the partition hierarchy that are created for the table mlp. This hierarchy consists of one subpartition level that contains two branches.

```
mlp_1_prt_11
    mlp_1_prt_11_2_prt_usa
    mlp_1_prt_11_2_prt_europe
    mlp_1_prt_11_2_prt_asia

mlp_1_prt_21
    mlp_1_prt_21_2_prt_usa
    mlp_1_prt_21_2_prt_europe
    mlp_1_prt_21_2_prt_asia
```

The hierarchy of the table is uniform, each partition contains a set of three child tables (subpartitions). The constraints for the region subpartitions are uniform, the set of constraints on the child tables for the branch table mlp_1_prt_11 are the same as the constraints on the child tables for the branch table mlp_1_prt_21.

As a quick check, this query displays the constraints for the partitions.

```sql
WITH tbl AS (SELECT oid, partitionlevel AS level, partitiontablename AS part
  FROM pg_partitions, pg_class
  WHERE tablename = 'mlp' AND partitiontablename=relname
      AND partitionlevel=1 )
SELECT tbl.part, consrc
  FROM tbl, pg_constraint
  WHERE tbl.oid = conrelid ORDER BY consrc;
```

<table>
<thead>
<tr>
<th>part</th>
<th>consrc</th>
</tr>
</thead>
<tbody>
<tr>
<td>mlp_1_prt_2_2_prt_asia</td>
<td>(region = 'asia':text)</td>
</tr>
<tr>
<td>mlp_1_prt_1_2_prt_asia</td>
<td>(region = 'asia':text)</td>
</tr>
<tr>
<td>mlp_1_prt_2_2_prt_europe</td>
<td>(region = 'europe':text)</td>
</tr>
<tr>
<td>mlp_1_prt_1_2_prt_europe</td>
<td>(region = 'europe':text)</td>
</tr>
<tr>
<td>mlp_1_prt_1_2_prt_usa</td>
<td>(region = 'usa':text)</td>
</tr>
<tr>
<td>mlp_1_prt_2_2_prt_usa</td>
<td>(region = 'usa':text)</td>
</tr>
<tr>
<td>mlp_1_prt_1_2_prt_asia</td>
<td>((year &gt;= 2006) AND (year &lt; 2011))</td>
</tr>
<tr>
<td>mlp_1_prt_1_2_prt_usa</td>
<td>((year &gt;= 2006) AND (year &lt; 2011))</td>
</tr>
</tbody>
</table>

Note: You will need modify the query for more complex partitioned tables. For example, the query does not account for table names in different schemas.

The `consrc` column displays constraints on the subpartitions. The set of region constraints for the subpartitions in mlp_1_prt_2 match the constraints for the subpartitions in mlp_1_prt_2. The constraints for year are inherited from the parent branch tables.
If you add a default partition to the example partitioned table with this command:

```
ALTER TABLE mlp ADD DEFAULT PARTITION def
```

The partitioned table remains a uniform partitioned table. The branch created for default partition contains three child tables and the set of constraints on the child tables match the existing sets of child table constraints.

In the above example, if you drop the subpartition `mlp_1_prt_21_2_prt_asia` and add another subpartition for the region `canada`, the constraints are no longer uniform.

```
ALTER TABLE mlp ALTER PARTITION FOR (RANK(2))
    DROP PARTITION asia ;

ALTER TABLE mlp ALTER PARTITION FOR (RANK(2))
    ADD PARTITION canada VALUES ('canada');
```

Also, if you add a partition `canada` under `mlp_1_prt_21`, the partitioning hierarchy is not uniform.

However, if you add the subpartition `canada` to both `mlp_1_prt_21` and `mlp_1_prt_11` the of the original partitioned table, it remains a uniform partitioned table.

**Note:** Only the constraints on the sets of partitions at a partition level must be the same. The names of the partitions can be different.

### Defining Queries

Greenplum Database is based on the PostgreSQL implementation of the SQL standard.

This topic describes how to construct SQL queries in Greenplum Database.

- SQL Lexicon
- SQL Value Expressions

### SQL Lexicon

SQL is a standard language for accessing databases. The language consists of elements that enable data storage, retrieval, analysis, viewing, manipulation, and so on. You use SQL commands to construct queries and commands that the Greenplum Database engine understands. SQL queries consist of a sequence of commands. Commands consist of a sequence of valid tokens in correct syntax order, terminated by a semicolon (`;`).

For more information about SQL commands, see the *Greenplum Database Reference Guide*.

Greenplum Database uses PostgreSQL's structure and syntax, with some exceptions. For more information about SQL rules and concepts in PostgreSQL, see "SQL Syntax" in the PostgreSQL documentation.

### SQL Value Expressions

SQL value expressions consist of one or more values, symbols, operators, SQL functions, and data. The expressions compare data or perform calculations and return a value as the result. Calculations include logical, arithmetic, and set operations.

The following are value expressions:
• An aggregate expression
• An array constructor
• A column reference
• A constant or literal value
• A correlated subquery
• A field selection expression
• A function call
• A new column value in an INSERT or UPDATE
• An operator invocation column reference
• A positional parameter reference, in the body of a function definition or prepared statement
• A row constructor
• A scalar subquery
• A search condition in a WHERE clause
• A target list of a SELECT command
• A type cast
• A value expression in parentheses, useful to group sub-expressions and override precedence
• A window expression

SQL constructs such as functions and operators are expressions but do not follow any general syntax rules. For more information about these constructs, see Using Functions and Operators.

Column References

A column reference has the form:

correlation.columnname

Here, correlation is the name of a table (possibly qualified with a schema name) or an alias for a table defined with a FROM clause or one of the keywords NEW or OLD. NEW and OLD can appear only in rewrite rules, but you can use other correlation names in any SQL statement. If the column name is unique across all tables in the query, you can omit the "correlation." part of the column reference.

Positional Parameters

Positional parameters are arguments to SQL statements or functions that you reference by their positions in a series of arguments. For example, $1 refers to the first argument, $2 to the second argument, and so on. The values of positional parameters are set from arguments external to the SQL statement or supplied when SQL functions are invoked. Some client libraries support specifying data values separately from the SQL command, in which case parameters refer to the out-of-line data values. A parameter reference has the form:

$number

For example:

CREATE FUNCTION dept(text) RETURNS dept
AS $$ SELECT * FROM dept WHERE name = $1 $$
LANGUAGE SQL;

Here, the $1 references the value of the first function argument whenever the function is invoked.
**Subscripts**

If an expression yields a value of an array type, you can extract a specific element of the array value as follows:

```
expression[subscript]
```

You can extract multiple adjacent elements, called an array slice, as follows (including the brackets):

```
expression[lower_subscript:upper_subscript]
```

Each subscript is an expression and yields an integer value.

Array expressions usually must be in parentheses, but you can omit the parentheses when the expression to be subscripted is a column reference or positional parameter. You can concatenate multiple subscripts when the original array is multidimensional. For example (including the parentheses):

```
mytable.arraycolumn[4]
mytable.two_d_column[17][34]
$1[10:42]
(arrayfunction(a,b))[42]
```

**Field Selection**

If an expression yields a value of a composite type (row type), you can extract a specific field of the row as follows:

```
expression.fieldname
```

The row expression usually must be in parentheses, but you can omit these parentheses when the expression to be selected from is a table reference or positional parameter. For example:

```
mytable.mycolumn
$1.somecolumn
(rowfunction(a,b)).col3
```

A qualified column reference is a special case of field selection syntax.

**Operator Invocations**

Operator invocations have the following possible syntaxes:

```
expression operator expression(binary infix operator)
operator expression(unary prefix operator)
expression operator(unary postfix operator)
```
Where `operator` is an operator token, one of the key words AND, OR, or NOT, or qualified operator name in the form:

```
OPERATOR(schema.operatorname)
```

Available operators and whether they are unary or binary depends on the operators that the system or user defines. For more information about built-in operators, see *Built-in Functions and Operators*.

**Function Calls**

The syntax for a function call is the name of a function (possibly qualified with a schema name), followed by its argument list enclosed in parentheses:

```
function ([expression [, expression ... ]])
```

For example, the following function call computes the square root of 2:

```
sqrt(2)
```

See the *Greenplum Database Reference Guide* for lists of the built-in functions by category. You can add custom functions, too.

**Aggregate Expressions**

An aggregate expression applies an aggregate function across the rows that a query selects. An aggregate function performs a calculation on a set of values and returns a single value, such as the sum or average of the set of values. The syntax of an aggregate expression is one of the following:

- `aggregate_name(expression [, ... ] )` — operates across all input rows for which the expected result value is non-null. ALL is the default.
- `aggregate_name(ALL expression [, ... ] )` — operates identically to the first form because ALL is the default.
- `aggregate_name(DISTINCT expression [, ... ] )` — operates across all distinct non-null values of input rows.
- `aggregate_name(*)` — operates on all rows with values both null and non-null. Generally, this form is most useful for the `count(*)` aggregate function.

Where `aggregate_name` is a previously defined aggregate (possibly schema-qualified) and `expression` is any value expression that does not contain an aggregate expression.

For example, `count(*)` yields the total number of input rows, `count(f1)` yields the number of input rows in which `f1` is non-null, and `count(distinct f1)` yields the number of distinct non-null values of `f1`.

For predefined aggregate functions, see *Built-in Functions and Operators*. You can also add custom aggregate functions.

Greenplum Database provides the `MEDIAN` aggregate function, which returns the fiftieth percentile of the `PERCENTILE_CONT` result and special aggregate expressions for inverse distribution functions as follows:

```
PERCENTILE_CONT(_percentage_) WITHIN GROUP (ORDER BY _expression_)
```

```
PERCENTILE_DISC(_percentage_) WITHIN GROUP (ORDER BY _expression_)
```

Currently you can use only these two expressions with the keyword `WITHIN GROUP`.

**Limitations of Aggregate Expressions**

The following are current limitations of the aggregate expressions:
Greenplum Database does not support the following keywords: ALL, DISTINCT, FILTER and OVER. See Table 54: Advanced Aggregate Functions for more details.

An aggregate expression can appear only in the result list or HAVING clause of a SELECT command. It is forbidden in other clauses, such as WHERE, because those clauses are logically evaluated before the results of aggregates form. This restriction applies to the query level to which the aggregate belongs.

When an aggregate expression appears in a subquery, the aggregate is normally evaluated over the rows of the subquery. If the aggregate's arguments contain only outer-level variables, the aggregate belongs to the nearest such outer level and evaluates over the rows of that query. The aggregate expression as a whole is then an outer reference for the subquery in which it appears, and the aggregate expression acts as a constant over any one evaluation of that subquery. See Scalar Subqueries and Table 52: Built-in functions and operators.

Greenplum Database does not support DISTINCT with multiple input expressions.

Greenplum Database does not support specifying an aggregate function as an argument to another aggregate function.

Greenplum Database does not support specifying a window function as an argument to another aggregate function.

Window Expressions

Window expressions allow application developers to more easily compose complex online analytical processing (OLAP) queries using standard SQL commands. For example, with window expressions, users can calculate moving averages or sums over various intervals, reset aggregations and ranks as selected column values change, and express complex ratios in simple terms.

A window expression represents the application of a window function applied to a window frame, which is defined in a special OVER() clause. A window partition is a set of rows that are grouped together to apply a window function. Unlike aggregate functions, which return a result value for each group of rows, window functions return a result value for every row, but that value is calculated with respect to the rows in a particular window partition. If no partition is specified, the window function is computed over the complete intermediate result set.

Greenplum Database does not support specifying a window function as an argument to another window function.

The syntax of a window expression is:

```
window_function ( [expression [, ...]] ) OVER ( window_specification )
```

Where `window_function` is one of the functions listed in Table 53: Window functions, `expression` is any value expression that does not contain a window expression, and `window_specification` is:

```
[window_name]
[PARTITION BY expression [, ...]]
[[ORDER BY expression [ASC | DESC | USING operator] [NULLS {FIRST | LAST}]
 [, ...]
 [{RANGE | ROWS}
 | UNBOUNDED PRECEDING
 | expression PRECEDING
 | CURRENT ROW
 | BETWEEN window_frame_bound AND window_frame_bound ]]
```

and where `window_frame_bound` can be one of:

- UNBOUNDED PRECEDING
- expression PRECEDING
- CURRENT ROW
- expression FOLLOWING
A window expression can appear only in the select list of a `SELECT` command. For example:

```
SELECT count(*) OVER(PARTITION BY customer_id), * FROM sales;
```

The `OVER` clause differentiates window functions from other aggregate or reporting functions. The `OVER` clause defines the `window_specification` to which the window function is applied. A window specification has the following characteristics:

- The `PARTITION BY` clause defines the window partitions to which the window function is applied. If omitted, the entire result set is treated as one partition.
- The `ORDER BY` clause defines the expression(s) for sorting rows within a window partition. The `ORDER BY` clause of a window specification is separate and distinct from the `ORDER BY` clause of a regular query expression. The `ORDER BY` clause is required for the window functions that calculate rankings, as it identifies the measure(s) for the ranking values. For OLAP aggregations, the `ORDER BY` clause is required to use window frames (the `ROWS` | `RANGE` clause).

**Note:** Columns of data types without a coherent ordering, such as `time`, are not good candidates for use in the `ORDER BY` clause of a window specification. Time, with or without a specified time zone, lacks a coherent ordering because addition and subtraction do not have the expected effects. For example, the following is not generally true:

```
x::time < x::time + '2 hour'::interval
```

- The `ROWS/RANGE` clause defines a window frame for aggregate (non-ranking) window functions. A window frame defines a set of rows within a window partition. When a window frame is defined, the window function computes on the contents of this moving frame rather than the fixed contents of the entire window partition. Window frames are row-based (`ROWS`) or value-based (`RANGE`).

### Type Casts

A type cast specifies a conversion from one data type to another. Greenplum Database accepts two equivalent syntaxes for type casts:

```
CAST ( expression AS type )
expression::type
```

The `CAST` syntax conforms to SQL; the syntax with `::` is historical PostgreSQL usage.

A cast applied to a value expression of a known type is a run-time type conversion. The cast succeeds only if a suitable type conversion function is defined. This differs from the use of casts with constants. A cast applied to a string literal represents the initial assignment of a type to a literal constant value, so it succeeds for any type if the contents of the string literal are acceptable input syntax for the data type.

You can usually omit an explicit type cast if there is no ambiguity about the type a value expression must produce; for example, when it is assigned to a table column, the system automatically applies a type cast. The system applies automatic casting only to casts marked "OK to apply implicitly" in system catalogs. Other casts must be invoked with explicit casting syntax to prevent unexpected conversions from being applied without the user's knowledge.

### Scalar Subqueries

A scalar subquery is a `SELECT` query in parentheses that returns exactly one row with one column. Do not use a `SELECT` query that returns multiple rows or columns as a scalar subquery. The query runs and uses the returned value in the surrounding value expression. A correlated scalar subquery contains references to the outer query block.

### Correlated Subqueries

A correlated subquery (CSQ) is a `SELECT` query with a `WHERE` clause or target list that contains references to the parent outer clause. CSQs efficiently express results in terms of results of another query. Greenplum
Database supports correlated subqueries that provide compatibility with many existing applications. A CSQ is a scalar or table subquery, depending on whether it returns one or multiple rows. Greenplum Database does not support correlated subqueries with skip-level correlations.

**Correlated Subquery Examples**

**Example 1 – Scalar correlated subquery**

```sql
SELECT * FROM t1 WHERE t1.x > (SELECT MAX(t2.x) FROM t2 WHERE t2.y = t1.y);
```

**Example 2 – Correlated EXISTS subquery**

```sql
SELECT * FROM t1 WHERE EXISTS (SELECT 1 FROM t2 WHERE t2.x = t1.x);
```

Greenplum Database uses one of the following methods to run CSQs:

- Unnest the CSQ into join operations – This method is most efficient, and it is how Greenplum Database runs most CSQs, including queries from the TPC-H benchmark.
- Run the CSQ on every row of the outer query – This method is relatively inefficient, and it is how Greenplum Database runs queries that contain CSQs in the `SELECT` list or are connected by `OR` conditions.

The following examples illustrate how to rewrite some of these types of queries to improve performance.

**Example 3 - CSQ in the Select List**

**Original Query**

```sql
SELECT T1.a,
      (SELECT COUNT(DISTINCT T2.z) FROM t2 WHERE t1.x = t2.y) dt2
FROM t1;
```

Rewrite this query to perform an inner join with `t1` first and then perform a left join with `t1` again. The rewrite applies for only an equijoin in the correlated condition.

**Rewritten Query**

```sql
SELECT t1.a, dt2 FROM t1
LEFT JOIN
  (SELECT t2.y AS csq_y, COUNT(DISTINCT t2.z) AS dt2
   FROM t1, t2 WHERE t1.x = t2.y
   GROUP BY t1.x)
ON (t1.x = csq_y);
```

**Example 4 - CSQs connected by OR Clauses**

**Original Query**

```sql
SELECT * FROM t1
WHERE
  x > (SELECT COUNT(*) FROM t2 WHERE t1.x = t2.x)
OR x < (SELECT COUNT(*) FROM t3 WHERE t1.y = t3.y)
```

Rewrite this query to separate it into two parts with a union on the `OR` conditions.
Rewritten Query

```sql
SELECT * FROM t1
WHERE x > (SELECT count(*) FROM t2 WHERE t1.x = t2.x)
UNION
SELECT * FROM t1
WHERE x < (SELECT count(*) FROM t3 WHERE t1.y = t3.y)
```

To view the query plan, use `EXPLAIN SELECT` or `EXPLAIN ANALYZE SELECT`. Subplan nodes in the query plan indicate that the query will run on every row of the outer query, and the query is a candidate for rewriting. For more information about these statements, see [Query Profiling](#).

Advanced Table Functions

Greenplum Database supports table functions with `TABLE` value expressions. You can sort input rows for advanced table functions with an `ORDER BY` clause. You can redistribute them with a `SCATTER BY` clause to specify one or more columns or an expression for which rows with the specified characteristics are available to the same process. This usage is similar to using a `DISTRIBUTED BY` clause when creating a table, but the redistribution occurs when the query runs.

**Note:** Based on the distribution of data, Greenplum Database automatically parallelizes table functions with `TABLE` value parameters over the nodes of the cluster.

The following command uses the `TABLE` function with the `SCATTER BY` clause in the the GPText function `gptext.index()` to populate the index `mytest.articles` with data from the `messages` table:

```sql
SELECT * FROM gptext.index(TABLE(SELECT * FROM messages
SCATTER BY distrib_id), 'mytest.articles');
```

For information about the function `gptext.index()`, see the Pivotal GPText documentation.

Array Constructors

An array constructor is an expression that builds an array value from values for its member elements. A simple array constructor consists of the keyword `ARRAY`, a left square bracket `[`, one or more expressions separated by commas for the array element values, and a right square bracket `]`. For example,

```sql
SELECT ARRAY[1,2,3+4];
array
---------
(1,2,7)
```

The array element type is the common type of its member expressions, determined using the same rules as for `UNION` or `CASE` constructs.

You can build multidimensional array values by nesting array constructors. In the inner constructors, you can omit the keyword `ARRAY`. For example, the following two `SELECT` statements produce the same result:

```sql
SELECT ARRAY[ARRAY[1,2], ARRAY[3,4]];
SELECT ARRAY[[1,2],[3,4]];
array
----------
{{1,2},{3,4}}
```

Since multidimensional arrays must be rectangular, inner constructors at the same level must produce sub-arrays of identical dimensions.

Multidimensional array constructor elements are not limited to a sub-`ARRAY` construct; they are anything that produces an array of the proper kind. For example:

```sql
CREATE TABLE arr(f1 int[], f2 int[]);
```
You can construct an array from the results of a subquery. Write the array constructor with the keyword ARRAY followed by a subquery in parentheses. For example:

```
SELECT ARRAY(SELECT oid FROM pg_proc WHERE proname LIKE 'bytea%');
```

The subquery must return a single column. The resulting one-dimensional array has an element for each row in the subquery result, with an element type matching that of the subquery's output column. The subscripts of an array value built with ARRAY always begin with 1.

### Row Constructors

A row constructor is an expression that builds a row value (also called a composite value) from values for its member fields. For example,

```
SELECT ROW(1,2.5,'this is a test');
```

Row constructors have the syntax `rowvalue.*`, which expands to a list of the elements of the row value, as when you use the syntax `.*` at the top level of a SELECT list. For example, if table `t` has columns `f1` and `f2`, the following queries are the same:

```
SELECT ROW(t.*, 42) FROM t;
SELECT ROW(t.f1, t.f2, 42) FROM t;
```

By default, the value created by a `ROW` expression has an anonymous record type. If necessary, it can be cast to a named composite type — either the row type of a table, or a composite type created with `CREATE TYPE AS`. To avoid ambiguity, you can explicitly cast the value if necessary. For example:

```
CREATE TABLE mytable(f1 int, f2 float, f3 text);
CREATE FUNCTION getf1(mytable) RETURNS int AS 'SELECT $1.f1' LANGUAGE SQL;
```

In the following query, you do not need to cast the value because there is only one `getf1()` function and therefore no ambiguity:

```
SELECT getf1(ROW(1,2.5,'this is a test'));
```

```
getf1
-------
1
```

```
CREATE TYPE myrowtype AS (f1 int, f2 text, f3 numeric);
CREATE FUNCTION getf1(myrowtype) RETURNS int AS 'SELECT $1.f1' LANGUAGE SQL;
```

Now we need a cast to indicate which function to call:

```
SELECT getf1(ROW(1,2.5,'this is a test')::mytable);
```

```
ERROR:  function getf1(record) is not unique
```

```
SELECT getf1(ROW(1,2.5,'this is a test')::mytable);
```

```
getf1
-------
1
```
You can use row constructors to build composite values to be stored in a composite-type table column or to be passed to a function that accepts a composite parameter.

**Expression Evaluation Rules**

The order of evaluation of subexpressions is undefined. The inputs of an operator or function are not necessarily evaluated left-to-right or in any other fixed order.

If you can determine the result of an expression by evaluating only some parts of the expression, then other subexpressions might not be evaluated at all. For example, in the following expression:

```sql
SELECT true OR somefunc();
```

`somefunc()` would probably not be called at all. The same is true in the following expression:

```sql
SELECT somefunc() OR true;
```

This is not the same as the left-to-right evaluation order that Boolean operators enforce in some programming languages.

Do not use functions with side effects as part of complex expressions, especially in `WHERE` and `HAVING` clauses, because those clauses are extensively reprocessed when developing an execution plan. Boolean expressions (AND/OR/NOT combinations) in those clauses can be reorganized in any manner that Boolean algebra laws allow.

Use a `CASE` construct to force evaluation order. The following example is an untrustworthy way to avoid division by zero in a `WHERE` clause:

```sql
SELECT ... WHERE x <> 0 AND y/x > 1.5;
```

The following example shows a trustworthy evaluation order:

```sql
SELECT ... WHERE CASE WHEN x <> 0 THEN y/x > 1.5 ELSE false END;
```

This `CASE` construct usage defeats optimization attempts; use it only when necessary.

**WITH Queries (Common Table Expressions)**

The `WITH` clause of the `SELECT` command provides a way to write subqueries for use in a larger `SELECT` query.

The subqueries, which are often referred to as Common Table Expressions or CTEs, can be thought of as defining temporary tables that exist just for the query. One use of this feature is to break down complicated queries into simpler parts. This example query displays per-product sales totals in only the top sales regions:

```sql
WITH regional_sales AS {
    SELECT region, SUM(amount) AS total_sales
    FROM orders
    GROUP BY region
}, top_regions AS {
    SELECT region
```
The query could have been written without the WITH clause, but would have required two levels of nested sub-SELECTs. It is easier to follow with the WITH clause.

The RECURSIVE keyword can be enabled by setting the server configuration parameter gp_recursive_cte_prototype to on.

Warning: The RECURSIVE keyword is an experimental feature and is not intended for use in a production environment. Experimental features are subject to change without notice in future releases.

The optional RECURSIVE keyword changes WITH accomplishes things not otherwise possible in standard SQL. Using RECURSIVE, a query in the WITH clause can refer to its own output. This is a simple example that computes the sum the integers from 1 through 100:

```sql
WITH RECURSIVE t(n) AS ( VALUES (1) UNION ALL SELECT n+1 FROM t WHERE n < 100 )
SELECT sum(n) FROM t;
```

The required form of a recursive WITH clause is a non-recursive term, followed by a UNION (or UNION ALL), and then a recursive term, where only the recursive term can contain a reference to the query output.

A recursive WITH query is executed as follows:

1. Evaluate the non-recursive term. For UNION (but not UNION ALL), discard duplicate rows. Include all remaining rows in the result of the recursive query, and also place them in a temporary working table.
2. As long as the working table is not empty, repeat these steps:
   a. Evaluate the recursive term, substituting the current contents of the working table for the recursive self-reference. For UNION (but not UNION ALL), discard duplicate rows and rows that duplicate any previous result row. Include all remaining rows in the result of the recursive query, and also place them in a temporary intermediate table.
   b. Replace the contents of the working table with the contents of the intermediate table, then empty the intermediate table.

Note: Strictly speaking, the process is iteration not recursion, but RECURSIVE is the terminology chosen by the SQL standards committee.

Recursive WITH queries are typically used to deal with hierarchical or tree-structured data. An example is this query to find all the direct and indirect sub-parts of a product, given only a table that shows immediate inclusions:

```sql
WITH RECURSIVE included_parts(sub_part, part, quantity) AS ( 
    SELECT sub_part, part, quantity FROM parts WHERE part = 'our_product' 
UNION ALL 
    SELECT p.sub_part, p.part, p.quantity 
    FROM included_parts pr, parts p 
) 
```
WHERE p.part = pr.sub_part
)
SELECT sub_part, SUM(quantity) as total_quantity
FROM included_parts
GROUP BY sub_part

When working with recursive WITH queries, you must ensure that the recursive part of the query eventually returns no tuples, or else the query loops indefinitely. In the example that computes the sum the integers, the working table contains a single row in each step, and it takes on the values from 1 through 100 in successive steps. In the 100th step, there is no output because of the WHERE clause, and the query terminates.

For some queries, using UNION instead of UNION ALL can ensure that the recursive part of the query eventually returns no tuples by discarding rows that duplicate previous output rows. However, often a cycle does not involve output rows that are complete duplicates: it might sufficient to check just one or a few fields to see if the same point has been reached before. The standard method for handling such situations is to compute an array of the visited values. For example, consider the following query that searches a table graph using a link field:

```sql
WITH RECURSIVE search_graph(id, link, data, depth) AS (  
    SELECT g.id, g.link, g.data, 1  
    FROM graph g  
    UNION ALL  
    SELECT g.id, g.link, g.data, sg.depth + 1  
    FROM graph g, search_graph sg  
    WHERE g.id = sg.link  
)  
SELECT * FROM search_graph;
```

This query loops if the link relationships contain cycles. Because the query requires a depth output, changing UNION ALL to UNION does not eliminate the looping. Instead the query needs to recognize whether it has reached the same row again while following a particular path of links. This modified query adds two columns path and cycle to the loop-prone query:

```sql
WITH RECURSIVE search_graph(id, link, data, depth, path, cycle) AS (  
    SELECT g.id, g.link, g.data, 1,  
    ARRAY[g.id],  
    false  
    FROM graph g  
    UNION ALL  
    SELECT g.id, g.link, g.data, sg.depth + 1,  
    path || g.id,  
    g.id = ANY(path)  
    FROM graph g, search_graph sg  
    WHERE g.id = sg.link AND NOT cycle  
)  
SELECT * FROM search_graph;
```

Aside from detecting cycles, the array value of path is useful in its own right since it represents the path taken to reach any particular row.

In the general case where more than one field needs to be checked to recognize a cycle, an array of rows can be used. For example, if we needed to compare fields f1 and f2:

```sql
WITH RECURSIVE search_graph(id, link, data, depth, path, cycle) AS (  
    SELECT g.id, g.link, g.data, 1,  
    ARRAY[ROW(g.f1, g.f2)],  
    false  
    FROM graph g  
    UNION ALL  
    SELECT g.id, g.link, g.data, sg.depth + 1,  
    path || g.id,  
    g.id = ANY(path)  
    FROM graph g, search_graph sg  
    WHERE g.id = sg.link AND NOT cycle  
)  
SELECT * FROM search_graph;
```
path || ROW(g.f1, g.f2),
    ROW(g.f1, g.f2) = ANY(path)
FROM graph g, search_graph sg
WHERE g.id = sg.link AND NOT cycle
)
SELECT * FROM search_graph;

**Tip:** Omit the `ROW()` syntax in the case where only one field needs to be checked to recognize a cycle. This uses a simple array rather than a composite-type array to be used, gaining efficiency.

**Tip:** The recursive query evaluation algorithm produces its output in breadth-first search order. You can display the results in depth-first search order by making the outer query `ORDER BY` a path column constructed in this way.

A helpful technique for testing a query when you are not certain if it might loop indefinitely is to place a `LIMIT` in the parent query. For example, this query would loop forever without the `LIMIT` clause:

```
WITH RECURSIVE t(n) AS (
    SELECT 1
    UNION ALL
    SELECT n+1 FROM t
)
SELECT n FROM t LIMIT 100;
```

The technique works because the recursive `WITH` implementation evaluates only as many rows of a `WITH` query as are actually fetched by the parent query. Using this technique in production is not recommended, because other systems might work differently. Also, the technique might not work if the outer query sorts the recursive `WITH` results or join the results to another table.

## Using Functions and Operators

Description of user-defined and built-in functions and operators in Greenplum Database.

- *Using Functions in Greenplum Database*
- *User-Defined Functions*
- *Built-in Functions and Operators*
- *Window Functions*
- *Advanced Aggregate Functions*

### Using Functions in Greenplum Database

**Table 51: Functions in Greenplum Database**

<table>
<thead>
<tr>
<th>Function Type</th>
<th>Greenplum Support</th>
<th>Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMMUTABLE</td>
<td>Yes</td>
<td>Relies only on information directly in its argument list. Given the same argument values, always returns the same result.</td>
<td></td>
</tr>
<tr>
<td>STABLE</td>
<td>Yes, in most cases</td>
<td>Within a single table scan, returns the same result for same argument values, but results change across SQL statements.</td>
<td>Results depend on database lookups or parameter values. <code>current_timestamp</code> family of functions is <code>STABLE</code>; values do not change within an execution.</td>
</tr>
</tbody>
</table>
### Function Type | Greenplum Support | Description | Comments
---|---|---|---
VOLATILE | Restricted | Function values can change within a single table scan. For example: `random()`, `timeofday()`. | Any function with side effects is volatile, even if its result is predictable. For example: `setval()`.

Refer to the PostgreSQL *Function Volatility Categories* documentation for additional information about the Greenplum Database function volatility classifications.

In Greenplum Database, data is divided up across segments — each segment is a distinct PostgreSQL database. To prevent inconsistent or unexpected results, do not execute functions classified as VOLATILE at the segment level if they contain SQL commands or modify the database in any way. For example, functions such as `setval()` are not allowed to execute on distributed data in Greenplum Database because they can cause inconsistent data between segment instances.

To ensure data consistency, you can safely use VOLATILE and STABLE functions in statements that are evaluated on and run from the master. For example, the following statements run on the master (statements without a `FROM` clause):

```
SELECT setval('myseq', 201);
SELECT foo();
```

If a statement has a `FROM` clause containing a distributed table and the function in the `FROM` clause returns a set of rows, the statement can run on the segments:

```
SELECT * from foo();
```

Greenplum Database does not support functions that return a table reference (`rangeFuncs`) or functions that use the `refCursor` datatype.

#### Function Volatility and Plan Caching

There is relatively little difference between the STABLE and IMMUTABLE function volatility categories for simple interactive queries that are planned and immediately executed. It does not matter much whether a function is executed once during planning or once during query execution startup. But there is a big difference when you save the plan and reuse it later. If you mislabel a function IMMUTABLE, Greenplum Database may prematurely fold it to a constant during planning, possibly reusing a stale value during subsequent execution of the plan. You may run into this hazard when using `PREPARE`d statements, or when using languages such as PL/pgSQL that cache plans.

#### User-Defined Functions

Greenplum Database supports user-defined functions. See *Extending SQL* in the PostgreSQL documentation for more information.

Use the `CREATE FUNCTION` statement to register user-defined functions that are used as described in *Using Functions in Greenplum Database*. By default, user-defined functions are declared as VOLATILE, so if your user-defined function is IMMUTABLE or STABLE, you must specify the correct volatility level when you register your function.

When you create user-defined functions, avoid using fatal errors or destructive calls. Greenplum Database may respond to such errors with a sudden shutdown or restart.

In Greenplum Database, the shared library files for user-created functions must reside in the same library path location on every host in the Greenplum Database array (masters, segments, and mirrors).
You can also create and execute anonymous code blocks that are written in a Greenplum Database procedural language such as PL/pgSQL. The anonymous blocks run as transient anonymous functions. For information about creating and executing anonymous blocks, see the `DO` command.

**Built-in Functions and Operators**

The following table lists the categories of built-in functions and operators supported by PostgreSQL. All functions and operators are supported in Greenplum Database as in PostgreSQL with the exception of `STABLE` and `VOLATILE` functions, which are subject to the restrictions noted in *Using Functions in Greenplum Database*. See the Functions and Operators section of the PostgreSQL documentation for more information about these built-in functions and operators.

Greenplum Database includes JSON processing functions that manipulate values the `json` data type. For information about JSON data, see *Working with JSON Data*.

**Table 52: Built-in functions and operators**

<table>
<thead>
<tr>
<th>Operator/Function Category</th>
<th>VOLATILE Functions</th>
<th>STABLE Functions</th>
<th>Restrictions</th>
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<td>Logical Operators</td>
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<tr>
<td>Comparison Operators</td>
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<tr>
<td>Mathematical Functions and Operators</td>
<td>random</td>
<td>convert</td>
<td></td>
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<td></td>
<td>setseed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>String Functions and Operators</td>
<td>All built-in conversion functions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>pg_client_encoding</td>
<td></td>
</tr>
<tr>
<td>Binary String Functions and Operators</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bit String Functions and Operators</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pattern Matching</td>
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<tr>
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<td>timeofday</td>
<td>age</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>current_date</td>
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<td>current_time</td>
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<td>now</td>
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<td>Enum Support Functions</td>
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<td>Geometric Functions and Operators</td>
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<tr>
<td>Network Address Functions and Operators</td>
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<tr>
<td>Operator/Function</td>
<td>VOLATILE Functions</td>
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<tr>
<td>Category</td>
<td>nextval()</td>
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<td>Sequence Manipulation Functions</td>
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<td>Array Functions and Operators</td>
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<td>Row and Array Comparisons</td>
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<td>Set Returning Functions</td>
<td>set_config</td>
<td>current_setting</td>
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<td>System Information Functions</td>
<td>pg_cancel_backend</td>
<td>All session information functions</td>
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<td></td>
<td>pg_terminate_backend</td>
<td>All access privilege inquiry functions</td>
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<td>pg_reload_conf</td>
<td>All schema visibility inquiry functions</td>
<td></td>
</tr>
<tr>
<td>System Administration Functions</td>
<td>pg_rotate_logfile</td>
<td>All system catalog information functions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pg_start_backup</td>
<td>All comment information functions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pg_stop_backup</td>
<td>All transaction ids and snapshots</td>
<td></td>
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<tr>
<td></td>
<td>pg_size_pretty</td>
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<td></td>
<td>pg_ls_dir</td>
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<tr>
<td></td>
<td>pg_read_file</td>
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<tr>
<td></td>
<td>pg_stat_file</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The function `pg_column_size` displays bytes required to store the value, possibly with TOAST compression.
<table>
<thead>
<tr>
<th>Operator/Function Category</th>
<th>VOLATILE Functions</th>
<th>STABLE Functions</th>
<th>Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>XML Functions and function-like expressions</td>
<td>cursor_to_xml(cursor refcursor, count int, nulls boolean, tableforest boolean, targetns text)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>cursor_to_xmlschema(cursor refcursor, nulls boolean, tableforest boolean, targetns text)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>database_to_xml(nulls boolean, tableforest boolean, targetns text)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>database_to_xmlschema(nulls boolean, tableforest boolean, targetns text)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>database_to_xml_and_xmlschema(nulls boolean, tableforest boolean, targetns text)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>query_to_xml(query text, nulls boolean, tableforest boolean, targetns text)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>query_to_xmlschema(query text, nulls boolean, tableforest boolean, targetns text)</td>
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</tr>
<tr>
<td></td>
<td>query_to_xml_and_xmlschema(query text, nulls boolean, tableforest boolean, targetns text)</td>
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<tr>
<td></td>
<td>schema_to_xml(schema name, nulls boolean, tableforest boolean, targetns text)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>schema_to_xmlschema(schema name, nulls boolean, tableforest boolean, targetns text)</td>
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</tr>
<tr>
<td></td>
<td>schema_to_xml_and_xmlschema(schema name, nulls boolean, tableforest boolean, targetns text)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>table_to_xml(tbl regclass, nulls boolean, tableforest boolean, targetns text)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>table_to_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns text)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operator/Function Category</td>
<td>VOLATILE Functions</td>
<td>STABLE Functions</td>
<td>Restrictions</td>
</tr>
<tr>
<td>---------------------------</td>
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</tr>
<tr>
<td></td>
<td>table_to_xml_and_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns text)</td>
<td>xmlagg(xml)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xmlconcat(xml[, ...])</td>
<td>xmlconcat(xml[, ...])</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xmlelement(name name [, xmlattributes(value [AS attname] [, ... ])) [ , content, ...])</td>
<td>xmlexists(text, xml)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xmlforest(content [AS name] [, ...])</td>
<td>xml_is_well_formed(text)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xml_is_well_formed_document(text)</td>
<td>xml_is_well_formed_document(text)</td>
<td></td>
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<tr>
<td></td>
<td>xml_is_well_formed_content(text)</td>
<td>xmlparse ( { DOCUMENT</td>
<td>CONTENT } value)</td>
</tr>
<tr>
<td></td>
<td>xpath(text, xml)</td>
<td>xpath(text, xml, text[])</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xpath_exists(text, xml)</td>
<td>xpath_exists(text, xml, text[])</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xmlpi(name target [, content])</td>
<td>xmlroot(xml, version text</td>
<td>no value [, standalone yes</td>
</tr>
<tr>
<td></td>
<td>xmlserialize ( { DOCUMENT</td>
<td>CONTENT } value AS type)</td>
<td>xmlserialize ( { DOCUMENT</td>
</tr>
<tr>
<td></td>
<td>xml(text)</td>
<td>text(xml)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xmlcomment(xml)</td>
<td>xmlconcat2(xml, xml)</td>
<td></td>
</tr>
</tbody>
</table>

**Window Functions**

The following built-in window functions are Greenplum extensions to the PostgreSQL database. All window functions are immutable. For more information about window functions, see [Window Expressions](#).
<table>
<thead>
<tr>
<th>Function</th>
<th>Return Type</th>
<th>Full Syntax</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cume_dist()</td>
<td>double precision</td>
<td><code>CUME_DIST() OVER ( [PARTITION BY expr ] ORDER BY expr )</code></td>
<td>Calculates the cumulative distribution of a value in a group of values. Rows with equal values always evaluate to the same cumulative distribution value.</td>
</tr>
<tr>
<td>dense_rank()</td>
<td>bigint</td>
<td><code>DENSE_RANK () OVER ( [PARTITION BY expr ] ORDER BY expr )</code></td>
<td>Computes the rank of a row in an ordered group of rows without skipping rank values. Rows with equal rank values are given the same rank value.</td>
</tr>
<tr>
<td>first_value(expr)</td>
<td>same as input expr type</td>
<td>`FIRST_VALUE(expr) OVER ( [PARTITION BY expr ] ORDER BY expr [ROWS</td>
<td>RANGE frame_expr ] )`</td>
</tr>
<tr>
<td>lag(expr [, offset] [, default])</td>
<td>same as input expr type</td>
<td><code>LAG( expr [, offset] [, default]) OVER ( [PARTITION BY expr ] ORDER BY expr )</code></td>
<td>Provides access to more than one row of the same table without doing a self join. Given a series of rows returned from a query and a position of the cursor, LAG provides access to a row at a given physical offset prior to that position. The default offset is 1. default sets the value that is returned if the offset goes beyond the scope of the window. If default is not specified, the default value is null.</td>
</tr>
<tr>
<td>last_value(expr)</td>
<td>same as input expr type</td>
<td>`LAST_VALUE(expr) OVER ( [PARTITION BY expr ] ORDER BY expr [ROWS</td>
<td>RANGE frame_expr ] )`</td>
</tr>
<tr>
<td>Function</td>
<td>Return Type</td>
<td>Full Syntax</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>lead(expr [,offset] [,default])</td>
<td>same as input expr type</td>
<td>LEAD(expr [,offset] [,exprdefault]) OVER ( [PARTITION BY expr] ORDER BY expr )</td>
<td>Provides access to more than one row of the same table without doing a self join. Given a series of rows returned from a query and a position of the cursor, lead provides access to a row at a given physical offset after that position. If offset is not specified, the default offset is 1. default sets the value that is returned if the offset goes beyond the scope of the window. If default is not specified, the default value is null.</td>
</tr>
<tr>
<td>ntile(expr)</td>
<td>bigint</td>
<td>NTILE(expr) OVER ( [PARTITION BY expr] ORDER BY expr )</td>
<td>Divides an ordered data set into a number of buckets (as defined by expr) and assigns a bucket number to each row.</td>
</tr>
<tr>
<td>percent_rank()</td>
<td>double precision</td>
<td>PERCENT_RANK () OVER ( [PARTITION BY expr] ORDER BY expr )</td>
<td>Calculates the rank of a hypothetical row R minus 1, divided by 1 less than the number of rows being evaluated (within a window partition).</td>
</tr>
<tr>
<td>rank()</td>
<td>bigint</td>
<td>RANK () OVER ( [PARTITION BY expr] ORDER BY expr )</td>
<td>Calculates the rank of a row in an ordered group of values. Rows with equal values for the ranking criteria receive the same rank. The number of tied rows are added to the rank number to calculate the next rank value. Ranks may not be consecutive numbers in this case.</td>
</tr>
<tr>
<td>row_number()</td>
<td>bigint</td>
<td>ROW_NUMBER () OVER ( [PARTITION BY expr] ORDER BY expr )</td>
<td>Assigns a unique number to each row to which it is applied (either each row in a window partition or each row of the query).</td>
</tr>
</tbody>
</table>

**Advanced Aggregate Functions**

The following built-in advanced aggregate functions are Greenplum extensions of the PostgreSQL database. These functions are *immutable*. 

**Note:** The Greenplum MADlib Extension for Analytics provides additional advanced functions to perform statistical analysis and machine learning with Greenplum Database data. See Greenplum MADlib Extension for Analytics in the Greenplum Database Reference Guide.

Table 54: Advanced Aggregate Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Return Type</th>
<th>Full Syntax</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEDIAN (expr)</td>
<td>timestamp, timestamptz, interval, float</td>
<td>MEDIAN (expression)</td>
<td>Can take a two-dimensional array as input. Treats such arrays as matrices.</td>
</tr>
<tr>
<td>PERCENTILE_CONT (expr) WITHIN GROUP (ORDER BY expr [DESC/ASC])</td>
<td>timestamp, timestamptz, interval, float</td>
<td>PERCENTILE_CONT(percentage) WITHIN GROUP (ORDER BY expression)</td>
<td>Performs an inverse distribution function that assumes a continuous distribution model. It takes a percentile value and a sort specification and returns the same datatype as the numeric datatype of the argument. This returned value is a computed result after performing linear interpolation. Null are ignored in this calculation.</td>
</tr>
<tr>
<td>PERCENTILE_DISC (expr) WITHIN GROUP (ORDER BY expr [DESC/ASC])</td>
<td>timestamp, timestamptz, interval, float</td>
<td>PERCENTILE_DISC(percentage) WITHIN GROUP (ORDER BY expression)</td>
<td>Performs an inverse distribution function that assumes a discrete distribution model. It takes a percentile value and a sort specification. This returned value is an element from the set. Null are ignored in this calculation.</td>
</tr>
</tbody>
</table>
### Working with JSON Data

Greenplum Database supports the `json` data type that stores JSON (JavaScript Object Notation) data.

Greenplum Database supports JSON as specified in the RFC 7159 document and enforces data validity according to the JSON rules. There are also JSON-specific functions and operators available for `json` data. See JSON Functions and Operators.

This section contains the following topics:

- About JSON Data
- JSON Input and Output Syntax
- Designing JSON documents
- JSON Functions and Operators

### About JSON Data

When Greenplum Database stores data as `json` data type, an exact copy of the input text is stored and the JSON processing functions reparse the data on each execution.

- Semantically-insignificant white space between tokens is retained, as well as the order of keys within JSON objects.
- All key/value pairs are kept even if a JSON object contains duplicate keys. For duplicate keys, JSON processing functions consider the last value as the operative one.

Greenplum Database allows only one character set encoding per database. It is not possible for the `json` type to conform rigidly to the JSON specification unless the database encoding is UTF8. Attempts to include characters that cannot be represented in the database encoding will fail. Characters that can be represented in the database encoding but not in UTF8 are allowed.
The RFC 7159 document permits JSON strings to contain Unicode escape sequences denoted by \uXXXX. For the json type, the Greenplum Database input function allows Unicode escapes regardless of the database encoding and checks Unicode escapes only for syntactic correctness (a \u followed by four hex digits).

**Note:** Many of the JSON processing functions described in JSON Functions and Operators convert Unicode escapes to regular characters. The functions throw an error for characters that cannot be represented in the database encoding. You should avoid mixing Unicode escapes in JSON with a non-UTF8 database encoding, if possible.

### JSON Input and Output Syntax

The input and output syntax for the json data type is as specified in RFC 7159.

The following are all valid json expressions:

- **Simple scalar/primitive value**
  
  ```
  SELECT '5'::json;
  ```

- **Array of zero or more elements (elements need not be of same type)**
  
  ```
  SELECT ' [1, 2, "foo", null]'::json;
  ```

- **Object containing pairs of keys and values**
  
  ```
  SELECT '{"bar": "baz", "balance": 7.77, "active": false}'::json;
  ```

- **Arrays and objects can be nested arbitrarily**
  
  ```
  SELECT '{"foo": [true, "bar"], "tags": {"a": 1, "b": null}}'::json;
  ```

### Designing JSON documents

Representing data as JSON can be considerably more flexible than the traditional relational data model, which is compelling in environments where requirements are fluid. It is quite possible for both approaches to co-exist and complement each other within the same application. However, even for applications where maximal flexibility is desired, it is still recommended that JSON documents have a somewhat fixed structure. The structure is typically unenforced (though enforcing some business rules declaratively is possible), but having a predictable structure makes it easier to write queries that usefully summarize a set of "documents" (datums) in a table.

JSON data is subject to the same concurrency-control considerations as any other data type when stored in a table. Although storing large documents is practicable, keep in mind that any update acquires a row-level lock on the whole row. Consider limiting JSON documents to a manageable size in order to decrease lock contention among updating transactions. Ideally, JSON documents should each represent an atomic datum that business rules dictate cannot reasonably be further subdivided into smaller datums that could be modified independently.

### JSON Functions and Operators

Built-in functions and operators that create and manipulate JSON data.

- **JSON Operators**
- **JSON Creation Functions**
- **JSON Processing Functions**

  **Note:** For json values, all key/value pairs are kept even if a JSON object contains duplicate keys. For duplicate keys, JSON processing functions consider the last value as the operative one.

### JSON Operators

This table describes the operators that are available for use with the json data type.
Table 55: json Operators

<table>
<thead>
<tr>
<th>Operator</th>
<th>Right Operand Type</th>
<th>Description</th>
<th>Example</th>
<th>Example Result</th>
</tr>
</thead>
</table>
| -> | int | Get JSON array element (indexed from zero). | '[["a":"foo"],
{"b":"bar"},
{"c":"baz"}]::json->2 | "c":"baz" |
| -> | text | Get JSON object field by key. | '{"a":
{"b":"foo"}}::json->'a' | "b":"foo" |
| ->> | int | Get JSON array element as text. | '[1,2,3]::json->>2 | 3 |
| ->> | text | Get JSON object field as text. | '{"a":1,"b":2}::json->
'b' | 2 |
| #> | text[] | Get JSON object at specified path. | '{"a": {"b":{"c":
"foo"}}}::json#>{a,b}' | "c": "foo" |
| #>> | text[] | Get JSON object at specified path as text. | '{"a":[1,2,3],"b":
[4,5,6]}::json#>>'[a,2]' | 3 |

JSON Creation Functions

This table describes the functions that create json values.

Table 56: JSON Creation Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Example</th>
<th>Example Result</th>
</tr>
</thead>
</table>
| array_to_json(anyarray [, pretty_bool]) | Returns the array as a JSON array. A Greenplum Database multidimensional array becomes a JSON array of arrays. Line feeds are added between dimension 1 elements if pretty_bool is true. | array_to_json('{{1,5},
{99,100}}::int[]) | [[1,5],[99,100]] |
| row_to_json(record [, pretty_bool]) | Returns the row as a JSON object. Line feeds are added between level 1 elements if pretty_bool is true. | row_to_json(row(1,'foo')) | {"f1":1,"f2":"foo"} |

JSON Processing Functions

This table describes the functions that process json values.
Greenplum Database Administrator Guide

OpenTopic

Table 57: JSON Processing Functions
Function

Return Type

Description

Example

json_
each(json)

setof key
text, value
json

Expands the
outermost JSON
object into a set of
key/value pairs.

select *
key | value
from json_
-----+------| "foo"
each('{"a":"foo", a
b
| "bar"
"b":"bar"}')

setof key
text, value
jsonb

Example Result

json_each_
text(json)

setof key
text, value
text

Expands the
outermost JSON
object into a set
of key/value pairs.
The returned
values are of type
text.

select * from
key | value
json_each_
-----+------| foo
text('{"a":"foo", a
b
| bar
"b":"bar"}')

json_extract_
path(from_json
json, VARIADIC
path_elems
text[])

json

Returns the JSON
value specified to
by path_elems.
Equivalent to #>
operator.

json_extract_
{"f5":99,"f6":"foo"}
path('{"f2":
{"f3":1},"f4":
{"f5":99,"f6":"foo"}}','f4')

json_
extract_path_
text(from_json
json, VARIADIC
path_elems
text[])

text

Returns the JSON
value specified to
by path_elems
as text. Equivalent
to #>> operator.

json_extract_
foo
path_text('{"f2":
{"f3":1},"f4":
{"f5":99,"f6":"foo"}}','f4',
'f6')

json_object_
keys(json)

setof text

Returns set
of keys in the
outermost JSON
object.

json_object_
json_object_
keys('{"f1":"abc","f2":
keys
-----------------{"f3":"a",
f1
"f4":"b"}}')
f2

json_populate_
record(base
anyelement,
from_json
json)

anyelement

Expands the
object in from_
json to a row
whose columns
match the record
type defined by
base. See Note.

select * from
a | b
json_populate_
---+--1 | 2
record(null::myrowtype,
'{"a":1,"b":2}')

json_populate_
recordset(base
anyelement,
from_json
json)

setof
anyelement

Expands the
outermost array of
objects in from_
json to a set
of rows whose
columns match
the record type
defined by base.
See Note.

select * from
a | b
json_populate_
---+--1 | 2
recordset(null::myrowtype,
3 | 4
'[{"a":1,"b":2},
{"a":3,"b":4}]')

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<table>
<thead>
<tr>
<th>Function</th>
<th>Return Type</th>
<th>Description</th>
<th>Example</th>
<th>Example Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>json_array_elements(json)</td>
<td>setof json</td>
<td>Expands a JSON array to a set of JSON values.</td>
<td>select * from json_array_elements('[1,true,[2,false]]')</td>
<td>value</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1true</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[2,false]</td>
</tr>
</tbody>
</table>

**Note:** Many of these functions and operators convert Unicode escapes in JSON strings to regular characters. The functions throw an error for characters that cannot be represented in the database encoding.

For `json_populate_record` and `json_populate_recordset`, type coercion from JSON is best effort and might not result in desired values for some types. JSON keys are matched to identical column names in the target row type. JSON fields that do not appear in the target row type are omitted from the output, and target columns that do not match any JSON field return `null`.

---

**Working with XML Data**

Greenplum Database supports the `xml` data type that stores XML data.

The `xml` data type checks the input values for well-formedness, providing an advantage over simply storing XML data in a text field. Additionally, support functions allow you to perform type-safe operations on this data; refer to [XML Function Reference](#), below.

The `xml` type can store well-formed "documents", as defined by the XML standard, as well as "content" fragments, which are defined by the production `XMLDecl? content` in the XML standard. Roughly, this means that content fragments can have more than one top-level element or character node. The expression `xmlvalue IS DOCUMENT` can be used to evaluate whether a particular `xml` value is a full document or only a content fragment.

This section contains the following topics:

- Creating XML Values
- Encoding Handling
- Accessing XML Values
- Processing XML
- Mapping Tables to XML
- Using XML Functions and Expressions

**Creating XML Values**

To produce a value of type `xml` from character data, use the function `xmlparse`:

```sql
xmlparse ( { DOCUMENT | CONTENT } value)
```

For example:

```sql
XMLPARSE (DOCUMENT '<?xml version="1.0"?><book><title>Manual</title><chapter>...</chapter></book>')
XMLPARSE (CONTENT 'abc<foo>bar</foo><bar>foo</bar>')
```

The above method converts character strings into XML values according to the SQL standard, but you can also use Greenplum Database syntax like the following:

```sql
xml '<foo>bar</foo>'
'<foo>bar</foo>':::xml
```
The `xml` type does not validate input values against a document type declaration (DTD), even when the input value specifies a DTD. There is also currently no built-in support for validating against other XML schema languages such as XML schema.

The inverse operation, producing a character string value from `xml`, uses the function `xmlserialize`:

```sql
xmlserialize ( { DOCUMENT | CONTENT } value AS type )
```

*type* can be `character`, `character varying`, or `text` (or an alias for one of those). Again, according to the SQL standard, this is the only way to convert between type `xml` and character types, but Greenplum Database also allows you to simply cast the value.

When a character string value is cast to or from type `xml` without going through `XMLPARSE` or `XMLSERIALIZE`, respectively, the choice of `DOCUMENT` versus `CONTENT` is determined by the `XML OPTION` session configuration parameter, which can be set using the standard command:

```sql
SET XML OPTION { DOCUMENT | CONTENT };
```

or simply like Greenplum Database:

```sql
SET XML OPTION TO { DOCUMENT | CONTENT };
```

The default is `CONTENT`, so all forms of XML data are allowed.

**Note:**

With the default XML option setting, you cannot directly cast character strings to type `xml` if they contain a document type declaration, because the definition of XML content fragment does not accept them. If you need to do that, either use `XMLPARSE` or change the `XML` option.

**Encoding Handling**

Be careful when dealing with multiple character encodings on the client, server, and in the XML data passed through them. When using the text mode to pass queries to the server and query results to the client (which is the normal mode), Greenplum Database converts all character data passed between the client and the server, and vice versa, to the character encoding of the respective endpoint; see Character Set Support. This includes string representations of XML values, such as in the above examples. Ordinarily, this means that encoding declarations contained in XML data can become invalid, as the character data is converted to other encodings while travelling between client and server, because the embedded encoding declaration is not changed. To cope with this behavior, encoding declarations contained in character strings presented for input to the `xml` type are ignored, and content is assumed to be in the current server encoding. Consequently, for correct processing, character strings of XML data must be sent from the client in the current client encoding. It is the responsibility of the client to either convert documents to the current client encoding before sending them to the server, or to adjust the client encoding appropriately. On output, values of type `xml` will not have an encoding declaration, and clients should assume all data is in the current client encoding.

When using binary mode to pass query parameters to the server and query results back to the client, no character set conversion is performed, so the situation is different. In this case, an encoding declaration in the XML data will be observed, and if it is absent, the data will be assumed to be in UTF-8 (as required by the XML standard; note that Greenplum Database does not support UTF-16). On output, data will have an encoding declaration specifying the client encoding, unless the client encoding is UTF-8, in which case it will be omitted.

**Note:**

Processing XML data with Greenplum Database will be less error-prone and more efficient if the XML data encoding, client encoding, and server encoding are the same. Because XML data is internally processed in UTF-8, computations will be most efficient if the server encoding is also UTF-8.
Accessing XML Values

The XML data type is unusual in that it does not provide any comparison operators. This is because there is no well-defined and universally useful comparison algorithm for XML data. One consequence of this is that you cannot retrieve rows by comparing an XML column against a search value. XML values should therefore typically be accompanied by a separate key field such as an ID. An alternative solution for comparing XML values is to convert them to character strings first, but note that character string comparison has little to do with a useful XML comparison method.

Because there are no comparison operators for the XML data type, it is not possible to create an index directly on a column of this type. If speedy searches in XML data are desired, possible workarounds include casting the expression to a character string type and indexing that, or indexing an XPath expression. Of course, the actual query would have to be adjusted to search by the indexed expression.

Processing XML

To process values of data type XML, Greenplum Database offers the functions xpath and xpath_exists, which evaluate XPath 1.0 expressions.

\[
\text{xpath}(\text{xpath}, \text{xml} [, \text{nsarray}])
\]

The function xpath evaluates the XPath expression xpath (a text value) against the XML value xml. It returns an array of XML values corresponding to the node set produced by the XPath expression.

The second argument must be a well-formed XML document. In particular, it must have a single root node element.

The optional third argument of the function is an array of namespace mappings. This array should be a two-dimensional text array with the length of the second axis being equal to 2 (i.e., it should be an array of arrays, each of which consists of exactly 2 elements). The first element of each array entry is the namespace name (alias), the second the namespace URI. It is not required that aliases provided in this array be the same as those being used in the XML document itself (in other words, both in the XML document and in the xpath function context, aliases are local).

Example:

\[
\]

\[
\text{xpath}
\]

\[
\{\text{test}\}
\]

(1 row)

To deal with default (anonymous) namespaces, do something like this:

\[
\text{SELECT xpath('//mydefns:b/text()', '<a xmlns="http://example.com"><b>test</b></a>', ARRAY[ARRAY['mydefns', 'http://example.com']])};
\]

\[
\text{xpath}
\]

\[
\{\text{test}\}
\]

(1 row)

\[
\text{xpath\_exists}(\text{xpath}, \text{xml} [, \text{nsarray}])
\]
The function `xpath_exists` is a specialized form of the `xpath` function. Instead of returning the individual XML values that satisfy the XPath, this function returns a Boolean indicating whether the query was satisfied or not. This function is equivalent to the standard `XML EXISTS` predicate, except that it also offers support for a namespace mapping argument.

Example:

```
                  ARRAY[ARRAY['my', 'http://example.com']]);
```

```
xpath_exists
-------------
t
(1 row)
```

**Mapping Tables to XML**

The following functions map the contents of relational tables to XML values. They can be thought of as XML export functionality:

- `table_to_xml(tbl regclass, nulls boolean, tableforest boolean, targetns text)`
- `query_to_xml(query text, nulls boolean, tableforest boolean, targetns text)`
- `cursor_to_xml(cursor refcursor, count int, nulls boolean, tableforest boolean, targetns text)`

The return type of each function is `xml`.

`table_to_xml` maps the content of the named table, passed as parameter `tbl`. The `regclass` type accepts strings identifying tables using the usual notation, including optional schema qualifications and double quotes. `query_to_xml` executes the query whose text is passed as parameter `query` and maps the result set. `cursor_to_xml` fetches the indicated number of rows from the cursor specified by the parameter `cursor`. This variant is recommended if large tables have to be mapped, because the result value is built up in memory by each function.

If `tableforest` is false, then the resulting XML document looks like this:

```
<tablename>
  <row>
    <columnname1>data</columnname1>
    <columnname2>data</columnname2>
  </row>

  ...

  ...
</tablename>
```

If `tableforest` is true, the result is an XML content fragment that looks like this:

```
<tablename>
  <columnname1>data</columnname1>
  <columnname2>data</columnname2>
</tablename>

<tablename>
  ...
</tablename>
```
If no table name is available, that is, when mapping a query or a cursor, the string `table` is used in the first format, `row` in the second format.

The choice between these formats is up to the user. The first format is a proper XML document, which will be important in many applications. The second format tends to be more useful in the `cursor_to_xml` function if the result values are to be later reassembled into one document. The functions for producing XML content discussed above, in particular `xml_element`, can be used to alter the results as desired.

The data values are mapped in the same way as described for the function `xml_element`, above.

The parameter `nulls` determines whether null values should be included in the output. If true, null values in columns are represented as:

```
<columnname xsi:nil="true"/>
```

where `xsi` is the XML namespace prefix for XML schema Instance. An appropriate namespace declaration will be added to the result value. If false, columns containing null values are simply omitted from the output.

The parameter `targetns` specifies the desired XML namespace of the result. If no particular namespace is wanted, an empty string should be passed.

The following functions return XML schema documents describing the mappings performed by the corresponding functions above:

```plaintext
able_to_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns text)
query_to_xmlschema(query text, nulls boolean, tableforest boolean, targetns text)
cursor_to_xmlschema(cursor refcursor, nulls boolean, tableforest boolean, targetns text)
```

It is essential that the same parameters are passed in order to obtain matching XML data mappings and XML schema documents.

The following functions produce XML data mappings and the corresponding XML schema in one document (or forest), linked together. They can be useful where self-contained and self-describing results are desired:

```plaintext
table_to_xml_and_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns text)
query_to_xml_and_xmlschema(query text, nulls boolean, tableforest boolean, targetns text)
```

In addition, the following functions are available to produce analogous mappings of entire schemas or the entire current database:

```plaintext
schema_to_xml(schema name, nulls boolean, tableforest boolean, targetns text)
schema_to_xmlschema(schema name, nulls boolean, tableforest boolean, targetns text)
schema_to_xml_and_xmlschema(schema name, nulls boolean, tableforest boolean, targetns text)
database_to_xml(nulls boolean, tableforest boolean, targetns text)
database_to_xmlschema(nulls boolean, tableforest boolean, targetns text)
database_to_xml_and_xmlschema(nulls boolean, tableforest boolean, targetns text)
```
Note that these potentially produce large amounts of data, which needs to be built up in memory. When requesting content mappings of large schemas or databases, consider mapping the tables separately instead, possibly even through a cursor.

The result of a schema content mapping looks like this:

```xml
<schemaname>
  table1-mapping
  table2-mapping
  ...
</schemaname>
```

where the format of a table mapping depends on the `tableforest` parameter, as explained above.

The result of a database content mapping looks like this:

```xml
<dbname>
  <schemaname>
    ...
  </schemaname>
  ...
  ...
  ...
  ...
<dbname>
```

where the schema mapping is as above.

The example below demonstrates using the output produced by these functions. The example shows an XSLT stylesheet that converts the output of `table_to_xml_and_xmlschema` to an HTML document containing a tabular rendition of the table data. In a similar manner, the results from these functions can be converted into other XML-based formats.

```xml
<?xml version="1.0"?>
<xsl:stylesheet version="1.0"
  xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  xmlns="http://www.w3.org/1999/xhtml">
  <xsl:output method="xml"
    doctype-system="http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd"
    doctype-public="-//W3C/DTD XHTML 1.0 Strict//EN"
    indent="yes"/>
  <xsl:template match="/*">
    <xsl:variable name="schema" select="//xsd:schema"/>
    <xsl:variable name="tabletypename" select="$schema/xsd:complexType[@name=$tabletypename]/xsd:sequence/xsd:element[@name='row']/@type"/>
    <html>
XML Function Reference

The functions described in this section operate on values of type xml. The section XML Predicates also contains information about the xml functions and function-like expressions.

Function:
xmlcomment

Synopsis:

xmlcomment(text)

The function xmlcomment creates an XML value containing an XML comment with the specified text as content. The text cannot contain "--" or end with a "-" so that the resulting construct is a valid XML comment. If the argument is null, the result is null.

Example:

SELECT xmlcomment('hello');
xmlcomment
-----------------
<!--hello-->
Example:

```sql
SELECT xmlconcat('<abc/>', '<bar>foo</bar>');
```

xmlconcat
----------------------
<abc/> <bar>foo</bar>

XML declarations, if present, are combined as follows:

- If all argument values have the same XML version declaration, that version is used in the result, else no version is used.
- If all argument values have the standalone declaration value "yes", then that value is used in the result.
- If all argument values have a standalone declaration value and at least one is "no", then that is used in the result. Otherwise, the result will have no standalone declaration.
- If the result is determined to require a standalone declaration but no version declaration, a version declaration with version 1.0 will be used because XML requires an XML declaration to contain a version declaration.

Encoding declarations are ignored and removed in all cases.

Example:

```sql
SELECT xmlconcat('<?xml version="1.1"?><foo/>', '<?xml version="1.1" standalone="no"?><bar/>');
```

xmlconcat
-----------------------------------
<?xml version="1.1"?><foo/> <bar/>

Function:

xmlelement

Synopsis:

```
xmlelement(name name [, xmlattributes(value [AS attname] [, ... ])] [, content, ...])
```

The `xmlelement` expression produces an XML element with the given name, attributes, and content.

Examples:

```sql
SELECT xmlelement(name foo);
```

xmlelement
------------
<foo/>

```sql
SELECT xmlelement(name foo, xmlattributes('xyz' as bar));
```

xmlelement
------------------
<foo bar="xyz"/>

```sql
SELECT xmlelement(name foo, xmlattributes(current_date as bar), 'cont', 'ent');
```

xmlelement
-------------------------------------
<foo bar="2017-01-26">content</foo>
Element and attribute names that are not valid XML names are escaped by replacing the offending characters by the sequence \_xHHHH\_, where HHHH is the character's Unicode codepoint in hexadecimal notation. For example:

```sql
SELECT xmlelement(name "foo\$bar", xmlattributes('xyz' as "a\&b"));
```

```
<foo_x0024_bar a_x0026_b="xyz"/>
```

An explicit attribute name need not be specified if the attribute value is a column reference, in which case the column's name will be used as the attribute name by default. In other cases, the attribute must be given an explicit name. So this example is valid:

```sql
CREATE TABLE test (a xml, b xml);
SELECT xmlelement(name test, xmlattributes(a, b)) FROM test;
```

But these are not:

```sql
SELECT xmlelement(name test, xmlattributes('constant'), a, b) FROM test;
SELECT xmlelement(name test, xmlattributes(func(a, b))) FROM test;
```

Element content, if specified, will be formatted according to its data type. If the content is itself of type xml, complex XML documents can be constructed. For example:

```sql
SELECT xmlelement(name foo, xmlattributes('xyz' as bar),
    xmlelement(name abc),
    xmlcomment('test'),
    xmlelement(name xyz));
```

```
<foo bar="xyz"><abc/>!--test--><xyz/></foo>
```

Content of other types will be formatted into valid XML character data. This means in particular that the characters <, >, and & will be converted to entities. Binary data (data type bytea) will be represented in base64 or hex encoding, depending on the setting of the configuration parameter xmlbinary. The particular behavior for individual data types is expected to evolve in order to align the SQL and Greenplum Database data types with the XML schema specification, at which point a more precise description will appear.

**Function:**

xmlforest

**Synopsis:**

```sql
xmlforest(content [AS name] [, ...])
```

The xmlforest expression produces an XML forest (sequence) of elements using the given names and content.

**Examples:**

```sql
SELECT xmlforest('abc' AS foo, 123 AS bar);
```

```
<foo>abc</foo><bar>123</bar>
```

```sql
SELECT xmlforest(table_name, column_name)
```
FROM information_schema.columns
WHERE table_schema = 'pg_catalog';

xmlforest
-----------------------
<table_name>pg_authid</table_name><column_name>rolname</column_name>
<table_name>pg_authid</table_name><column_name>rolsuper</column_name>

As seen in the second example, the element name can be omitted if the content value is a column reference, in which case the column name is used by default. Otherwise, a name must be specified. Element names that are not valid XML names are escaped as shown for xmlelement above. Similarly, content data is escaped to make valid XML content, unless it is already of type xml.

Note that XML forests are not valid XML documents if they consist of more than one element, so it might be useful to wrap xmlforest expressions in xmlelement.

Function:
xmlpi

Synopsis:
xmlpi(name target [, content])

The xmlpi expression creates an XML processing instruction. The content, if present, must not contain the character sequence `?>`.

Example:

SELECT xmlpi(name php, 'echo "hello world";');
xmlpi
-----------------------
<?php echo "hello world";?>

Function:
xmlroot

Synopsis:
xmlroot(xml, version text | no value [, standalone yes|no|no value])

The xmlroot expression alters the properties of the root node of an XML value. If a version is specified, it replaces the value in the root node's version declaration; if a standalone setting is specified, it replaces the value in the root node's standalone declaration.

SELECT xmlroot(xmlparse(document '<?xml version="1.1"?><content>abc</content>'),
version '1.0', standalone yes);
xmlroot
-----------------------
<?xml version="1.0" standalone="yes"?><content>abc</content>

Function:
xmlagg

xmlagg (xml)
The function `xmlagg` is, unlike the other functions described here, an aggregate function. It concatenates the input values to the aggregate function call, much like `xmlconcat` does, except that concatenation occurs across rows rather than across expressions in a single row. See Using Functions and Operators for additional information about aggregate functions.

Example:

```sql
CREATE TABLE test (y int, x xml);
INSERT INTO test VALUES (1, '<foo>abc</foo>');
INSERT INTO test VALUES (2, '<bar/>');
SELECT xmlagg(x) FROM test;

xmlagg
----------------------
<foo>abc</foo><bar/>
```

To determine the order of the concatenation, an `ORDER BY` clause may be added to the aggregate call. For example:

```sql
SELECT xmlagg(x ORDER BY y DESC) FROM test;

xmlagg
----------------------
<bar/><foo>abc</foo>
```

The following non-standard approach used to be recommended in previous versions, and may still be useful in specific cases:

```sql
SELECT xmlagg(x) FROM (SELECT * FROM test ORDER BY y DESC) AS tab;

xmlagg
----------------------
<bar/><foo>abc</foo>
```

**XML Predicates**

The expressions described in this section check properties of `xml` values.

**Expression:**

IS DOCUMENT

**Synopsis:**

```sql
xml IS DOCUMENT
```

The expression `IS DOCUMENT` returns true if the argument XML value is a proper XML document, false if it is not (that is, it is a content fragment), or null if the argument is null.

**Expression:**

XMLEXISTS

**Synopsis:**

```sql
XMLEXISTS(text PASSING [BY REF] xml [BY REF])
```

The function `xmlexists` returns true if the XPath expression in the first argument returns any nodes, and false otherwise. (If either argument is null, the result is null.)

Example:

```sql
SELECT xmlexists(path='//town[text() = 'Toronto']') PASSING BY REF '<towns><town>Toronto</town><town>Ottawa</town></towns>');</sql>
The **BY REF** clauses have no effect in Greenplum Database, but are allowed for SQL conformance and compatibility with other implementations. Per SQL standard, the first **BY REF** is required, the second is optional. Also note that the SQL standard specifies the `xmlexists` construct to take an XQuery expression as first argument, but Greenplum Database currently only supports XPath, which is a subset of XQuery.

**Expression:**

`xml_is_well_formed`

**Synopsis:**

```sql
xml_is_well_formed(text)
xml_is_well_formed_document(text)
xml_is_well_formed_content(text)
```

These functions check whether a text string is well-formed XML, returning a Boolean result. `xml_is_well_formed_document` checks for a well-formed document, while `xml_is_well_formed_content` checks for well-formed content. `xml_is_well_formed` does the former if the `xmloption` configuration parameter is set to `DOCUMENT`, or the latter if it is set to `CONTENT`. This means that `xml_is_well_formed` is useful for seeing whether a simple cast to type `xml` will succeed, whereas the other two functions are useful for seeing whether the corresponding variants of `XMLPARSE` will succeed.

**Examples:**

```sql
SET xmloption TO DOCUMENT;
SELECT xml_is_well_formed('<>');
xml_is_well_formed
----------------------
f
(1 row)

SELECT xml_is_well_formed('<abc/>');
xml_is_well_formed
----------------------
t
(1 row)

SET xmloption TO CONTENT;
SELECT xml_is_well_formed('abc');
xml_is_well_formed
----------------------
t
(1 row)

SELECT xml_is_well_formed_document('<pg:foo xmlns:pg="http://postgresql.org/stuff">bar</pg:foo>');</nxml_is_well_formed_document
----------------------
t
(1 row)

SELECT xml_is_well_formed_document('<pg:foo xmlns:pg="http://postgresql.org/stuff">bar</my:foo>');</nxml_is_well_formed_document
----------------------
f
```
The last example shows that the checks include whether namespaces are correctly matched.

**Query Performance**

Greenplum Database dynamically eliminates irrelevant partitions in a table and optimally allocates memory for different operators in a query. These enhancements scan less data for a query, accelerate query processing, and support more concurrency.

- **Dynamic Partition Elimination**
  In Greenplum Database, values available only when a query runs are used to dynamically prune partitions, which improves query processing speed. Enable or disable dynamic partition elimination by setting the server configuration parameter `gp_dynamic_partition_pruning` to **ON** or **OFF**; it is **ON** by default.

- **Memory Optimizations**
  Greenplum Database allocates memory optimally for different operators in a query and frees and re-allocates memory during the stages of processing a query.

  **Note:** Greenplum Database uses GPORCA, the Greenplum next generation query optimizer, by default. GPORCA extends the planning and optimization capabilities of the Greenplum Database legacy optimizer. For information about the features and limitations of GPORCA, see *Overview of GPORCA*.

**Managing Spill Files Generated by Queries**

Greenplum Database creates spill files, also known as workfiles, on disk if it does not have sufficient memory to execute an SQL query in memory. The default value of 100,000 spill files is sufficient for the majority of queries. However, if a query creates more than the specified number of spill files, Greenplum Database returns this error:

```
ERROR: number of workfiles per query limit exceeded
```

Reasons that cause a large number of spill files to be generated include:

- Data skew is present in the queried data.
- The amount memory allocated for the query is too low.

You might be able to run the query successfully by changing the query, changing the data distribution, or changing the system memory configuration. You can use the `gp_workfile_*` views to see spill file usage information. You can control the maximum amount of memory that can used by a query with the Greenplum Database server configuration parameters `max_statement_mem`, `statement_mem`, or through resource queues.

*Monitoring a Greenplum System* contains the following information:

- Information about skew and how to check for data skew
- Information about using the `gp_workfile_*` views

For information about server configuration parameters, see the *Greenplum Database Reference Guide*. For information about resource queues, see *Using Resource Queues*.

If you have determined that the query must create more spill files than allowed by the value of server configuration parameter `gp_workfile_limit_files_per_query`, you can increase the value of the parameter.

**Query Profiling**

Examine the query plans of poorly performing queries to identify possible performance tuning opportunities.
Greenplum Database devises a *query plan* for each query. Choosing the right query plan to match the query and data structure is necessary for good performance. A query plan defines how Greenplum Database will run the query in the parallel execution environment.

The query optimizer uses data statistics maintained by the database to choose a query plan with the lowest possible cost. Cost is measured in disk I/O, shown as units of disk page fetches. The goal is to minimize the total execution cost for the plan.

View the plan for a given query with the `EXPLAIN` command. `EXPLAIN` shows the query optimizer's estimated cost for the query plan. For example:

```sql
EXPLAIN SELECT * FROM names WHERE id=22;
```

`EXPLAIN ANALYZE` runs the statement in addition to displaying its plan. This is useful for determining how close the optimizer's estimates are to reality. For example:

```sql
EXPLAIN ANALYZE SELECT * FROM names WHERE id=22;
```

**Note:** In Greenplum Database, the default GPORCA optimizer co-exists with the legacy query optimizer. The `EXPLAIN` output generated by GPORCA is different than the output generated by the legacy query optimizer.

By default, Greenplum Database uses GPORCA to generate an execution plan for a query when possible.

When the `EXPLAIN ANALYZE` command uses GPORCA, the `EXPLAIN` plan shows only the number of partitions that are being eliminated. The scanned partitions are not shown. To show name of the scanned partitions in the segment logs set the server configuration parameter `gp_log_dynamic_partition_pruning` to `on`. This example `SET` command enables the parameter.

```sql
SET gp_log_dynamic_partition_pruning = on;
```

For information about GPORCA, see *Querying Data*.

### Reading EXPLAIN Output

A query plan is a tree of nodes. Each node in the plan represents a single operation, such as a table scan, join, aggregation, or sort.

Read plans from the bottom to the top: each node feeds rows into the node directly above it. The bottom nodes of a plan are usually table scan operations: sequential, index, or bitmap index scans. If the query requires joins, aggregations, sorts, or other operations on the rows, there are additional nodes above the scan nodes to perform these operations. The topmost plan nodes are usually Greenplum Database motion nodes: redistribute, explicit redistribute, broadcast, or gather motions. These operations move rows between segment instances during query processing.

The output of `EXPLAIN` has one line for each node in the plan tree and shows the basic node type and the following execution cost estimates for that plan node:

- **cost** — Measured in units of disk page fetches. 1.0 equals one sequential disk page read. The first estimate is the start-up cost of getting the first row and the second is the total cost of cost of getting all rows. The total cost assumes all rows will be retrieved, which is not always true; for example, if the query uses `LIMIT`, not all rows are retrieved.
- **rows** — The total number of rows output by this plan node. This number is usually less than the number of rows processed or scanned by the plan node, reflecting the estimated selectivity of any `WHERE` clause conditions. Ideally, the estimate for the topmost node approximates the number of rows that the query actually returns, updates, or deletes.
- **width** — The total bytes of all the rows that this plan node outputs.
Note the following:

- The cost of a node includes the cost of its child nodes. The topmost plan node has the estimated total execution cost for the plan. This is the number the optimizer intends to minimize.
- The cost reflects only the aspects of plan execution that the query optimizer takes into consideration. For example, the cost does not reflect time spent transmitting result rows to the client.

**EXPLAIN Example**

The following example describes how to read an EXPLAIN query plan for a query:

```
EXPLAIN SELECT * FROM names WHERE name = 'Joelle';
QUERY PLAN
------------------------------------------------------------
Gather Motion 2:1 (slice1) (cost=0.00..20.88 rows=1 width=13)
  -> Seq Scan on 'names' (cost=0.00..20.88 rows=1 width=13)
      Filter: name::text ~~ 'Joelle'::text
```

Read the plan from the bottom to the top. To start, the query optimizer sequentially scans the *names* table. Notice the `WHERE` clause is applied as a `filter` condition. This means the scan operation checks the condition for each row it scans and outputs only the rows that satisfy the condition.

The results of the scan operation are passed to a `gather motion` operation. In Greenplum Database, a gather motion is when segments send rows to the master. In this example, we have two segment instances that send to one master instance. This operation is working on slice1 of the parallel query execution plan. A query plan is divided into slices so the segments can work on portions of the query plan in parallel.

The estimated startup cost for this plan is 00.00 (no cost) and a total cost of 20.88 disk page fetches. The optimizer estimates this query will return one row.

**Reading EXPLAIN ANALYZE Output**

EXPLAIN ANALYZE plans and runs the statement. The EXPLAIN ANALYZE plan shows the actual execution cost along with the optimizer’s estimates. This allows you to see if the optimizer’s estimates are close to reality. EXPLAIN ANALYZE also shows the following:

- The total runtime (in milliseconds) in which the query executed.
- The memory used by each slice of the query plan, as well as the memory reserved for the whole query statement.
- The number of workers (segments) involved in a plan node operation. Only segments that return rows are counted.
- The maximum number of rows returned by the segment that produced the most rows for the operation. If multiple segments produce an equal number of rows, EXPLAIN ANALYZE shows the segment with the longest `<time> to end.`
- The segment id of the segment that produced the most rows for an operation.
- For relevant operations, the amount of memory (`work_mem`) used by the operation. If the `work_mem` was insufficient to perform the operation in memory, the plan shows the amount of data spilled to disk for the lowest-performing segment. For example:

  Work_mem used: 64K bytes avg, 64K bytes max (seg0).
  Work_mem wanted: 90K bytes avg, 90K bytes max (seg0) to lessen workfile I/O affecting 2 workers.

- The time (in milliseconds) in which the segment that produced the most rows retrieved the first row, and the time taken for that segment to retrieve all rows. The result may omit `<time> to first row` if it is the same as the `<time> to end.`
**EXPLAIN ANALYZE Examples**

This example describes how to read an EXPLAIN ANALYZE query plan using the same query. The bold parts of the plan show actual timing and rows returned for each plan node, as well as memory and time statistics for the whole query.

```sql
EXPLAIN ANALYZE SELECT * FROM names WHERE name = 'Joelle';
```

---

<table>
<thead>
<tr>
<th>QUERY PLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gather Motion 2:1 (slice1; segments: 2) (cost=0.00..20.88 rows=1 width=13)</td>
</tr>
<tr>
<td>Rows out: 1 rows at destination with 0.305 ms to first row, 0.537 ms to end, start offset by 0.289 ms.</td>
</tr>
<tr>
<td>-&gt; Seq Scan on names (cost=0.00..20.88 rows=1 width=13)</td>
</tr>
<tr>
<td>Rows out: Avg 1 rows x 2 workers. Max 1 rows (seg0) with 0.255 ms to first row, 0.486 ms to end, start offset by 0.968 ms.</td>
</tr>
<tr>
<td>Filter: name = 'Joelle'::text</td>
</tr>
</tbody>
</table>

Slice statistics:

(slice0) Executor memory: 135K bytes.

(slicel) Executor memory: 151K bytes avg x 2 workers, 151K bytes max (seg0).

Statement statistics:

Memory used: 12800K bytes
Total runtime: 22.548 ms

Read the plan from the bottom to the top. The total elapsed time to run this query was 22.548 milliseconds.

The sequential scan operation had only one segment (seg0) that returned rows, and it returned just 1 row. It took 0.255 milliseconds to find the first row and 0.486 to scan all rows. This result is close to the optimizer's estimate: the query optimizer estimated it would return one row for this query. The gather motion (segments sending data to the master) received 1 row. The total elapsed time for this operation was 0.537 milliseconds.

**Determining the Query Optimizer**

You can view EXPLAIN output to determine if GPORCA is enabled for the query plan and whether GPORCA or the legacy query optimizer generated the explain plan. The information appears at the end of the EXPLAIN output. The Settings line displays the setting of the server configuration parameter OPTIMIZER. The Optimizer status line displays whether GPORCA or the legacy query optimizer generated the explain plan.

For these two example query plans, GPORCA is enabled, the server configuration parameter OPTIMIZER is on. For the first plan, GPORCA generated the EXPLAIN plan. For the second plan, Greenplum Database fell back to the legacy query optimizer to generate the query plan.

```sql
explain select count(*) from part;
```
For this query, the server configuration parameter `OPTIMIZER` is off.

```
explain select count(*) from part;
```

```
Aggregate  (cost=3519.05..3519.06 rows=1 width=8)
  ->  Gather Motion 2:1  (slice1; segments: 2)  (cost=3518.99..3519.03 rows=1 width=8)
      ->  Aggregate  (cost=3518.99..3519.00 rows=1 width=8)
          ->  Seq Scan on part  (cost=0.00..3018.79 rows=100040)
          Settings: optimizer=off
          Optimizer status: legacy query optimizer
(5 rows)
```

Examine Query Plans to Solve Problems

If a query performs poorly, examine its query plan and ask the following questions:

- **Do operations in the plan take an exceptionally long time?** Look for an operation consumes the majority of query processing time. For example, if an index scan takes longer than expected, the index could be out-of-date and need to be reindexed. Or, adjust `enable_<operator>` parameters to see if you can force the legacy query optimizer (planner) to choose a different plan by disabling a particular query plan operator for that query.

- **Are the optimizer's estimates close to reality?** Run `EXPLAIN ANALYZE` and see if the number of rows the optimizer estimates is close to the number of rows the query operation actually returns. If there is a large discrepancy, collect more statistics on the relevant columns.

See the Greenplum Database Reference Guide for more information on the `EXPLAIN ANALYZE` and `ANALYZE` commands.

- **Are selective predicates applied early in the plan?** Apply the most selective filters early in the plan so fewer rows move up the plan tree. If the query plan does not correctly estimate query predicate selectivity, collect more statistics on the relevant columns. See the `ANALYZE` command in the Greenplum Database Reference Guide for more information collecting statistics. You can also try reordering the `WHERE` clause of your SQL statement.

- **Does the optimizer choose the best join order?** When you have a query that joins multiple tables, make sure that the optimizer chooses the most selective join order. Joins that eliminate the largest number of rows should be done earlier in the plan so fewer rows move up the plan tree.

  If the plan is not choosing the optimal join order, set `joinCollapse_limit=1` and use explicit `JOIN` syntax in your SQL statement to force the legacy query optimizer (planner) to the specified join order. You can also collect more statistics on the relevant join columns.

See the `ANALYZE` command in the Greenplum Database Reference Guide for more information collecting statistics.
• **Does the optimizer selectively scan partitioned tables?** If you use table partitioning, is the optimizer selectively scanning only the child tables required to satisfy the query predicates? Scans of the parent tables should return 0 rows since the parent tables do not contain any data. See [Verifying Your Partition Strategy](#) for an example of a query plan that shows a selective partition scan.

• **Does the optimizer choose hash aggregate and hash join operations where applicable?** Hash operations are typically much faster than other types of joins or aggregations. Row comparison and sorting is done in memory rather than reading/writing from disk. To enable the query optimizer to choose hash operations, there must be sufficient memory available to hold the estimated number of rows. Try increasing work memory to improve performance for a query. If possible, run an EXPLAIN ANALYZE for the query to show which plan operations spilled to disk, how much work memory they used, and how much memory was required to avoid spilling to disk. For example:

  Work_mem used: 23430K bytes avg, 23430K bytes max (seg0). Work_mem wanted: 33649K bytes avg, 33649K bytes max (seg0) to lessen workfile I/O affecting 2 workers.

  The "bytes wanted" message from EXPLAIN ANALYZE is based on the amount of data written to work files and is not exact. The minimum work_mem needed can differ from the suggested value.
Working with External Data

External tables provide access to data stored in data sources outside of Greenplum Database as if the data were stored in regular database tables. Data can be read from or written to external tables.

An external table is a Greenplum database table backed with data that resides outside of the database. An external table is either readable or writable. It can be used like a regular database table in SQL commands such as \texttt{SELECT} and \texttt{INSERT} and joined with other tables. External tables are most often used to load and unload database data.

Web-based external tables provide access to data served by an HTTP server or an operating system process. See \textit{Creating and Using External Web Tables} for more about web-based tables.

Defining External Tables

External tables enable accessing external data as if it were a regular database table. They are often used to move data into and out of a Greenplum database.

To create an external table definition, you specify the format of your input files and the location of your external data sources. For information input file formats, see \textit{Formatting Data Files}.

Use one of the following protocols to access external table data sources. You cannot mix protocols in \texttt{CREATE EXTERNAL TABLE} statements:

- \texttt{file://} accesses external data files on segment host that the Greenplum Database superuser (\texttt{gpadmin}) can access. See \textit{file:// Protocol}.
- \texttt{gpfdist://} points to a directory on the file host and serves external data files to all Greenplum Database segments in parallel. See \textit{gpfdist:// Protocol}.
- \texttt{gpfdists://} is the secure version of \texttt{gpfdist}. See \textit{gpfdists:// Protocol}.
- \texttt{gphdfs://} accesses files on a Hadoop Distributed File System (HDFS). See \textit{gphdfs:// Protocol}.

The files can be stored on an Amazon EMR instance HDFS. See \textit{Using Amazon EMR with Greenplum Database installed on AWS}.

- \texttt{s3://} accesses files in an Amazon S3 bucket. See \textit{s3:// Protocol}.
- The \texttt{pxf://} protocol accesses external HDFS files and Hive tables using the Greenplum Platform Extension Framework (pxf). See \textit{pxf:// Protocol}.

External tables access external files from within the database as if they are regular database tables. External tables defined with the \texttt{gpfdist/gpfdists}, \texttt{gphdfs}, and \texttt{s3} protocols utilize Greenplum parallelism by using the resources of all Greenplum Database segments to load or unload data. The \texttt{gphdfs} protocol leverages the parallel architecture of the Hadoop Distributed File System to access files on that system. The \texttt{s3} protocol utilizes the Amazon Web Services (AWS) capabilities.

You can query external table data directly and in parallel using SQL commands such as \texttt{SELECT}, \texttt{JOIN}, or \texttt{SORT EXTERNAL TABLE DATA}, and you can create views for external tables.

The steps for using external tables are:

1. Define the external table.
   - To use the \texttt{s3} protocol, you must also configure Greenplum Database and enable the protocol. See \textit{s3:// Protocol}.
2. Do one of the following:
   - Start the Greenplum Database file server(s) when using the \texttt{gpfdist} or \texttt{gpfdists} protocols.
   - Verify that you have already set up the required one-time configuration for the \texttt{gphdfs} protocol.
   - Verify the Greenplum Database configuration for the \texttt{s3} protocol.
3. Place the data files in the correct locations.
4. Query the external table with SQL commands.
Greenplum Database provides readable and writable external tables:

- Readable external tables for data loading. Readable external tables support basic extraction, transformation, and loading (ETL) tasks common in data warehousing. Greenplum Database segment instances read external table data in parallel to optimize large load operations. You cannot modify readable external tables.

- Writable external tables for data unloading. Writable external tables support:
  - Selecting data from database tables to insert into the writable external table.
  - Sending data to an application as a stream of data. For example, unload data from Greenplum Database and send it to an application that connects to another database or ETL tool to load the data elsewhere.
  - Receiving output from Greenplum parallel MapReduce calculations.

Writable external tables allow only `INSERT` operations.

External tables can be file-based or web-based. External tables using the `file://` protocol are read-only tables.

- Regular (file-based) external tables access static flat files. Regular external tables are rescannable: the data is static while the query runs.
- Web (web-based) external tables access dynamic data sources, either on a web server with the `http://` protocol or by executing OS commands or scripts. External web tables are not rescannable: the data can change while the query runs.

Dump and restore operate only on external and external web table `definitions`, not on the data sources.

**file:// Protocol**

The `file://` protocol is used in a URI that specifies the location of an operating system file.

The URI includes the host name, port, and path to the file. Each file must reside on a segment host in a location accessible by the Greenplum superuser (`gpadmin`). The host name used in the URI must match a segment host name registered in the `gp_segment_configuration` system catalog table.

The `LOCATION` clause can have multiple URIs, as shown in this example:

```sql
CREATE EXTERNAL TABLE ext_expenses (
    name text, date date, amount float4, category text, desc1 text
) LOCATION ('file://host1:5432/data/expense/*.csv',
             'file://host2:5432/data/expense/*.csv',
             'file://host3:5432/data/expense/*.csv')
FORMAT 'CSV' (HEADER);
```

The number of URIs you specify in the `LOCATION` clause is the number of segment instances that will work in parallel to access the external table. For each URI, Greenplum assigns a primary segment on the specified host to the file. For maximum parallelism when loading data, divide the data into as many equally sized files as you have primary segments. This ensures that all segments participate in the load. The number of external files per segment host cannot exceed the number of primary segment instances on that host. For example, if your array has four primary segment instances per segment host, you can place four external files on each segment host. Tables based on the `file://` protocol can only be readable tables.

The system view `pg_max_external_files` shows how many external table files are permitted per external table. This view lists the available file slots per segment host when using the `file://` protocol. The view is only applicable for the `file://` protocol. For example:

```sql
SELECT * FROM pg_max_external_files;
```
gpfdist:// Protocol
The gpfdist:// protocol is used in a URI to reference a running gpfdist instance.

The gpfdist utility serves external data files from a directory on a file host to all Greenplum Database segments in parallel.

gpfdist is located in the $GPHOME/bin directory on your Greenplum Database master host and on each segment host.

Run gpfdist on the host where the external data files reside. gpfdist uncompresses gzip (.gz) and bzip2 (.bz2) files automatically. You can use the wildcard character (*) or other C-style pattern matching to denote multiple files to read. The files specified are assumed to be relative to the directory that you specified when you started the gpfdist instance.

All primary segments access the external file(s) in parallel, subject to the number of segments set in the gp_external_max_segments server configuration parameter. Use multiple gpfdist data sources in a CREATE EXTERNAL TABLE statement to scale the external table's scan performance.

gpfdist supports data transformations. You can write a transformation process to convert external data from or to a format that is not directly supported with Greenplum Database external tables.

For more information about configuring gpfdist, see Using the Greenplum Parallel File Server (gpfdist).

See the gpfdist reference documentation for more information about using gpfdist with external tables.

gpfdists:// Protocol
The gpfdists:// protocol is a secure version of the gpfdist:// protocol.

To use it, you run the gpfdist utility with the --ssl option. When specified in a URI, the gpfdists:// protocol enables encrypted communication and secure identification of the file server and the Greenplum Database to protect against attacks such as eavesdropping and man-in-the-middle attacks.

gpfdists implements SSL security in a client/server scheme with the following attributes and limitations:

- Client certificates are required.
- Multilingual certificates are not supported.
- A Certificate Revocation List (CRL) is not supported.
- The TLSv1 protocol is used with the TLS_RSA_WITH_AES_128_CBC_SHA encryption algorithm.
- SSL parameters cannot be changed.
- SSL renegotiation is supported.
- The SSL ignore host mismatch parameter is set to false.
- Private keys containing a passphrase are not supported for the gpfdist file server (server.key) and for the Greenplum Database (client.key).
- Issuing certificates that are appropriate for the operating system in use is the user's responsibility. Generally, converting certificates as shown in https://www.sslshopper.com/ssl-converter.html is supported.

  Note: A server started with the gpfdist --ssl option can only communicate with the gpfdists protocol. A server that was started with gpfdist without the --ssl option can only communicate with the gpfdist protocol.

- The client certificate file, client.crt
- The client private key file, client.key

Use one of the following methods to invoke the gpfdists protocol.

- Run gpfdist with the --ssl option and then use the gpfdists protocol in the LOCATION clause of a CREATE EXTERNAL TABLE statement.
• Use a `gpload` YAML control file with the SSL option set to true. Running `gpload` starts the `gpfdist` server with the `--ssl` option, then uses the `gpfdists` protocol.

Using `gpfdists` requires that the following client certificates reside in the `$PGDATA/gpfdists` directory on each segment.

- The client certificate file, `client.crt`
- The client private key file, `client.key`
- The trusted certificate authorities, `root.crt`

For an example of loading data into an external table security, see Example 3—Multiple `gpfdists` instances.

The server configuration parameter `verify_gpfdists_cert` controls whether SSL certificate authentication is enabled when Greenplum Database communicates with the `gpfdist` utility to either read data from or write data to an external data source. You can set the parameter value to `false` to disable authentication when testing the communication between the Greenplum Database external table and the `gpfdist` utility that is serving the external data. If the value is `false`, these SSL exceptions are ignored:

- The self-signed SSL certificate that is used by `gpfdist` is not trusted by Greenplum Database.
- The host name contained in the SSL certificate does not match the host name that is running `gpfdist`.

**Warning:** Disabling SSL certificate authentication exposes a security risk by not validating the `gpfdists` SSL certificate.

**gphdfs:// Protocol**

The `gphdfs://` protocol specifies an external file path on a Hadoop Distributed File System (HDFS).

The protocol allows specifying external files in Hadoop clusters configured with or without Hadoop HA (high availability) and in MapR clusters. File names may contain wildcard characters and the files can be in CSV, TEXT, or custom formats.

When Greenplum links with HDFS files, all the data is read in parallel from the HDFS data nodes into the Greenplum segments for rapid processing. Greenplum determines the connections between the segments and nodes.

Each Greenplum segment reads one set of Hadoop data blocks. For writing, each Greenplum segment writes only the data it contains. The following figure illustrates an external table located on a HDFS file system.
The `FORMAT` clause describes the format of the external table files. Valid file formats are similar to the formatting options available with the PostgreSQL `COPY` command and user-defined formats for the `gphdfs` protocol. If the data in the file does not use the default column delimiter, escape character, null string and so on, you must specify the additional formatting options so that Greenplum Database reads the data in the external file correctly. The `gphdfs` protocol requires a one-time setup. See *One-time HDFS Protocol Installation*.

**pxf:// Protocol**

You can use the Greenplum Platform Extension Framework (PXF) `pxf://` protocol to access data on external HDFS, Hive, and HBase systems.

The PXF `pxf` protocol is packaged as a Greenplum Database extension. The `pxf` protocol supports reading from HDFS, Hive, and HBase data stores. You can also write text and binary data to HDFS with the `pxf` protocol.

When you use the `pxf` protocol to query HDFS, Hive, or HBase systems, you specify the HDFS file or Hive or HBase table that you want to access. PXF requests the data from the data store and delivers the relevant portions in parallel to each Greenplum Database segment instance serving the query.

You must explicitly initialize and start PXF before you can use the `pxf` protocol to read external data. You must also grant permissions to the `pxf` protocol and enable PXF in each database in which you want to create external tables to access external data.

For detailed information about configuring and using PXF and the `pxf` protocol, refer to *Accessing External Data with PXF*. 
s3:/// Protocol
The s3 protocol is used in a URL that specifies the location of an Amazon S3 bucket and a prefix to use for reading or writing files in the bucket.

Amazon Simple Storage Service (Amazon S3) provides secure, durable, highly-scalable object storage. For information about Amazon S3, see Amazon S3.

You can define read-only external tables that use existing data files in the S3 bucket for table data, or writable external tables that store the data from INSERT operations to files in the S3 bucket. Greenplum Database uses the S3 URL and prefix specified in the protocol URL either to select one or more files for a read-only table, or to define the location and filename format to use when uploading S3 files for INSERT operations to writable tables.

The s3 protocol also supports Dell EMC Elastic Cloud Storage (ECS), an Amazon S3 compatible service.

This topic contains the sections:

• Configuring and Using S3 External Tables
• About the S3 Protocol URL
• About S3 Data Files
• s3 Protocol AWS Server-Side Encryption Support
• s3 Protocol Proxy Support
• About the s3 Protocol config Parameter
• s3 Protocol Configuration File
• s3 Protocol Limitations
• Using the gpcheckcloud Utility

Configuring and Using S3 External Tables
Follow these basic steps to configure the S3 protocol and use S3 external tables, using the available links for more information. See also s3 Protocol Limitations to better understand the capabilities and limitations of S3 external tables:

1. Configure each database to support the s3 protocol:
   a. In each database that will access an S3 bucket with the s3 protocol, create the read and write functions for the s3 protocol library:

```
CREATE OR REPLACE FUNCTION write_to_s3() RETURNS integer AS '$libdir/gps3ext.so', 's3_export' LANGUAGE C STABLE;
```

```
CREATE OR REPLACE FUNCTION read_from_s3() RETURNS integer AS '$libdir/gps3ext.so', 's3_import' LANGUAGE C STABLE;
```

b. In each database that will access an S3 bucket, declare the s3 protocol and specify the read and write functions you created in the previous step:

```
CREATE PROTOCOL s3 (writefunc = write_to_s3, readfunc = read_from_s3);
```

Note: The protocol name s3 must be the same as the protocol of the URL specified for the external table you create to access an S3 resource.

The corresponding function is called by every Greenplum Database segment instance. All segment hosts must have access to the S3 bucket.

2. On each Greenplum Database segment, create and install the s3 protocol configuration file:
a. Create a template \texttt{s3} protocol configuration file using the \texttt{gpcheckcloud} utility:

```
   gpcheckcloud -t > ./mytest_s3.config
```

b. Edit the template file to specify the \texttt{accessid} and \texttt{secret} required to connect to the S3 location. See \texttt{s3 Protocol Configuration File} for information about other \texttt{s3} protocol configuration parameters.

c. Copy the file to the same location and filename for all Greenplum Database segments on all hosts. The default file location is \texttt{gpseg_data_dir/gpseg_prefixN/s3/s3.conf}. \texttt{gpseg_data_dir} is the path to the Greenplum Database segment data directory, \texttt{gpseg_prefix} is the segment prefix, and \texttt{N} is the segment ID. The segment data directory, prefix, and ID are set when you initialize a Greenplum Database system.

   If you copy the file to a different location or filename, then you must specify the location with the \texttt{config} parameter in the \texttt{s3} protocol URL. See \texttt{About the s3 Protocol config Parameter}.

d. Use the \texttt{gpcheckcloud} utility to validate connectivity to the S3 bucket:

```
   gpcheckcloud -c "s3://<s3-endpoint>/<s3-bucket> config=./mytest_s3.config"
```

   Specify the correct path to the configuration file for your system, as well as the S3 endpoint name and bucket that you want to check. \texttt{gpcheckcloud} attempts to connect to the S3 endpoint and lists any files in the S3 bucket, if available. A successful connection ends with the message:

```
   Your configuration works well.
```

   You can optionally use \texttt{gpcheckcloud} to validate uploading to and downloading from the S3 bucket, as described in \texttt{Using the gpcheckcloud Utility}.

3. After completing the previous steps to create and configure the \texttt{s3} protocol, you can specify an \texttt{s3} protocol URL in the \texttt{CREATE EXTERNAL TABLE} command to define S3 external tables. For read-only S3 tables, the URL defines the location and prefix used to select existing data files that comprise the S3 table. For example:

```
   CREATE READABLE EXTERNAL TABLE S3TBL (date text, time text, amt int)
   LOCATION('s3://s3-us-west-2.amazonaws.com/s3test.example.com/dataset1/
   normal/
   config=/home/gpadmin/aws_s3/s3.conf')
   FORMAT 'csv';
```

   For writable S3 tables, the protocol URL defines the S3 location in which Greenplum database stores data files for the table, as well as a prefix to use when creating files for table \texttt{INSERT} operations. For example:

```
   CREATE WRITABLE EXTERNAL TABLE S3WRIT (LIKE S3TBL)
   LOCATION('s3://s3-us-west-2.amazonaws.com/s3test.example.com/dataset1/
   normal/
   config=/home/gpadmin/aws_s3/s3.conf')
   FORMAT 'csv';
```

   See \texttt{About the S3 Protocol URL} for more information.

**About the S3 Protocol URL**

For the \texttt{s3} protocol, you specify a location for files and an optional configuration file location in the \texttt{LOCATION} clause of the \texttt{CREATE EXTERNAL TABLE} command. This is the syntax:

```
's3://S3_endpoint:[port]/bucket_name/[S3_prefix] [region=S3_region]
[config=config_file_location]'
```
The s3 protocol requires that you specify the S3 endpoint and S3 bucket name. Each Greenplum Database segment instance must have access to the S3 location. The optional S3_prefix value is used to select files for read-only S3 tables, or as a filename prefix to use when uploading files for S3 writable tables.

**Note:** The Greenplum Database s3 protocol URL must include the S3 endpoint hostname.

To specify an ECS endpoint (an Amazon S3 compatible service) in the LOCATION clause, you must set the s3 configuration file parameter version to 2. The version parameter controls whether the region parameter is used in the LOCATION clause. You can also specify an Amazon S3 location when the version parameter is 2. For information about version parameter, see s3 Protocol Configuration File.

**Note:** Although the S3_prefix is an optional part of the syntax, you should always include an S3 prefix for both writable and read-only S3 tables to separate datasets as part of the CREATE EXTERNAL TABLE syntax.

For writable S3 tables, the s3 protocol URL specifies the endpoint and bucket name where Greenplum Database uploads data files for the table. The S3 bucket permissions must be Upload/Delete for the S3 user ID that uploads the files. The S3 file prefix is used for each new file uploaded to the S3 location as a result of inserting data to the table. See About S3 Data Files.

For read-only S3 tables, the S3 file prefix is optional. If you specify an S3_prefix, then the s3 protocol selects all files that start with the specified prefix as data files for the external table. The s3 protocol does not use the slash character (/) as a delimiter, so a slash character following a prefix is treated as part of the prefix itself.

For example, consider the following 5 files that each have the S3_endpoint named s3-us-west-2.amazonaws.com and the bucket_name test1:

```
s3://s3-us-west-2.amazonaws.com/test1/abc
s3://s3-us-west-2.amazonaws.com/test1/abc/
s3://s3-us-west-2.amazonaws.com/test1/abc/xx
s3://s3-us-west-2.amazonaws.com/test1/abcdef
s3://s3-us-west-2.amazonaws.com/test1/abcdefff
```

- If the S3 URL is provided as s3://s3-us-west-2.amazonaws.com/test1/abc, then the abc prefix selects all 5 files.
- If the S3 URL is provided as s3://s3-us-west-2.amazonaws.com/test1/abc/, then the abc/ prefix selects the files s3://s3-us-west-2.amazonaws.com/test1/abc/ and s3://s3-us-west-2.amazonaws.com/test1/abc/xx.
- If the S3 URL is provided as s3://s3-us-west-2.amazonaws.com/test1/abcd, then the abcd prefix selects the files s3://s3-us-west-2.amazonaws.com/test1/abcdef and s3://s3-us-west-2.amazonaws.com/test1/abcdefff

Wildcard characters are not supported in an S3_prefix; however, the S3 prefix functions as if a wildcard character immediately followed the prefix itself.

All of the files selected by the S3 URL (S3_endpoint/bucket_name/S3_prefix) are used as the source for the external table, so they must have the same format. Each file must also contain complete data rows. A data row cannot be split between files. The S3 file permissions must be Open/Download and View for the S3 user ID that is accessing the files.

For information about the Amazon S3 endpoints see http://docs.aws.amazon.com/general/latest/gr/rande.html#s3_region. For information about S3 buckets and folders, see the Amazon S3 documentation https://aws.amazon.com/documentation/s3/. For information about the S3 file prefix, see the Amazon S3 documentation Listing Keys Hierarchically Using a Prefix andDelimiter.

The config parameter specifies the location of the required s3 protocol configuration file that contains AWS connection credentials and communication parameters. See About the s3 Protocol config Parameter.
About S3 Data Files

For each INSERT operation to a writable S3 table, each Greenplum Database segment uploads a single file to the configured S3 bucket using the filename format <prefix><segment_id><random>,<extension>[.gz] where:

- <prefix> is the prefix specified in the S3 URL.
- <segment_id> is the Greenplum Database segment ID.
- <random> is a random number that is used to ensure that the filename is unique.
- <extension> describes the file type ( .txt or .csv, depending on the value you provide in the FORMAT clause of CREATE WRITABLE EXTERNAL TABLE). Files created by the gpcheckcloud utility always use the extension .data.
- .gz is appended to the filename if compression is enabled for S3 writable tables (the default).

For writable S3 tables, you can configure the buffer size and the number of threads that segments use for uploading files. See s3 Protocol Configuration File.

For read-only S3 tables, all of the files specified by the S3 file location (S3_endpoint/bucket_name/S3_prefix) are used as the source for the external table and must have the same format. Each file must also contain complete data rows. If the files contain an optional header row, the column names in the header row cannot contain a newline character (\n) or a carriage return (\r). Also, the column delimiter cannot be a newline character (\n) or a carriage return character (\r).

The s3 protocol recognizes the gzip format and uncompress the files. Only the gzip compression format is supported.

The S3 file permissions must be Open/Download and View for the S3 user ID that is accessing the files. Writable S3 tables require the S3 user ID to have Upload/Delete permissions.

For read-only S3 tables, each segment can download one file at a time from S3 location using several threads. To take advantage of the parallel processing performed by the Greenplum Database segments, the files in the S3 location should be similar in size and the number of files should allow for multiple segments to download the data from the S3 location. For example, if the Greenplum Database system consists of 16 segments and there was sufficient network bandwidth, creating 16 files in the S3 location allows each segment to download a file from the S3 location. In contrast, if the location contained only 1 or 2 files, only 1 or 2 segments download data.

s3 Protocol AWS Server-Side Encryption Support

Greenplum Database supports server-side encryption using Amazon S3-managed keys (SSE-S3) for AWS S3 files you access with readable and writable external tables created using the s3 protocol. SSE-S3 encrypts your object data as it writes to disk, and transparently decrypts the data for you when you access it.

**Note:** The s3 protocol supports SSE-S3 only for Amazon Web Services S3 files. SS3-SE is not supported when accessing files in S3 compatible services.

Your S3 accessid and secret permissions govern your access to all S3 bucket objects, whether the data is encrypted or not. However, you must configure your client to use S3-managed keys for accessing encrypted data.

Refer to Protecting Data Using Server-Side Encryption in the AWS documentation for additional information about AWS Server-Side Encryption.

Configuring S3 Server-Side Encryption

s3 protocol server-side encryption is disabled by default. To take advantage of server-side encryption on AWS S3 objects you write using the Greenplum Database s3 protocol, you must set the server_side_encryption configuration parameter in your s3 configuration file to the value sse-s3:

```
server_side_encryption = sse-s3
```
When the configuration file you provide to a `CREATE WRITABLE EXTERNAL TABLE` call using the `s3` protocol includes the `server_side_encryption = sse-s3` setting, Greenplum Database applies encryption headers for you on all `INSERT` operations on that external table. S3 then encrypts on write the object(s) identified by the URL you provided in the `LOCATION` clause.

S3 transparently decrypts data during read operations of encrypted files accessed via readable external tables you create using the `s3` protocol. No additional configuration is required.

For further encryption configuration granularity, you may consider creating Amazon Web Services S3 Bucket Policy(s), identifying the objects you want to encrypt and the write actions on those objects as described in the `Protecting Data Using Server-Side Encryption with Amazon S3-Managed Encryption Keys (SSE-S3)` AWS documentation.

### s3 Protocol Proxy Support

You can specify a URL that is the proxy that S3 uses to connect to a data source. S3 supports these protocols: HTTP, HTTPS, and SOCKS (4, 4a, 5, 5h). You can specify a proxy with the `s3` protocol configuration parameter `proxy` or an environment variable. If the configuration parameter is set, the environment variables are ignored.

To specify proxy with an environment variable, you set the environment variable based on the protocol: `http_proxy`, `https_proxy`, or `socks_proxy`. You can specify a different URL for each protocol by setting the appropriate environment variable. S3 supports these environment variables:

- `all_proxy` specifies the proxy URL that is used if an environment variable for a specific protocol is not set.
- `no_proxy` specifies a comma-separated list of hosts names that do not use the proxy specified by an environment variable.

The environment variables must be set must and must be accessible to Greenplum Database on all Greenplum Database hosts.

For information about the configuration parameter `proxy`, see `s3 Protocol Configuration File`.

### About the s3 Protocol config Parameter

The optional `config` parameter specifies the location of the required `s3` protocol configuration file. The file contains Amazon Web Services (AWS) connection credentials and communication parameters. For information about the file, see `s3 Protocol Configuration File`.

The configuration file is required on all Greenplum Database segment hosts. This is default location is a location in the data directory of each Greenplum Database segment instance.

```
gpseg_data_dir/gpseg_prefixN/s3/s3.conf
```

The `gpseg_data_dir` is the path to the Greenplum Database segment data directory, the `gpseg_prefix` is the segment prefix, and `N` is the segment ID. The segment data directory, prefix, and ID are set when you initialize a Greenplum Database system.

If you have multiple segment instances on segment hosts, you can simplify the configuration by creating a single location on each segment host. Then you specify the absolute path to the location with the `config` parameter in the `s3` protocol `LOCATION` clause. This example specifies a location in the `gpadmin` home directory.

```
LOCATION ('s3://s3-us-west-2.amazonaws.com/test/my_data config=/home/gpadmin/s3.conf')
```

All segment instances on the hosts use the file `/home/gpadmin/s3.conf`.
s3 Protocol Configuration File

When using the s3 protocol, an s3 protocol configuration file is required on all Greenplum Database segments. The default location is:

```
gpseg_data_dir/gpseg-prefixN/s3/s3.conf
```

The `gpseg_data_dir` is the path to the Greenplum Database segment data directory, the `gpseg-prefix` is the segment prefix, and `N` is the segment ID. The segment data directory, prefix, and ID are set when you initialize a Greenplum Database system.

If you have multiple segment instances on segment hosts, you can simplify the configuration by creating a single location on each segment host. Then you can specify the absolute path to the location with the `config` parameter in the `s3` protocol `LOCATION` clause. However, note that both read-only and writable S3 external tables use the same parameter values for their connections. If you want to configure protocol parameters differently for read-only and writable S3 tables, then you must use two different s3 protocol configuration files and specify the correct file in the `CREATE EXTERNAL TABLE` statement when you create each table.

This example specifies a single file location in the s3 directory of the gpadmin home directory:

```
config=/home/gpadmin/s3/s3.conf
```

All segment instances on the hosts use the file `/home/gpadmin/s3/s3.conf`.

The s3 protocol configuration file is a text file that consists of a `[default]` section and parameters. This is an example configuration file:

```
[default]
secret = "secret"
accessid = "user access id"
threadnum = 3
chunksize = 67108864
```

You can use the Greenplum Database gpcheckcloud utility to test the S3 configuration file. See Using the gpcheckcloud Utility.

s3 Configuration File Parameters

**accessid**

Required. AWS S3 ID to access the S3 bucket.

**secret**

Required. AWS S3 passcode for the S3 ID to access the S3 bucket.

**autocompress**

For writable S3 external tables, this parameter specifies whether to compress files (using gzip) before uploading to S3. Files are compressed by default if you do not specify this parameter.

**chunksize**

The buffer size that each segment thread uses for reading from or writing to the S3 server. The default is 64 MB. The minimum is 8MB and the maximum is 128MB.

When inserting data to a writable S3 table, each Greenplum Database segment writes the data into its buffer (using multiple threads up to the `threadnum` value) until it is full, after which it writes the buffer to a file in the S3 bucket. This process is then repeated as necessary on each segment until the insert operation completes.

Because Amazon S3 allows a maximum of 10,000 parts for multipart uploads, the minimum `chunksize` value of 8MB supports a maximum insert size of 80GB per Greenplum database segment. The maximum `chunksize` value of 128MB supports a
maximum insert size 1.28TB per segment. For writable S3 tables, you must ensure that the chunksize setting can support the anticipated table size of your table. See *Multipart Upload Overview* in the S3 documentation for more information about uploads to S3.

**encryption**

Use connections that are secured with Secure Sockets Layer (SSL). Default value is true. The values true, t, on, yes, and y (case insensitive) are treated as true. Any other value is treated as false.

If the port is not specified in the URL in the LOCATION clause of the CREATE EXTERNAL TABLE command, the configuration file encryption parameter affects the port used by the s3 protocol (port 80 for HTTP or port 443 for HTTPS). If the port is specified, that port is used regardless of the encryption setting.

**gpcheckcloud_newline**

When downloading files from an S3 location, the gpcheckcloud utility appends a new line character to last line of a file if the last line of a file does not have an EOL (end of line) character. The default character is \n (newline). The value can be \n, \r (carriage return), or \n\r (newline/carriage return).

Adding an EOL character prevents the last line of one file from being concatenated with the first line of next file.

**low_speed_limit**

The upload/download speed lower limit, in bytes per second. The default speed is 10240 (10K). If the upload or download speed is slower than the limit for longer than the time specified by low_speed_time, then the connection is aborted and retried. After 3 retries, the s3 protocol returns an error. A value of 0 specifies no lower limit.

**low_speed_time**

When the connection speed is less than low_speed_limit, this parameter specified the amount of time, in seconds, to wait before aborting an upload to or a download from the S3 bucket. The default is 60 seconds. A value of 0 specifies no time limit.

**proxy**

Specify a URL that is the proxy that S3 uses to connect to a data source. S3 supports these protocols: HTTP, HTTPS, and SOCKS (4, 4a, 5, 5h). This is the format for the parameter.

```
proxy = protocol://[user:password@]proxyhost[:port]
```

If this parameter is not set or is an empty string (proxy = ""), S3 uses the proxy specified by the environment variable `http_proxy`, `https_proxy`, or `socks_proxy` (and the environment variables `all_proxy` and `no_proxy`). The environment variable that S3 uses depends on the protocol. For information about the environment variables, see *S3 Protocol Proxy Support* in the *Greenplum Database Administrator Guide*.

There can be at most one proxy parameter in the configuration file. The URL specified by the parameter is the proxy for all supported protocols.

**server_side_encryption**

The S3 server-side encryption method that has been configured for the bucket. Greenplum Database supports only server-side encryption with Amazon S3-managed keys, identified by the configuration parameter value `sse-s3`. Server-side encryption is disabled (none) by default.

**threadnum**

The maximum number of concurrent threads a segment can create when uploading data to or downloading data from the S3 bucket. The default is 4. The minimum is 1 and the maximum is 8.
**verycert**

Controls how the s3 protocol handles authentication when establishing encrypted communication between a client and an S3 data source over HTTPS. The value is either true or false. The default value is true.

- **verycert=false** - Ignores authentication errors and allows encrypted communication over HTTPS.
- **verycert=true** - Requires valid authentication (a proper certificate) for encrypted communication over HTTPS.

Setting the value to false can be useful in testing and development environments to allow communication without changing certificates.

**Warning:** Setting the value to false exposes a security risk by ignoring invalid credentials when establishing communication between a client and a S3 data store.

**version**

Specifies the version of the information specified in the LOCATION clause of the CREATE EXTERNAL TABLE command. The value is either 1 or 2. The default value is 1.

If the value is 1, the LOCATION clause supports an Amazon S3 URL, and does not contain the region parameter. If the value is 2, the LOCATION clause supports S3 compatible services and must include the region parameter. The region parameter specifies the S3 data source region. For this S3 URL s3://s3-us-west-2.amazonaws.com/s3test.example.com/dataset1/normal/, the AWS S3 region is us-west-2.

If version is 1 or is not specified, this is an example of the LOCATION clause of the CREATE EXTERNAL TABLE command that specifies an Amazon S3 endpoint.

```
LOCATION ('s3://s3-us-west-2.amazonaws.com/s3test.example.com/dataset1/normal/
           config=/home/gpadmin/aws_s3/s3.conf')
```

If version is 2, this is an example LOCATION clause with the region parameter for an AWS S3 compatible service.

```
LOCATION ('s3://test.company.com/s3test.company/test1/normal/
           region=local-test
           config=/home/gpadmin/aws_s3/s3.conf')
```

If version is 2, the LOCATION clause can also specify an Amazon S3 endpoint. This example specifies an Amazon S3 endpoint that uses the region parameter.

```
LOCATION ('s3://s3-us-west-2.amazonaws.com/s3test.example.com/dataset1/normal/
           region=us-west-2
           config=/home/gpadmin/aws_s3/s3.conf')
```

**Note:** Greenplum Database can require up to threadnum * chunksize memory on each segment host when uploading or downloading S3 files. Consider this s3 protocol memory requirement when you configure overall Greenplum Database memory.

**s3 Protocol Limitations**

These are s3 protocol limitations:

- Only the S3 path-style URL is supported.

```
s3://S3_endpoint/bucketname/[S3_prefix]
```
• Only the S3 endpoint is supported. The protocol does not support virtual hosting of S3 buckets (binding a domain name to an S3 bucket).

• AWS signature version 4 signing process is supported.

For information about the S3 endpoints supported by each signing process, see http://docs.aws.amazon.com/general/latest/gr/rande.html#s3_region.

• Only a single URL and optional configuration file is supported in the LOCATION clause of the CREATE EXTERNAL TABLE command.

• If the NEWLINE parameter is not specified in the CREATE EXTERNAL TABLE command, the newline character must be identical in all data files for specific prefix. If the newline character is different in some data files with the same prefix, read operations on the files might fail.

• For writable S3 external tables, only the INSERT operation is supported. UPDATE, DELETE, and TRUNCATE operations are not supported.

• Because Amazon S3 allows a maximum of 10,000 parts for multipart uploads, the maximum chunksize value of 128MB supports a maximum insert size of 1.28TB per Greenplum database segment for writable s3 tables. You must ensure that the chunksize setting can support the anticipated table size of your table. See Multipart Upload Overview in the S3 documentation for more information about uploads to S3.

• To take advantage of the parallel processing performed by the Greenplum Database segment instances, the files in the S3 location for read-only S3 tables should be similar in size and the number of files should allow for multiple segments to download the data from the S3 location. For example, if the Greenplum Database system consists of 16 segments and there was sufficient network bandwidth, creating 16 files in the S3 location allows each segment to download a file from the S3 location. In contrast, if the location contained only 1 or 2 files, only 1 or 2 segments download data.

Using the gpcheckcloud Utility

The Greenplum Database utility gpcheckcloud helps users create an s3 protocol configuration file and test a configuration file. You can specify options to test the ability to access an S3 bucket with a configuration file, and optionally upload data to or download data from files in the bucket.

If you run the utility without any options, it sends a template configuration file to STDOUT. You can capture the output and create an s3 configuration file to connect to Amazon S3.

The utility is installed in the Greenplum Database $GPHOME/bin directory.

Syntax

```
gpcheckcloud { -c | -d } "s3://S3_endpoint/bucketname/[S3_prefix]
  [config=path_to_config_file]"

gpcheckcloud -u <file_to_upload> "s3://S3_endpoint/bucketname/[S3_prefix]
  [config=path_to_config_file]"
gpcheckcloud -t

gpcheckcloud -h
```

Options

- **-c**
  Connect to the specified S3 location with the configuration specified in the s3 protocol URL and return information about the files in the S3 location.
  If the connection fails, the utility displays information about failures such as invalid credentials, prefix, or server address (DNS error), or server not available.

- **-d**
  Download data from the specified S3 location with the configuration specified in the s3 protocol URL and send the output to STDOUT.
  If files are gzip compressed, the uncompressed data is sent to STDOUT.
-u
Upload a file to the S3 bucket specified in the s3 protocol URL using the specified configuration file if available. Use this option to test compression and chunksize and autocompress settings for your configuration.

-t
Sends a template configuration file to STDOUT. You can capture the output and create an s3 configuration file to connect to Amazon S3.

-h
Display gpcheckcloud help.

Examples

This example runs the utility without options to create a template s3 configuration file mytest_s3.config in the current directory.

```
gpcheckcloud -t > ./mytest_s3.config
```

This example attempts to upload a local file, test-data.csv to an S3 bucket location using the s3 configuration file s3.mytestconf:

```
gpcheckcloud -u ./test-data.csv "s3://s3-us-west-2.amazonaws.com/test1/abc
config=s3.mytestconf"
```

A successful upload results in one or more files placed in the S3 bucket using the filename format abc<segment_id><random>.data[.gz]. See About S3 Data Files.

This example attempts to connect to an S3 bucket location with the s3 configuration file s3.mytestconf.

```
gpcheckcloud -c "s3://s3-us-west-2.amazonaws.com/test1/abc
config=s3.mytestconf"
```

Download all files from the S3 bucket location and send the output to STDOUT.

```
gpcheckcloud -d "s3://s3-us-west-2.amazonaws.com/test1/abc
config=s3.mytestconf"
```

Using a Custom Protocol

A custom protocol allows you to connect Greenplum Database to a data source that cannot be accessed with the file://, gpfdist://, or gphdfs:// protocols.

Creating a custom protocol requires that you implement a set of C functions with specified interfaces, declare the functions in Greenplum Database, and then use the CREATE TRUSTED PROTOCOL command to enable the protocol in the database.

See Example Custom Data Access Protocol for an example.

Handling Errors in External Table Data

By default, if external table data contains an error, the command fails and no data loads into the target database table.

Define the external table with single row error handling to enable loading correctly formatted rows and to isolate data errors in external table data. See Handling Load Errors.

The gpfdist file server uses the HTTP protocol. External table queries that use LIMIT end the connection after retrieving the rows, causing an HTTP socket error. If you use LIMIT in queries of external tables that use the gpfdist:// or http:// protocols, ignore these errors – data is returned to the database as expected.
Creating and Using External Web Tables

External web tables allow Greenplum Database to treat dynamic data sources like regular database tables. Because web table data can change as a query runs, the data is not rescannable.

`CREATE EXTERNAL WEB TABLE` creates a web table definition. You can define command-based or URL-based external web tables. The definition forms are distinct: you cannot mix command-based and URL-based definitions.

**Command-based External Web Tables**

The output of a shell command or script defines command-based web table data. Specify the command in the `EXECUTE` clause of `CREATE EXTERNAL WEB TABLE`. The data is current as of the time the command runs. The `EXECUTE` clause runs the shell command or script on the specified master, and/or segment host or hosts. The command or script must reside on the hosts corresponding to the host(s) defined in the `EXECUTE` clause.

By default, the command is run on segment hosts when active segments have output rows to process. For example, if each segment host runs four primary segment instances that have output rows to process, the command runs four times per segment host. You can optionally limit the number of segment instances that execute the web table command. All segments included in the web table definition in the `ON` clause run the command in parallel.

The command that you specify in the external table definition executes from the database and cannot access environment variables from `.bashrc` or `.profile`. Set environment variables in the `EXECUTE` clause. For example:

```
=# CREATE EXTERNAL WEB TABLE output (output text)
   EXECUTE 'PATH=/home/gpadmin/programs; export PATH; myprogram.sh'
   FORMAT 'TEXT';
```

Scripts must be executable by the `gpadmin` user and reside in the same location on the master or segment hosts.

The following command defines a web table that runs a script. The script runs on each segment host where a segment has output rows to process.

```
=# CREATE EXTERNAL WEB TABLE log_output
   (linenum int, message text)
   EXECUTE '/var/load_scripts/get_log_data.sh' ON HOST
   FORMAT 'TEXT' (DELIMITER '|');
```

**URL-based External Web Tables**

A URL-based web table accesses data from a web server using the HTTP protocol. Web table data is dynamic; the data is not rescannable.

Specify the `LOCATION` of files on a web server using `http://`. The web data file(s) must reside on a web server that Greenplum segment hosts can access. The number of URLs specified corresponds to the number of segment instances that work in parallel to access the web table. For example, if you specify two external files to a Greenplum Database system with eight primary segments, two of the eight segments access the web table in parallel at query runtime.

The following sample command defines a web table that gets data from several URLs.

```
=# CREATE EXTERNAL WEB TABLE ext_expenses (name text,
    date date, amount float4, category text, description text)
   LOCATION ('http://intranet.company.com/expenses/sales/file.csv',
```
Examples for Creating External Tables

These examples show how to define external data with different protocols. Each `CREATE EXTERNAL TABLE` command can contain only one protocol.

**Note:** When using IPv6, always enclose the numeric IP addresses in square brackets.

Start `gpfdist` before you create external tables with the `gpfdist` protocol. The following code starts the `gpfdist` file server program in the background on port **8081** serving files from directory `/var/data/staging`. The logs are saved in `/home/gpadmin/log`.

```
gpfdist -p 8081 -d /var/data/staging -l /home/gpadmin/log &
```

**Example 1—Single gpfdist instance on single-NIC machine**

Creates a readable external table, `ext_expenses`, using the `gpfdist` protocol. The files are formatted with a pipe (`|`) as the column delimiter.

```
=# CREATE EXTERNAL TABLE ext_expenses ( name text, 
   date date, amount float4, category text, desc1 text )
   LOCATION ('gpfdist://etlhost-1:8081/*')
   FORMAT 'TEXT' (DELIMITER '|');
```

**Example 2—Multiple gpfdist instances**

Creates a readable external table, `ext_expenses`, using the `gpfdist` protocol from all files with the `txt` extension. The column delimiter is a pipe (`|`) and NULL (`"`) is a space.

```
=# CREATE EXTERNAL TABLE ext_expenses ( name text, 
   date date, amount float4, category text, desc1 text )
   LOCATION ('gpfdist://etlhost-1:8081/*.txt',
   'gpfdist://etlhost-2:8081/*.txt')
   FORMAT 'TEXT' ( DELIMITER '|' NULL ' ') ;
```

**Example 3—Multiple gpfdists instances**

Creates a readable external table, `ext_expenses`, from all files with the `txt` extension using the `gpfdists` protocol. The column delimiter is a pipe (`|`) and NULL (`"`) is a space. For information about the location of security certificates, see `gpfdists:// Protocol`.

1. Run `gpfdist` with the `--ssl` option.
2. Run the following command.

```
=# CREATE EXTERNAL TABLE ext_expenses ( name text, 
   date date, amount float4, category text, desc1 text )
   LOCATION ('gpfdists://etlhost-1:8081/*.txt',
   'gpfdists://etlhost-2:8082/*.txt')
   FORMAT 'TEXT' ( DELIMITER '|' NULL ' ') ;
```
**Example 4—Single gpfdist instance with error logging**

Uses the gpfdist protocol to create a readable external table, `ext_expenses`, from all files with the `.txt` extension. The column delimiter is a pipe (`|`) and `NULL` (`' '`) is a space.

Access to the external table is single row error isolation mode. Input data formatting errors are captured internally in Greenplum Database with a description of the error. See [Viewing Bad Rows in the Error Log](#) for information about investigating error rows. If the error count on a segment is greater than five (the `SEGMENT REJECT LIMIT` value), the entire external table operation fails and no rows are processed.

```sql
=# CREATE EXTERNAL TABLE ext_expenses ( name text,
   date date, amount float4, category text, desc1 text )
 LOCATION ('gpfdist://etlhost-1:8081/*.txt',
   'gpfdist://etlhost-2:8082/*.txt')
 FORMAT 'TEXT' ( DELIMITER '|' NULL ' ')
 LOG ERRORS SEGMENT REJECT LIMIT 5;
```

To create the readable `ext_expenses` table from CSV-formatted text files:

```sql
=# CREATE EXTERNAL TABLE ext_expenses ( name text,
   date date, amount float4, category text, desc1 text )
 LOCATION ('gpfdist://etlhost-1:8081/*.txt',
   'gpfdist://etlhost-2:8082/*.txt')
 FORMAT 'CSV' (DELIMITER ',')
 LOG ERRORS SEGMENT REJECT LIMIT 5;
```

**Example 5—TEXT Format on a Hadoop Distributed File Server**

Creates a readable external table, `ext_expenses`, using the `gphdfs` protocol. The column delimiter is a pipe (`|`).

```sql
=# CREATE EXTERNAL TABLE ext_expenses ( name text,
   date date, amount float4, category text, desc1 text )
 LOCATION ('gphdfs://hdfshost-1:8081/data/filename.txt')
 FORMAT 'TEXT' (DELIMITER '|');
```

`gphdfs` requires only one data path.

For examples of reading and writing custom formatted data on a Hadoop Distributed File System, see [Reading and Writing Custom-Formatted HDFS Data](#).

**Example 6—Multiple files in CSV format with header rows**

Creates a readable external table, `ext_expenses`, using the `file` protocol. The files are CSV format and have a header row.

```sql
=# CREATE EXTERNAL TABLE ext_expenses ( name text,
   date date, amount float4, category text, desc1 text )
 LOCATION ('file://filehost/data/international/*',
   'file://filehost/data/regional/*',
   'file://filehost/data/supplement/*.csv')
 FORMAT 'CSV' (HEADER);
```
Example 7—Readable External Web Table with Script

Creates a readable external web table that executes a script once per segment host:

```sql
=# CREATE EXTERNAL WEB TABLE log_output (linenum int, message text) EXECUTE '/var/load_scripts/get_log_data.sh' ON HOST FORMAT 'TEXT' (DELIMITER '|');
```

Example 8—Writable External Table with gpfdist

Creates a writable external table, `sales_out`, that uses `gpfdist` to write output data to the file `sales.out`. The column delimiter is a pipe (`|`) and NULL (`") is a space. The file will be created in the directory specified when you started the gpfdist file server.

```sql
=# CREATE WRITABLE EXTERNAL TABLE sales_out (LIKE sales) LOCATION ('gpfdist://etl1:8081/sales.out') FORMAT 'TEXT' (DELIMITER '|' NULL ' ') DISTRIBUTED BY (txn_id);
```

Example 9—Writable External Web Table with Script

Creates a writable external web table, `campaign_out`, that pipes output data received by the segments to an executable script, `to_adreport_etl.sh`:

```sql
=# CREATE WRITABLE EXTERNAL WEB TABLE campaign_out (LIKE campaign) EXECUTE '/var/unload_scripts/to_adreport_etl.sh' FORMAT 'TEXT' (DELIMITER '|');
```

Example 10—Readable and Writable External Tables with XML Transformations

Greenplum Database can read and write XML data to and from external tables with gpfdist. For information about setting up an XML transform, see transforming external data with gpfdist and gpload.

Accessing External Data with PXF

Data managed by your organization may already reside in external sources. The Greenplum Platform Extension Framework (PXF) provides access to this external data via built-in connectors that map an external data source to a Greenplum Database table definition.

PXF is installed with HDFS, Hive, and HBase connectors. These connectors enable you to read external HDFS file system and Hive and HBase table data stored in text, Avro, JSON, RCFile, Parquet, SequenceFile, and ORC formats.

**Note:** PXF does not currently support filter predicate pushdown in the HDFS, Hive, and HBase connectors.

The Greenplum Platform Extension Framework includes a protocol C library and a Java service. After you configure and initialize PXF, you start a single PXF JVM process on each Greenplum Database segment host. This long-running process concurrently serves multiple query requests.

For detailed information about the architecture of and using PXF, refer to the Greenplum Platform Extension Framework (PXF) documentation.
**Accessing HDFS Data with gphdfs**

Greenplum Database leverages the parallel architecture of a Hadoop Distributed File System to read and write data files efficiently using the `gphdfs` protocol.

There are three steps to using the `gphdfs` protocol with HDFS:

- **One-time gphdfs Protocol Installation**
- **Grant Privileges for the gphdfs Protocol**
- **Specify gphdfs Protocol in an External Table Definition**

For information about using Greenplum Database external tables with Amazon EMR when Greenplum Database is installed on Amazon Web Services (AWS), also see [*Using Amazon EMR with Greenplum Database installed on AWS*](#).

**One-time gphdfs Protocol Installation**

Install and configure Hadoop for use with `gphdfs` as follows:

1. Install Java 1.7 or later on **all** Greenplum Database hosts: master, segment, and standby master.
2. Install a compatible Hadoop distribution on all hosts. The distribution must be the same on all hosts. For Hadoop installation information, see the Hadoop distribution documentation.
   - See the [*Greenplum Database Release Notes*](#) for information about compatible Hadoop distributions.
3. After installation, ensure that the Greenplum system user (`gpadmin`) has read and execute access to the Hadoop libraries or to the Greenplum MR client.
4. Set the following environment variables on **all** segments:
   - `JAVA_HOME` – the Java home directory
   - `HADOOP_HOME` – the Hadoop home directory

   For example, add lines such as the following to the `gpadmin` user `.bashrc` profile.

   ```bash
   export JAVA_HOME=/usr/java/default
   export HADOOP_HOME=/usr/lib/gphd
   ```

   The variables must be set in the `~gpadmin/.bashrc` or the `~gpadmin/.bash_profile` file so that the `gpadmin` user shell environment can locate the Java home and Hadoop home.
5. Set the following Greenplum Database server configuration parameters and restart Greenplum Database.

**Table 58: Server Configuration Parameters for Hadoop Targets**

<table>
<thead>
<tr>
<th>Configuration Parameter</th>
<th>Description</th>
<th>Default Value</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>gp_hadoop_target_version</code></td>
<td>The Hadoop target. Choose one of the following:</td>
<td><code>hadoop</code></td>
<td>master, session, reload</td>
</tr>
<tr>
<td></td>
<td>cdh</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>hadoop</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>hdp</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>mpr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Configuration Parameter</td>
<td>Description</td>
<td>Default Value</td>
<td>Set Classifications</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------</td>
<td>---------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>gp_hadoop_home</td>
<td>This parameter specifies the installation directory for Hadoop.</td>
<td>NULL</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

For example, the following commands use the Greenplum Database utilities `gpconfig` and `gpstop` to set the server configuration parameters and restart Greenplum Database:

```
   gpconfig -c gp_hadoop_target_version -v 'hdp'
gpstop -u
```

For information about the Greenplum Database utilities `gpconfig` and `gpstop`, see the *Greenplum Database Utility Guide*.

6. If needed, ensure that the `CLASSPATH` environment variable generated by the `$GPHOME/lib/hadoop/hadoop_env.sh` file on every Greenplum Database host contains the path to JAR files that contain Java classes that are required for `gphdfs`.

   For example, if `gphdfs` returns a class not found exception, ensure the JAR file containing the class is on every Greenplum Database host and update the `$GPHOME/lib/hadoop/hadoop_env.sh` file so that the `CLASSPATH` environment variable created by file contains the JAR file.

**About gphdfs JVM Memory**

When Greenplum Database accesses external table data from an HDFS location with the `gphdfs` protocol, each Greenplum Database segment on a host system starts a JVM for use by the protocol. The default JVM heapsize is 1GB and should be enough for most workloads.

If the `gphdfs` JVM runs out of memory, the issue might be related to the density of tuples inside the Hadoop HDFS block assigned to the `gphdfs` segment worker. A higher density of tuples per block requires more `gphdfs` memory. HDFS block size is usually 128MB, 256MB, or 512MB depending on the Hadoop cluster configuration.

You can increase the JVM heapsize by changing the `GP_JAVA_OPT` variable in the file `$GPHOME/lib/hadoop/hadoop_env.sh`. In this example line, the option `-Xmx1000m` specifies that the JVM consumes 1GB of virtual memory.

```
   export GP_JAVA_OPT=-Xmx1000m -XX:+DisplayVMOutputToStderr
```

The `$GPHOME/lib/hadoop/hadoop_env.sh` must be updated for every segment instance in the Greenplum Database system.

**Important:** Before increasing the `gphdfs` JVM memory, ensure that you have sufficient memory on the host. For example, 8 primary segments consume 8GB of virtual memory for the `gphdfs` JVM when using default. Increasing the Java `-Xmx` value to 2GB results in 16GB allocated in that environment of 8 segments per host.

**Grant Privileges for the gphdfs Protocol**

To enable privileges required to create external tables that access files on HDFS using `gphdfs`:

1. Grant the following privileges on `gphdfs` to the owner of the external table.
   - Grant `SELECT` privileges to enable creating readable external tables on HDFS.
   - Grant `INSERT` privileges to enable creating writable external tables on HDFS.
Use the **GRANT** command to grant read privileges (**SELECT**) and, if needed, write privileges (**INSERT**) on HDFS to the Greenplum system user (**gpadmin**).

```
grant insert on protocol gphdfs to gpadmin;
```

2. Greenplum Database uses OS credentials to connect to HDFS. Grant privileges and, if needed, write privileges to HDFS to the Greenplum administrative user (**gpadmin OS user**).

## Specify gphdfs Protocol in an External Table Definition

The **gphdfs** **LOCATION** clause of the **CREATE EXTERNAL TABLE** command for HDFS files differs slightly for Hadoop HA (High Availability) clusters, Hadoop clusters without HA, and MapR clusters.

In a Hadoop HA cluster, the **LOCATION** clause references the logical nameservices id (the **dfs.nameservices** property in the **hdfs-site.xml** configuration file). The **hdfs-site.xml** file with the nameservices configuration must be installed on the Greenplum master and on each segment host.

For example, if **dfs.nameservices** is set to **mycluster** the **LOCATION** clause takes this format:

```
location ('gphdfs://mycluster/path/filename.txt')
```

A cluster without HA specifies the hostname and port of the name node in the **LOCATION** clause:

```
location ('gphdfs://hdfs_host[:port]/path/filename.txt')
```

If you are using MapR clusters, you specify a specific cluster and the file:

- To specify the default cluster, the first entry in the MapR configuration file `/opt/mapr/conf/mapr-clusters.conf`, specify the location of your table with this syntax:

  ```
  location ('gphdfs://file_path')
  ```

  The **file_path** is the path to the file.

- To specify another MapR cluster listed in the configuration file, specify the file with this syntax:

  ```
  location ('gphdfs:///mapr/cluster_name/file_path')
  ```

  The **cluster_name** is the name of the cluster specified in the configuration file and **file_path** is the path to the file.

For information about MapR clusters, see the MapR documentation.

Restrictions for **HDFS** files are as follows.

- You can specify one path for a readable external table with **gphdfs**. Wildcard characters are allowed. If you specify a directory, the default is all files in the directory.

  You can specify only a directory for writable external tables.

- The URI of the **LOCATION** clause cannot contain any of these four characters: \\',\',\<,\>. The **CREATE EXTERNAL TABLE** returns a an error if the URI contains any of the characters.

- Format restrictions are as follows.

  - Only the **gphdfs_import** formatter is allowed for readable external tables with a custom format.
  - Only the **gphdfs_export** formatter is allowed for writable external tables with a custom format.
  - You can set compression only for writable external tables. Compression settings are automatic for readable external tables.
**Setting Compression Options for Hadoop Writable External Tables**

Compression options for Hadoop Writable External Tables use the form of a URI query and begin with a question mark. Specify multiple compression options with an ampersand (&).

<table>
<thead>
<tr>
<th>Compression Option</th>
<th>Values</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>compress</td>
<td>true or false</td>
<td>false</td>
</tr>
<tr>
<td>compression_type</td>
<td>BLOCK or RECORD</td>
<td>RECORD</td>
</tr>
<tr>
<td>codec</td>
<td>Codec class name</td>
<td>GzipCodec for text format and DefaultCodec for gphdfs_export format. For AVRO format, the value is either deflate (the default) or snappy</td>
</tr>
<tr>
<td>codec_level (for AVRO format and deflate codec only)</td>
<td>integer between 1 and 9</td>
<td>6 The level controls the trade-off between speed and compression. Valid values are 1 to 9, where 1 is the fastest and 9 is the most compressed.</td>
</tr>
</tbody>
</table>

Place compression options in the query portion of the URI.

**Support for Avro Files**

You can use the Greenplum Database gphdfs protocol to access Avro files on a Hadoop file system (HDFS).

**About the Avro File Format**

An Avro file stores both the data definition (schema) and the data together in one file making it easy for programs to dynamically understand the information stored in an Avro file. The Avro schema is in JSON format, the data is in a binary format making it compact and efficient.

The following example Avro schema defines an Avro record with 3 fields:

- name
- favorite_number
- favorite_color

```json
{"namespace": "example.avro",
"type": "record", "name": "User",
"fields": [
  {"name": "name", "type": "string"},
  {"name": "favorite_number", "type": ["int", "null"]},
  {"name": "favorite_color", "type": ["string", "null"]}
]
}
```

These are two rows of data based on the schema:

```json
{ "name" : "miguno" , "favorite_number" : 6 , "favorite_color" : "red" }
```
For information about the Avro file format, see [http://avro.apache.org/docs/1.7.7/](http://avro.apache.org/docs/1.7.7/)

**Required Avro Jar Files**

Support for the Avro file format requires these jar files:

- avro-1.7.7.jar
- avro-tools-1.7.7.jar
- avro-mapred-1.7.5-hadoop2.jar (available with Apache Pig)

**Note:** Hadoop 2 distributions include the Avro jar file `$HADOOP_HOME/share/hadoop/common/lib/avro-1.7.4.jar`. To avoid conflicts, you can rename the file to another file such as `avro-1.7.4.jar.bak`.

For the Cloudera 5.4.x Hadoop distribution, only the jar file `avro-mapred-1.7.5-hadoop2.jar` needs to be downloaded and installed. The distribution contains the other required jar files. The other files are included in the classpath used by the `gphdfs` protocol.

For information about downloading the Avro jar files, see [https://avro.apache.org/releases.html](https://avro.apache.org/releases.html).

On all the Greenplum Database hosts, ensure that the jar files are installed and are on the classpath used by the `gphdfs` protocol. The classpath is specified by the shell script `$GPHOME/lib/hadoop/hadoop_env.sh`.

As an example, if the directory `$HADOOP_HOME/share/hadoop/common/lib` does not exist, create it on all Greenplum Database hosts as the `gpadmin` user. Then, add the add the jar files to the directory on all hosts.

The `hadoop_env.sh` script file adds the jar files to classpath for the `gphdfs` protocol. This fragment in the script file adds the jar files to the classpath.

```bash
if [ -d "${HADOOP_HOME}/share/hadoop/common/lib" ]; then
    for f in ${HADOOP_HOME}/share/hadoop/common/lib/*.jar; do
        CLASSPATH=${CLASSPATH}:${f};
    done
```

**Avro File Format Support**

The Greenplum Database `gphdfs` protocol supports the Avro file type as an external table:

- Avro file format - GPDB certified with Avro version 1.7.7
- Reading and writing Avro files
- Support for overriding the Avro schema when reading an Avro file
- Compressing Avro files during writing
- Automatic Avro schema generation when writing an Avro file

Greenplum Database returns an error if the Avro file contains unsupported features or if the specified schema does not match the data.

**Reading from and Writing to Avro Files**

To read from or write to an Avro file, you create an external table and specify the location of the Avro file in the `LOCATION` clause and `AVRO` in the `FORMAT` clause. For example, this is the syntax for a readable external table.

```sql
CREATE EXTERNAL TABLE tablename (column_spec) LOCATION ('gphdfs://location') FORMAT 'AVRO'
```
The *location* can be an individual Avro file or a directory containing a set of Avro files. If the location specifies multiple files (a directory name or a file name containing wildcard characters), Greenplum Database uses the schema in the first file of the directory as the schema of the whole directory. For the file name you can specify the wildcard character * to match any number of characters.

You can add parameters after the file specified in the *location*. You add parameters with the http query string syntax that starts with ? and & between field and value pairs.

For readable external tables, the only valid parameter is *schema*. The gphdfs uses this schema instead of the Avro file schema when reading Avro files. See *Avro Schema Overrides for Readable External Tables*.

For writable external tables, you can specify *schema*, *namespace*, and parameters for compression.

**Table 60: Avro External Table Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Readable/Writable</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>schema</td>
<td>URL_to_schema_file</td>
<td>Read and Write</td>
<td>None.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For a readable external table</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• The specified schema overrides the schema in the</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Avro file. See <em>Avro Schema Overrides</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• If not specified, Greenplum Database uses the</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Avro file schema.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For a writable external table</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Uses the specified schema when creating the Avro</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>file.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• If not specified, Greenplum Database creates a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>schema according to the external table definition.</td>
</tr>
<tr>
<td>namespace</td>
<td>avro_namespace</td>
<td>Write only</td>
<td>public.avro</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>If specified, a valid Avro namespace.</td>
</tr>
<tr>
<td>compress</td>
<td>true or false</td>
<td>Write only</td>
<td>false</td>
</tr>
<tr>
<td>compression_type</td>
<td>block</td>
<td>Write only</td>
<td>Optional.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For <em>avro format</em>, <em>compression_type</em> must be</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>block if <em>compress</em> is true.</td>
</tr>
<tr>
<td>codec</td>
<td>deflate or snappy</td>
<td>Write only</td>
<td>deflate</td>
</tr>
<tr>
<td>codec_level</td>
<td>integer between 1 and 9</td>
<td>Write only</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The level controls the trade-off between speed and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>compression. Valid values are 1 to 9, where 1 is</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>the fastest and 9 is the most compressed.</td>
</tr>
</tbody>
</table>

This set of parameters specify *snappy* compression:

'compress=true&codec=snappy'
These two sets of parameters specify `deflate` compression and are equivalent:

```sql
'compress=true&codec=deflate&codec_level=1'
'compress=true&codec_level=1'
```

**Data Conversion When Reading Avro Files**

When you create a readable external table to Avro file data, Greenplum Database converts Avro data types to Greenplum Database data types.

**Note:** When reading an Avro, Greenplum Database converts the Avro field data at the top level of the Avro schema to a Greenplum Database table column. This is how the `gphdfs` protocol converts the Avro data types.

- An Avro primitive data type, Greenplum Database converts the data to a Greenplum Database type.
- An Avro complex data type that is not `map` or `record`, Greenplum Database converts the data to a Greenplum Database type.
- An Avro `record` that is a sub-record (nested within the top level Avro schema record), Greenplum Database converts the data XML.

This table lists the Avro primitive data types and the Greenplum Database type it is converted to.

### Table 61: Avro Primitive Data Type Support for Readable External Tables

<table>
<thead>
<tr>
<th>Avro Data Type</th>
<th>Greenplum Database Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>null</td>
<td>Supported only in a Avro union data type. See <strong>Data Conversion when Writing Avro Files.</strong></td>
</tr>
<tr>
<td>boolean</td>
<td>boolean</td>
</tr>
<tr>
<td>int</td>
<td>int or smallint</td>
</tr>
<tr>
<td>long</td>
<td>bigint</td>
</tr>
<tr>
<td>float</td>
<td>real</td>
</tr>
<tr>
<td>double</td>
<td>double</td>
</tr>
<tr>
<td>bytes</td>
<td>bytea</td>
</tr>
<tr>
<td>string</td>
<td>text</td>
</tr>
</tbody>
</table>

**Note:** When reading the Avro int data type as Greenplum Database smallint data type, you must ensure that the Avro int values do not exceed the Greenplum Database maximum smallint value. If the Avro value is too large, the Greenplum Database value will be incorrect.

The `gphdfs` protocol converts performs this conversion for smallint::short result = (short)IntValue;

This table lists the Avro complex data types and the and the Greenplum Database type it is converted to.

### Table 62: Avro Complex Data Type Support for Readable External Tables

<table>
<thead>
<tr>
<th>Avro Data Type</th>
<th>Greenplum Database Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>enum</td>
<td>int</td>
</tr>
<tr>
<td></td>
<td>The integer represents the zero-based position of the symbol in the schema.</td>
</tr>
</tbody>
</table>
The Greenplum Database array dimensions match the Avro array dimensions. The element type is converted from the Avro data type to the Greenplum Database data type.

<table>
<thead>
<tr>
<th>Avro Data Type</th>
<th>Greenplum Database Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>array</td>
<td>array</td>
</tr>
<tr>
<td>maps</td>
<td>Not supported</td>
</tr>
<tr>
<td>union</td>
<td>The first non-null data type.</td>
</tr>
<tr>
<td>fixed</td>
<td>bytea</td>
</tr>
<tr>
<td>record</td>
<td>XML data</td>
</tr>
</tbody>
</table>

**Example Avro Schema**

This is an example Avro schema. When reading the data from the Avro file the `gphdfs` protocol performs these conversions:

- name and color data are converted to Greenplum Database string.
- age data is converted to Greenplum Database int.
- clist records are converted to XML.

```json
{
  "namespace": "example.avro",
  "type": "record",
  "name": "User",
  "fields": [
    {
      "name": "name", "type": "string"},
    {
      "name": "number", "type": ["int", "null"]},
    {
      "name": "color", "type": ["string", "null"]},
    {
      "name": "clist",
      "type": {
        "type": "record",
        "name": "clistRecord",
        "fields": [
          {
            "name": "class", "type": ["string", "null"]},
          {
            "name": "score", "type": ["double", "null"]},
          {
            "name": "grade",
            "type": {
              "type": "record",
              "name": "inner2",
              "fields": [
                {
                  "name": "a", "type": ["double", "null"]},
                {
                  "name": "b", "type": ["string", "null"]}
              ]
            }
          }
        ]
      }
    }
  ]
}
```
This XML is an example of how the gpfist protocol converts Avro data from the clist field to XML data based on the previous schema. For records nested in the Avro top-level record, gpfist protocol converts the Avro element name to the XML element name and the name of the record is an attribute of the XML element. For example, the name of the top most element clist and the type attribute is the name of the Avro record element clistRecord.

<clist type="clistRecord">
  <class type="string">math</class>
  <score type="double">99.5</score>
  <grade type="inner2">
    <a type="double">88.8</a>
    <b type="string">subb0</b>
  </grade>
  <grade2 type="inner">
    <a type="double">77.7</a>
    <b type="string">subb20</b>
    <c type="inner3">
      <c1 type="string">subc</c1>
      <c2 type="int">0</c2>
    </c>
  </grade2>
</clist>

**Avro Schema Overrides for Readable External Tables**

When you specify schema for a readable external table that specifies an Avro file as a source, Greenplum Database uses the schema when reading data from the Avro file. The specified schema overrides the Avro file schema.

You can specify a file that contains an Avro schema as part of the location parameter `CREATE EXTERNAL TABLE` command, to override the Avro file schema. If a set of Avro files contain different, related schemas, you can specify an Avro schema to retrieve the data common to all the files.

Greenplum Database extracts the data from the Avro files based on the field name. If an Avro file contains a field with same name, Greenplum Database reads the data, otherwise a NULL is returned.

For example, if a set of Avro files contain one of the two different schemas. This is the original schema.

```json
{
  "type":"record",
  "name":"tav2",
  "namespace":"public.avro",
  "doc":"
  "fields":[
    {"name":"id","type":null,"int"},{"null","int"},{"null","int"},
    {"name":"name","type":null,"string"},{"null","string"},{"null","string"},
    {"name":"age","type":null,"long"},{"null","long"},{"null","long"}
  ]
}
```

This updated schema contains a comment field.

```json
{
  "type":"record",
  "name":"tav2",
  "namespace":"public.avro",
  "doc":"
  "fields":
    {"name":"id","type":null,"int"},{"null","int"},{"null","int"},
    {"name":"name","type":null,"string"},{"null","string"},{"null","string"},
    {"name":"age","type":null,"long"},{"null","long"},{"null","long"}
  ]
}
```
You can specify a file containing this Avro schema in a `CREATE EXTERNAL TABLE` command, to read the `id`, `name`, `birth`, and `comment` fields from the Avro files.

```json
{
"type": "record",
"name": "tav2",
"namespace": "public.avro",
"doc": "",
"fields": [
{"name": "id", "type": ["null", "int"], "doc": ""},
{"name": "name", "type": ["null", "string"], "doc": ""},
{"name": "birth", "type": ["null", "string"], "doc": ""},
{"name": "age", "type": ["null", "long"], "doc": ","},
{"name": "comment", "type": ["null", "string"], "doc": ""
]
}
```

In this example command, the customer data is in the Avro files `tmp/cust*.avro`. Each file uses one of the schemas listed previously. The file `avro/cust.avsc` is a text file that contains the Avro schema used to override the schemas in the customer files.

```sql
CREATE WRITABLE EXTERNAL TABLE cust_avro(id int, name text, birth date)
LOCATION ('gphdfs://my_hdfs:8020/tmp/cust*.avro
?schema=hdfs://my_hdfs:8020/avro/cust.avsc')
FORMAT 'avro';
```

When reading the Avro data, if Greenplum Database reads a file that does not contain a `comment` field, a `NULL` is returned for the `comment` data.

### Data Conversion when Writing Avro Files

When you create a writable external table to write data to an Avro file, each table row is an Avro record and each table column is an Avro field. When writing an Avro file, the default compression algorithm is `deflate`.

For a writable external table, if the `schema` option is not specified, Greenplum Database creates an Avro schema for the Avro file based on the Greenplum Database external table definition. The name of the table column is the Avro field name. The data type is a union data type. See the following table:

#### Table 63: Avro Data Types Generated by Greenplum Database

<table>
<thead>
<tr>
<th>Greenplum Database Data Type</th>
<th>Avro Union Data Type Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>boolean</td>
<td>[&quot;boolean&quot;, &quot;null&quot;]</td>
</tr>
<tr>
<td>int</td>
<td>[&quot;int&quot;, &quot;null&quot;]</td>
</tr>
<tr>
<td>bigint</td>
<td>[&quot;long&quot;, &quot;null&quot;]</td>
</tr>
<tr>
<td>smallint</td>
<td>[&quot;int&quot;, &quot;null&quot;]</td>
</tr>
<tr>
<td>Greenplum Database Data Type</td>
<td>Avro Union Data Type Definition</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>real</td>
<td>[&quot;float&quot;, &quot;null&quot;]</td>
</tr>
<tr>
<td>double</td>
<td>[&quot;double&quot;, &quot;null&quot;]</td>
</tr>
<tr>
<td>bytea</td>
<td>[&quot;bytes&quot;, &quot;null&quot;]</td>
</tr>
<tr>
<td>text</td>
<td>[&quot;string&quot;, &quot;null&quot;]</td>
</tr>
<tr>
<td>array</td>
<td>[&quot;string&quot;, &quot;null&quot;]</td>
</tr>
</tbody>
</table>

The Greenplum Database array is converted to an Avro array with same dimensions and same element type as the Greenplum Database array.

other data types | ["string", "null"]

Data are formatted strings. The gphdfs protocol casts the data to Greenplum Database text and writes the text to the Avro file as an Avro string. For example, date and time data are formatted as date and time strings and converted to Avro string type.

You can specify a schema with the `schema` option. When you specify a schema, the file can be on the segment hosts or a file on the HDFS that is accessible to Greenplum Database. For a local file, the file must exist in all segment hosts in the same location. For a file on the HDFS, the file must exist in the same cluster as the data file.

This example `schema` option specifies a schema on an HDFS.

```sql
'schema=hdfs://mytest:8000/avro/array_simple.avsc'
```

This example `schema` option specifies a schema on the host file system.

```sql
'schema=file:///mydata/avro_schema/array_simple.avsc'
```

**gphdfs Limitations for Avro Files**

For a Greenplum Database writable external table definition, columns cannot specify the NOT NULL clause.

Greenplum Database supports only a single top-level schema in Avro files or specified with the `schema` parameter in the `CREATE EXTERNAL TABLE` command. An error is returned if Greenplum Database detects multiple top-level schemas.

Greenplum Database does not support the Avro map data type and returns an error when encountered.

When Greenplum Database reads an array from an Avro file, the array is converted to the literal text value. For example, the array `[1,3]` is converted to `'{1,3}'`.

User defined types (UDT), including array UDT, are supported. For a writable external table, the type is converted to string.

**Examples**

Simple `CREATE EXTERNAL TABLE` command that reads data from the two Avro fields `id` and `ba`.

```sql
CREATE EXTERNAL TABLE avro1 (id int, ba bytea[])
    LOCATION ('gphdfs://my_hdfs:8020/avro/singleAvro/array2.avro')
    FORMAT 'avro';
```
CREATE WRITABLE EXTERNAL TABLE command specifies the Avro schema that is the gphdfs protocol uses to create the Avro file.

```
CREATE WRITABLE EXTERNAL TABLE at1w(id int, names text[], nums int[])
    LOCATION ('gphdfs://my_hdfs:8020/tmp/at1
    ?schema=hdfs://my_hdfs:8020/avro/array_simple.avsc')
    FORMAT 'avro';
```

CREATE WRITABLE EXTERNAL TABLE command that writes to an Avro file and specifies a namespace for the Avro schema.

```
CREATE WRITABLE EXTERNAL TABLE atudtl (id int, info myt, birth date, salary numeric )
    LOCATION ('gphdfs://my_hdfs:8020/tmp/emp01.avro
    ?namespace=public.example.avro')
    FORMAT 'avro';
```

### Support for Parquet Files

You can use the Greenplum Database gphdfs protocol to access Parquet files on a Hadoop file system (HDFS).

#### About the Parquet File Format

The Parquet file format is designed to take advantage of compressed, efficient columnar data representation available to projects in the Hadoop ecosystem. Parquet supports complex nested data structures and uses Dremel record shredding and assembly algorithms. Parquet supports very efficient compression and encoding schemes. Parquet allows compression schemes to be specified on a per-column level, and supports adding more encodings as they are invented and implemented.

For information about the Parquet file format, see the Parquet documentation [http://parquet.apache.org/documentation/latest/](http://parquet.apache.org/documentation/latest/).


#### Required Parquet Jar Files

Support for the Parquet file format requires these jar files:

- parquet-hadoop-1.7.0.jar
- parquet-common-1.7.0.jar
- parquet-encoding-1.7.0.jar
- parquet-column-1.7.0.jar
- parquet-generator-1.7.0.jar
- parquet-format-2.3.0-incubating.jar

**Note:** The Cloudera 5.4.x Hadoop distribution includes some Parquet jar files. However, the Java class names in the jar files are `parquet.xxx`. The gphdfs protocol uses the Java class names `org.apache.parquet.xxx`. The jar files with the class name `org.apache.parquet` can be downloaded and installed on the Greenplum Database hosts.

The gphdfs protocol also supports using `parquet-hadoop-bundle-1.7.0.jar` that contains the classes required to use Parquet within a Hadoop environment. These versions of `parquet-hadoop-bundle` are not supported:

- Version 1.6 and earlier. The versions do not use the Java class names `org.apache.parquet`
- Version 1.8 and later. The versions contain the class `VersionParser` that is not supported by gphdfs.
For information about downloading the Parquet jar files, see [http://parquet.apache.org/downloads/](http://parquet.apache.org/downloads/)

On all the Greenplum Database hosts, ensure that the jar files are installed and are on the classpath used by the gphdfs protocol. The classpath is specified by the shell script `$GPHOME/lib/hadoop/hadoop_env.sh`. As a Hadoop 2 example, you can install the jar files in `$HADOOP_HOME/share/hadoop/common/lib`. The `hadoop_env.sh` script file adds the jar files to the classpath.

As an example, if the directory `$HADOOP_HOME/share/hadoop/common/lib` does not exist, create it on all Greenplum Database hosts as the `gpadmin` user. Then, add the add the jar files to the directory on all hosts.

The `hadoop_env.sh` script file adds the jar files to classpath for the gphdfs protocol. This fragment in the script file adds the jar files to the classpath.

```bash
if [ -d "${HADOOP_HOME}/share/hadoop/common/lib" ]; then
    for f in ${HADOOP_HOME}/share/hadoop/common/lib/*/jar; do
        CLASSPATH=${CLASSPATH}:${f};
    done
    done
```

### Parquet File Format Support

The Greenplum Database gphdfs protocol supports the Parquet file format version 1 or 2. Parquet takes advantage of compressed, columnar data representation on HDFS. In a Parquet file, the metadata (Parquet schema definition) contains data structure information is written after the data to allow for single pass writing.

This is an example of the Parquet schema definition format:

```plaintext
message test {
    repeated byte_array binary_field;
    required int32 int32_field;
    optional int64 int64_field;
    required boolean boolean_field;
    required fixed_len_byte_array(3) flba_field;
    required byte_array someDay (utf8);
}
```

The definition for last field `someDay` specifies the `binary` data type with the `utf8` annotation. The data type and annotation defines the data as a UTF-8 encoded character string.

### Reading from and Writing to Parquet Files

To read from or write to a Parquet file, you create an external table and specify the location of the parquet file in the `LOCATION` clause and `PARQUET` in the `FORMAT` clause. For example, this is the syntax for a readable external table.

```sql
CREATE EXTERNAL TABLE tablename (column_spec) LOCATION
    ('gphdfs://location') FORMAT 'PARQUET'
```

The `location` can be an Parquet file or a directory containing a set of Parquet files. For the file name you can specify the wildcard character `*` to match any number of characters. If the location specifies multiple files when reading Parquet files, Greenplum Database uses the schema in the first file that is read as the schema for the other files.

### Reading a Parquet File

The following table identifies how Greenplum database converts the Parquet data type if the Parquet schema definition does not contain an annotation.
### Table 64: Data Type Conversion when Reading a Parquet File

<table>
<thead>
<tr>
<th>Parquet Data Type</th>
<th>Greenplum Database Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>boolean</td>
<td>boolean</td>
</tr>
<tr>
<td>int32</td>
<td>int or smallint</td>
</tr>
<tr>
<td>int64</td>
<td>long</td>
</tr>
<tr>
<td>int96</td>
<td>bytea</td>
</tr>
<tr>
<td>float</td>
<td>real</td>
</tr>
<tr>
<td>double</td>
<td>double</td>
</tr>
<tr>
<td>byte_array</td>
<td>bytea</td>
</tr>
<tr>
<td>fixed_len_byte_array</td>
<td>bytea</td>
</tr>
</tbody>
</table>

**Note:** When reading the Parquet `int` data type as Greenplum Database `smallint` data type, you must ensure that the Parquet `int` values do not exceed the Greenplum Database maximum `smallint` value. If the value is too large, the Greenplum Database value will be incorrect.

The `gphdfs` protocol considers Parquet schema annotations for these cases. Otherwise, data conversion is based on the parquet schema primitive type:

### Table 65: Data Type (with Annotation) Conversion when Reading Parquet File

<table>
<thead>
<tr>
<th>Parquet Schema Data Type and Annotation</th>
<th>Greenplum Database Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>binary with <code>json</code> or <code>utf8</code> annotation</td>
<td>text</td>
</tr>
<tr>
<td>binary and the Greenplum Database column data type is text</td>
<td>text</td>
</tr>
<tr>
<td>int32 with <code>int_16</code> annotation</td>
<td>smallint</td>
</tr>
<tr>
<td>int32, int64, fixed_len_byte_array, or binary with decimal</td>
<td>decimal</td>
</tr>
<tr>
<td>repeated</td>
<td>array column - The data type is converted according to <em>Table 64: Data Type Conversion when Reading a Parquet File</em></td>
</tr>
<tr>
<td>optional, required</td>
<td>Data type is converted according to <em>Table 64: Data Type Conversion when Reading a Parquet File</em></td>
</tr>
</tbody>
</table>

**Note:** See *Limitations and Notes* and the Parquet documentation when specifying `decimal`, `date`, `interval`, or `time*` annotations.

The `gphdfs` protocol converts the field data to text if the Parquet field type is binary without any annotation, and the data type is defined as text for the corresponding Greenplum Database external table column.

When reading Parquet type `group`, the `gphdfs` protocol converts the `group` data into an XML document. This schema contains a required group with the name `inner`.

```plaintext
message test {
  required byte_array binary_field;
  required int64 int64_field;
  required group inner {
    int32 age;
  }
}"
```
This is how a single row of the group data would be converted to XML.

```
message test {
  required byte_array binary_field;
  required int64 int64_field;
  repeated group inner {
    int32 age;
    required boolean test;
    required byte_array name (UTF8);
  }
}
```

This example schema contains a repeated group with the name `inner`.

```
<inner type="group">
  <age type="int">50</age>
  <test type="boolean">true</test>
  <name type="string">fred</name>
</inner>
```

For a repeated group, the Parquet file can contain multiple sets of the group data in a single row. For the example schema, the data for the `inner` group is converted into XML data.

This is sample output if the data in the Parquet file contained two sets of data for the `inner` group.

```
<inner type="repeated">
  <inner type="group">
    <age type="int">50</age>
    <test type="boolean">true</test>
    <name type="string">fred</name>
  </inner>
  <inner>
    <age type="int">23</age>
    <test type="boolean">false</test>
    <name type="string">sam</name>
  </inner>
</inner>
```

**Reading a Hive Generated Parquet File**

The Apache Hive data warehouse software can manage and query large datasets that reside in distributed storage. Apache Hive 0.13.0 and later can store data in Parquet format files. For information about Parquet used by Apache Hive, see [https://cwiki.apache.org/confluence/display/Hive/Parquet](https://cwiki.apache.org/confluence/display/Hive/Parquet).

For Hive 1.1 data stored in Parquet files, this table lists how Greenplum database converts the data. The conversion is based on the Parquet schema that is generated by Hive. For information about the Parquet schema generated by Hive, see [Notes on the Hive Generated Parquet Schema](https://cwiki.apache.org/confluence/display/Hive/Parquet).

**Table 66: Data Type Conversion when Reading a Hive Generated Parquet File**

<table>
<thead>
<tr>
<th>Hive Data Type</th>
<th>Greenplum Database Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>tinyint</td>
<td>int</td>
</tr>
<tr>
<td>smallint</td>
<td>int</td>
</tr>
</tbody>
</table>
### Notes on the Hive Generated Parquet Schema

- **When writing data to Parquet files**, Hive treats all integer data types `tinyint`, `smallint`, `int` as `int32`. When you create an external table in Greenplum Database for a Hive generated Parquet file, specify the column data type as `int`. For example, this Hive `CREATE TABLE` command stores data in Parquet files.

```sql
CREATE TABLE hpSimple(c1 tinyint, c2 smallint, c3 int, c4 bigint,
c5 float, c6 double, c7 boolean, c8 string)
STORED AS PARQUET;
```

This is the Hive generated Parquet schema for the `hpSimple` table data.

```java
message hive_schema {
  optional int32 c1;
  optional int32 c2;
  optional int32 c3;
  optional int64 c4;
  optional float c5;
  optional double c6;
  optional boolean c7;
  optional binary c8 (UTF8);
}
```

The `gphdfs` protocol converts the Parquet integer data types to the Greenplum Database data type `int`.

- For the Hive `char` data type, the Greenplum Database column data types can be either `text` or `char`. For the Hive `varchar` data type, the Greenplum Database column data type can be either `text` or `varchar`.

- Based on the Hive generated Parquet schema, some Hive data is converted to Greenplum Database XML data. For example, Hive array column data that is stored in a Parquet file is converted to XML.
data. As an example, this the Hive generated Parquet schema for a Hive column col1 of data type array[int].

```sql
optional group col1 (LIST) {
  repeated group bag {
    optional int32 array_element;
  }
}
```

The gphdfs protocol converts the Parquet group data to the Greenplum Database data type XML.

- For the Hive timestamp data type, the Hive generated Parquet schema for the data type specifies that the data is stored as data type int96. The gphdfs protocol converts the int96 data type to the Greenplum Database bytea data type.

**Writing a Parquet File**

For writable external tables, you can add parameters after the file specified in the location. You add parameters with the http query string syntax that starts with ? and & between field and value pairs.

**Table 67: Parquet Format External Table location Parameters**

<table>
<thead>
<tr>
<th>Option</th>
<th>Values</th>
<th>Readable/Writable</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>schema</td>
<td>URL_to_schema</td>
<td>Write only</td>
<td>None. If not specified, the gphdfs protocol creates a schema according to the external table definition.</td>
</tr>
<tr>
<td>pagesize</td>
<td>&gt; 1024 Bytes</td>
<td>Write only</td>
<td>1 MB</td>
</tr>
<tr>
<td>rowgroupsize</td>
<td>&gt; 1024 Bytes</td>
<td>Write only</td>
<td>8 MB</td>
</tr>
<tr>
<td>version</td>
<td>v1, v2</td>
<td>Write only</td>
<td>v1</td>
</tr>
<tr>
<td>codec</td>
<td>UNCOMPRESSED, GZIP, LZO, snappy</td>
<td>Write only</td>
<td>UNCOMPRESSED</td>
</tr>
<tr>
<td>dictionaryenable</td>
<td>true, false</td>
<td>Write only</td>
<td>false</td>
</tr>
<tr>
<td>dictionarypagesize</td>
<td>&gt; 1024 Bytes</td>
<td>Write only</td>
<td>512 KB</td>
</tr>
</tbody>
</table>

**Note:**

1. Creates an internal dictionary. Enabling a dictionary can improve Parquet file compression if text columns contain similar or duplicate data.

When writing a Parquet file, the gphdfs protocol can generate a Parquet schema based on the table definition.

- The table name is used as the Parquet message name.
- The column name is uses as the Parquet field name.

When creating the Parquet schema from a Greenplum Database table definition, the schema is generated based on the column data type.

**Table 68: Schema Data Type Conversion when Writing a Parquet File**

<table>
<thead>
<tr>
<th>Greenplum Database Data Type</th>
<th>Parquet Schema Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>boolean</td>
<td>optional boolean</td>
</tr>
</tbody>
</table>
Greenplum Database Data Type | Parquet Schema Data Type
--- | ---
smallint | optional int32 with annotation `int_16`
int | optional int32
bigint | optional int64
real | optional float
double | optional double
numeric or decimal | binary with annotation `decimal`
bytea | optional binary
array column | repeated field - The data type is the same data type as the Greenplum Database the array. For example, `array[int]` is converted to repeated `int`

Others | binary with annotation `utf8`

**Note:** To support null data, `gphdfs` protocol specifies the Parquet optional schema annotation when creating a Parquet schema.

A simple example of a Greenplum Database table definition and the Parquet schema generated by the `gphdfs` protocol.

An example external table definition for a Parquet file.

```sql
CREATE WRITABLE EXTERNAL TABLE films (  
  code char(5),  
  title varchar(40),  
  id integer,  
  date_prod date,  
  subtitle boolean  
) LOCATION ( 'gphdfs://my-films') FORMAT 'PARQUET' ;
```

This is the Parquet schema for the Parquet file `my-films` generated by the `gphdfs` protocol.

```plaintext
message films {  
  optional byte_array code;  
  optional byte_array title (utf8);  
  optional int32 id;  
  optional binary date_prod (utf8);  
  optional boolean subtitle;  
};
```

**Limitations and Notes**

- For writable external tables, column definitions in Greenplum Database external table cannot specify `NOT NULL` to support automatically generating a Parquet schema. When the `gphdfs` protocol automatically generates a Parquet schema, the `gphdfs` protocol specifies the field attribute `optional` to support null in the Parquet schema. Repeated fields can be null in Parquet.
- The `gphdfs` protocol supports Parquet nested `group` structures only for readable external files. The nested structures are converted to an XML document.
- Greenplum Database does not have an unsigned `int` data type. Greenplum Database converts the Parquet unsigned `int` data type to the next largest Greenplum Database `int` type. For example, `Parquet uint_8` is converted to Greenplum Database `int (32 bit).`
• Greenplum Database supports any UDT data type or UDT array data type. Greenplum Database attempts to convert the UDT to a sting. If the UDT cannot be converted to a sting, Greenplum Database returns an error.

• The definition of the Interval data type in Parquet is significantly different than the Interval definition in Greenplum Database and cannot be converted. The Parquet Interval data is formatted as bytea.

• The Date data type in Parquet is starts from 1970.1.1, while Date in Greenplum Database starts from 4173 BC, Greenplum Database cannot convert date data types because largest values are different. A similar situation occurs between Timestamp_millis in Parquet and Timestamp in Greenplum Database.

### HDFS Readable and Writable External Table Examples

The following code defines a readable external table for an HDFS file named `filename.txt` on port 8081.

```sql
=# CREATE EXTERNAL TABLE ext_expenses (  
  name text,  
  date date,  
  amount float4,  
  category text,  
  descr text  
)  
LOCATION ('gphdfs://hdfshost-1:8081/data/filename.txt')  
FORMAT 'TEXT' (DELIMITER ',');
```

The following code defines a set of readable external tables that have a custom format located in the same HDFS directory on port 8081.

```sql
=# CREATE EXTERNAL TABLE ext_expenses  
  LOCATION ('gphdfs://hdfshost-1:8081/data/custdat*.dat')  
  FORMAT 'custom' (formatter='gphdfs_import');
```

The following code defines an HDFS directory for a writable external table on port 8081 with all compression options specified.

```sql
=# CREATE WRITABLE EXTERNAL TABLE ext_expenses  
  LOCATION ('gphdfs://hdfshost-1:8081/data/?  
  compress=true&compression_type=RECORD  
  &codec=org.apache.hadoop.io.compress.DefaultCodec')  
  FORMAT 'custom' (formatter='gphdfs_export');
```

Because the previous code uses the default compression options for compression_type and codec, the following command is equivalent.

```sql
=# CREATE WRITABLE EXTERNAL TABLE ext_expenses  
  LOCATION ('gphdfs://hdfshost-1:8081/data?compress=true')  
  FORMAT 'custom' (formatter='gphdfs_export');
```

### Reading and Writing Custom-Formatted HDFS Data

Use MapReduce and the `CREATE EXTERNAL TABLE` command to read and write data with custom formats on HDFS.

To read custom-formatted data:

1. Author and run a MapReduce job that creates a copy of the data in a format accessible to Greenplum Database.
2. Use `CREATE EXTERNAL TABLE` to read the data into Greenplum Database.
See Example 1 - Read Custom-Formatted Data from HDFS.

To write custom-formatted data:

1. Write the data.
2. Author and run a MapReduce program to convert the data to the custom format and place it on the Hadoop Distributed File System.

See Example 2 - Write Custom-Formatted Data from Greenplum Database to HDFS.

MapReduce code is written in Java. Greenplum provides Java APIs for use in the MapReduce code. The Javadoc is available in the $GPHOME/docs directory. To view the Javadoc, expand the file gnet-1.2-javadoc.tar and open index.html. The Javadoc documents the following packages:

   com.emc.greenplum.gpdb.hadoop.io
   com.emc.greenplum.gpdb.hadoop.mapreduce.lib.input
   com.emc.greenplum.gpdb.hadoop.mapreduce.lib.output

The HDFS cross-connect packages contain the Java library, which contains the packages GPDBWritable, GPDBInputFormat, and GPDBOutputFormat. The Java packages are available in $GPHOME/lib/hadoop. Compile and run the MapReduce job with the cross-connect package. For example, compile and run the MapReduce job with hdp-gnet-1.2.0.0.jar if you use the HDP distribution of Hadoop.

To make the Java library available to all Hadoop users, the Hadoop cluster administrator should place the corresponding gphdfs connector jar in the $HADOOP_HOME/lib directory and restart the job tracker. If this is not done, a Hadoop user can still use the gphdfs connector jar; but with the distributed cache technique.

**Example 1 - Read Custom-Formatted Data from HDFS**

The sample code makes the following assumptions.

- The data is contained in HDFS directory /demo/data/temp and the name node is running on port 8081.
- This code writes the data in Greenplum Database format to /demo/data/MRTest1 on HDFS.
- The data contains the following columns, in order.
  1. A long integer
  2. A Boolean
  3. A text string

**Sample MapReduce Code**

```java
import com.emc.greenplum.gpdb.hadoop.io.GPDBWritable;
import com.emc.greenplum.gpdb.hadoop.mapreduce.lib.input.GPDBInputFormat;
import com.emc.greenplum.gpdb.hadoop.mapreduce.lib.output.GPDBOutputFormat;
import java.io.*;
import java.util.*;
import org.apache.hadoop.fs.Path;
import org.apache.hadoop.conf.*;
import org.apache.hadoop.io.*;
import org.apache.hadoop.mapreduce.*;
import org.apache.hadoop.mapreduce.lib.output.*;
import org.apache.hadoop.mapreduce.lib.input.*;
import org.apache.hadoop.util.*;

public class demoMR {
    /*
     * Helper routine to create our generic record. This section shows the
```
* format of the data. Modify as necessary.
*/
public static GPDBWritable generateGenericRecord() throws IOException {
    int[] colType = new int[3];
    colType[0] = GPDBWritable.BIGINT;
    colType[1] = GPDBWritable.BOOLEAN;
    colType[2] = GPDBWritable.VARCHAR;
    
    /*
     * This section passes the values of the data. Modify as necessary.
     */
    GPDBWritable gw = new GPDBWritable(colType);
    gw.setLong (0, (long)12345);
    gw.setBoolean(1, true);
    gw.setString (2, "abcdef");
    return gw;
}

/*
 * DEMO Map/Reduce class test1
 * -- Regardless of the input, this section dumps the generic record
 * into GPDBFormat/
 */
public static class Map_test1
    extends Mapper<LongWritable, Text, LongWritable, GPDBWritable> {
    private LongWritable word = new LongWritable(1);
    
    public void map(LongWritable key, Text value, Context context) throws IOException {
        try {
            GPDBWritable gw = generateGenericRecord();
            context.write(word, gw);
        } 
        catch (Exception e) { 
            throw new IOException (e.getMessage());
        }
    }
}

Configuration conf = new Configuration(true);
Job job = new Job(conf, "test1");
job.setJarByClass(demoMR.class);
job.setInputFormatClass(TextInputFormat.class);
job.setOutputKeyClass (LongWritable.class);
job.setOutputValueClass (GPDBWritable.class);
job.setOutputFormatClass(GPDBOutputFormat.class);
job.setMapperClass(Map_test1.class);
FileInputFormat.setInputPaths (job, new Path("/demo/data/tmp"));
GPDBOutputFormat.setOutputPath(job, new Path("/demo/data/MRTest1"));
job.waitForCompletion(true);
}

**Run CREATE EXTERNAL TABLE**
The Hadoop location corresponds to the output path in the MapReduce job.

=# CREATE EXTERNAL TABLE demodata
    LOCATION ('gphdfs://hdfshost-1:8081/demo/data/MRTest1')
    FORMAT 'custom' (formatter='gphdfs_import');
Example 2 - Write Custom-Formatted Data from Greenplum Database to HDFS

The sample code makes the following assumptions.

- The data in Greenplum Database format is located on the Hadoop Distributed File System on `/demo/data/writeFromGPDB_42` on port 8081.
- This code writes the data to `/demo/data/MRTest2` on port 8081.

1. Run a SQL command to create the writable table.

```sql
=# CREATE WRITABLE EXTERNAL TABLE demodata
   LOCATION ('gphdfs://hdfshost-1:8081/demo/data/MRTest2')
   FORMAT 'custom' (formatter='gphdfs_export');
```

2. Author and run code for a MapReduce job. Use the same import statements shown in Example 1 - Read Custom-Formatted Data from HDFS.

Sample MapReduce Code

```java
/*
 * DEMO Map/Reduce class test2
 * -- Convert GPDBFormat back to TEXT
 */
public static class Map_test2 extends Mapper<LongWritable, GPDBWritable, Text, NullWritable> {
    public void map(LongWritable key, GPDBWritable value, Context context)
    throws IOException {
        try {
            context.write(new Text(value.toString()), NullWritable.get());
        } catch (Exception e) { throw new IOException (e.getMessage()); }
    }
}

public static void runTest2() throws Exception{
    Configuration conf = new Configuration(true);
    Job job = new Job(conf, "test2");
    job.setJarByClass(demoMR.class);
    job.setInputFormatClass(GPDBInputFormat.class);
    job.setOutputKeyLClass (Text.class);
    job.setOutputValueClass(NullWritable.class);
    job.setOutputFormatClass(TextOutputFormat.class);
    job.setMapperClass(Map_test2.class);
    GPDBInputFormat.setInputPaths (job, new Path("/demo/data/writeFromGPDB_42"));
    GPDBOutputFormat.setOutputPath(job, new Path("/demo/data/MRTest2"));
    job.waitForCompletion(true);
}
```

Using Amazon EMR with Greenplum Database installed on AWS

Amazon Elastic MapReduce (EMR) is a managed cluster platform that can run big data frameworks, such as Apache Hadoop and Apache Spark, on Amazon Web Services (AWS) to process and analyze data. For a Greenplum Database system that is installed on Amazon Web Services (AWS), you can define Greenplum Database external tables that use the gphdfs protocol to access files on an Amazon EMR instance HDFS.

In addition to the steps described in One-time gphdfs Protocol Installation, you must also ensure Greenplum Database can access the EMR instance. If your Greenplum Database system is running on an
Amazon Elastic Compute Cloud (EC2) instance, you configure the Greenplum Database system and the EMR security group.

For information about Amazon EMR, see https://aws.amazon.com/emr/. For information about Amazon EC2, see https://aws.amazon.com/ec2/

Configuring Greenplum Database and Amazon EMR

These steps describe how to set up Greenplum Database system and an Amazon EMR instance to support Greenplum Database external tables:

1. Ensure that the appropriate Java (including JDK) and Hadoop environments are correctly installed on all Greenplum Database segment hosts.
   
   For example, Amazon EMR Release 4.0.0 includes Apache Hadoop 2.6.0. This Amazon page describes Amazon EMR Release 4.0.0.
   
   For information about Hadoop versions used by EMR and Greenplum Database, see Table 69: EMR Hadoop Configuration Information.

2. Ensure the environment variables and Greenplum Database server configuration parameters are set:
   
   • System environment variables:
     - HADOOP_HOME
     - JAVA_HOME
   
   • Greenplum Database server configuration parameters:
     - gp_hadoop_target_version
     - gp_hadoop_home

3. Configure communication between Greenplum Database and the EMR instance Hadoop master.
   
   For example, open port 8020 in the AWS security group.

4. Configure for communication between Greenplum Database and EMR instance Hadoop data nodes. Open a TCP/IP port for so that Greenplum Database segments hosts can communicate with EMR instance Hadoop data nodes.
   
   For example, open port 50010 in the AWS security manager.

This table lists EMR and Hadoop version information that can be used to configure Greenplum Database.

Table 69: EMR Hadoop Configuration Information

<table>
<thead>
<tr>
<th>EMR Version</th>
<th>EMR Apache Hadoop Version</th>
<th>EMR Hadoop Master Port</th>
<th>gp_hadoop_target_version</th>
<th>Hadoop Version on Greenplum Database Segment Hosts</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>2.6</td>
<td>8020</td>
<td>hadoop2</td>
<td>Apache Hadoop 2.x</td>
</tr>
<tr>
<td>3.9</td>
<td>2.4</td>
<td>9000</td>
<td>hadoop2</td>
<td>Apache Hadoop 2.x</td>
</tr>
<tr>
<td>3.8</td>
<td>2.4</td>
<td>9000</td>
<td>hadoop2</td>
<td>Apache Hadoop 2.x</td>
</tr>
<tr>
<td>3.3</td>
<td>2.4</td>
<td>9000</td>
<td>hadoop2</td>
<td>Apache Hadoop 2.x</td>
</tr>
</tbody>
</table>

Using the Greenplum Parallel File Server (gpfdist)

The gpfdist protocol is used in a CREATE EXTERNAL TABLE SQL command to access external data served by the Greenplum Database gpfdist file server utility. When external data is served by gpfdist, all segments in the Greenplum Database system can read or write external table data in parallel.

This topic describes the setup and management tasks for using gpfdist with external tables.

- About gpfdist and External Tables
• About gpfdist Setup and Performance
• Controlling Segment Parallelism
• Installing gpfdist
• Starting and Stopping gpfdist
• Troubleshooting gpfdist

About gpfdist and External Tables

The gpfdist file server utility is located in the $GPHOME/bin directory on your Greenplum Database master host and on each segment host. When you start a gpfdist instance you specify a listen port and the path to a directory containing files to read or where files are to be written. For example, this command runs gpfdist in the background, listening on port 8801, and serving files in the /home/gpadmin/external_files directory:

```
$ gpfdist -p 8801 -d /home/gpadmin/external_files &
```

The CREATE EXTERNAL TABLE command LOCATION clause connects an external table definition to one or more gpfdist instances. If the external table is readable, the gpfdist server reads data records from files from in specified directory, packs them into a block, and sends the block in a response to a Greenplum Database segment's request. The segments unpack rows they receive and distribute them according to the external table's distribution policy. If the external table is a writable table, segments send blocks of rows in a request to gpfdist and gpfdist writes them to the external file.

External data files can contain rows in CSV format or any delimited text format supported by the FORMAT clause of the CREATE EXTERNAL TABLE command. In addition, gpfdist can be configured with a YAML-formatted file to transform external data files between a supported text format and another format, for example XML or JSON. See <ref> for an example that shows how to use gpfdist to read external XML files into a Greenplum Database readable external table.

For readable external tables, gpfdist uncompresses gzip (.gz) and bzip2 (.bz2) files automatically. You can use the wildcard character (*) or other C-style pattern matching to denote multiple files to read. External files are assumed to be relative to the directory specified when you started the gpfdist instance.

About gpfdist Setup and Performance

You can run gpfdist instances on multiple hosts and you can run multiple gpfdist instances on each host. This allows you to deploy gpfdist servers strategically so that you can attain fast data load and unload rates by utilizing all of the available network bandwidth and Greenplum Database's parallelism.

• Allow network traffic to use all ETL host network interfaces simultaneously. Run one instance of gpfdist for each interface on the ETL host, then declare the host name of each NIC in the LOCATION clause of your external table definition (see Examples for Creating External Tables).
Figure 28: External Table Using Single gpfdist Instance with Multiple NICs

- Divide external table data equally among multiple gpfdist instances on the ETL host. For example, on an ETL system with two NICs, run two gpfdist instances (one on each NIC) to optimize data load performance and divide the external table data files evenly between the two gpfdist servers.

Figure 29: External Tables Using Multiple gpfdist Instances with Multiple NICs
**Note:** Use pipes (|) to separate formatted text when you submit files to gpfdist. Greenplum Database encloses comma-separated text strings in single or double quotes. gpfdist has to remove the quotes to parse the strings. Using pipes to separate formatted text avoids the extra step and improves performance.

## Controlling Segment Parallelism

The `gp_external_max_segs` server configuration parameter controls the number of segment instances that can access a single `gpfdist` instance simultaneously. 64 is the default. You can set the number of segments such that some segments process external data files and some perform other database processing. Set this parameter in the `postgresql.conf` file of your master instance.

## Installing gpfdist

`gpfdist` is installed in `$GPHOME/bin` of your Greenplum Database master host installation. Run `gpfdist` on a machine other than the Greenplum Database master or standby master, such as on a machine devoted to ETL processing. Running `gpfdist` on the master or standby master can have a performance impact on query execution. To install `gpfdist` on your ETL server, get it from the Greenplum Load Tools package and follow its installation instructions.

## Starting and Stopping gpfdist

You can start `gpfdist` in your current directory location or in any directory that you specify. The default port is 8080.

From your current directory, type:

```
$ gpfdist &
```

From a different directory, specify the directory from which to serve files, and optionally, the HTTP port to run on.

To start `gpfdist` in the background and log output messages and errors to a log file:

```
$ gpfdist -d /var/load_files -p 8081 -l /home/gpadmin/log &
```

For multiple `gpfdist` instances on the same ETL host (see Figure 28: External Table Using Single gpfdist Instance with Multiple NICs), use a different base directory and port for each instance. For example:

```
$ gpfdist -d /var/load_files1 -p 8081 -l /home/gpadmin/log1 &
$ gpfdist -d /var/load_files2 -p 8082 -l /home/gpadmin/log2 &
```

To stop `gpfdist` when it is running in the background:

First find its process id:

```
$ ps -ef | grep gpfdist
```

Then kill the process, for example (where 3456 is the process ID in this example):

```
$ kill 3456
```
Troubleshooting gpfdist

The segments access gpfdist at runtime. Ensure that the Greenplum segment hosts have network access to gpfdist. gpfdist is a web server: test connectivity by running the following command from each host in the Greenplum array (segments and master):

```
$ wget http://gpfdist_hostname:port/filename
```

The CREATE EXTERNAL TABLE definition must have the correct host name, port, and file names for gpfdist. Specify file names and paths relative to the directory from which gpfdist serves files (the directory path specified when gpfdist started). See Examples for Creating External Tables.

If you start gpfdist on your system and IPv6 networking is disabled, gpfdist displays this warning message when testing for an IPv6 port.

```
[WRN gpfdist.c:2050] Creating the socket failed
```

If the corresponding IPv4 port is available, gpfdist uses that port and the warning for IPv6 port can be ignored. To see information about the ports that gpfdist tests, use the -V option.

For information about IPv6 and IPv4 networking, see your operating system documentation.

When reading or writing data with the gpfdist or gfdists protocol, the gpfdist utility rejects HTTP requests that do not include X-GP-PROTO in the request header. If X-GP-PROTO is not detected in the header request gpfdist returns a 400 error in the status line of the HTTP response header: 400 invalid request (no gp-proto).

Greenplum Database includes X-GP-PROTO in the HTTP request header to indicate that the request is from Greenplum Database.

If the gpfdist utility hangs with no read or write activity occurring, you can generate a core dump the next time a hang occurs to help debug the issue. Set the environment variable GPFDIST_WATCHDOG_TIMER to the number of seconds of no activity to wait before gpfdist is forced to exit. When the environment variable is set and gpfdist hangs, the utility aborts after the specified number of seconds, creates a core dump, and sends abort information to the log file.

This example sets the environment variable on a Linux system so that gpfdist exits after 300 seconds (5 minutes) of no activity.

```
export GPFDIST_WATCHDOG_TIMER=300
```
Loading and Unloading Data

The topics in this section describe methods for loading and writing data into and out of a Greenplum Database, and how to format data files.

Greenplum Database supports high-performance parallel data loading and unloading, and for smaller amounts of data, single file, non-parallel data import and export.

Greenplum Database can read from and write to several types of external data sources, including text files, Hadoop file systems, Amazon S3, and web servers.

- The COPY SQL command transfers data between an external text file on the master host, or multiple text files on segment hosts, and a Greenplum Database table.
- Readable external tables allow you to query data outside of the database directly and in parallel using SQL commands such as SELECT, JOIN, or SORT EXTERNAL TABLE DATA, and you can create views for external tables. External tables are often used to load external data into a regular database table using a command such as CREATE TABLE table AS SELECT * FROM ext_table.
- External web tables provide access to dynamic data. They can be backed with data from URLs accessed using the HTTP protocol or by the output of an OS script running on one or more segments.
- The gpfdist utility is the Greenplum Database parallel file distribution program. It is an HTTP server that is used with external tables to allow Greenplum Database segments to load external data in parallel, from multiple file systems. You can run multiple instances of gpfdist on different hosts and network interfaces and access them in parallel.
- The gpload utility automates the steps of a load task using gpfdist and a YAML-formatted control file.
- The GemFire-Greenplum Connector allows the transfer of data between a Pivotal GemFire region and a Greenplum Database table. Pivotal GemFire is an in-memory data management system that provides reliable asynchronous event notifications and guaranteed message delivery. For information about using GemFire-Greenplum Connector, see http://ggc.docs.pivotal.io/. For information about Pivotal GemFire, see http://gemfire.docs.pivotal.io/.
- The Greenplum-Spark Connector provides high speed, parallel data transfer between Pivotal Greenplum Database and Apache Spark. For information about using the Greenplum-Spark Connector, refer to the documentation at https://greenplum-spark.docs.pivotal.io/.

The method you choose to load data depends on the characteristics of the source data—its location, size, format, and any transformations required.

In the simplest case, the COPY SQL command loads data into a table from a text file that is accessible to the Greenplum Database master instance. This requires no setup and provides good performance for smaller amounts of data. With the COPY command, the data copied into or out of the database passes between a single file on the master host and the database. This limits the total size of the dataset to the capacity of the file system where the external file resides and limits the data transfer to a single file write stream.

More efficient data loading options for large datasets take advantage of the Greenplum Database MPP architecture, using the Greenplum Database segments to load data in parallel. These methods allow data to load simultaneously from multiple file systems, through multiple NICs, on multiple hosts, achieving very high data transfer rates. External tables allow you to access external files from within the database as if they are regular database tables. When used with gpfdist, the Greenplum Database parallel file distribution program, external tables provide full parallelism by using the resources of all Greenplum Database segments to load or unload data.

Greenplum Database leverages the parallel architecture of the Hadoop Distributed File System to access files on that system.
## Loading Data Using an External Table

Use SQL commands such as `INSERT` and `SELECT` to query a readable external table, the same way that you query a regular database table. For example, to load travel expense data from an external table, `ext_expenses`, into a database table, `expenses_travel`:

```sql
=# INSERT INTO expenses_travel
    SELECT * from ext_expenses where category='travel';
```

To load all data into a new database table:

```sql
=# CREATE TABLE expenses AS SELECT * from ext_expenses;
```

## Loading and Writing Non-HDFS Custom Data

Greenplum Database supports `TEXT` and `CSV` formats for importing and exporting data through external tables. You can load and save data in other formats by defining a custom format or custom protocol or by setting up a transformation with the `gpfdist` parallel file server.

For information about importing custom data from HDFS, see [Reading and Writing Custom-Formatted HDFS Data](#).

### Using a Custom Format

You specify a custom data format in the `FORMAT` clause of `CREATE EXTERNAL TABLE`.

```
FORMAT 'CUSTOM' (formatter=format_function, key1=val1,...keyn=valn)
```

Where the `CUSTOM` keyword indicates that the data has a custom format and `formatter` specifies the function to use to format the data, followed by comma-separated parameters to the formatter function.

Greenplum Database provides functions for formatting fixed-width data, but you must author the formatter functions for variable-width data. The steps are as follows.

1. Author and compile input and output functions as a shared library.
2. Specify the shared library function with `CREATE FUNCTION` in Greenplum Database.
3. Use the `formatter` parameter of `CREATE EXTERNAL TABLE`'s `FORMAT` clause to call the function.

### Importing and Exporting Fixed Width Data

Specify custom formats for fixed-width data with the Greenplum Database functions `fixedwith_in` and `fixedwidth_out`. These functions already exist in the file `$GPHOME/share/postgresql/cdb_external_extensions.sql`. The following example declares a custom format, then calls the `fixedwidth_in` function to format the data.

```
CREATE READABLE EXTERNAL TABLE students (name varchar(20), address varchar(30), age int)
    LOCATION ('file://<host>/file/path/')
    FORMAT 'CUSTOM' (formatter=fixedwidth_in, name='20', address='30', age='4');
```

The following options specify how to import fixed width data.

- Read all the data.

  To load all the fields on a line of fixed with data, you must load them in their physical order. You must specify the field length, but cannot specify a starting and ending position. The fields names in the
fixed width arguments must match the order in the field list at the beginning of the CREATE TABLE command.

- Set options for blank and null characters.

  Trailing blanks are trimmed by default. To keep trailing blanks, use the preserve_blanks=on option. You can reset the trailing blanks option to the default with the preserve_blanks=off option.

  Use the null='null_string_value' option to specify a value for null characters.

- If you specify preserve_blanks=on, you must also define a value for null characters.

- If you specify preserve_blanks=off, null is not defined, and the field contains only blanks, Greenplum writes a null to the table. If null is defined, Greenplum writes an empty string to the table.

  Use the line_delim='line_ending' parameter to specify the line ending character. The following examples cover most cases. The E specifies an escape string constant.

```sql
line_delim=E'\n'
line_delim=E'\r'
line_delim=E'\r\n'
line_delim='abc'
```

**Examples: Read Fixed-Width Data**

The following examples show how to read fixed-width data.

**Example 1 – Loading a table with all fields defined**

```sql
CREATE READABLE EXTERNAL TABLE students (  
  name varchar(20), address varchar(30), age int  
) LOCATION ('file://<host>/file/path/')  
FORMAT 'CUSTOM' (formatter=fixedwidth_in,  
  name=20, address=30, age=4);  
```

**Example 2 – Loading a table with PRESERVED_BLANKS on**

```sql
CREATE READABLE EXTERNAL TABLE students (  
  name varchar(20), address varchar(30), age int  
) LOCATION ('gpfdist://<host>:<portNum>/file/path/')  
FORMAT 'CUSTOM' (formatter=fixedwidth_in,  
  name=20, address=30, age=4,  
  preserve_blanks='on',null='NULL');  
```

**Example 3 – Loading data with no line delimiter**

```sql
CREATE READABLE EXTERNAL TABLE students (  
  name varchar(20), address varchar(30), age int  
) LOCATION ('file://<host>/file/path/')  
FORMAT 'CUSTOM' (formatter=fixedwidth_in,  
  name='20', address='30', age='4', line_delim='?@')  
```

**Example 4 – Create a writable external table with a \n line delimiter**

```sql
CREATE WRITABLE EXTERNAL TABLE students_out (  
  name varchar(20), address varchar(30), age int  
) LOCATION ('gpfdist://<host>:<portNum>/file/path/students_out.txt')  
FORMAT 'CUSTOM' (formatter=fixedwidth_out,  
  name=20, address=30, age=4, line_delim=E'\r\n');  
```
Using a Custom Protocol

Greenplum Database provides protocols such as `gpfdist`, `http`, and `file` for accessing data over a network, or you can author a custom protocol. You can use the standard data formats, `TEXT` and `CSV`, or a custom data format with custom protocols.

You can create a custom protocol whenever the available built-in protocols do not suffice for a particular need. For example, you could connect Greenplum Database in parallel to another system directly, and stream data from one to the other without the need to materialize the data on disk or use an intermediate process such as `gpfdist`.

1. Author the send, receive, and (optionally) validator functions in C, with a predefined API. These functions are compiled and registered with the Greenplum Database. For an example custom protocol, see [Example Custom Data Access Protocol](#).

2. After writing and compiling the read and write functions into a shared object (.so), declare a database function that points to the .so file and function names.

   The following examples use the compiled import and export code.

   ```sql
   CREATE FUNCTION myread() RETURNS integer
   as '$libdir/gpextprotocol.so', 'myprot_import'
   LANGUAGE C STABLE;
   CREATE FUNCTION mywrite() RETURNS integer
   as '$libdir/gpextprotocol.so', 'myprot_export'
   LANGUAGE C STABLE;
   ```

   The format of the optional validator function is:

   ```sql
   CREATE OR REPLACE FUNCTION myvalidate() RETURNS void
   AS '$libdir/gpextprotocol.so', 'myprot_validate'
   LANGUAGE C STABLE;
   ```

3. Create a protocol that accesses these functions. Validatorfunc is optional.

   ```sql
   CREATE TRUSTED PROTOCOL myprot(
       writefunc='mywrite',
       readfunc='myread',
       validatorfunc='myvalidate');
   ```

4. Grant access to any other users, as necessary.

   ```sql
   GRANT ALL ON PROTOCOL myprot TO otheruser;
   ```

5. Use the protocol in readable or writable external tables.

   ```sql
   CREATE WRITABLE EXTERNAL TABLE ext_sales(LIKE sales)
   LOCATION ('myprot://<meta>/<meta>/...')
   FORMAT 'TEXT';
   CREATE READABLE EXTERNAL TABLE ext_sales(LIKE sales)
   LOCATION('myprot://<meta>/<meta>/...')
   FORMAT 'TEXT';
   ```

Declare custom protocols with the SQL command `CREATE TRUSTED PROTOCOL`, then use the `GRANT` command to grant access to your users. For example:

- Allow a user to create a readable external table with a trusted protocol

  ```sql
  GRANT SELECT ON PROTOCOL <protocol name> TO <user name>;
  ```
• Allow a user to create a writable external table with a trusted protocol

GRANT INSERT ON PROTOCOL <protocol name> TO <user name>;

• Allow a user to create readable and writable external tables with a trusted protocol

GRANT ALL ON PROTOCOL <protocol name> TO <user name>;

Handling Load Errors

Readable external tables are most commonly used to select data to load into regular database tables. You use the CREATE TABLE AS SELECT or INSERT INTO commands to query the external table data. By default, if the data contains an error, the entire command fails and the data is not loaded into the target database table.

The SEGMENT REJECT LIMIT clause allows you to isolate format errors in external table data and to continue loading correctly formatted rows. Use SEGMENT REJECT LIMIT to set an error threshold, specifying the reject limit count as number of ROWS (the default) or as a PERCENT of total rows (1-100).

The entire external table operation is aborted, and no rows are processed, if the number of error rows reaches the SEGMENT REJECT LIMIT. The limit of error rows is per-segment, not per entire operation. The operation processes all good rows, and it discards and optionally logs formatting errors for erroneous rows, if the number of error rows does not reach the SEGMENT REJECT LIMIT.

The LOG ERRORS clause allows you to keep error rows for further examination. For information about the LOG ERRORS clause, see the CREATE EXTERNAL TABLE command in the Greenplum Database Reference Guide.

When you set SEGMENT REJECT LIMIT, Greenplum scans the external data in single row error isolation mode. Single row error isolation mode applies to external data rows with format errors such as extra or missing attributes, attributes of a wrong data type, or invalid client encoding sequences. Greenplum does not check constraint errors, but you can filter constraint errors by limiting the SELECT from an external table at runtime. For example, to eliminate duplicate key errors:

```sql
=# INSERT INTO table_with_pkeys
    SELECT DISTINCT * FROM external_table;
```

**Note:** When loading data with the COPY command or an external table, the value of the server configuration parameter gp_initial_bad_row_limit limits the initial number of rows that are processed that are not formatted properly. The default is to stop processing if the first 1000 rows contain formatting errors. See the Greenplum Database Reference Guide for information about the parameter.

Define an External Table with Single Row Error Isolation

The following example logs errors internally in Greenplum Database and sets an error threshold of 10 errors.

```sql
=# CREATE EXTERNAL TABLE ext_expenses ( name text, date date, amount float4, category text, desc1 text )
    LOCATION ('gpfdist://etlhost-1:8081/**',
              'gpfdist://etlhost-2:8082/**')
    FORMAT 'TEXT' (DELIMITER '|')
    LOG ERRORS SEGMENT REJECT LIMIT 10
    ROWS;
```
Use the built-in SQL function `gp_read_error_log('external_table')` to read the error log data. This example command displays the log errors for `ext_expenses`:

```
SELECT gp_read_error_log('ext_expenses');
```

For information about the format of the error log, see Viewing Bad Rows in the Error Log.

The built-in SQL function `gp_truncate_error_log('external_table')` deletes the error data. This example deletes the error log data created from the previous external table example:

```
SELECT gp_truncate_error_log('ext_expenses');
```

### Capture Row Formatting Errors and Declare a Reject Limit

The following SQL fragment captures formatting errors internally in Greenplum Database and declares a reject limit of 10 rows.

```
LOG ERRORS SEGMENT REJECT LIMIT 10 ROWS
```

Use the built-in SQL function `gp_read_error_log()` to read the error log data. For information about viewing log errors, see Viewing Bad Rows in the Error Log.

### Viewing Bad Rows in the Error Log

If you use single row error isolation (see Define an External Table with Single Row Error Isolation or Running COPY in Single Row Error Isolation Mode), any rows with formatting errors are logged internally by Greenplum Database.

Greenplum Database captures the following error information in a table format:

#### Table 70: Error Log Format

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cmdtime</td>
<td>timestamptz</td>
<td>Timestamp when the error occurred.</td>
</tr>
<tr>
<td>relname</td>
<td>text</td>
<td>The name of the external table or the target table of a COPY command.</td>
</tr>
<tr>
<td>filename</td>
<td>text</td>
<td>The name of the load file that contains the error.</td>
</tr>
<tr>
<td>linenum</td>
<td>int</td>
<td>If COPY was used, the line number in the load file where the error occurred. For external tables using file:// protocol or gpfdist:// protocol and CSV format, the file name and line number is logged.</td>
</tr>
<tr>
<td>bytenum</td>
<td>int</td>
<td>For external tables with the gpfdist:// protocol and data in TEXT format: the byte offset in the load file where the error occurred. gpfdist parses TEXT files in blocks, so logging a line number is not possible. CSV files are parsed a line at a time so line number tracking is possible for CSV files.</td>
</tr>
<tr>
<td>errmsg</td>
<td>text</td>
<td>The error message text.</td>
</tr>
<tr>
<td>rawdata</td>
<td>text</td>
<td>The raw data of the rejected row.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>description</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>rawbytes</td>
<td>bytea</td>
<td>In cases where there is a database encoding error (the client encoding used cannot be converted to a server-side encoding), it is not possible to log the encoding error as rawdata. Instead the raw bytes are stored and you will see the octal code for any non seven bit ASCII characters.</td>
</tr>
</tbody>
</table>

You can use the Greenplum Database built-in SQL function `gp_read_error_log()` to display formatting errors that are logged internally. For example, this command displays the error log information for the table `ext_expenses`:

```
SELECT gp_read_error_log('ext_expenses');
```

For information about managing formatting errors that are logged internally, see the command `COPY` or `CREATE EXTERNAL TABLE` in the *Greenplum Database Reference Guide*.

### Identifying Invalid CSV Files in Error Table Data

If a CSV file contains invalid formatting, the `rawdata` field in the error table can contain several combined rows. For example, if a closing quote for a specific field is missing, all the following newlines are treated as embedded newlines. When this happens, Greenplum stops parsing a row when it reaches 64K, puts that 64K of data into the error table as a single row, resets the quote flag, and continues. If this happens three times during load processing, the load file is considered invalid and the entire load fails with the message "rejected N or more rows". See *Escaping in CSV Formatted Files* for more information on the correct use of quotes in CSV files.

### Moving Data between Tables

You can use `CREATE TABLE AS` or `INSERT...SELECT` to load external and external web table data into another (non-external) database table, and the data will be loaded in parallel according to the external or external web table definition.

If an external table file or external web table data source has an error, one of the following will happen, depending on the isolation mode used:

- **Tables without error isolation mode**: any operation that reads from that table fails. Loading from external and external web tables without error isolation mode is an all or nothing operation.
- **Tables with error isolation mode**: the entire file will be loaded, except for the problematic rows (subject to the configured `REJECT_LIMIT`)

### Loading Data with gpload

The Greenplum `gpload` utility loads data using readable external tables and the Greenplum parallel file server (gpfdist or gpfdists). It handles parallel file-based external table setup and allows users to configure their data format, external table definition, and `gpfdist` or `gpfdists` setup in a single configuration file.

To use gpload

1. Ensure that your environment is set up to run gpload. Some dependent files from your Greenplum Database installation are required, such as `gpfdist` and Python, as well as network access to the Greenplum segment hosts.

   See the *Greenplum Database Reference Guide* for details.

2. Create your load control file. This is a YAML-formatted file that specifies the Greenplum Database connection information, `gpfdist` configuration information, external table options, and data format.
See the *Greenplum Database Reference Guide* for details.

For example:

```
---
VERSION: 1.0.0.1
DATABASE: ops
USER: gpadmin
HOST: mdw-1
PORT: 5432
GPLOAD:
  INPUT:
    - SOURCE:
      LOCAL_HOSTNAME:
      - etl1-1
      - etl1-2
      - etl1-3
      - etl1-4
      PORT: 8081
      FILE:
        - /var/load/data/*
    - COLUMNS:
      - name: text
      - amount: float4
      - category: text
      - desc: text
      - date: date
    - FORMAT: text
    - DELIMITER: '|' 
    - ERROR_LIMIT: 25
    - LOG_ERRORS: true
  OUTPUT:
    - TABLE: payables.expenses
    - MODE: INSERT
  PRELOAD:
    - REUSE_TABLES: true
SQL:
  - BEFORE: "INSERT INTO audit VALUES('start', current_timestamp)"
  - AFTER: "INSERT INTO audit VALUES('end', current_timestamp)"
```

3. Run `gpload`, passing in the load control file. For example:

   `gpload -f my_load.yml`

### Transforming External Data with gpfdist and gpload

The *gpfdist* parallel file server allows you to set up transformations that enable Greenplum Database external tables to read and write files in formats that are not supported with the `CREATE EXTERNAL TABLE` command's `FORMAT` clause. An input transformation reads a file in the foreign data format and outputs rows to *gpfdist* in the CSV or other text format specified in the external table's `FORMAT` clause. An output transformation receives rows from *gpfdist* in text format and converts them to the foreign data format.

This topic describes the tasks to set up data transformations that work with *gpfdist* to read or write external data files with formats that Greenplum Database does not support.

- About *gpfdist* Transformations
- Determine the Transformation Schema
- Write a Transformation
- Write the *gpfdist* Configuration File
- Transfer the Data
About gpfdist Transformations

To set up a transformation for a data format, you provide an executable command that gpfdist can call with the name of the file containing data. For example, you could write a shell script that runs an XSLT transformation on an XML file to output rows with columns delimited with a vertical bar (|) character and rows delimited with linefeeds.

Transformations are configured in a YAML-formatted configuration file passed to gpfdist on the command line.

If you want to load the external data into a table in the Greenplum database, you can use the gpload utility to automate the tasks to create an external table, run gpfdist, and load the transformed data into the database table.

Accessing data in external XML files from within the database is a common example requiring transformation. The following diagram shows gpfdist performing a transformation on XML files on an ETL server.

---

Figure 30: External Tables using XML Transformations

Following are the high-level steps to set up a gpfdist transformation for external data files. The process is illustrated with an XML example.

1. Determine the transformation schema.
2. Write a transformation.
3. Write the gpfdist configuration file.
4. Transfer the data.

Determine the Transformation Schema

To prepare for the transformation project:

1. Determine the goal of the project, such as indexing data, analyzing data, combining data, and so on.
2. Examine the source files and note the file structure and element names.
3. Choose the elements to import and decide if any other limits are appropriate.
For example, the following XML file, `prices.xml`, is a simple XML file that contains price records. Each price record contains two fields: an item number and a price.

```
<?xml version="1.0" encoding="ISO-8859-1" ?>
<prices>
    <pricerecord>
        <itemnumber>708421</itemnumber>
        <price>19.99</price>
    </pricerecord>
    <pricerecord>
        <itemnumber>708466</itemnumber>
        <price>59.25</price>
    </pricerecord>
    <pricerecord>
        <itemnumber>711121</itemnumber>
        <price>24.99</price>
    </pricerecord>
</prices>
```

The goal of this transformation is to import all the data into a Greenplum Database readable external table with an integer `itemnumber` column and a decimal `price` column.

### Write a Transformation

The transformation specifies what to extract from the data. You can use any authoring environment and language appropriate for your project. For XML transformations choose from technologies such as XSLT, Joost (STX), Java, Python, or Perl, based on the goals and scope of the project.

In the price example, the next step is to transform the XML data into a two-column delimited text format.

```
708421|19.99
708466|59.25
711121|24.99
```

The following STX transform, called `input_transform.stx`, performs the data transformation.

```
<?xml version="1.0"?><stx:transform version="1.0"
    xmlns:stx="http://stx.sourceforge.net/2002/ns"
    pass-through="none">
    <!-- declare variables -->
    <stx:variable name="itemnumber"/>
    <stx:variable name="price"/>
    <!-- match and output prices as columns delimited by | -->
    <stx:template match="/prices/pricerecord">
        <stx:process-children/>
        <stx:value-of select="$itemnumber"/>
        <stx:text>|</stx:text>
        <stx:value-of select="$price"/>
    </stx:template>
    <stx:template match="itemnumber">
        <stx:assign name="itemnumber" select="."/>
    </stx:template>
    <stx:template match="price">
        <stx:assign name="price" select="."/>
    </stx:template>
</stx:transform>
```

This STX transform declares two temporary variables, `itemnumber` and `price`, and the following rules.
1. When an element that satisfies the XPath expression /prices/pricerecord is found, examine the child elements and generate output that contains the value of the itemnumber variable, a | character, the value of the price variable, and a newline.
2. When an <itemnumber> element is found, store the content of that element in the variable itemnumber.
3. When a <price> element is found, store the content of that element in the variable price.

Write the gpfdist Configuration File

The gpfdist configuration is specified as a YAML 1.1 document. It contains rules that gpfdist uses to select a transformation to apply when loading or extracting data.

This example gpfdist configuration contains the following items that are required for the prices.xml transformation scenario:

- the config.yaml file defining TRANSFORMATIONS
- the input_transform.sh wrapper script, referenced in the config.yaml file
- the input_transform.stx joost transformation, called from input_transform.sh

Aside from the ordinary YAML rules, such as starting the document with three dashes (---), a gpfdist configuration must conform to the following restrictions:

1. A VERSION setting must be present with the value 1.0.0.1.
2. A TRANSFORMATIONS setting must be present and contain one or more mappings.
3. Each mapping in the TRANSFORMATION must contain:
   - a TYPE with the value 'input' or 'output'
   - a COMMAND indicating how the transformation is run.
4. Each mapping in the TRANSFORMATION can contain optional CONTENT, SAFE, and STDERR settings.

The following gpfdist configuration, called config.yaml, applies to the prices example. The initial indentation on each line is significant and reflects the hierarchical nature of the specification. The transformation name prices_input in the following example will be referenced later when creating the table in SQL.

```yaml
---
 VERSION: 1.0.0.1
 TRANSFORMATIONS:
   prices_input:
     TYPE:     input
     COMMAND:  /bin/bash input_transform.sh %filename%
```

The COMMAND setting uses a wrapper script called input_transform.sh with a %filename% placeholder. When gpfdist runs the prices_input transform, it invokes input_transform.sh with /bin/bash and replaces the %filename% placeholder with the path to the input file to transform. The wrapper script called input_transform.sh contains the logic to invoke the STX transformation and return the output.

If Joost is used, the Joost STX engine must be installed.

```bash
#!/bin/bash
# input_transform.sh - sample input transformation,
# demonstrating use of Java and Joost STX to convert XML into
# text to load into Greenplum Database.
# java arguments:
#   -jar joost.jar         joost STX engine
#   -nodecl                  don't generate a <?xml?> declaration
#   $1                        filename to process
#   input_transform.stx    the STX transformation
#
# the AWK step eliminates a blank line joost emits at the end
```
```java
java \
 -jar joost.jar \
 -nodecl \
 $1 \ 
 input_transform.stx \
 | awk 'NF>0
```

The `input_transform.sh` file uses the Joost STX engine with the AWK interpreter. The following diagram shows the process flow as `gpfdist` runs the transformation.

### Transfer the Data

Create the target database tables with SQL statements based on the appropriate schema.

There are no special requirements for Greenplum Database tables that hold loaded data. In the prices example, the following command creates the `prices` table, where the data is to be loaded.

```sql
CREATE TABLE prices (
    itemnumber integer,
    price       decimal
) 
DISTRIBUTED BY (itemnumber);
```

Next, use one of the following approaches to transform the data with `gpdist`.

- `gpload` supports only input transformations, but in many cases is easier to implement.
- `gpdist` with `INSERT INTO SELECT FROM` supports both input and output transformations, but exposes details that `gpload` automates for you.

### Transforming with `gpload`

The Greenplum Database `gpload` utility orchestrates a data load operation using the `gpfdist` parallel file server and a YAML-formatted configuration file. `gpload` automates these tasks:

- Creates a readable external table in the database.
- Starts `gpdist` instances with the configuration file that contains the transformation.
- Runs `INSERT INTO table_name SELECT FROM external_table` to load the data.
- Removes the external table definition.
Transforming data with `gpload` requires that the settings `TRANSFORM` and `TRANSFORM_CONFIG` appear in the `INPUT` section of the `gpload` control file.

For more information about the syntax and placement of these settings in the `gpload` control file, see the `Greenplum Database Reference Guide`.

- `TRANSFORM_CONFIG` specifies the name of the `gpfdist` configuration file.
- The `TRANSFORM` setting indicates the name of the transformation that is described in the file named in `TRANSFORM_CONFIG`.

```plaintext
---
VERSION: 1.0.0.1
DATABASE: ops
USER: gpadmin
GPLOAD:
  INPUT:
    - TRANSFORM_CONFIG: config.yaml
    - TRANSFORM: prices_input
    - SOURCE:
      FILE: prices.xml
---
```

The transformation name must appear in two places: in the `TRANSFORM` setting of the `gpfdist` configuration file and in the `TRANSFORMATIONS` section of the file named in the `TRANSFORM_CONFIG` section.

In the `gpload` control file, the optional parameter `MAX_LINE_LENGTH` specifies the maximum length of a line in the XML transformation data that is passed to `gpload`.

The following diagram shows the relationships between the `gpload` control file, the `gpfdist` configuration file, and the XML data file.

---

**Transforming with `gpfdist` and `INSERT INTO SELECT FROM`**

With this load method, you perform each of the tasks that `gpload` automates. You start `gpfdist`, create an external table, load the data, and clean up by dropping the table and stopping `gpfdist`. 
Specify the transformation in the `CREATE EXTERNAL TABLE` definition's `LOCATION` clause. For example, the transform is shown in bold in the following command. (Run `gpfdist` first, using the command `gpfdist -c config.yaml`).

```sql
CREATE READABLE EXTERNAL TABLE prices_readable (LIKE prices)
    LOCATION ('gpfdist://hostname:8080/prices.xml#transform=prices_input')
    FORMAT 'TEXT' (DELIMITER '|')
    LOG ERRORS SEGMENT REJECT LIMIT 10;
```

In the command above, change `hostname` to your hostname. `prices_input` comes from the `gpfdist` configuration file.

The following query then loads the data into the `prices` table.

```sql
INSERT INTO prices SELECT * FROM prices_readable;
```

**Configuration File Format**

The `gpfdist` configuration file uses the YAML 1.1 document format and implements a schema for defining the transformation parameters. The configuration file must be a valid YAML document.

The `gpfdist` program processes the document in order and uses indentation (spaces) to determine the document hierarchy and relationships of the sections to one another. The use of white space is significant. Do not use white space for formatting and do not use tabs.

The following is the basic structure of a configuration file.

```
---
VERSION:   1.0.0.1
TRANSFORMATIONS:
  transformation_name1:
    TYPE:      input | output
    COMMAND:   command
    CONTENT:   data | paths
    SAFE:      posix-regex
    STDERR:    server | console
  transformation_name2:
    TYPE:      input | output
    COMMAND:   command
  ...
---
```

**VERSION**

Required. The version of the `gpfdist` configuration file schema. The current version is 1.0.0.1.

**TRANSFORMATIONS**

Required. Begins the transformation specification section. A configuration file must have at least one transformation. When `gpfdist` receives a transformation request, it looks in this section for an entry with the matching transformation name.

**TYPE**

Required. Specifies the direction of transformation. Values are `input` or `output`.

- `input`: `gpfdist` treats the standard output of the transformation process as a stream of records to load into Greenplum Database.
- `output`: `gpfdist` treats the standard input of the transformation process as a stream of records from Greenplum Database to transform and write to the appropriate output.

**COMMAND**

Required. Specifies the command `gpfdist` will execute to perform the transformation.
For input transformations, gpfdist invokes the command specified in the CONTENT setting. The command is expected to open the underlying file(s) as appropriate and produce one line of TEXT for each row to load into Greenplum Database. The input transform determines whether the entire content should be converted to one row or to multiple rows.

For output transformations, gpfdist invokes this command as specified in the CONTENT setting. The output command is expected to open and write to the underlying file(s) as appropriate. The output transformation determines the final placement of the converted output.

**CONTENT**

Optional. The values are data and paths. The default value is data.

- When CONTENT specifies data, the text `%filename%` in the COMMAND section is replaced by the path to the file to read or write.
- When CONTENT specifies paths, the text `%filename%` in the COMMAND section is replaced by the path to the temporary file that contains the list of files to read or write.

The following is an example of a COMMAND section showing the text `%filename%` that is replaced.

```
COMMAND: /bin/bash input_transform.sh %filename%
```

**SAFE**

Optional. A POSIX regular expression that the paths must match to be passed to the transformation. Specify SAFE when there is a concern about injection or improper interpretation of paths passed to the command. The default is no restriction on paths.

**STDERR**

Optional. The values are server and console.

This setting specifies how to handle standard error output from the transformation. The default, server, specifies that gpfdist will capture the standard error output from the transformation in a temporary file and send the first 8k of that file to Greenplum Database as an error message. The error message will appear as an SQL error. Console specifies that gpfdist does not redirect or transmit the standard error output from the transformation.

**XML Transformation Examples**

The following examples demonstrate the complete process for different types of XML data and STX transformations. Files and detailed instructions associated with these examples are in the GitHub repo github.com://greenplum-db/gpdb in the gpMgmt/demo/gpfdist_transform directory. Read the README file in the Before You Begin section before you run the examples. The README file explains how to download the example data file used in the examples.

**Command-based External Web Tables**

The output of a shell command or script defines command-based web table data. Specify the command in the EXECUTE clause of CREATE EXTERNAL WEB TABLE. The data is current as of the time the command runs. The EXECUTE clause runs the shell command or script on the specified master, and/or segment host or hosts. The command or script must reside on the hosts corresponding to the host(s) defined in the EXECUTE clause.

By default, the command is run on segment hosts when active segments have output rows to process. For example, if each segment host runs four primary segment instances that have output rows to process, the command runs four times per segment host. You can optionally limit the number of segment instances that
execute the web table command. All segments included in the web table definition in the ON clause run the command in parallel.

The command that you specify in the external table definition executes from the database and cannot access environment variables from .bashrc or .profile. Set environment variables in the EXECUTE clause. For example:

```sql
=# CREATE EXTERNAL WEB TABLE output (output text)
   EXECUTE 'PATH=/home/gpadmin/programs; export PATH; myprogram.sh'
   FORMAT 'TEXT';
```

Scripts must be executable by the gpadmin user and reside in the same location on the master or segment hosts.

The following command defines a web table that runs a script. The script runs on each segment host where a segment has output rows to process.

```sql
=# CREATE EXTERNAL WEB TABLE log_output
   (linenum int, message text)
   EXECUTE '/var/load_scripts/get_log_data.sh' ON HOST
   FORMAT 'TEXT' (DELIMITER '|');
```

### IRS MeF XML Files (In demo Directory)

This example demonstrates loading a sample IRS Modernized eFile tax return using a Joost STX transformation. The data is in the form of a complex XML file.

The U.S. Internal Revenue Service (IRS) made a significant commitment to XML and specifies its use in its Modernized e-File (MeF) system. In MeF, each tax return is an XML document with a deep hierarchical structure that closely reflects the particular form of the underlying tax code.

XML, XML Schema and stylesheets play a role in their data representation and business workflow. The actual XML data is extracted from a ZIP file attached to a MIME "transmission file" message. For more information about MeF, see [Modernized e-File (Overview)] on the IRS web site.

The sample XML document, `RET990EZ_2006.xml`, is about 350KB in size with two elements:

- ReturnHeader
- ReturnData

The <ReturnHeader> element contains general details about the tax return such as the taxpayer's name, the tax year of the return, and the preparer. The <ReturnData> element contains multiple sections with specific details about the tax return and associated schedules.

The following is an abridged sample of the XML file.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<Return returnVersion="2006v2.0"
   xmlns="https://www.irs.gov/efile"
   xmlns:efile="https://www.irs.gov/efile"
   xsi:schemaLocation="https://www.irs.gov/efile"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
   <ReturnHeader binaryAttachmentCount="1">
     <ReturnId>AAAAAAAAAAAAAAAAAAAA</ReturnId>
     <Timestamp>1999-05-30T12:01:01+05:01</Timestamp>
     <ReturnType>990EZ</ReturnType>
     <TaxPeriodBeginDate>2005-01-01</TaxPeriodBeginDate>
     <TaxPeriodEndDate>2005-12-31</TaxPeriodEndDate>
     <Filer>
       <EIN>011248772</EIN>
       ... more data ...
     </Filer>
     <Preparer>
```

```xml
```
The goal is to import all the data into a Greenplum database. First, convert the XML document into text with newlines “escaped”, with two columns: ReturnId and a single column on the end for the entire MeF tax return. For example:

```
AAAAAAAAAAAAAAAAAAAAA|<Return returnVersion="2006v2.0"
```

Load the data into Greenplum Database.

**WITSML™ Files (In demo Directory)**

This example demonstrates loading sample data describing an oil rig using a Joost STX transformation. The data is in the form of a complex XML file downloaded from energistics.org.

The Wellsite Information Transfer Standard Markup Language (WITSML™) is an oil industry initiative to provide open, non-proprietary, standard interfaces for technology and software to share information among oil companies, service companies, drilling contractors, application vendors, and regulatory agencies. For more information about WITSML™, see [http://www.energistics.org/](http://www.energistics.org/).

The oil rig information consists of a top level `<rigs>` element with multiple child elements such as `<documentInfo>`, `<rig>`, and so on. The following excerpt from the file shows the type of information in the `<rig>` tag.

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet href="../stylesheets/rig.xsl" type="text/xsl" media="screen"?>
<rigs
    xmlns="http://www.energistics.org/schemas/131"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.energistics.org/schemas/131 ../obj_rig.xsd"
    version="1.3.1.1">
    <documentInfo>
        ... misc data ...
    </documentInfo>
    <rig uidWell="W-12" uidWellbore="B-01" uid="xr31">
        <nameWell>6507/7-A-42</nameWell>
        <nameWellbore>A-42</nameWellbore>
        <name>Deep Drill #5</name>
        <owner>Deep Drilling Co.</owner>
        <typeRig>floater</typeRig>
        <manufacturer>Fitsui Engineering</manufacturer>
        <yearEntService>1980</yearEntService>
        <classRig>ABS Class A1 M CSDU AMS ACCU</classRig>
        <approvals>DNV</approvals>
        ... more data ...
    </rig>
</rigs>
```

The goal is to import the information for this rig into Greenplum Database.

The sample document, `rig.xml`, is about 11KB in size. The input does not contain tabs so the relevant information can be converted into records delimited with a pipe (|).

```
W-12|6507/7-A-42|xr31|Deep Drill #5|Deep Drilling Co.|John Doe|
John.Doe@example.com|
```

With the columns:

- `well_uid` text, -- e.g. W-12
• well_name text, -- e.g. 6507/7-A-42
• rig_uid text, -- e.g. xr31
• rig_name text, -- e.g. Deep Drill #5
• rig_owner text, -- e.g. Deep Drilling Co.
• rig_contact text, -- e.g. John Doe
• rig_email text, -- e.g. John.Doe@example.com
• doc xml

Then, load the data into Greenplum Database.

### Loading Data with COPY

COPY FROM copies data from a file or standard input into a table and appends the data to the table contents. COPY is non-parallel: data is loaded in a single process using the Greenplum master instance. Using COPY is only recommended for very small data files.

The COPY source file must be accessible to the master host. Specify the COPY source file name relative to the master host location.

Greenplum copies data from STDIN or STDOUT using the connection between the client and the master server.

### Running COPY in Single Row Error Isolation Mode

By default, COPY stops an operation at the first error: if the data contains an error, the operation fails and no data loads. If you run COPY FROM in single row error isolation mode, Greenplum skips rows that contain format errors and loads properly formatted rows. Single row error isolation mode applies only to rows in the input file that contain format errors. If the data contains a constraint error such as violation of a NOT NULL, CHECK, or UNIQUE constraint, the operation fails and no data loads.

Specifying SEGMENT REJECT LIMIT runs the COPY operation in single row error isolation mode. Specify the acceptable number of error rows on each segment, after which the entire COPY FROM operation fails and no rows load. The error row count is for each Greenplum Database segment, not for the entire load operation.

If the COPY operation does not reach the error limit, Greenplum loads all correctly-formatted rows and discards the error rows. Use the LOG ERRORS clause to capture data formatting errors internally in Greenplum Database. For example:

```sql
=> COPY country FROM '/data/gpdb/country_data'
WITH DELIMITER '|' LOG ERRORS
SEGMENT REJECT LIMIT 10 ROWS;
```

See Viewing Bad Rows in the Error Log for information about investigating error rows.

### Optimizing Data Load and Query Performance

Use the following tips to help optimize your data load and subsequent query performance.

• Drop indexes before loading data into existing tables.

  Creating an index on pre-existing data is faster than updating it incrementally as each row is loaded.
  You can temporarily increase the maintenance_work_mem server configuration parameter to help speed up CREATE INDEX commands, though load performance is affected. Drop and recreate indexes only when there are no active users on the system.

• Create indexes last when loading data into new tables. Create the table, load the data, and create any required indexes.
Run `ANALYZE` after loading data. If you significantly altered the data in a table, run `ANALYZE` or `VACUUM ANALYZE` to update table statistics for the query optimizer. Current statistics ensure that the optimizer makes the best decisions during query planning and avoids poor performance due to inaccurate or nonexistent statistics.

Run `VACUUM` after load errors. If the load operation does not run in single row error isolation mode, the operation stops at the first error. The target table contains the rows loaded before the error occurred. You cannot access these rows, but they occupy disk space. Use the `VACUUM` command to recover the wasted space.

**Unloading Data from Greenplum Database**

A writable external table allows you to select rows from other database tables and output the rows to files, named pipes, to applications, or as output targets for Greenplum parallel MapReduce calculations. You can define file-based and web-based writable external tables.

This topic describes how to unload data from Greenplum Database using parallel unload (writable external tables) and non-parallel unload (`COPY`).

**Defining a File-Based Writable External Table**

Writable external tables that output data to files use the Greenplum parallel file server program, `gpfdist`, or the Hadoop Distributed File System interface, `gphdfs`.

Use the `CREATE WRITABLE EXTERNAL TABLE` command to define the external table and specify the location and format of the output files. See [Using the Greenplum Parallel File Server (gpfdist)](https://www.greenplum.com/docs/GP-ADMINISTRATOR-GUIDE/5.1) for instructions on setting up `gpfdist` for use with an external table and [Accessing HDFS Data with gphdfs](https://www.greenplum.com/docs/GP-ADMINISTRATOR-GUIDE/5.1) for instructions on setting up `gphdfs` for use with an external table.

- With a writable external table using the `gpfdist` protocol, the Greenplum segments send their data to `gpfdist`, which writes the data to the named file. `gpfdist` must run on a host that the Greenplum segments can access over the network. `gpfdist` points to a file location on the output host and writes data received from the Greenplum segments to the file. To divide the output data among multiple files, list multiple `gpfdist` URIs in your writable external table definition.

- A writable external web table sends data to an application as a stream of data. For example, unload data from Greenplum Database and send it to an application that connects to another database or ETL tool to load the data elsewhere. Writable external web tables use the `EXECUTE` clause to specify a shell command, script, or application to run on the segment hosts and accept an input stream of data. See [Defining a Command-Based Writable External Web Table](https://www.greenplum.com/docs/GP-ADMINISTRATOR-GUIDE/5.1) for more information about using `EXECUTE` commands in a writable external table definition.

You can optionally declare a distribution policy for your writable external tables. By default, writable external tables use a random distribution policy. If the source table you are exporting data from has a hash distribution policy, defining the same distribution key column(s) for the writable external table improves unload performance by eliminating the requirement to move rows over the interconnect. If you unload data from a particular table, you can use the `LIKE` clause to copy the column definitions and distribution policy from the source table.

**Example 1—Greenplum file server (gpfdist)**

```sql
=# CREATE WRITABLE EXTERNAL TABLE unload_expenses
   ( LIKE expenses )
   LOCATION ('gpfdist://etlhost-1:8081/expenses1.out',
             'gpfdist://etlhost-2:8081/expenses2.out')
   FORMAT 'TEXT' (DELIMITER ',')
   DISTRIBUTED BY (exp_id);
```
Example 2—Hadoop file server (gphdfs)

```sql
=# CREATE WRITABLE EXTERNAL TABLE unload_expenses
   ( LIKE expenses )
   LOCATION ('gphdfs://hdfs1host-1:8081/path')
   FORMAT 'TEXT' (DELIMITER ',')
   DISTRIBUTED BY (exp_id);
```

You can only specify a directory for a writable external table with the gphdfs protocol. (You can only specify one file for a readable external table with the gphdfs protocol)

**Note:** The default port number is 9000.

Defining a Command-Based Writable External Web Table

You can define writable external web tables to send output rows to an application or script. The application must accept an input stream, reside in the same location on all of the Greenplum segment hosts, and be executable by the gpadmin user. All segments in the Greenplum system run the application or script, whether or not a segment has output rows to process.

Use `CREATE WRITABLE EXTERNAL WEB TABLE` to define the external table and specify the application or script to run on the segment hosts. Commands execute from within the database and cannot access environment variables (such as $PATH). Set environment variables in the `EXECUTE` clause of your writable external table definition. For example:

```sql
=# CREATE WRITABLE EXTERNAL WEB TABLE output (output text)
   EXECUTE 'export PATH=$PATH:/home/gpadmin/programs;
               myprogram.sh'
   FORMAT 'TEXT'
   DISTRIBUTED RANDOMLY;
```

The following Greenplum Database variables are available for use in OS commands executed by a web or writable external table. Set these variables as environment variables in the shell that executes the command(s). They can be used to identify a set of requests made by an external table statement across the Greenplum Database array of hosts and segment instances.

**Table 71: External Table EXECUTE Variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$GP_CID</td>
<td>Command count of the transaction executing the external table statement.</td>
</tr>
<tr>
<td>$GP_DATABASE</td>
<td>The database in which the external table definition resides.</td>
</tr>
<tr>
<td>$GP_DATE</td>
<td>The date on which the external table command ran.</td>
</tr>
<tr>
<td>$GP_MASTER_HOST</td>
<td>The host name of the Greenplum master host from which the external table</td>
</tr>
<tr>
<td></td>
<td>statement was dispatched.</td>
</tr>
<tr>
<td>$GP_MASTER_PORT</td>
<td>The port number of the Greenplum master instance from which the external</td>
</tr>
<tr>
<td></td>
<td>table statement was dispatched.</td>
</tr>
<tr>
<td>$GP_SEG_DATADIR</td>
<td>The location of the data directory of the segment instance executing</td>
</tr>
<tr>
<td></td>
<td>the external table command.</td>
</tr>
<tr>
<td>$GP_SEG_PG_CONF</td>
<td>The location of the <code>postgresql.conf</code> file of the segment instance</td>
</tr>
<tr>
<td></td>
<td>executing the external table command.</td>
</tr>
</tbody>
</table>
### Variable Description

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$GP_SEG_PORT</td>
<td>The port number of the segment instance executing the external table command.</td>
</tr>
<tr>
<td>$GP_SEGMENT_COUNT</td>
<td>The total number of primary segment instances in the Greenplum Database system.</td>
</tr>
<tr>
<td>$GP_SEGMENT_ID</td>
<td>The ID number of the segment instance executing the external table command (same as dbid in gp_segment_configuration).</td>
</tr>
<tr>
<td>$GP_SESSION_ID</td>
<td>The database session identifier number associated with the external table statement.</td>
</tr>
<tr>
<td>$GP_SN</td>
<td>Serial number of the external table scan node in the query plan of the external table statement.</td>
</tr>
<tr>
<td>$GP_TIME</td>
<td>The time the external table command was executed.</td>
</tr>
<tr>
<td>$GP_USER</td>
<td>The database user executing the external table statement.</td>
</tr>
<tr>
<td>$GP_XID</td>
<td>The transaction ID of the external table statement.</td>
</tr>
</tbody>
</table>

### Disabling EXECUTE for Web or Writable External Tables

There is a security risk associated with allowing external tables to execute OS commands or scripts. To disable the use of EXECUTE in web and writable external table definitions, set the `gp_external_enable_exec` server configuration parameter to off in your master `postgresql.conf` file:

```
gp_external_enable_exec = off
```

### Unloading Data Using a Writable External Table

Writable external tables allow only INSERT operations. You must grant INSERT permission on a table to enable access to users who are not the table owner or a superuser. For example:

```
GRANT INSERT ON writable_ext_table TO admin;
```

To unload data using a writable external table, select the data from the source table(s) and insert it into the writable external table. The resulting rows are output to the writable external table. For example:

```
INSERT INTO writable_ext_table SELECT * FROM regular_table;
```

### Unloading Data Using COPY

COPY TO copies data from a table to a file (or standard input) on the Greenplum master host using a single process on the Greenplum master instance. Use COPY to output a table's entire contents, or filter the output using a SELECT statement. For example:

```
COPY (SELECT * FROM country WHERE country_name LIKE 'A%')
TO '/home/gpadmin/a_list_countries.out';
```

### Formatting Data Files

When you use the Greenplum tools for loading and unloading data, you must specify how your data is formatted. COPY, CREATE EXTERNAL TABLE, and gpload have clauses that allow you to specify how your data is formatted. Data can be delimited text (TEXT) or comma separated values (CSV) format.
External data must be formatted correctly to be read by Greenplum Database. This topic explains the format of data files expected by Greenplum Database.

Formatting Rows

Greenplum Database expects rows of data to be separated by the LF character (Line feed, 0x0A), CR (Carriage return, 0x0D), or CR followed by LF (CR+LF, 0x0D 0x0A). LF is the standard newline representation on UNIX or UNIX-like operating systems. Operating systems such as Windows or Mac OS X use CR or CR+LF. All of these representations of a newline are supported by Greenplum Database as a row delimiter. For more information, see Importing and Exporting Fixed Width Data.

Formatting Columns

The default column or field delimiter is the horizontal TAB character (0x09) for text files and the comma character (0x2C) for CSV files. You can declare a single character delimiter using the DELIMITER clause of COPY, CREATE EXTERNAL TABLE or gpload when you define your data format. The delimiter character must appear between any two data value fields. Do not place a delimiter at the beginning or end of a row. For example, if the pipe character ( | ) is your delimiter:

```
data value 1|data value 2|data value 3
```

The following command shows the use of the pipe character as a column delimiter:

```
=# CREATE EXTERNAL TABLE ext_table (name text, date date)
LOCATION ('gpfdist://<hostname>/filename.txt)
FORMAT 'TEXT' (DELIMITER '|');
```

Representing NULL Values

NULL represents an unknown piece of data in a column or field. Within your data files you can designate a string to represent null values. The default string is \N (backslash-N) in TEXT mode, or an empty value with no quotations in CSV mode. You can also declare a different string using the NULL clause of COPY, CREATE EXTERNAL TABLE or gpload when defining your data format. For example, you can use an empty string if you do not want to distinguish nulls from empty strings. When using the Greenplum Database loading tools, any data item that matches the designated null string is considered a null value.

Escaping

There are two reserved characters that have special meaning to Greenplum Database:

- The designated delimiter character separates columns or fields in the data file.
- The newline character designates a new row in the data file.

If your data contains either of these characters, you must escape the character so that Greenplum treats it as data and not as a field separator or new row. By default, the escape character is a \ (backslash) for text-formatted files and a double quote (") for csv-formatted files.

Escaping in Text Formatted Files

By default, the escape character is a \ (backslash) for text-formatted files. You can declare a different escape character in the ESCAPE clause of COPY, CREATE EXTERNAL TABLE or gpload. If your escape character appears in your data, use it to escape itself.

For example, suppose you have a table with three columns and you want to load the following three fields:

- backslash = \
- vertical bar = |'
- exclamation point = !
Your designated delimiter character is | (pipe character), and your designated escape character is \ (backslash). The formatted row in your data file looks like this:

```
backslash = \ | vertical bar = \| | exclamation point = !
```

Notice how the backslash character that is part of the data is escaped with another backslash character, and the pipe character that is part of the data is escaped with a backslash character.

You can use the escape character to escape octal and hexadecimal sequences. The escaped value is converted to the equivalent character when loaded into Greenplum Database. For example, to load the ampersand character (&), use the escape character to escape its equivalent hexadecimal (\0x26) or octal (\046) representation.

You can disable escaping in TEXT-formatted files using the ESCAPE clause of COPY, CREATE EXTERNAL TABLE or gpload as follows:

```
ESCAPE 'OFF'
```

This is useful for input data that contains many backslash characters, such as web log data.

**Escaping in CSV Formatted Files**

By default, the escape character is a " (double quote) for CSV-formatted files. If you want to use a different escape character, use the ESCAPE clause of COPY, CREATE EXTERNAL TABLE or gpload to declare a different escape character. In cases where your selected escape character is present in your data, you can use it to escape itself.

For example, suppose you have a table with three columns and you want to load the following three fields:

- Free trip to A,B
- 5.89
- Special rate "1.79"

Your designated delimiter character is , (comma), and your designated escape character is " (double quote). The formatted row in your data file looks like this:

```
"Free trip to A,B","5.89","Special rate "1.79"
```

The data value with a comma character that is part of the data is enclosed in double quotes. The double quotes that are part of the data are escaped with a double quote even though the field value is enclosed in double quotes.

Embedding the entire field inside a set of double quotes guarantees preservation of leading and trailing whitespace characters:

```
"Free trip to A,B ","5.89 ","Special rate ","1.79"
```

**Note:** In CSV mode, all characters are significant. A quoted value surrounded by white space, or any characters other than DELIMITER, includes those characters. This can cause errors if you import data from a system that pads CSV lines with white space to some fixed width. In this case, preprocess the CSV file to remove the trailing white space before importing the data into Greenplum Database.

**Character Encoding**

Character encoding systems consist of a code that pairs each character from a character set with something else, such as a sequence of numbers or octets, to facilitate data transmission and storage. Greenplum Database supports a variety of character sets, including single-byte character sets such as
the ISO 8859 series and multiple-byte character sets such as EUC (Extended UNIX Code), UTF-8, and Mule internal code. The server-side character set is defined during database initialization, UTF-8 is the default and can be changed. Clients can use all supported character sets transparently, but a few are not supported for use within the server as a server-side encoding. When loading or inserting data into Greenplum Database, Greenplum transparently converts the data from the specified client encoding into the server encoding. When sending data back to the client, Greenplum converts the data from the server character encoding into the specified client encoding.

Data files must be in a character encoding recognized by Greenplum Database. See the Greenplum Database Reference Guide for the supported character sets. Data files that contain invalid or unsupported encoding sequences encounter errors when loading into Greenplum Database.

Note: On data files generated on a Microsoft Windows operating system, run the dos2unix system command to remove any Windows-only characters before loading into Greenplum Database.

**Changing the Client-Side Character Encoding**

The client-side character encoding can be changed for a session by setting the server configuration parameter `client_encoding`

```
SET client_encoding TO 'latin1';
```

Change the client-side character encoding back to the default value:

```
RESET client_encoding;
```

Show the current client-side character encoding setting:

```
SHOW client_encoding;
```

**Example Custom Data Access Protocol**

The following is the API for the Greenplum Database custom data access protocol. The example protocol implementation `gpextprotocol.c` is written in C and shows how the API can be used. For information about accessing a custom data access protocol, see Using a Custom Protocol.

```
/* ---- Read/Write function API ------*/
CALLED_AS_EXTPROTOCOL(fcinfo)
EXTPROTOCOL_GET_URL(fcinfo)(fcinfo)
EXTPROTOCOL_GET_DATABUF(fcinfo)
EXTPROTOCOL_GET_DATALEN(fcinfo)
EXTPROTOCOL_GET_SCANQUALS(fcinfo)
EXTPROTOCOL_GET_USER_CTX(fcinfo)
EXTPROTOCOL_IS_LAST_CALL(fcinfo)
EXTPROTOCOL_SET_LAST_CALL(fcinfo)
EXTPROTOCOL_SET_USER_CTX(fcinfo, p)

/* ------ Validator function API ------*/
CALLED_AS_EXTPROTOCOL_VALIDATOR(fcinfo)
EXTPROTOCOL_VALIDATOR_GET_URL_LIST(fcinfo)
EXTPROTOCOL_VALIDATOR_GET_NUM_URLS(fcinfo)
EXTPROTOCOL_VALIDATOR_GET_NTH_URL(fcinfo, n)
EXTPROTOCOL_VALIDATOR_GET_DIRECTION(fcinfo)
```

**Notes**

The protocol corresponds to the example described in Using a Custom Protocol. The source code file name and shared object are `gpextprotocol.c` and `gpextprotocol.so`. 
The protocol has the following properties:

- The name defined for the protocol is `myprot`.
- The protocol has the following simple form: the protocol name and a path, separated by `://`.
  ```
  myprot://path
  ```
- Three functions are implemented:
  - `myprot_import()` a read function
  - `myprot_export()` a write function
  - `myprot_validate_urls()` a validation function

  These functions are referenced in the `CREATE PROTOCOL` statement when the protocol is created and declared in the database.

The example implementation `gprotocal.c` uses `fopen()` and `fread()` to simulate a simple protocol that reads local files. In practice, however, the protocol would implement functionality such as a remote connection to some process over the network.

### Installing the External Table Protocol

To use the example external table protocol, you use the C compiler `cc` to compile and link the source code to create a shared object that can be dynamically loaded by Greenplum Database. The commands to compile and link the source code on a Linux system are similar to this:

```bash
cc -fpic -c gprotocal.c cc -shared -o gprotocal.so gprotocal.o
```

The option `-fpic` specifies creating position-independent code (PIC) and the `-c` option compiles the source code without linking and creates an object file. The object file needs to be created as position-independent code (PIC) so that it can be loaded at any arbitrary location in memory by Greenplum Database.

The flag `-shared` specifies creating a shared object (shared library) and the `-o` option specifies the shared object file name `gprotocal.so`. Refer to the GCC manual for more information on the `cc` options.

The header files that are declared as include files in `gprotocal.c` are located in subdirectories of `$GPHOME/include/postgresql/`.

For more information on compiling and linking dynamically-loaded functions and examples of compiling C source code to create a shared library on other operating systems, see the Postgres documentation at https://www.postgresql.org/docs/8.4/static/xfunc-c.html#DFUNC.

The manual pages for the C compiler `cc` and the link editor `ld` for your operating system also contain information on compiling and linking source code on your system.

The compiled code (shared object file) for the custom protocol must be placed in the same location on every host in your Greenplum Database array (master and all segments). This location must also be in the `LD_LIBRARY_PATH` so that the server can locate the files. It is recommended to locate shared libraries either relative to `$libdir` (which is located at `$GPHOME/lib`) or through the dynamic library path (set by the `dynamic_library_path` server configuration parameter) on all master segment instances in the Greenplum Database array. You can use the Greenplum Database utilities `gpssh` and `gpscp` to update segments.

```c
#include "postgres.h"
#include "fmgr.h"
#include "funcapi.h"
#include "access/extprotocol.h"
#include "catalog/pg_proc.h"
#include "utils/array.h"
```
typedef struct DemoUri {
    char *protocol;
    char *path;
} DemoUri;

static DemoUri *ParseDemoUri(const char *uri_str);
static void FreeDemoUri(DemoUri* uri);

/* Do the module magic dance */
PG_MODULE_MAGIC;
PG_FUNCTION_INFO_V1(demoprot_export);
PG_FUNCTION_INFO_V1(demoprot_import);
PG_FUNCTION_INFO_V1(demoprot_validate_urls);

Datum demoprot_export(PG_FUNCTION_ARGS);
Datum demoprot_import(PG_FUNCTION_ARGS);
Datum demoprot_validate_urls(PG_FUNCTION_ARGS);

/* A user context that persists across calls. Can be declared in any other way */
typedef struct {
    char *url;
    char *filename;
    FILE *file;
} extprotocol_t;

/* The read function - Import data into GPDB */
Datum myprot_import(PG_FUNCTION_ARGS)
{
    extprotocol_t *myData;
    char *data;
    int datlen;
    size_t nread = 0;

    /* Must be called via the external table format manager */
    if (!CALLED_AS_EXTPROTOCOL(fcinfo))
        elog(ERROR, "myprot_import: not called by external protocol manager");

    /* Get our internal description of the protocol */
    myData = (extprotocol_t *) EXTPROTOCOL_GET_USER_CTX(fcinfo);

    if (myData == NULL)
        /* first call. do any desired init */
const char *p_name = "myprot";
DemoUri *parsed_url;
char *url = EXTPROTO_GET_URL(fcinfo);
myData = palloc(sizeof(extprotocol_t));

myData->url = pstrdup(url);
parsed_url = ParseDemoUri(myData->url);
myData->filename = pstrdup(parsed_url->path);

if(strcasecmp(parsed_url->protocol, p_name) != 0)
  elog(ERROR, "internal error: myprot called with a different protocol (%s)",
       parsed_url->protocol);

FreeDemoUri(parsed_url);

/* open the destination file (or connect to remote server in other cases) */
myData->file = fopen(myData->filename, "r");

if (myData->file == NULL)
  ereport(ERROR,
          (errcode_for_file_access(),
           errmsg("myprot_import: could not open file \"%s\" for reading: %m",
                   myData->filename),
           errOmitLocation(true)));

EXTPROTO_SET_USER_CTX(fcinfo, myData);
}

/* ==========================================*/
/*          DO THE IMPORT                      */
/* ========================================== */
data = EXTPROTO_GET_DATABUF(fcinfo);
datlen = EXTPROTO_GET_DATALEN(fcinfo);

/* read some bytes (with fread in this example, but normally in some other method over the network) */
if(datlen > 0)
{
  nread = fread(data, 1, datlen, myData->file);
  if (ferror(myData->file))
    ereport(ERROR,
            (errcode_for_file_access(),
             errmsg("myprot_import: could not write to file \"%s\": %m",
                     myData->filename)));
}

PG_RETURN_INT32((int)nread);
}

/* Write function - Export data out of GPDB */
Datum myprot_export(PG_FUNCTION_ARGS)
{
  extprotocol_t *myData;
  char *data;
  int datlen;
  size_t wrote = 0;

  /* Must be called via the external table format manager */
  if (!CALLED_AS_EXTPROTO(fcinfo))
elog(ERROR, "myprot_export: not called by external protocol manager");

/* Get our internal description of the protocol */
myData = (extprotocol_t *) EXTPROTOCOL_GET_USER_CTX(fcinfo);
if(EXTPROTOCOL_IS_LAST_CALL(fcinfo))
{
    /* we're done sending data. close our connection */
    if(myData && myData->file)
        if(fclose(myData->file))
            ereport(ERROR,
                (errcode_for_file_access(),
                errmsg("could not close file "%s": %m",
                myData->filename));

    PG_RETURN_INT32(0);
}
if (myData == NULL)
{
    /* first call. do any desired init */
    const char *p_name = "myprot";
    DemoUri *parsed_url;
    char *url = EXTPROTOCOL_GET_URL(fcinfo);
    myData = palloc(sizeof(extprotocol_t));
    myData->url = pstrdup(url);
    parsed_url = ParseDemoUri(myData->url);
    myData->filename = pstrdup(parsed_url->path);
    if(strcasecmp(parsed_url->protocol, p_name) != 0)
        elog(ERROR, "internal error: myprot called with a different protocol (%s)",
        parsed_url->protocol);
    FreeDemoUri(parsed_url);

    /* open the destination file (or connect to remote server in other cases) */
    myData->file = fopen(myData->filename, "a");
    if (myData->file == NULL)
        ereport(ERROR,
            (errcode_for_file_access(),
            errmsg("myprot_export: could not open file "%s" for writing: %m",
            myData->filename),
            errOmitLocation(true));

    EXTPROTOCOL_SET_USER_CTX(fcinfo, myData);
}
/* =============================== *
* DO THE EXPORT *
* =============================== */
data = EXTPROTOCOL_GET_DATABUF(fcinfo);
datlen = EXTPROTOCOL_GET_DATALEN(fcinfo);

if(datlen > 0)
{
    wrote = fwrite(data, 1, datlen, myData->file);
    if (ferror(myData->file))
        ereport(ERROR,
            (errcode_for_file_access(),
            errmsg("myprot_import: could not read from file");
}
pg prot validate urls (PG_FUNCTION_ARGS)
{
    List *urls;
    int nurls;
    int i;
    ValidatorDirection direction;

    /* Must be called via the external table format manager */
    if (!CALLED_AS_EXTPROTOCOL_VALIDATOR(fcinfo))
        elog(ERROR, "myprot validate urls: not called by external
            protocol manager");

    nurls = EXTPROTOCOL_VALIDATOR_GET_NUM_URLS(fcinfo);
    urls = EXTPROTOCOL_VALIDATOR_GET_URL_LIST(fcinfo);
    direction = EXTPROTOCOL_VALIDATOR_GET_DIRECTION(fcinfo);

    /* Dumb example 1: search each url for a substring
        * we don't want to be used in a url. in this example
        * it's 'secured_directory'.
        */
    for (i = 1 ; i <= nurls ; i++)
    {
        char *url = EXTPROTOCOL_VALIDATOR_GET_NTH_URL(fcinfo, i);

        if (strstr(url, "secured_directory") != 0)
            { ereport(ERROR,
                (errcode(ERRCODE_PROTOCOL_VIOLATION),
                errmsg("using 'secured_directory' in a url
                    isn't allowed ")));
            }
    }
    /*
        * Dumb example 2: set a limit on the number of urls
        * used. In this example we limit readable external
        * tables that use our protocol to 2 urls max.
        */
    if(direction == EXT_VALIDATE_READ && nurls > 2)
    {
        ereport(ERROR,
            (errcode(ERRCODE_PROTOCOL_VIOLATION),
            errmsg("more than 2 urls aren't allowed in this protocol ")));
    }

    PG_RETURN_VOID();
}
/* --- utility functions --- */
static DemoUri *ParseDemoUri(const char *uri_str)
{
    DemoUri *uri = (DemoUri *) palloc0(sizeof(DemoUri));
    int protocol_len;

    uri->path = NULL;
    uri->protocol = NULL;
    /*
        * parse protocol
        */
    char *post_protocol = strstr(uri_str, "://");
    /*
        */
    /*"%s": %m",
        myData->filename));
    } 
    PG_RETURN_INT32((int)wrote);
}
if(!post_protocol)
{
    ereport(ERROR,
        (errcode(ERRCODE_SYNTAX_ERROR),
        errmsg("invalid protocol URI \'%s\'", uri_str),
        errOmitLocation(true));
}

protocol_len = post_protocol - uri_str;
uri->protocol = (char *)palloc0(protocol_len + 1);
strncpy(uri->protocol, uri_str, protocol_len);

/* make sure there is more to the uri string */
if (strlen(uri_str) <= protocol_len)
    ereport(ERROR,
        (errcode(ERRCODE_SYNTAX_ERROR),
        errmsg("invalid myprot URI \'%s\' : missing path",
                uri_str),
        errOmitLocation(true));

/* parse path */
uri->path = pstrdup(uri_str + protocol_len + strlen("://"));

    return uri;
}
static
void FreeDemoUri(DemoUri *uri)
{
    if (uri->path)
        pfree(uri->path);
    if (uri->protocol)
        pfree(uri->protocol);

    pfree(uri);
}
Managing Performance

The topics in this section cover Greenplum Database performance management, including how to monitor performance and how to configure workloads to prioritize resource utilization.

This section contains the following topics:

- Defining Database Performance
- Common Causes of Performance Issues
- Using Resource Queues
- Investigating a Performance Problem

Defining Database Performance

Managing system performance includes measuring performance, identifying the causes of performance problems, and applying the tools and techniques available to you to remedy the problems.

Greenplum measures database performance based on the rate at which the database management system (DBMS) supplies information to requesters.

Understanding the Performance Factors

Several key performance factors influence database performance. Understanding these factors helps identify performance opportunities and avoid problems:

- System Resources
- Workload
- Throughput
- Contention
- Optimization

System Resources

Database performance relies heavily on disk I/O and memory usage. To accurately set performance expectations, you need to know the baseline performance of the hardware on which your DBMS is deployed. Performance of hardware components such as CPUs, hard disks, disk controllers, RAM, and network interfaces will significantly affect how fast your database performs.

Workload

The workload equals the total demand from the DBMS, and it varies over time. The total workload is a combination of user queries, applications, batch jobs, transactions, and system commands directed through the DBMS at any given time. For example, it can increase when month-end reports are run or decrease on weekends when most users are out of the office. Workload strongly influences database performance. Knowing your workload and peak demand times helps you plan for the most efficient use of your system resources and enables processing the largest possible workload.

Throughput

A system’s throughput defines its overall capability to process data. DBMS throughput is measured in queries per second, transactions per second, or average response times. DBMS throughput is closely related to the processing capacity of the underlying systems (disk I/O, CPU speed, memory bandwidth, and so on), so it is important to know the throughput capacity of your hardware when setting DBMS throughput goals.
**Contestion**

Contestion is the condition in which two or more components of the workload attempt to use the system in a conflicting way — for example, multiple queries that try to update the same piece of data at the same time or multiple large workloads that compete for system resources. As contention increases, throughput decreases.

**Optimization**

DBMS optimizations can affect the overall system performance. SQL formulation, database configuration parameters, table design, data distribution, and so on enable the database query optimizer to create the most efficient access plans.

**Determining Acceptable Performance**

When approaching a performance tuning initiative, you should know your system's expected level of performance and define measurable performance requirements so you can accurately evaluate your system's performance. Consider the following when setting performance goals:

- **Baseline Hardware Performance**
- **Performance Benchmarks**

**Baseline Hardware Performance**

Most database performance problems are caused not by the database, but by the underlying systems on which the database runs. I/O bottlenecks, memory problems, and network issues can notably degrade database performance. Knowing the baseline capabilities of your hardware and operating system (OS) will help you identify and troubleshoot hardware-related problems before you explore database-level or query-level tuning initiatives.

See the [Greenplum Database Reference Guide](http://www.greenplum.com) for information about running the `gpcheckperf` utility to validate hardware and network performance.

**Performance Benchmarks**

To maintain good performance or fix performance issues, you should know the capabilities of your DBMS on a defined workload. A benchmark is a predefined workload that produces a known result set. Periodically run the same benchmark tests to help identify system-related performance degradation over time. Use benchmarks to compare workloads and identify queries or applications that need optimization.

Many third-party organizations, such as the Transaction Processing Performance Council (TPC), provide benchmark tools for the database industry. TPC provides TPC-H, a decision support system that examines large volumes of data, executes queries with a high degree of complexity, and gives answers to critical business questions. For more information about TPC-H, go to:

[http://www.tpc.org/tpch](http://www.tpc.org/tpch)

**Common Causes of Performance Issues**

This section explains the troubleshooting processes for common performance issues and potential solutions to these issues.

**Identifying Hardware and Segment Failures**

The performance of Greenplum Database depends on the hardware and IT infrastructure on which it runs. Greenplum Database is comprised of several servers (hosts) acting together as one cohesive system (array); as a first step in diagnosing performance problems, ensure that all Greenplum Database segments are online. Greenplum Database's performance will be as fast as the slowest host in the array. Problems
with CPU utilization, memory management, I/O processing, or network load affect performance. Common hardware-related issues are:

- **Disk Failure** – Although a single disk failure should not dramatically affect database performance if you are using RAID, disk resynchronization does consume resources on the host with failed disks. The `gpcheckper` utility can help identify segment hosts that have disk I/O issues.

- **Host Failure** – When a host is offline, the segments on that host are nonoperational. This means other hosts in the array must perform twice their usual workload because they are running the primary segments and multiple mirrors. If mirrors are not enabled, service is interrupted. Service is temporarily interrupted to recover failed segments. The `gpstate` utility helps identify failed segments.

- **Network Failure** – Failure of a network interface card, a switch, or DNS server can bring down segments. If host names or IP addresses cannot be resolved within your Greenplum array, these manifest themselves as interconnect errors in Greenplum Database. The `gpcheckper` utility helps identify segment hosts that have network issues.

- **Disk Capacity** – Disk capacity on your segment hosts should never exceed 70 percent full. Greenplum Database needs some free space for runtime processing. To reclaim disk space that deleted rows occupy, run `VACUUM` after loads or updates. The `gp_toolkit` administrative schema has many views for checking the size of distributed database objects.

  See the *Greenplum Database Reference Guide* for information about checking database object sizes and disk space.

### Managing Workload

A database system has a limited CPU capacity, memory, and disk I/O resources. When multiple workloads compete for access to these resources, database performance suffers. Resource management maximizes system throughput while meeting varied business requirements. Greenplum Database provides resource queues and resource groups to help you manage these system resources.

Resource queues and resource groups limit resource usage and the total number of concurrent queries executing in the particular queue or group. By assigning database roles to the appropriate queue or group, administrators can control concurrent user queries and prevent system overload. For more information about resource queues and resource groups, including selecting the appropriate scheme for your Greenplum Database environment, see *Managing Resources*.

Greenplum Database administrators should run maintenance workloads such as data loads and `VACUUM` `ANALYZE` operations after business hours. Do not compete with database users for system resources; perform administrative tasks at low-usage times.

### Avoiding Contention

Contention arises when multiple users or workloads try to use the system in a conflicting way; for example, contention occurs when two transactions try to update a table simultaneously. A transaction that seeks a table-level or row-level lock will wait indefinitely for conflicting locks to be released. Applications should not hold transactions open for long periods of time, for example, while waiting for user input.

### Maintaining Database Statistics

Greenplum Database uses a cost-based query optimizer that relies on database statistics. Accurate statistics allow the query optimizer to better estimate the number of rows retrieved by a query to choose the most efficient query plan. Without database statistics, the query optimizer cannot estimate how many records will be returned. The optimizer does not assume it has sufficient memory to perform certain operations such as aggregations, so it takes the most conservative action and does these operations by reading and writing from disk. This is significantly slower than doing them in memory. `ANALYZE` collects statistics about the database that the query optimizer needs.

**Note:** When executing an SQL command with GPORCA, Greenplum Database issues a warning if the command performance could be improved by collecting statistics on a column or set of columns
referred by the command. The warning is issued on the command line and information is added to the Greenplum Database log file. For information about collecting statistics on table columns, see the `ANALYZE` command in the *Greenplum Database Reference Guide*

**Identifying Statistics Problems in Query Plans**

Before you interpret a query plan for a query using `EXPLAIN` or `EXPLAIN ANALYZE`, familiarize yourself with the data to help identify possible statistics problems. Check the plan for the following indicators of inaccurate statistics:

- **Are the optimizer's estimates close to reality?** Run `EXPLAIN ANALYZE` and see if the number of rows the optimizer estimated is close to the number of rows the query operation returned.
- **Are selective predicates applied early in the plan?** The most selective filters should be applied early in the plan so fewer rows move up the plan tree.
- **Is the optimizer choosing the best join order?** When you have a query that joins multiple tables, make sure the optimizer chooses the most selective join order. Joins that eliminate the largest number of rows should be done earlier in the plan so fewer rows move up the plan tree.

See *Query Profiling* for more information about reading query plans.

**Tuning Statistics Collection**

The following configuration parameters control the amount of data sampled for statistics collection:

- `default_statistics_target`
- `gp_analyze_relative_error`

These parameters control statistics sampling at the system level. It is better to sample only increased statistics for columns used most frequently in query predicates. You can adjust statistics for a particular column using the command:

```
ALTER TABLE...SET STATISTICS
```

For example:

```
ALTER TABLE sales ALTER COLUMN region SET STATISTICS 50;
```

This is equivalent to changing `default_statistics_target` for a particular column. Subsequent `ANALYZE` operations will then gather more statistics data for that column and produce better query plans as a result.

**Optimizing Data Distribution**

When you create a table in Greenplum Database, you must declare a distribution key that allows for even data distribution across all segments in the system. Because the segments work on a query in parallel, Greenplum Database will always be as fast as the slowest segment. If the data is unbalanced, the segments that have more data will return their results slower and therefore slow down the entire system.

**Optimizing Your Database Design**

Many performance issues can be improved by database design. Examine your database design and consider the following:

- Does the schema reflect the way the data is accessed?
- Can larger tables be broken down into partitions?
- Are you using the smallest data type possible to store column values?
- Are columns used to join tables of the same datatype?
- Are your indexes being used?
**Greenplum Database Maximum Limits**

To help optimize database design, review the maximum limits that Greenplum Database supports:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Database Size</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Table Size</td>
<td>Unlimited, 128 TB per partition per segment</td>
</tr>
<tr>
<td>Row Size</td>
<td>1.6 TB (1600 columns * 1 GB)</td>
</tr>
<tr>
<td>Field Size</td>
<td>1 GB</td>
</tr>
<tr>
<td>Rows per Table</td>
<td>281474976710656 (2^48)</td>
</tr>
<tr>
<td>Columns per Table/View</td>
<td>1600</td>
</tr>
<tr>
<td>Indexes per Table</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Columns per Index</td>
<td>32</td>
</tr>
<tr>
<td>Table-level Constraints per Table</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Table Name Length</td>
<td>63 Bytes (Limited by name data type)</td>
</tr>
</tbody>
</table>

Dimensions listed as unlimited are not intrinsically limited by Greenplum Database. However, they are limited in practice to available disk space and memory/swap space. Performance may suffer when these values are unusually large.

**Note:**

There is a maximum limit on the number of objects (tables, indexes, and views, but not rows) that may exist at one time. This limit is 4294967296 (2^32).

**Greenplum Database Memory Overview**

Memory is a key resource for a Greenplum Database system and, when used efficiently, can ensure high performance and throughput. This topic describes how segment host memory is allocated between segments and the options available to administrators to configure memory.

A Greenplum Database segment host runs multiple PostgreSQL instances, all sharing the host's memory. The segments have an identical configuration and they consume similar amounts of memory, CPU, and disk IO simultaneously, while working on queries in parallel.

For best query throughput, the memory configuration should be managed carefully. There are memory configuration options at every level in Greenplum Database, from operating system parameters, to managing resources with resource queues and resource groups, to setting the amount of memory allocated to an individual query.

**Segment Host Memory**

On a Greenplum Database segment host, the available host memory is shared among all the processes executing on the computer, including the operating system, Greenplum Database segment instances, and other application processes. Administrators must determine what Greenplum Database and non-Greenplum Database processes share the hosts' memory and configure the system to use the memory efficiently. It is equally important to monitor memory usage regularly to detect any changes in the way host memory is consumed by Greenplum Database or other processes.

The following figure illustrates how memory is consumed on a Greenplum Database segment host.
Figure 31: Greenplum Database Segment Host Memory

Beginning at the bottom of the illustration, the line labeled $A$ represents the total host memory. The line directly above line $A$ shows that the total host memory comprises both physical RAM and swap space.

The line labelled $B$ shows that the total memory available must be shared by Greenplum Database and all other processes on the host. Non-Greenplum Database processes include the operating system and any other applications, for example system monitoring agents. Some applications may use a significant portion of memory and, as a result, you may have to adjust the number of segments per Greenplum Database host or the amount of memory per segment.

The segments (C) each get an equal share of the Greenplum Database Memory (B).

Within a segment, the currently active resource management scheme, Resource Queues or Resource Groups, governs how memory is allocated to execute a SQL statement. These constructs allow you to translate business requirements into execution policies in your Greenplum Database system and to guard against queries that could degrade performance. For an overview of resource groups and resource queues, refer to Managing Resources.

Options for Configuring Segment Host Memory

Host memory is the total memory shared by all applications on the segment host. You can configure the amount of host memory using any of the following methods:

- Add more RAM to the nodes to increase the physical memory.
- Allocate swap space to increase the size of virtual memory.
- Set the kernel parameters `vm.overcommit_memory` and `vm.overcommit_ratio` to configure how the operating system handles large memory allocation requests.

The physical RAM and OS configuration are usually managed by the platform team and system administrators. See the Greenplum Database Installation Guide for the recommended kernel parameter settings.

The amount of memory to reserve for the operating system and other processes is workload dependent. The minimum recommendation for operating system memory is 32GB, but if there is much concurrency in Greenplum Database, increasing to 64GB of reserved memory may be required. The largest user of operating system memory is SLAB, which increases as Greenplum Database concurrency and the number of sockets used increases.
The `vm.overcommit_memory` kernel parameter should always be set to 2, the only safe value for Greenplum Database.

The `vm.overcommit_ratio` kernel parameter sets the percentage of RAM that is used for application processes, the remainder reserved for the operating system. The default for Red Hat is 50 (50%). Setting this parameter too high may result in insufficient memory reserved for the operating system, which can cause segment host failure or database failure. Leaving the setting at the default of 50 is generally safe, but conservative. Setting the value too low reduces the amount of concurrency and the complexity of queries you can run at the same time by reducing the amount of memory available to Greenplum Database. When increasing `vm.overcommit_ratio`, it is important to remember to always reserve some memory for operating system activities.

To calculate a safe value for `vm.overcommit_ratio` when resource queue-based resource management is active, first determine the total memory available to Greenplum Database processes, called `gp_vmem_rq`, with this formula:

\[
gp_vmem_rq = \frac{(SWAP + RAM) - (7.5GB + 0.05 \times RAM)}{1.7}
\]

where `SWAP` is the swap space on the host in GB, and `RAM` is the number of GB of RAM installed on the host. When resource queue-based resource management is active, use `gp_vmem_rq` to calculate the `vm.overcommit_ratio` value with this formula:

\[
vm.overcommit_ratio = \frac{RAM - 0.026 \times gp_vmem_rq}{RAM}
\]

When resource group-based resource management is active, the operating system `vm.overcommit_ratio` default value is a good starting point. Tune as necessary. If your memory utilization is too low, increase the value; if your memory or swap usage is too high, decrease the setting.

**Configuring Greenplum Database Memory**

Greenplum Database Memory is the amount of memory available to all Greenplum Database segment instances.

When you set up the Greenplum Database cluster, you determine the number of primary segments to run per host and the amount of memory to allocate for each segment. Depending on the CPU cores, amount of physical RAM, and workload characteristics, the number of segments is usually a value between 4 and 8. With segment mirroring enabled, it is important to allocate memory for the maximum number of primary segments executing on a host during a failure. For example, if you use the default grouping mirror configuration, a segment host failure doubles the number of acting primaries on the host that has the failed host’s mirrors. Mirror configurations that spread each host’s mirrors over multiple other hosts can lower the maximum, allowing more memory to be allocated for each segment. For example, if you use a block mirroring configuration with 4 hosts per block and 8 primary segments per host, a single host failure would cause other hosts in the block to have a maximum of 11 active primaries, compared to 16 for the default grouping mirror configuration.

When resource queue-based resource management is active, the `gp_vmem_protect_limit` server configuration parameter value identifies the amount of memory to allocate to each segment. This value is estimated by calculating the memory available for all Greenplum Database processes and dividing by the maximum number of primary segments during a failure. If `gp_vmem_protect_limit` is set too high, queries can fail. Use the following formula to calculate a safe value for `gp_vmem_protect_limit`; provide the `gp_vmem_rq` value you calculated earlier.

\[
gp_vmem_protect_limit = \frac{gp_vmem_rq}{max_acting_primary_segments}
\]

where `max_acting_primary_segments` is the maximum number of primary segments that could be running on a host when mirror segments are activated due to a host or segment failure.
gp_vmem_protect_limit does not affect segment memory when using resource groups for Greenplum Database resource management.

When resource group-based resource management is active, the amount of memory allocated to each segment on a segment host is the memory available to Greenplum Database multiplied by the gp_resource_group_memory_limit server configuration parameter and divided by the number of active primary segments on the host. Use the following formula to calculate a safe value for segment memory when using resource groups for resource management.

\[ \text{rg_perseg_mem} = \left( \frac{\text{RAM} \times \left( \frac{\text{vm.overcommit_ratio}}{100} \right) + \text{SWAP}}{\text{gp_resource_group_memory_limit}} \right) / \text{num_active_primary_segments} \]

Resource queues and resource groups support additional configuration parameters that enable you to further control and refine the amount of memory allocated for queries.

**Managing Resources**

Greenplum Database provides features to help you prioritize and allocate resources to queries according to business requirements and to prevent queries from starting when resources are unavailable.

You can use resource management features to limit the number of concurrent queries, the amount of memory used to execute a query, and the relative amount of CPU devoted to processing a query. Greenplum Database provides two schemes to manage resources - Resource Queues and Resource Groups.

**Important:** Significant Greenplum Database performance degradation has been observed when enabling resource group-based workload management on RedHat 6.x, CentOS 6.x, and SuSE 11 systems. This issue is caused by a Linux cgroup kernel bug. This kernel bug has been fixed in CentOS 7.x and Red Hat 7.x systems, and on SuSE 12 SP2/SP3 systems with kernel version 4.4.73-5.1 or newer.

If you use RedHat 6 and the performance with resource groups is acceptable for your use case, upgrade your kernel to version 2.6.32-696 or higher to benefit from other fixes to the cgroups implementation.

SuSE 11 does not have a kernel version that resolves this issue; resource groups are still considered to be an experimental feature on this platform. Resource groups are not supported on SuSE 11 for production use.

Either the resource queue or the resource group management scheme can be active in Greenplum Database; both schemes cannot be active at the same time.

Resource queues are enabled by default when you install your Greenplum Database cluster. While you can create and assign resource groups when resource queues are active, you must explicitly enable resource groups to start using that management scheme.

The following table summarizes some of the differences between Resource Queues and Resource Groups.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Resource Queues</th>
<th>Resource Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concurrency</td>
<td>Managed at the query level</td>
<td>Managed at the transaction level</td>
</tr>
<tr>
<td>CPU</td>
<td>Specify query priority</td>
<td>Specify percentage of CPU resources; uses Linux Control Groups</td>
</tr>
<tr>
<td>Memory</td>
<td>Managed at the queue and operator level; users can over-subscribe</td>
<td>Managed at the transaction level, with enhanced allocation and tracking; users cannot over-subscribe</td>
</tr>
</tbody>
</table>
### Using Resource Queues

Use Greenplum Database resource queues to prioritize and allocate resources to queries according to business requirements and to prevent queries from starting when resources are unavailable.

Resource queues are one tool to manage the degree of concurrency in a Greenplum Database system. Resource queues are database objects that you create with the `CREATE RESOURCE QUEUE` SQL statement. You can use them to manage the number of active queries that may execute concurrently, the amount of memory each type of query is allocated, and the relative priority of queries. Resource queues can also guard against queries that would consume too many resources and degrade overall system performance.

Each database role is associated with a single resource queue; multiple roles can share the same resource queue. Roles are assigned to resource queues using the `RESOURCE QUEUE` phrase of the `CREATE ROLE` or `ALTER ROLE` statements. If a resource queue is not specified, the role is associated with the default resource queue, `pg_default`.

When the user submits a query for execution, the query is evaluated against the resource queue's limits. If the query does not cause the queue to exceed its resource limits, then that query will run immediately. If the query causes the queue to exceed its limits (for example, if the maximum number of active statement slots are currently in use), then the query must wait until queue resources are free before it can run.

Queries are evaluated on a first in, first out basis. If query prioritization is enabled, the active workload on the system is periodically assessed and processing resources are reallocated according to query priority (see *How Priorities Work*). Roles with the `SUPERUSER` attribute are exempt from resource queue limits. Superuser queries always run immediately regardless of limits imposed by their assigned resource queue.
Figure 32: Resource Queue Process

Resource queues define classes of queries with similar resource requirements. Administrators should create resource queues for the various types of workloads in their organization. For example, you could create resource queues for the following classes of queries, corresponding to different service level agreements:

- ETL queries
- Reporting queries
- Executive queries

A resource queue has the following characteristics:

**MEMORY LIMIT**

The amount of memory used by all the queries in the queue (per segment). For example, setting `MEMORY_LIMIT` to 2GB on the ETL queue allows ETL queries to use up to 2GB of memory in each segment.

**ACTIVE_STATEMENTS**

The number of slots for a queue; the maximum concurrency level for a queue. When all slots are used, new queries must wait. Each query uses an equal amount of memory by default.

For example, the `pg_default` resource queue has `ACTIVE_STATEMENTS = 20`.

**PRIORITY**

The relative CPU usage for queries. This may be one of the following levels: LOW, MEDIUM, HIGH, MAX. The default level is MEDIUM. The query prioritization mechanism monitors the CPU usage of all the queries running in the system, and adjusts the CPU usage for each to conform to its priority level. For example, you could set MAX priority to the executive resource queue and MEDIUM to other queues to ensure that executive queries receive a greater share of CPU.

**MAX_COST**

Query plan cost limit.

The Greenplum Database optimizer assigns a numeric cost to each query. If the cost exceeds the `MAX_COST` value set for the resource queue, the query is rejected as too expensive.

**Note:** GPORCA and the legacy Greenplum Database query optimizer utilize different query costing models and may compute different costs for the same query. The Greenplum Database resource queue resource management scheme neither differentiates nor aligns costs between GPORCA and the
legacy optimizer; it uses the literal cost value returned from the optimizer to throttle queries.

When resource queue-based resource management is active, use the MEMORY_LIMIT and ACTIVE_STATEMENTS limits for resource queues rather than configuring cost-based limits. Even when using GPORCA, Greenplum Database may fall back to using the legacy query optimizer for certain queries, so using cost-based limits can lead to unexpected results.

The default configuration for a Greenplum Database system has a single default resource queue named pg_default. The pg_default resource queue has an ACTIVE_STATEMENTS setting of 20, no MEMORY_LIMIT, medium PRIORITY, and no set MAX_COST. This means that all queries are accepted and run immediately, at the same priority and with no memory limitations; however, only twenty queries may execute concurrently.

The number of concurrent queries a resource queue allows depends on whether the MEMORY_LIMIT parameter is set:

- If no MEMORY_LIMIT is set for a resource queue, the amount of memory allocated per query is the value of the statement_mem server configuration parameter. The maximum memory the resource queue can use is the product of statement_mem and ACTIVE_STATEMENTS.
- When a MEMORY_LIMIT is set on a resource queue, the number of queries that the queue can execute concurrently is limited by the queue's available memory.

A query admitted to the system is allocated an amount of memory and a query plan tree is generated for it. Each node of the tree is an operator, such as a sort or hash join. Each operator is a separate execution thread and is allocated a fraction of the overall statement memory, at minimum 100KB. If the plan has a large number of operators, the minimum memory required for operators can exceed the available memory and the query will be rejected with an insufficient memory error. Operators determine if they can complete their tasks in the memory allocated, or if they must spill data to disk, in work files. The mechanism that allocates and controls the amount of memory used by each operator is called memory quota.

Not all SQL statements submitted through a resource queue are evaluated against the queue limits. By default only SELECT, SELECT INTO, CREATE TABLE AS SELECT, and DECLARE CURSOR statements are evaluated. If the server configuration parameter resource_select_only is set to off, then INSERT, UPDATE, and DELETE statements will be evaluated as well.

Also, an SQL statement that is run during the execution of an EXPLAIN ANALYZE command is excluded from resource queues.

**Resource Queue Example**

The default resource queue, pg_default, allows a maximum of 20 active queries and allocates the same amount of memory to each. This is generally not adequate resource control for production systems. To ensure that the system meets performance expectations, you can define classes of queries and assign them to resource queues configured to execute them with the concurrency, memory, and CPU resources best suited for that class of query.

The following illustration shows an example resource queue configuration for a Greenplum Database system with gp_vmem_protect_limit set to 8GB:
Figure 33: Resource Queue Configuration Example

This example has three classes of queries with different characteristics and service level agreements (SLAs). Three resource queues are configured for them. A portion of the segment memory is reserved as a safety margin.

<table>
<thead>
<tr>
<th>Resource Queue Name</th>
<th>Active Statements</th>
<th>Memory Limit</th>
<th>Memory per Query</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETL</td>
<td>3</td>
<td>2GB</td>
<td>667MB</td>
</tr>
<tr>
<td>Reporting</td>
<td>7</td>
<td>3GB</td>
<td>429MB</td>
</tr>
<tr>
<td>Executive</td>
<td>1</td>
<td>1.4GB</td>
<td>1.4GB</td>
</tr>
</tbody>
</table>

The total memory allocated to the queues is 6.4GB, or 80% of the total segment memory defined by the `gp_vmem_protect_limit` server configuration parameter. Allowing a safety margin of 20% accommodates some operators and queries that are known to use more memory than they are allocated by the resource queue.

See the CREATE RESOURCE QUEUE and CREATE/ALTER ROLE statements in the Greenplum Database Reference Guide for help with command syntax and detailed reference information.

How Memory Limits Work

Setting `MEMORY_LIMIT` on a resource queue sets the maximum amount of memory that all active queries submitted through the queue can consume for a segment instance. The amount of memory allotted to a query is the queue memory limit divided by the active statement limit. (Use the memory limits in conjunction with statement-based queues rather than cost-based queues.) For example, if a queue has a memory limit of 2000MB and an active statement limit of 10, each query submitted through the queue is allotted 200MB of memory by default. The default memory allotment can be overridden on a per-query basis using the `statement_mem` server configuration parameter (up to the queue memory limit). Once a query has started executing, it holds its allotted memory in the queue until it completes, even if during execution it actually consumes less than its allotted amount of memory.

You can use the `statement_mem` server configuration parameter to override memory limits set by the current resource queue. At the session level, you can increase `statement_mem` up to the resource queue’s `MEMORY_LIMIT`. This will allow an individual query to use all of the memory allocated for the entire queue without affecting other resource queues.

The value of `statement_mem` is capped using the `max_statement_mem` configuration parameter (a superuser parameter). For a query in a resource queue with `MEMORY_LIMIT` set, the maximum value for `statement_mem` is `min(MEMORY_LIMIT, max_statement_mem)`. When a query is admitted, the memory allocated to it is subtracted from `MEMORY_LIMIT`. If `MEMORY_LIMIT` is exhausted, new queries in the same resource queue must wait. This happens even if `ACTIVE_STATEMENTS` has not yet been reached. Note that this can happen only when `statement_mem` is used to override the memory allocated by the resource queue.

For example, consider a resource queue named `adhoc` with the following settings:
- `MEMORY_LIMIT` is 1.5GB
- `ACTIVE_STATEMENTS` is 3
By default each statement submitted to the queue is allocated 500MB of memory. Now consider the following series of events:

1. User ADHOC_1 submits query Q1, overriding STATEMENT_MEM to 800MB. The Q1 statement is admitted into the system.
2. User ADHOC_2 submits query Q2, using the default 500MB.
3. With Q1 and Q2 still running, user ADHOC3 submits query Q3, using the default 500MB.

Queries Q1 and Q2 have used 1300MB of the queue's 1500MB. Therefore, Q3 must wait for Q1 or Q2 to complete before it can run.

If MEMORY_LIMIT is not set on a queue, queries are admitted until all of the ACTIVE_STATEMENTS slots are in use, and each query can set an arbitrarily high statement_mem. This could lead to a resource queue using unbounded amounts of memory.

For more information on configuring memory limits on a resource queue, and other memory utilization controls, see Creating Queues with Memory Limits.

**statement_mem and Low Memory Queries**

A low statement_mem setting (for example, in the 1-3MB range) has been shown to increase the performance of queries with low memory requirements. Use the statement_mem server configuration parameter to override the setting on a per-query basis. For example:

```
SET statement_mem='2MB';
```

**How Priorities Work**

The PRIORITY setting for a resource queue differs from the MEMORY_LIMIT and ACTIVE_STATEMENTS settings, which determine whether a query will be admitted to the queue and eventually executed. The PRIORITY setting applies to queries after they become active. Active queries share available CPU resources as determined by the priority settings for its resource queue. When a statement from a high-priority queue enters the group of actively running statements, it may claim a greater share of the available CPU, reducing the share allocated to already-running statements in queues with a lesser priority setting.

The comparative size or complexity of the queries does not affect the allotment of CPU. If a simple, low-cost query is running simultaneously with a large, complex query, and their priority settings are the same, they will be allocated the same share of available CPU resources. When a new query becomes active, the CPU shares will be recalculated, but queries of equal priority will still have equal amounts of CPU.

For example, an administrator creates three resource queues: adhoc for ongoing queries submitted by business analysts, reporting for scheduled reporting jobs, and executive for queries submitted by executive user roles. The administrator wants to ensure that scheduled reporting jobs are not heavily affected by unpredictable resource demands from ad-hoc analyst queries. Also, the administrator wants to make sure that queries submitted by executive roles are allotted a significant share of CPU. Accordingly, the resource queue priorities are set as shown:

- **adhoc** — Low priority
- **reporting** — High priority
- **executive** — Maximum priority

At runtime, the CPU share of active statements is determined by these priority settings. If queries 1 and 2 from the reporting queue are running simultaneously, they have equal shares of CPU. When an ad-hoc query becomes active, it claims a smaller share of CPU. The exact share used by the reporting queries is adjusted, but remains equal due to their equal priority setting:
Figure 34: CPU share readjusted according to priority

Note:

The percentages shown in these illustrations are approximate. CPU usage between high, low and maximum priority queues is not always calculated in precisely these proportions.

When an executive query enters the group of running statements, CPU usage is adjusted to account for its maximum priority setting. It may be a simple query compared to the analyst and reporting queries, but until it is completed, it will claim the largest share of CPU.
Steps to Enable Resource Management

Enabling and using resource management in Greenplum Database involves the following high-level tasks:

2. Create the resource queues and set limits on them. See Creating Resource Queues and Modifying Resource Queues.
3. Assign a queue to one or more user roles. See Assigning Roles (Users) to a Resource Queue.
4. Use the resource management system views to monitor and manage the resource queues. See Checking Resource Queue Status.

Configuring Resource Management

Resource scheduling is enabled by default when you install Greenplum Database, and is required for all roles. The default resource queue, pg_default, has an active statement limit of 20, no memory limit, and a medium priority setting. Create resource queues for the various types of workloads.

To configure resource management

1. The following parameters are for the general configuration of resource queues:
   - max_resource_queues - Sets the maximum number of resource queues.
   - max_resource_portals_per_transaction - Sets the maximum number of simultaneously open cursors allowed per transaction. Note that an open cursor will hold an active query slot in a resource queue.
2. The following parameters are related to memory utilization:

- **resource_select_only** - If set to on, then SELECT, SELECT INTO, CREATE TABLE ASSELECT, and DECLARE CURSOR commands are evaluated. If set to off, INSERT, UPDATE, and DELETE commands will be evaluated as well.
- **resource_cleanup_gangs_on_wait** - Cleans up idle segment worker processes before taking a slot in the resource queue.
- **stats_queue_level** - Enables statistics collection on resource queue usage, which can then be viewed by querying the pg_stat_resqueues system view.

2. The following parameters are related to memory utilization:

- **gp_resqueue_memory_policy** - Enables Greenplum Database memory management features.
  
  In Greenplum Database 4.2 and later, the distribution algorithm eager_free takes advantage of the fact that not all operators execute at the same time. The query plan is divided into stages and Greenplum Database eagerly frees memory allocated to a previous stage at the end of that stage's execution, then allocates the eagerly freed memory to the new stage.

  When set to none, memory management is the same as in Greenplum Database releases prior to 4.1. When set to auto, query memory usage is controlled by statement_mem and resource queue memory limits.

- **statement_mem** and **max_statement_mem** - Used to allocate memory to a particular query at runtime (override the default allocation assigned by the resource queue). max_statement_mem is set by database superusers to prevent regular database users from over-allocation.

- **gp_vmem_protect_limit** - Sets the upper boundary that all query processes can consume and should not exceed the amount of physical memory of a segment host. When a segment host reaches this limit during query execution, the queries that cause the limit to be exceeded will be cancelled.

- **gp_vmem_idle_resource_timeout** and **gp_vmem_protect_segworker_cache_limit** - Used to free memory on segment hosts held by idle database processes. Administrators may want to adjust these settings on systems with lots of concurrency.

- **shared_buffers** - Sets the amount of memory a Greenplum server instance uses for shared memory buffers. This setting must be at least 128 kilobytes and at least 16 kilobytes times max_connections. The value must not exceed the operating system shared memory maximum allocation request size, shmmax on Linux. See the Greenplum Database Installation Guide for recommended OS memory settings for your platform.

3. The following parameters are related to query prioritization. Note that the following parameters are all local parameters, meaning they must be set in the postgresql.conf files of the master and all segments:

- **gp_resqueue_priority** - The query prioritization feature is enabled by default.
- **gp_resqueue_priority_sweeper_interval** - Sets the interval at which CPU usage is recalculated for all active statements. The default value for this parameter should be sufficient for typical database operations.
- **gp_resqueue_priority_cpucores_per_segment** - Specifies the number of CPU cores allocated per segment instance. The default value is 4 for the master and segments. For Greenplum Data Computing Appliance Version 2, the default value is 4 for segments and 25 for the master.

  Each host checks its own postgresql.conf file for the value of this parameter. This parameter also affects the master node, where it should be set to a value reflecting the higher ratio of CPU cores. For example, on a cluster that has 10 CPU cores per host and 4 segments per host, you would specify these values for gp_resqueue_priority_cpucores_per_segment:

  10 for the master and standby master. Typically, only the master instance is on the master host.

  2.5 for segment instances on the segment hosts.

  If the parameter value is not set correctly, either the CPU might not be fully utilized, or query prioritization might not work as expected. For example, if the Greenplum Database cluster has fewer than one segment instance per CPU core on your segment hosts, make sure you adjust this value accordingly.
Actual CPU core utilization is based on the ability of Greenplum Database to parallelize a query and the resources required to execute the query.

Note: Any CPU core that is available to the operating system is included in the number of CPU cores. For example, virtual CPU cores are included in the number of CPU cores.

4. If you wish to view or change any of the resource management parameter values, you can use the `gpconfig` utility.

5. For example, to see the setting of a particular parameter:

   ```bash
   $ gpconfig --show gp_vmem_protect_limit
   ```

6. For example, to set one value on all segment instances and a different value on the master:

   ```bash
   $ gpconfig -c gp_resqueue_priority_cpucores_per_segment -v 2 -m 8
   ```

7. Restart Greenplum Database to make the configuration changes effective:

   ```bash
   $ gpstop -r
   ```

**Creating Resource Queues**

Creating a resource queue involves giving it a name, setting an active query limit, and optionally a query priority on the resource queue. Use the `CREATE RESOURCE QUEUE` command to create new resource queues.

**Creating Queues with an Active Query Limit**

Resource queues with an `ACTIVE_STATEMENTS` setting limit the number of queries that can be executed by roles assigned to that queue. For example, to create a resource queue named `adhoc` with an active query limit of three:

```
=# CREATE RESOURCE QUEUE adhoc WITH (ACTIVE_STATEMENTS=3);
```

This means that for all roles assigned to the `adhoc` resource queue, only three active queries can be running on the system at any given time. If this queue has three queries running, and a fourth query is submitted by a role in that queue, that query must wait until a slot is free before it can run.

**Creating Queues with Memory Limits**

Resource queues with a `MEMORY_LIMIT` setting control the amount of memory for all the queries submitted through the queue. The total memory should not exceed the physical memory available per-segment. Set `MEMORY_LIMIT` to 90% of memory available on a per-segment basis. For example, if a host has 48 GB of physical memory and 6 segment instances, then the memory available per segment instance is 8 GB. You can calculate the recommended `MEMORY_LIMIT` for a single queue as 0.90*8=7.2 GB. If there are multiple queues created on the system, their total memory limits must also add up to 7.2 GB.

When used in conjunction with `ACTIVE_STATEMENTS`, the default amount of memory allotted per query is: `MEMORY_LIMIT / ACTIVE_STATEMENTS`. When used in conjunction with `MAX_COST`, the default amount of memory allotted per query is: `MEMORY_LIMIT * (query_cost / MAX_COST)`. Use `MEMORY_LIMIT` in conjunction with `ACTIVE_STATEMENTS` rather than with `MAX_COST`.

For example, to create a resource queue with an active query limit of 10 and a total memory limit of 2000MB (each query will be allocated 200MB of segment host memory at execution time):

```
=# CREATE RESOURCE QUEUE myqueue WITH (ACTIVE_STATEMENTS=20, MEMORY_LIMIT='2000MB');
```
The default memory allotment can be overridden on a per-query basis using the `statement_mem` server configuration parameter, provided that `MEMORY_LIMIT` or `max_statement_mem` is not exceeded. For example, to allocate more memory to a particular query:

```sql
=> SET statement_mem='2GB';
=> SELECT * FROM my_big_table WHERE column='value' ORDER BY id;
=> RESET statement_mem;
```

As a general guideline, `MEMORY_LIMIT` for all of your resource queues should not exceed the amount of physical memory of a segment host. If workloads are staggered over multiple queues, it may be OK to oversubscribe memory allocations, keeping in mind that queries may be cancelled during execution if the segment host memory limit (`gp_vmem_protect_limit`) is exceeded.

### Setting Priority Levels

To control a resource queue's consumption of available CPU resources, an administrator can assign an appropriate priority level. When high concurrency causes contention for CPU resources, queries and statements associated with a high-priority resource queue will claim a larger share of available CPU than lower priority queries and statements.

Priority settings are created or altered using the `WITH` parameter of the commands `CREATE RESOURCE QUEUE` and `ALTER RESOURCE QUEUE`. For example, to specify priority settings for the `adhoc` and `reporting` queues, an administrator would use the following commands:

```sql
=# ALTER RESOURCE QUEUE adhoc WITH (PRIORITY=LOW);
=# ALTER RESOURCE QUEUE reporting WITH (PRIORITY=HIGH);
```

To create the `executive` queue with maximum priority, an administrator would use the following command:

```sql
=# CREATE RESOURCE QUEUE executive WITH (ACTIVE_STATEMENTS=3, PRIORITY=MAX);
```

When the query prioritization feature is enabled, resource queues are given a `MEDIUM` priority by default if not explicitly assigned. For more information on how priority settings are evaluated at runtime, see How Priorities Work.

**Important:** In order for resource queue priority levels to be enforced on the active query workload, you must enable the query prioritization feature by setting the associated server configuration parameters. See Configuring Resource Management.

### Assigning Roles (Users) to a Resource Queue

Once a resource queue is created, you must assign roles (users) to their appropriate resource queue. If roles are not explicitly assigned to a resource queue, they will go to the default resource queue, `pg_default`. The default resource queue has an active statement limit of 20, no cost limit, and a medium priority setting.

Use the `ALTER ROLE` or `CREATE ROLE` commands to assign a role to a resource queue. For example:

```sql
=# ALTER ROLE name RESOURCE QUEUE queue_name;
=# CREATE ROLE name WITH LOGIN RESOURCE QUEUE queue_name;
```

A role can only be assigned to one resource queue at any given time, so you can use the `ALTER ROLE` command to initially assign or change a role's resource queue.

Resource queues must be assigned on a user-by-user basis. If you have a role hierarchy (for example, a group-level role) then assigning a resource queue to the group does not propagate down to the users in that group.

Superusers are always exempt from resource queue limits. Superuser queries will always run regardless of the limits set on their assigned queue.
Removing a Role from a Resource Queue

All users must be assigned to a resource queue. If not explicitly assigned to a particular queue, users will go into the default resource queue, pg_default. If you wish to remove a role from a resource queue and put them in the default queue, change the role's queue assignment to none. For example:

```sql
=# ALTER ROLE role_name RESOURCE QUEUE none;
```

Modifying Resource Queues

After a resource queue has been created, you can change or reset the queue limits using the ALTER RESOURCE QUEUE command. You can remove a resource queue using the DROP RESOURCE QUEUE command. To change the roles (users) assigned to a resource queue, Assigning Roles (Users) to a Resource Queue.

Altering a Resource Queue

The ALTER RESOURCE QUEUE command changes the limits of a resource queue. To change the limits of a resource queue, specify the new values you want for the queue. For example:

```sql
=# ALTER RESOURCE QUEUE adhoc WITH (ACTIVE_STATEMENTS=5);
=# ALTER RESOURCE QUEUE exec WITH (PRIORITY=MAX);
```

To reset active statements or memory limit to no limit, enter a value of -1. To reset the maximum query cost to no limit, enter a value of -1.0. For example:

```sql
=# ALTER RESOURCE QUEUE adhoc WITH (MAX_COST=-1.0, MEMORY_LIMIT='2GB');
```

You can use the ALTER RESOURCE QUEUE command to change the priority of queries associated with a resource queue. For example, to set a queue to the minimum priority level:

```sql
ALTER RESOURCE QUEUE webuser WITH (PRIORITY=MIN);
```

Dropping a Resource Queue

The DROP RESOURCE QUEUE command drops a resource queue. To drop a resource queue, the queue cannot have any roles assigned to it, nor can it have any statements waiting in the queue. See Removing a Role from a Resource Queue and Clearing a Waiting Statement From a Resource Queue for instructions on emptying a resource queue. To drop a resource queue:

```sql
=# DROP RESOURCE QUEUE name;
```

Checking Resource Queue Status

Checking resource queue status involves the following tasks:

- Viewing Queued Statements and Resource Queue Status
- Viewing Resource Queue Statistics
- Viewing the Roles Assigned to a Resource Queue
- Viewing the Waiting Queries for a Resource Queue
- Clearing a Waiting Statement From a Resource Queue
- Viewing the Priority of Active Statements
- Resetting the Priority of an Active Statement
Viewing Queued Statements and Resource Queue Status

The `gp_toolkit.gp_resqueue_status` view allows administrators to see status and activity for a resource queue. It shows how many queries are waiting to run and how many queries are currently active in the system from a particular resource queue. To see the resource queues created in the system, their limit attributes, and their current status:

```sql
=# SELECT * FROM gp_toolkit.gp_resqueue_status;
```

Viewing Resource Queue Statistics

If you want to track statistics and performance of resource queues over time, you can enable statistics collecting for resource queues. This is done by setting the following server configuration parameter in your `postgresql.conf` file:

```sql
stats_queue_level = on
```

Once this is enabled, you can use the `pg_stat_resqueues` system view to see the statistics collected on resource queue usage. Note that enabling this feature does incur slight performance overhead, as each query submitted through a resource queue must be tracked. It may be useful to enable statistics collecting on resource queues for initial diagnostics and administrative planning, and then disable the feature for continued use.

See the Statistics Collector section in the PostgreSQL documentation for more information about collecting statistics in Greenplum Database.

Viewing the Roles Assigned to a Resource Queue

To see the roles assigned to a resource queue, perform the following query of the `pg_roles` and `gp_toolkit.gp_resqueue_status` system catalog tables:

```sql
=# SELECT rolname, rsqname FROM pg_roles, gp_toolkit.gp_resqueue_status
    WHERE pg_roles.rolresqueue=gp_toolkit.gp_resqueue_status.queueid;
```

You may want to create a view of this query to simplify future inquiries. For example:

```sql
=# CREATE VIEW role2queue AS
    SELECT rolname, rsqname FROM pg_roles, pg_resqueue
    WHERE pg_roles.rolresqueue=gp_toolkit.gp_resqueue_status.queueid;
```

Then you can just query the view:

```sql
=# SELECT * FROM role2queue;
```

Viewing the Waiting Queries for a Resource Queue

When a slot is in use for a resource queue, it is recorded in the `pg_locks` system catalog table. This is where you can see all of the currently active and waiting queries for all resource queues. To check that statements are being queued (even statements that are not waiting), you can also use the `gp_toolkit.gp_locks_on_resqueue` view. For example:

```sql
=# SELECT * FROM gp_toolkit.gp_locks_on_resqueue WHERE lorwaiting='true';
```

If this query returns no results, then that means there are currently no statements waiting in a resource queue.
Clearing a Waiting Statement From a Resource Queue

In some cases, you may want to clear a waiting statement from a resource queue. For example, you may want to remove a query that is waiting in the queue but has not been executed yet. You may also want to stop a query that has been started if it is taking too long to execute, or if it is sitting idle in a transaction and taking up resource queue slots that are needed by other users. To do this, you must first identify the statement you want to clear, determine its process id (pid), and then, use `pg_cancel_backend` with the process id to end that process, as shown below. An optional message to the process can be passed as the second parameter, to indicate to the user why the process was cancelled.

For example, to see process information about all statements currently active or waiting in all resource queues, run the following query:

```sql
=# SELECT rolname, rsqname, pid, granted, current_query, datname
   FROM pg_roles, gp_toolkit.gp_resqueue_status, pg_locks,
        pg_stat_activity
   WHERE pg_roles.rolresqueue=pg_locks.objid
     AND pg_locks.objid=gp_toolkit.gp_resqueue_status.queueid
     AND pg_stat_activity.procpid=pg_locks.pid
     AND pg_stat_activity.usename=pg_roles.rolname;
```

If this query returns no results, then that means there are currently no statements in a resource queue. A sample of a resource queue with two statements in it looks something like this:

<table>
<thead>
<tr>
<th>rolname</th>
<th>rsqname</th>
<th>pid</th>
<th>granted</th>
<th>current_query</th>
<th>datname</th>
</tr>
</thead>
<tbody>
<tr>
<td>sammy</td>
<td>webuser</td>
<td>31861</td>
<td>t</td>
<td>&lt;IDLE&gt; in transaction</td>
<td>namesdb</td>
</tr>
<tr>
<td>daria</td>
<td>webuser</td>
<td>31905</td>
<td>f</td>
<td>SELECT * FROM topten;</td>
<td>namesdb</td>
</tr>
</tbody>
</table>

Use this output to identify the process id (pid) of the statement you want to clear from the resource queue. To clear the statement, you would then open a terminal window (as the `gpadmin` database superuser or as root) on the master host and cancel the corresponding process. For example:

```sql
=# pg_cancel_backend(31905)
```

**Note:**

Do not use any operating system `KILL` command.

Viewing the Priority of Active Statements

The `gp_toolkit` administrative schema has a view called `gp_resq_priority_statement`, which lists all statements currently being executed and provides the priority, session ID, and other information.

This view is only available through the `gp_toolkit` administrative schema. See the Greenplum Database Reference Guide for more information.

Resetting the Priority of an Active Statement

Superusers can adjust the priority of a statement currently being executed using the built-in function `gp_adjust_priority(session_id, statement_count, priority)`. Using this function, superusers can raise or lower the priority of any query. For example:

```sql
=# SELECT gp_adjust_priority(752, 24905, 'HIGH')
```

To obtain the session ID and statement count parameters required by this function, superusers can use the `gp_toolkit` administrative schema view, `gp_resq_priority_statement`. From the view, use these values for the function parameters:

- The value of the `rqpsession` column for the `session_id` parameter
The value of the `rqpcommand` column for the `statement_count` parameter

The value of `rqppriority` column is the current priority. You can specify a string value of MAX, HIGH, MEDIUM, or LOW as the priority.

**Note:** The `gp_adjust_priority()` function affects only the specified statement. Subsequent statements in the same resource queue are executed using the queue's normally assigned priority.

## Using Resource Groups

You use resource groups to set and enforce CPU, memory, and concurrent transaction limits in Greenplum Database. After you define a resource group, you can then assign the group to one or more Greenplum Database roles, or to an external component such as PL/Container, in order to control the resources used by those roles or components.

When you assign a resource group to a role (a role-based resource group), the resource limits that you define for the group apply to all of the roles to which you assign the group. For example, the CPU limit for a resource group identifies the maximum CPU usage for all running transactions submitted by Greenplum Database users in all roles to which you assign the group.

Similarly, when you assign a resource group to an external component, the group limits apply to all running instances of the component. For example, if you create a resource group for a PL/Container external component, the memory limit that you define for the group specifies the maximum memory usage for all running instances of each PL/Container runtime to which you assign the group.

This topic includes the following subtopics:

- Understanding Role and Component Resource Groups
- Resource Group Attributes and Limits
  - Memory Auditor
  - Transaction Concurrency Limit
  - CPU Limit
  - Memory Limits
- Using Resource Groups
  - Enabling Resource Groups
  - Creating Resource Groups
  - Assigning a Resource Group to a Role
  - Monitoring Resource Group Status
- Resource Group Frequently Asked Questions

### Understanding Role and Component Resource Groups

Greenplum Database supports two types of resource groups: groups that manage resources for roles, and groups that manage resources for external components such as PL/Container.

The most common application for resource groups is to manage the number of active queries that different roles may execute concurrently in your Greenplum Database cluster. You can also manage the amount of CPU and memory resources that Greenplum allocates to each query.

Resource groups for roles use Linux control groups (cgroups) for CPU resource management. Greenplum Database tracks virtual memory internally for these resource groups using a memory auditor referred to as `vmtracker`.

When the user executes a query, Greenplum Database evaluates the query against a set of limits defined for the resource group. Greenplum Database executes the query immediately if the group's resource limits have not yet been reached and the query does not cause the group to exceed the concurrent transaction limit. If these conditions are not met, Greenplum Database queues the query. For example, if the maximum number of concurrent transactions for the resource group has already been reached, a subsequent query is queued and must wait until other queries complete before it runs. Greenplum Database may also
execute a pending query when the resource group’s concurrency and memory limits are altered to large enough values.

Within a resource group for roles, transactions are evaluated on a first in, first out basis. Greenplum Database periodically assesses the active workload of the system, reallocating resources and starting/queuing jobs as necessary.

You can also use resource groups to manage the CPU and memory resources of external components such as PL/Container. Resource groups for external components use Linux cgroups to manage both the total CPU and total memory resources for the component.

**Resource Group Attributes and Limits**

When you create a resource group, you:

- Specify the type of resource group by identifying how memory for the group is audited.
- Provide a set of limits that determine the amount of CPU and memory resources available to the group.

Resource group attributes and limits:

<table>
<thead>
<tr>
<th>Limit Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEMORY_AUDITOR</td>
<td>The memory auditor in use for the resource group. <strong>vmtracker</strong> (the default) required if you want to assign the resource group to roles. Specify <strong>cgroup</strong> to assign the resource group to an external component.</td>
</tr>
<tr>
<td>CONCURRENCY</td>
<td>The maximum number of concurrent transactions, including active and idle transactions, that are permitted in the resource group.</td>
</tr>
<tr>
<td>CPU_RATE_LIMIT</td>
<td>The percentage of CPU resources available to this resource group.</td>
</tr>
<tr>
<td>MEMORY_LIMIT</td>
<td>The percentage of memory resources available to this resource group.</td>
</tr>
<tr>
<td>MEMORY_SHARED_QUOTA</td>
<td>The percentage of memory to share across transactions submitted in this resource group.</td>
</tr>
<tr>
<td>MEMORY_SPILL_RATIO</td>
<td>The memory usage threshold for memory-intensive transactions. When a transaction reaches this threshold, it spills to disk.</td>
</tr>
</tbody>
</table>

**Note:** Resource limits are not enforced on **SET**, **RESET**, and **SHOW** commands.

**Memory Auditor**

The **MEMORY_AUDITOR** attribute specifies the type of resource group by identifying the memory auditor for the group. A resource group that specifies the **vmtracker** **MEMORY_AUDITOR** identifies a resource group for roles. A resource group specifying the **cgroup** **MEMORY_AUDITOR** identifies a resource group for external components.

The default **MEMORY_AUDITOR** is **vmtracker**.

The **MEMORY_AUDITOR** that you specify for a resource group determines if and how Greenplum Database uses the limit attributes to manage CPU and memory resources:
<table>
<thead>
<tr>
<th>Limit Type</th>
<th>Resource Group for Roles</th>
<th>Resource Group for External Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCURRENCY</td>
<td>Yes</td>
<td>No; must be zero (0)</td>
</tr>
<tr>
<td>CPU_RATE_LIMIT</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>MEMORY_LIMIT</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>MEMORY_SHARED_QUOTA</td>
<td>Yes</td>
<td>Component-specific</td>
</tr>
<tr>
<td>MEMORY_SPILL_RATIO</td>
<td>Yes</td>
<td>Component-specific</td>
</tr>
</tbody>
</table>

**Transaction Concurrency Limit**

The `CONCURRENCY` limit controls the maximum number of concurrent transactions permitted for a resource group for roles.

- **Note:** The `CONCURRENCY` limit is not applicable to resource groups for external components and must be set to zero (0) for such groups.

Each resource group for roles is logically divided into a fixed number of slots equal to the `CONCURRENCY` limit. Greenplum Database allocates these slots an equal, fixed percentage of memory resources.

The default `CONCURRENCY` limit value for a resource group for roles is 20.

Greenplum Database queues any transactions submitted after the resource group reaches its `CONCURRENCY` limit. When a running transaction completes, Greenplum Database un-queues and executes the earliest queued transaction if sufficient memory resources exist.

**CPU Limit**

The `gp_resource_group_cpu_limit` server configuration parameter identifies the maximum percentage of system CPU resources to allocate to resource groups on each Greenplum Database segment host. The remaining CPU resources are used for the OS kernel and the Greenplum Database auxiliary daemon processes. The default `gp_resource_group_cpu_limit` value is .9 (90%).

- **Note:** The default `gp_resource_group_cpu_limit` value may not leave sufficient CPU resources if you are running other workloads on your Greenplum Database cluster nodes, so be sure to adjust this server configuration parameter accordingly.

- **Warning:** Avoid setting `gp_resource_group_cpu_limit` to a value higher than .9. Doing so may result in high workload queries taking near all CPU resources, potentially starving Greenplum Database auxiliary processes.

The Greenplum Database node CPU percentage is further divided equally among each segment on the Greenplum node. Each resource group reserves a percentage of the segment CPU for resource management. You identify this percentage via the `CPU_RATE_LIMIT` value that you provide when you create the resource group.

The minimum `CPU_RATE_LIMIT` percentage you can specify for a resource group is 1, the maximum is 100.

The sum of `CPU_RATE_LIMITS` specified for all resource groups that you define in your Greenplum Database cluster must not exceed 100.

CPU resource assignment is elastic in that Greenplum Database may allocate the CPU resources of an idle resource group to a busier one(s). In such situations, CPU resources are re-allocated to the previously idle resource group when that resource group next becomes active. If multiple resource groups are busy, they are allocated the CPU resources of any idle resource groups based on the ratio of their `CPU_RATE_LIMITS`. For example, a resource group created with a `CPU_RATE_LIMIT` of 40 will be allocated twice as much extra CPU resource as a resource group that you create with a `CPU_RATE_LIMIT` of 20.
Memory Limits

When resource groups are enabled, memory usage is managed at the Greenplum Database node, segment, and resource group levels. You can also manage memory at the transaction level with a resource group for roles.

The `gp_resource_group_memory_limit` server configuration parameter identifies the maximum percentage of system memory resources to allocate to resource groups on each Greenplum Database segment host. The default `gp_resource_group_memory_limit` value is .7 (70%).

The memory resource available on a Greenplum Database node is further divided equally among each segment on the node. When resource group-based resource management is active, the amount of memory allocated to each segment on a segment host is the memory available to Greenplum Database multiplied by the `gp_resource_group_memory_limit` server configuration parameter and divided by the number of active primary segments on the host:

\[
\text{rg_perseg_mem} = \left( \frac{\text{RAM} \times (\text{vm.overcommit_ratio} / 100) + \text{SWAP}}{\text{gp_resource_group_memory_limit}} \right) / \text{num_active_primary_segments}
\]

Each resource group reserves a percentage of the segment memory for resource management. You identify this percentage via the `MEMORY_LIMIT` value that you specify when you create the resource group. The minimum `MEMORY_LIMIT` percentage you can specify for a resource group is 1, the maximum is 100.

The sum of `MEMORY_LIMIT` specified for all resource groups that you define in your Greenplum Database cluster must not exceed 100.

Additional Memory Limits for Role-based Resource Groups

The memory reserved by a resource group for roles is further divided into fixed and shared components. The `MEMORY_SHARED_QUOTA` value that you specify when you create the resource group identifies the percentage of reserved resource group memory that may be shared among the currently running transactions. This memory is allotted on a first-come, first-served basis. A running transaction may use none, some, or all of the `MEMORY_SHARED_QUOTA`.

The minimum `MEMORY_SHARED_QUOTA` that you can specify is 0, the maximum is 100. The default `MEMORY_SHARED_QUOTA` is 20.

As mentioned previously, `CONCURRENCY` identifies the maximum number of concurrently running transactions permitted in a resource group for roles. The fixed memory reserved by a resource group is divided into `CONCURRENCY` number of transaction slots. Each slot is allocated a fixed, equal amount of resource group memory. Greenplum Database guarantees this fixed memory to each transaction.
When a query's memory usage exceeds the fixed per-transaction memory usage amount, Greenplum Database allocates available resource group shared memory to the query. The maximum amount of

Figure 36: Resource Group Memory Allotments

CREATE RESOURCE GROUP rg_sample
WITH (CONCURRENCY = 8,
     CPU_LIMIT = 30,
     MEMORY_LIMIT = 60,
     MEMORY_SHARED_QUOTA = 50)
resource group memory available to a specific transaction slot is the sum of the transaction's fixed memory
and the full resource group shared memory allotment.

**Note:** Greenplum Database tracks, but does not actively monitor, transaction memory usage in
resource groups. A transaction submitted in a resource group will fail and exit when memory usage
exceeds its fixed memory allotment, no available resource group shared memory exists, and the
transaction requests more memory.

**Global Shared Memory**

The sum of the MEMORY_LIMITs configured for all resource groups (including the default admin_group
and default_group groups) identifies the percentage of reserved resource group memory. If this sum is
less than 100, Greenplum Database allocates any unreserved memory to a resource group global shared
memory pool.

Resource group global shared memory is available only to role-based groups.

When available, Greenplum Database allocates global shared memory to a transaction after first allocating
slot and resource group shared memory. Greenplum Database allocates resource group global shared
memory to transactions on a first-come first-served basis.

**Query Operator Memory**

Most query operators are non-memory-intensive; that is, during processing, Greenplum Database can hold
their data in allocated memory. When memory-intensive query operators such as join and sort process
more data than can be held in memory, data is spilled to disk.

The gp_resgroup_memory_policy server configuration parameter governs the memory allocation and
distribution algorithm for all query operators. Greenplum Database supports eager-free (the default)
and auto memory policies for resource groups. When you specify the auto policy, Greenplum Database
uses resource group memory limits to distribute memory across query operators, allocating a fixed size
of memory to non-memory-intensive operators and the rest to memory-intensive operators. When the
eager_free policy is in place, Greenplum Database distributes memory among operators more optimally
by re-allocating memory released by operators that have completed their processing to operators in a later
query stage.

MEMORY_SPILL_RATIO identifies the memory usage threshold for memory-intensive operators in a
transaction. When the transaction reaches this memory threshold, it spills to disk. Greenplum Database
uses the MEMORY_SPILL_RATIO to determine the initial memory to allocate to a transaction.

The minimum MEMORY_SPILL_RATIO percentage that you can specify for a resource group is 0. The
maximum is 100. The default MEMORY_SPILL_RATIO is 20.

You define the MEMORY_SPILL_RATIO when you create a resource group for roles. You can selectively
set this limit on a per-query basis at the session level with the memory_spill_ratio server configuration
parameter.

**memory_spill_ratio and Low Memory Queries**

A low memory_spill_ratio setting (for example, in the 0-2 range) has been shown to increase
the performance of queries with low memory requirements. Use the memory_spill_ratio server
configuration parameter to override the setting on a per-query basis. For example:

```sql
SET memory_spill_ratio=0;
```

**Other Memory Considerations**

Resource groups for roles track all Greenplum Database memory allocated via the palloc() function.
Memory that you allocate using the Linux malloc() function is not managed by these resource groups.
To ensure that resource groups for roles are accurately tracking memory usage, avoid using malloc() to
allocate large amounts of memory in custom Greenplum Database user-defined functions.
Using Resource Groups

**Important:** Significant Greenplum Database performance degradation has been observed when enabling resource group-based workload management on RedHat 6.x, CentOS 6.x, and SuSE 11 systems. This issue is caused by a Linux cgroup kernel bug. This kernel bug has been fixed in CentOS 7.x and Red Hat 7.x systems, and on SuSE 12 SP2/SP3 systems with kernel version 4.4.73-5.1 or newer.

If you use RedHat 6 and the performance with resource groups is acceptable for your use case, upgrade your kernel to version 2.6.32-696 or higher to benefit from other fixes to the cgroups implementation.

SuSE 11 does not have a kernel version that resolves this issue; resource groups are still considered to be an experimental feature on this platform. Resource groups are not supported on SuSE 11 for production use.

Prerequisite

Greenplum Database resource groups use Linux Control Groups (cgroups) to manage CPU resources. Greenplum Database also uses cgroups to manage memory for resource groups for external components. With cgroups, Greenplum isolates the CPU and external component memory usage of your Greenplum processes from other processes on the node. This allows Greenplum to support CPU and external component memory usage restrictions on a per-resource-group basis.

For detailed information about cgroups, refer to the Control Groups documentation for your Linux distribution.

Complete the following tasks on each node in your Greenplum Database cluster to set up cgroups for use with resource groups:

1. If you are running the SuSE 11+ operating system on your Greenplum Database cluster nodes, you must enable swap accounting on each node and restart your Greenplum Database cluster. The `swapaccount` kernel boot parameter governs the swap accounting setting on SuSE 11+ systems. After setting this boot parameter, you must reboot your systems. For details, refer to the *Cgroup Swap Control* discussion in the SuSE 11 release notes. You must be the superuser or have `sudo` access to configure kernel boot parameters and reboot systems.

2. Create the Greenplum Database cgroups configuration file `/etc/cgconfig.d/gpdb.conf`. You must be the superuser or have `sudo` access to create this file:

   ```bash
   sudo vi /etc/cgconfig.d/gpdb.conf
   ```

3. Add the following configuration information to `/etc/cgconfig.d/gpdb.conf`:

   ```bash
   group gpdb {
   perm {
       task {
           uid = gpadmin;
           gid = gpadmin;
       }
       admin {
           uid = gpadmin;
           gid = gpadmin;
       }
   }
   cpu {
   }
   cpuacct {
   }
   }
   ```
This content configures CPU and CPU accounting control groups managed by the `gpadmin` user.

4. If you plan to use resource groups to manage PL/Container instances, you must add a memory block to the `gpdb.conf` file. Be sure to add the block before the closing curly-brace (`{}`):

```plaintext
    cpuacct {
    }
    memory {
    }
```

5. If not already installed and running, install the Control Groups operating system package and start the cgroups service on each Greenplum Database node. The commands that you run to perform these tasks will differ based on the operating system installed on the node. You must be the superuser or have `sudo` access to run these commands:

- Redhat/CentOS 7.x systems:
  ```bash
  sudo yum install libcgroup-tools
  sudo cgconfigparser -l /etc/cgconfig.d/gpdb.conf
  ```

- Redhat/CentOS 6.x systems:
  ```bash
  sudo yum install libcgroup
  sudo service cgconfig start
  ```

- SuSE 11+ systems:
  ```bash
  sudo zypper install libcgroup-tools
  sudo cgconfigparser -l /etc/cgconfig.d/gpdb.conf
  ```

6. Identify the `cgroup` directory mount point for the node:

```bash
grep cgroup /proc/mounts
```

The first line of output identifies the `cgroup` mount point.

7. Verify that you set up the Greenplum Database cgroups configuration correctly by running the following commands. Replace `<cgroup_mount_point>` with the mount point that you identified in the previous step:

```bash
ls -l <cgroup_mount_point>/cpu/gpdb
ls -l <cgroup_mount_point>/cpuacct/gpdb
ls -l <cgroup_mount_point>/memory/gpdb
```

If these directories exist and are owned by `gpadmin:gpadmin`, you have successfully configured cgroups for Greenplum Database CPU resource management.

8. To automatically recreate Greenplum Database required cgroup hierarchies and parameters when your system is restarted, configure your system to enable the Linux cgroup service daemon `cgconfig.service` (Redhat/CentOS 7.x and SuSE 11+) or `cgconfig` (Redhat/CentOS 6.x) at node start-up. For example, configure one of the following cgroup service commands in your preferred service auto-start tool:

- Redhat/CentOS 7.x and SuSE11+ systems:
  ```bash
  sudo systemctl enable cgconfig.service
  ```

- Redhat/CentOS 6.x systems:
  ```bash
  sudo chkconfig cgconfig on
  ```
You may choose a different method to recreate the Greenplum Database resource group cgroup hierarchies.

**Procedure**

To use resource groups in your Greenplum Database cluster, you:

1. **Enable resource groups for your Greenplum Database cluster.**
2. **Create resource groups.**
3. **Assign the resource groups to one or more roles.**
4. **Use resource management system views to monitor and manage the resource groups.**

**Enabling Resource Groups**

When you install Greenplum Database, resource queues are enabled by default. To use resource groups instead of resource queues, you must set the `gp_resource_manager` server configuration parameter.

1. **Set the `gp_resource_manager` server configuration parameter to the value "group":**

   ```
   gpconfig -s gp_resource_manager
   gpconfig -c gp_resource_manager -v "group"
   ```

2. **Restart Greenplum Database:**

   ```
   gpstop
   gpstart
   ```

Once enabled, any transaction submitted by a role is directed to the resource group assigned to the role, and is governed by that resource group's concurrency, memory, and CPU limits. Similarly, CPU and memory usage by an external component is governed by the CPU and memory limits configured for the resource group assigned to the component.

Greenplum Database creates two default resource groups for roles named `admin_group` and `default_group`. When you enable resources groups, any role that was not explicitly assigned a resource group is assigned the default group for the role's capability. SUPERUSER roles are assigned the `admin_group`, non-admin roles are assigned the group named `default_group`.

The default resource groups `admin_group` and `default_group` are created with the following resource limits:

<table>
<thead>
<tr>
<th>Limit Type</th>
<th>admin_group</th>
<th>default_group</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCURRENCY</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>CPU_RATE_LIMIT</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>MEMORY_LIMIT</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>MEMORY_SHARED_QUOTA</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>MEMORY_SPILL_RATIO</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

Keep in mind that the CPU_RATE_LIMIT and MEMORY_LIMIT values for the default resource groups `admin_group` and `default_group` contribute to the total percentages on a segment host. You may find that you need to adjust these limits for `admin_group` and/or `default_group` as you create and add new resource groups to your Greenplum Database deployment.
Creating Resource Groups

When you create a resource group for a role, you provide a name, CPU limit, and memory limit. You can optionally provide a concurrent transaction limit and memory shared quota and spill ratio. Use the `CREATE RESOURCE GROUP` command to create a new resource group.

When you create a resource group for a role, you must provide `CPU_RATE_LIMIT` and `MEMORY_LIMIT` limit values. These limits identify the percentage of Greenplum Database resources to allocate to this resource group. For example, to create a resource group named `rgroup1` with a CPU limit of 20 and a memory limit of 25:

```sql
=# CREATE RESOURCE GROUP rgroup1 WITH (CPU_RATE_LIMIT=20, MEMORY_LIMIT=25);
```

The CPU limit of 20 is shared by every role to which `rgroup1` is assigned. Similarly, the memory limit of 25 is shared by every role to which `rgroup1` is assigned. `rgroup1` utilizes the default `MEMORY_AUDITOR vmtracker` and the default `CONCURRENCY` setting of 20.

When you create a resource group for an external component, you must provide `CPU_RATE_LIMIT` and `MEMORY_LIMIT` limit values. You must also provide the `MEMORY_AUDITOR` and explicitly set `CONCURRENCY` to zero (0). For example, to create a resource group named `rgroup_extcomp` with a CPU limit of 10 and a memory limit of 15:

```sql
=# CREATE RESOURCE GROUP rgroup_extcomp WITH (MEMORY_AUDITOR=cgroup,
       CONCURRENCY=0,
       CPU_RATE_LIMIT=10, MEMORY_LIMIT=15);
```

The `ALTER RESOURCE GROUP` command updates the limits of a resource group. To change the limits of a resource group, specify the new values that you want for the group. For example:

```sql
=# ALTER RESOURCE GROUP rg_role_light SET CONCURRENCY 7;
=# ALTER RESOURCE GROUP exec SET MEMORY_LIMIT 25;
```

**Note:** You cannot set or alter the `CONCURRENCY` value for the `admin_group` to zero (0).

The `DROP RESOURCE GROUP` command drops a resource group. To drop a resource group for a role, the group cannot be assigned to any role, nor can there be any transactions active or waiting in the resource group. Dropping a resource group for an external component in which there are running instances kills the running instances.

To drop a resource group:

```sql
=# DROP RESOURCE GROUP exec;
```

Assigning a Resource Group to a Role

When you create a resource group with the default `MEMORY_AUDITOR vmtracker`, the group is available for assignment to one or more roles (users). You assign a resource group to a database role using the `RESOURCE GROUP` clause of the `CREATE ROLE` or `ALTER ROLE` commands. If you do not specify a resource group for a role, the role is assigned the default group for the role’s capability. `SUPERUSER` roles are assigned the `admin_group`, non-admin roles are assigned the group named `default_group`.

Use the `ALTER ROLE` or `CREATE ROLE` commands to assign a resource group to a role. For example:

```sql
=# ALTER ROLE bill RESOURCE GROUP rg_light;
=# CREATE ROLE mary RESOURCE GROUP exec;
```

You can assign a resource group to one or more roles. If you have defined a role hierarchy, assigning a resource group to a parent role does not propagate down to the members of that role group.
**Note:** You cannot assign a resource group that you create for an external component to a role. If you wish to remove a resource group assignment from a role and assign the role the default group, change the role's group name assignment to *NONE*. For example:

```
=# ALTER ROLE mary RESOURCE GROUP NONE;
```

### Monitoring Resource Group Status

Monitoring the status of your resource groups and queries may involve the following tasks:

- Viewing Resource Group Limits
- Viewing Resource Group Query Status and CPU/Memory Usage
- Viewing the Resource Group Assigned to a Role
- Viewing a Resource Group’s Running and Pending Queries
- Cancelling a Running or Queued Transaction in a Resource Group

#### Viewing Resource Group Limits

The `gp_resgroup_config` system view displays the current and proposed limits for a resource group. The proposed limit differs from the current limit when you alter the limit but the new value can not be immediately applied. To view the limits of all resource groups:

```
=# SELECT * FROM gp_toolkit.gp_resgroup_config;
```

#### Viewing Resource Group Query Status and CPU/Memory Usage

The `gp_resgroup_status` system view enables you to view the status and activity of a resource group. The view displays the number of running and queued transactions. It also displays the real-time CPU and memory usage of the resource group. To view this information:

```
=# SELECT * FROM gp_toolkit.gp_resgroup_status;
```

#### Viewing the Resource Group Assigned to a Role

To view the resource group-to-role assignments, perform the following query on the `pg_roles` and `pg_resgroup` system catalog tables:

```
=# SELECT rolname, rsgname FROM pg_roles, pg_resgroup
    WHERE pg_roles.rolresgroup=pg_resgroup.oid;
```

#### Viewing a Resource Group’s Running and Pending Queries

To view a resource group’s running queries, pending queries, and how long the pending queries have been queued, examine the `pg_stat_activity` system catalog table:

```
=# SELECT current_query, waiting, rsgname, rsgqueueduration
    FROM pg_stat_activity;
```

`pg_stat_activity` displays information about the user/role that initiated a query. A query that uses an external component such as PL/Container is composed of two parts: the query operator that runs in Greenplum Database and the UDF that runs in a PL/Container instance. Greenplum Database processes the query operators under the resource group assigned to the role that initiated the query. A UDF running in a PL/Container instance runs under the resource group assigned to the PL/Container runtime. The latter is not represented in the `pg_stat_activity` view; Greenplum Database does not have any insight into how external components such as PL/Container manage memory in running instances.
Cancelling a Running or Queued Transaction in a Resource Group

There may be cases when you want to cancel a running or queued transaction in a resource group. For example, you may want to remove a query that is waiting in the resource group queue but has not yet been executed. Or, you may want to stop a running query that is taking too long to execute, or one that is sitting idle in a transaction and taking up resource group transaction slots that are needed by other users.

To cancel a running or queued transaction, you must first determine the process id (pid) associated with the transaction. Once you have obtained the process id, you can invoke \texttt{pg\_cancel\_backend()} to end that process, as shown below.

For example, to view the process information associated with all statements currently active or waiting in all resource groups, run the following query. If the query returns no results, then there are no running or queued transactions in any resource group.

\begin{verbatim}
=# SELECT rolname, g.rsgname, procpid, waiting, current_query, datname
    FROM pg_roles, gp_toolkit.gp_resgroup_status g, pg_stat_activity
    WHERE pg_roles.rolresgroup=g.groupid
    AND pg_stat_activity.usename=pg_roles.rolname;
\end{verbatim}

Sample partial query output:

\begin{verbatim}
    rolname | rsgname | procpid | waiting | current_query | datname
    ---------+----------+---------+---------+-----------------------+---------
sammy    | rg_light |  31861  |    f    | <IDLE> in transaction | testdb  
billy    | rg_light |  31905  |    t    | SELECT * FROM topten; | testdb  
\end{verbatim}

Use this output to identify the process id (procpid) of the transaction you want to cancel, and then cancel the process. For example, to cancel the pending query identified in the sample output above:

\begin{verbatim}
=# SELECT pg\_cancel\_backend(31905);
\end{verbatim}

You can provide an optional message in a second argument to \texttt{pg\_cancel\_backend()} to indicate to the user why the process was cancelled.

Note:

Do not use an operating system \texttt{KILL} command to cancel any Greenplum Database process.

Resource Group Frequently Asked Questions

CPU

• Why is CPU usage lower than the \texttt{CPU\_RATE\_LIMIT} configured for the resource group?

You may run into this situation when a low number of queries and slices are running in the resource group, and these processes are not utilizing all of the cores on the system.

• Why is CPU usage for the resource group higher than the configured \texttt{CPU\_RATE\_LIMIT}?

This situation can occur in the following circumstances:

• A resource group may utilize more CPU than its \texttt{CPU\_RATE\_LIMIT} when other resource groups are idle. In this situation, Greenplum Database allocates the CPU resource of an idle resource group to a busier one. This resource group feature is called CPU burst.

• The operating system CPU scheduler may cause CPU usage to spike, then drop down. If you believe this might be occurring, calculate the average CPU usage within a given period of time (for example, 5 seconds) and use that average to determine if CPU usage is higher than the configured limit.
Memory

• Why did my query return an "out of memory" error?
  A transaction submitted in a resource group fails and exits when memory usage exceeds its fixed memory allotment, no available resource group shared memory exists, and the transaction requests more memory.

• Why did my query return a "memory limit reached" error?
  Greenplum Database automatically adjusts transaction and group memory to the new settings when you use `ALTER RESOURCE GROUP` to change a resource group's memory and/or concurrency limits. An "out of memory" error may occur if you recently altered resource group attributes and there is no longer a sufficient amount of memory available for a currently running query.

• Why does the actual memory usage of my resource group exceed the amount configured for the group?
  The actual memory usage of a resource group may exceed the configured amount when one or more queries running in the group is allocated memory from the global shared memory pool. (If no global shared memory is available, queries fail and do not impact the memory resources of other resource groups.)

  When global shared memory is available, memory usage may exceed the configured amount when a transaction spills to disk. Greenplum Database statements continue to request memory when they start to spill to disk because:
  • Spilling to disk requires extra memory to work.
  • Other operators may continue to request memory.

  Memory usage grows in spill situations; when global shared memory is available, the resource group may eventually use up to 200-300% of its configured group memory limit.

Concurrency

• Why is the number of running transactions lower than the `CONCURRENCY` limit configured for the resource group?
  Greenplum Database considers memory availability before running a transaction, and will queue the transaction if there is not enough memory available to serve it. If you use `ALTER RESOURCE GROUP` to increase the `CONCURRENCY` limit for a resource group but do not also adjust memory limits, currently running transactions may be consuming all allotted memory resources for the group. When in this state, Greenplum Database queues subsequent transactions in the resource group.

• Why is the number of running transactions in the resource group higher than the configured `CONCURRENCY` limit?
  The resource group may be running `SET` and `SHOW` commands, which bypass resource group transaction checks.

Investigating a Performance Problem

This section provides guidelines for identifying and troubleshooting performance problems in a Greenplum Database system.

This topic lists steps you can take to help identify the cause of a performance problem. If the problem affects a particular workload or query, you can focus on tuning that particular workload. If the performance problem is system-wide, then hardware problems, system failures, or resource contention may be the cause.
Checking System State

Use the `gpstate` utility to identify failed segments. A Greenplum Database system will incur performance degradation when segment instances are down because other hosts must pick up the processing responsibilities of the down segments.

Failed segments can indicate a hardware failure, such as a failed disk drive or network card. Greenplum Database provides the hardware verification tool `gpcheckperf` to help identify the segment hosts with hardware issues.

Checking Database Activity

- **Checking for Active Sessions (Workload)**
- **Checking for Locks (Contention)**
- **Checking Query Status and System Utilization**

**Checking for Active Sessions (Workload)**

The `pg_stat_activity` system catalog view shows one row per server process; it shows the database OID, database name, process ID, user OID, user name, current query, time at which the current query began execution, time at which the process was started, client address, and port number. To obtain the most information about the current system workload, query this view as the database superuser. For example:

```sql
SELECT * FROM pg_stat_activity;
```

Note that the information does not update instantaneously.

**Checking for Locks (Contention)**

The `pg_locks` system catalog view allows you to see information about outstanding locks. If a transaction is holding a lock on an object, any other queries must wait for that lock to be released before they can continue. This may appear to the user as if a query is hanging.

Examine `pg_locks` for ungranted locks to help identify contention between database client sessions. `pg_locks` provides a global view of all locks in the database system, not only those relevant to the current database. You can join its relation column against `pg_class.oid` to identify locked relations (such as tables), but this works correctly only for relations in the current database. You can join the `pid` column to the `pg_stat_activity.procpid` to see more information about the session holding or waiting to hold a lock. For example:

```sql
SELECT locktype, database, c.relname, l.relation, l.transactionid, l.pid, l.mode, l.granted, a.current_query
FROM pg_locks l, pg_class c, pg_stat_activity a
WHERE l.relation=c.oid AND l.pid=a.procpid
ORDER BY c.relname;
```

If you use resource groups, queries that are waiting will also show in `pg_locks`. To see how many queries are waiting to run in a resource group, use the `gp_resgroup_status` system catalog view. For example:

```sql
SELECT * FROM gp_toolkit.gp_resgroup_status;
```

Similarly, if you use resource queues, queries that are waiting in a queue also show in `pg_locks`. To see how many queries are waiting to run from a resource queue, use the `gp_resqueue_status` system catalog view. For example:

```sql
SELECT * FROM gp_toolkit.gp_resqueue_status;
```
Checking Query Status and System Utilization

You can use system monitoring utilities such as `ps`, `top`, `iostat`, `vmstat`, `netstat` and so on to monitor database activity on the hosts in your Greenplum Database array. These tools can help identify Greenplum Database processes (postgres processes) currently running on the system and the most resource intensive tasks with regards to CPU, memory, disk I/O, or network activity. Look at these system statistics to identify queries that degrade database performance by overloading the system and consuming excessive resources. Greenplum Database's management tool `gpssh` allows you to run these system monitoring commands on several hosts simultaneously.

You can create and use the Greenplum Database `session_level_memory_consumption` view that provides information about the current memory utilization and idle time for sessions that are running queries on Greenplum Database. For information about the view, see Viewing Session Memory Usage Information.

You can enable a dedicated database, `gpperfmon`, in which data collection agents running on each segment host save query and system utilization metrics. Refer to the `gpperfmon_install` management utility reference in the Greenplum Database Management Utility Reference Guide for help creating the `gpperfmon` database and managing the agents. See documentation for the tables and views in the `gpperfmon` database in the Greenplum Database Reference Guide.

The optional Greenplum Command Center web-based user interface graphically displays query and system utilization metrics saved in the `gpperfmon` database. See the Greenplum Command Center Documentation web site for procedures to enable Greenplum Command Center.

Troubleshooting Problem Queries

If a query performs poorly, look at its query plan to help identify problems. The `EXPLAIN` command shows the query plan for a given query. See Query Profiling for more information about reading query plans and identifying problems.

When an out of memory event occurs during query execution, the Greenplum Database memory accounting framework reports detailed memory consumption of every query running at the time of the event. The information is written to the Greenplum Database segment logs.

Investigating Error Messages

Greenplum Database log messages are written to files in the `pg_log` directory within the master's or segment's data directory. Because the master log file contains the most information, you should always check it first. Log files roll over daily and use the naming convention: `gpdb-YYYY-MM-DD_hhmms.csv`. To locate the log files on the master host:

```
$ cd $MASTER_DATA_DIRECTORY/pg_log
```

Log lines have the format of:

```
timestamp | user | database | statement_id | con#cmd#  
|:-LOG_LEVEL: log_message
```

You may want to focus your search for WARNING, ERROR, FATAL or PANIC log level messages. You can use the Greenplum utility `gplogfilter` to search through Greenplum Database log files. For example, when you run the following command on the master host, it checks for problem log messages in the standard logging locations:

```
$ gplogfilter -t
```

To search for related log entries in the segment log files, you can run `gplogfilter` on the segment hosts using `gpssh`. You can identify corresponding log entries by the `statement_id` or `con#` (session...
identifier). For example, to search for log messages in the segment log files containing the string `con6` and save output to a file:

```
gpssh -f seg_hosts_file -e 'source /usr/local/greenplum-db/greenplum_path.sh ; gplogfilter -f con6 /gpdata/*/pg_log/gpdb*.csv' > seglog.out
```

**Gathering Information for Pivotal Customer Support**

The Greenplum Magic Tool (GPMT) utility can run diagnostics and collect information from a Greenplum Database system. You can then send the information to Pivotal Customer Support to aid the diagnosis of Greenplum Database errors or system failures.

The GPMT utility is available from the *Pivotal Knowledge Base* on the *GPMT* page.
Chapter 9

Greenplum Database Security Configuration Guide

This guide describes how to secure a Greenplum Database system. The guide assumes knowledge of Linux/UNIX system administration and database management systems. Familiarity with structured query language (SQL) is helpful.

Because Greenplum Database is based on PostgreSQL8.3.23, this guide assumes some familiarity with PostgreSQL. References to PostgreSQL documentation are provided throughout this guide for features that are similar to those in Greenplum Database.

This information is intended for system administrators responsible for administering a Greenplum Database system.
Securing the Database

Introduces Greenplum Database security topics.

The intent of security configuration is to configure the Greenplum Database server to eliminate as many security vulnerabilities as possible. This guide provides a baseline for minimum security requirements, and is supplemented by additional security documentation.

The essential security requirements fall into the following categories:

- **Authentication** covers the mechanisms that are supported and that can be used by the Greenplum database server to establish the identity of a client application.
- **Authorization** pertains to the privilege and permission models used by the database to authorize client access.
- **Auditing**, or log settings, covers the logging options available in Greenplum Database to track successful or failed user actions.
- **Data Encryption** addresses the encryption capabilities that are available for protecting data at rest and data in transit. This includes the security certifications that are relevant to the Greenplum Database.

Accessing a Kerberized Hadoop Cluster

Greenplum Database can read or write external tables in a Hadoop file system. If the Hadoop cluster is secured with Kerberos ("Kerberized"), Greenplum Database must be configured to allow external table owners to authenticate with Kerberos. See Enabling gphdfs Authentication with a Kerberos-secured Hadoop Cluster for the steps to perform this setup.

Platform Hardening

Platform hardening involves assessing and minimizing system vulnerability by following best practices and enforcing federal security standards. Hardening the product is based on the US Department of Defense (DoD) guidelines Security Template Implementation Guides (STIG). Hardening removes unnecessary packages, disables services that are not required, sets up restrictive file and directory permissions, removes unowned files and directories, performs authentication for single-user mode, and provides options for end users to configure the package to be compliant to the latest STIGs.
Greenplum Database Ports and Protocols

Lists network ports and protocols used within the Greenplum cluster.

Greenplum Database clients connect with TCP to the Greenplum master instance at the client connection port, 5432 by default. The listen port can be reconfigured in the `postgresql.conf` configuration file. Client connections use the PostgreSQL libpq API. The `psql` command-line interface, several Greenplum utilities, and language-specific programming APIs all either use the libpq library directly or implement the libpq protocol internally.

Each segment instance also has a client connection port, used solely by the master instance to coordinate database operations with the segments. The `gpstate -p` command, executed on the Greenplum master, lists the port assignments for the Greenplum master and the primary segments and mirrors. For example:

```
[gadmin@mdw ~]$ gpstate -p
  Version: 'postgres (Greenplum Database) 4.3.6.0 build 62994'
  Version: 'PostgreSQL 8.2.15 (Greenplum Database 4.3.6.0 build 62994) on
  x86_64-unknown-linux-gnu, compiled by GCC gcc (GCC) 4.4.2 compiled on Jul
  24 2015 11:35:08'
details from master...
  instance /data/master/gpseg-1 port = 5432
  assignments
  Port
  40000
  50000
  50001
  50000
  50000
```

Additional Greenplum Database network connections are created for features such as standby replication, segment mirroring, statistics collection, and data exchange between segments. Some persistent connections are established when the database starts up and other transient connections are created during operations such as query execution. Transient connections for query execution processes, data movement, and statistics collection use available ports in the range 1025 to 65535 with both TCP and UDP protocols.

**Note:** To avoid port conflicts between Greenplum Database and other applications when initializing Greenplum Database, do not specify Greenplum Database ports in the range specified...
by the operating system parameter `net.ipv4.ip_local_port_range`. For example, if
`net.ipv4.ip_local_port_range = 10000 65535`, you could set the Greenplum Database
base port numbers to values outside of that range:

```
PORT_BASE = 6000
MIRROR_PORT_BASE = 7000
REPLICATION_PORT_BASE = 8000
MIRROR_REPLICATION_PORT_BASE = 9000
```

Some add-on products and services that work with Greenplum Database have additional networking
requirements. The following table lists ports and protocols used within the Greenplum cluster, and includes
services and applications that integrate with Greenplum Database.

### Table 73: Greenplum Database Ports and Protocols

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<th>Protocol/Port</th>
<th>Description</th>
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<td>TCP 5432, libpq</td>
<td>SQL client connection port on the Greenplum master host. Supports clients using the PostgreSQL libpq API. Configurable.</td>
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<tr>
<td>Segment SQL client connection</td>
<td>varies, libpq</td>
<td>The SQL client connection port for a segment instance. Each primary and mirror segment on a host must have a unique port. Ports are assigned when the Greenplum system is initialized or expanded. The <code>gp_segment_configuration</code> system catalog records port numbers for each segment in the <code>port</code> column. Run <code>gpstate -p</code> to view the ports in use.</td>
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<tr>
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<tr>
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</tr>
<tr>
<td>Service</td>
<td>Protocol/Port</td>
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<td>Greenplum database file load and transfer utilities: gpfdist, gpload,</td>
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<td>The gpfdist file serving utility can run on Greenplum hosts or external hosts. Specify the connection port with the (-p) option when starting the server. The gpload and gptransfer utilities run one or more instances of gpfdist with ports or port ranges specified in a configuration file.</td>
</tr>
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<td>gptransfer</td>
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<tr>
<td>GPCC agents</td>
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<td>Backup completion notification</td>
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<tr>
<td>Greenplum Database secure shell (SSH): gpssh, gpscp, gpssh-exkeys,</td>
<td>TCP 22, SSH</td>
<td>Many Greenplum utilities use scp and ssh to transfer files between hosts and manage the Greenplum system within the cluster.</td>
</tr>
<tr>
<td>gppkg, gpseginstall</td>
<td>TCP 8020</td>
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<tr>
<td>gphdfs</td>
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<tr>
<td>EMC Data Domain and DD Boost</td>
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</tr>
<tr>
<td></td>
<td>TCP 2052</td>
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</tr>
<tr>
<td></td>
<td>TCP 2049, NFS</td>
<td>Main port used by NFS. This port can be configured using the \text{nfs set server-port command} on the Data Domain server.</td>
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<tr>
<td></td>
<td>TCP 2051, replication</td>
<td>Used when replication is configured on the Data Domain system. This port can be configured using the \text{replication modify command} on the Data Domain server.</td>
</tr>
<tr>
<td>Service</td>
<td>Protocol/Port</td>
<td>Description</td>
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<td>Symantec NetBackup</td>
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<tr>
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</tr>
<tr>
<td>Pgbouncer connection pooler</td>
<td></td>
<td>The pgbouncer connection pooler runs between libpq clients and Greenplum (or PostgreSQL) databases. It can be run on the Greenplum master host, but running it on a host outside of the Greenplum cluster is recommended. When it runs on a separate host, pgbouncer can act as a warm standby mechanism for the Greenplum master host, switching to the Greenplum standby host without requiring clients to reconfigure. Set the client connection port and the Greenplum master host address and port in the <em>pgbouncer.ini</em> configuration file.</td>
</tr>
<tr>
<td>stunnel SSL proxy</td>
<td>TCP, ssh, libpq</td>
<td>A stunnel SSL proxy can be used to add SSL support for database clients accessing the database through a pgbouncer connection pool. A secure tunnel can be set up by setting up stunnel on the client and the pgbouncer host. Newer versions of stunnel that support encrypted libpq connections only require stunnel on the pgbouncer host. The stunnel proxy’s connection ports and the pgbouncer host and port are specified in the <em>stunnel.conf</em> configuration file.</td>
</tr>
</tbody>
</table>
Configuring Client Authentication

Describes the available methods for authenticating Greenplum Database clients.

When a Greenplum Database system is first initialized, the system contains one predefined superuser role. This role will have the same name as the operating system user who initialized the Greenplum Database system. This role is referred to as gpadmin. By default, the system is configured to only allow local connections to the database from the gpadmin role. If you want to allow any other roles to connect, or if you want to allow connections from remote hosts, you have to configure Greenplum Database to allow such connections. This section explains how to configure client connections and authentication to Greenplum Database.

- Allowing Connections to Greenplum Database
- Editing the pg_hba.conf File
- Authentication Methods
- Limiting Concurrent Connections
- Encrypting Client/Server Connections

Allowing Connections to Greenplum Database

Client access and authentication is controlled by a configuration file named pg_hba.conf (the standard PostgreSQL host-based authentication file). For detailed information about this file, see The pg_hba.conf File in the PostgreSQL documentation.

In Greenplum Database, the pg_hba.conf file of the master instance controls client access and authentication to your Greenplum system. The segments also have pg_hba.conf files, but these are already correctly configured to only allow client connections from the master host. The segments never accept outside client connections, so there is no need to alter the pg_hba.conf file on segments.

The general format of the pg_hba.conf file is a set of records, one per line. Blank lines are ignored, as is any text after a # comment character. A record is made up of a number of fields which are separated by spaces and/or tabs. Fields can contain white space if the field value is quoted. Records cannot be continued across lines. Each remote client access record is in this format:

```
host   database   role   CIDR-address   authentication-method
```

A UNIX-domain socket access record is in this format:

```
local   database   role   authentication-method
```

The meaning of the pg_hba.conf fields is as follows:

- **local**
  Matches connection attempts using UNIX-domain sockets. Without a record of this type, UNIX-domain socket connections are disallowed.

- **host**
  Matches connection attempts made using TCP/IP. Remote TCP/IP connections will not be possible unless the server is started with an appropriate value for the listen_addresses server configuration parameter.

- **hostssl**
  Matches connection attempts made using TCP/IP, but only when the connection is made with SSL encryption. SSL must be enabled at server start time by setting the ssl configuration parameter. Requires SSL authentication be configured in postgresql.conf. See Configuring postgresql.conf for SSL Authentication.
hostnossl
Matches connection attempts made over TCP/IP that do not use SSL. Requires SSL authentication be configured in postgresql.conf. See Configuring postgresql.conf for SSL Authentication.

database
Specifies which database names this record matches. The value all specifies that it matches all databases. Multiple database names can be supplied by separating them with commas. A separate file containing database names can be specified by preceding the file name with @.

role
Specifies which database role names this record matches. The value all specifies that it matches all roles. If the specified role is a group and you want all members of that group to be included, precede the role name with a +. Multiple role names can be supplied by separating them with commas. A separate file containing role names can be specified by preceding the file name with @.

CIDR-address
Specifies the client machine IP address range that this record matches. It contains an IP address in standard dotted decimal notation and a CIDR mask length. IP addresses can only be specified numerically, not as domain or host names. The mask length indicates the number of high-order bits of the client IP address that must match. Bits to the right of this must be zero in the given IP address. There must not be any white space between the IP address, the /, and the CIDR mask length.

Typical examples of a CIDR-address are 172.20.143.89/32 for a single host, or 172.20.143.0/24 for a small network, or 10.6.0.0/16 for a larger one. To specify a single host, use a CIDR mask of 32 for IPv4 or 128 for IPv6. In a network address, do not omit trailing zeroes.

IP-address
IP-mask
These fields can be used as an alternative to the CIDR-address notation. Instead of specifying the mask length, the actual mask is specified in a separate column. For example, 255.0.0.0 represents an IPv4 CIDR mask length of 8, and 255.255.255.255 represents a CIDR mask length of 32. These fields only apply to host, hostssl, and hostnossl records.

authentication-method
Specifies the authentication method to use when connecting. See Authentication Methods for options.

Caution: For a more secure system, consider removing records for remote connections that use trust authentication from the pg_hba.conf file. Trust authentication grants any user who can connect to the server access to the database using any role they specify. You can safely replace trust authentication with ident authentication for local UNIX-socket connections. You can also use ident authentication for local and remote TCP clients, but the client host must be running an ident service and you must trust the integrity of that machine.

Editing the pg_hba.conf File
Initially, the pg_hba.conf file is set up with generous permissions for the gpadmin user and no database access for other Greenplum Database roles. You will need to edit the pg_hba.conf file to enable users’ access to databases and to secure the gpadmin user. Consider removing entries that have trust authentication, since they allow anyone with access to the server to connect with any role they choose. For local (UNIX socket) connections, use ident authentication, which requires the operating system user to match the role specified. For local and remote TCP connections, ident authentication requires the client's
host to run an ident service. You could install an ident service on the master host and then use ident authentication for local TCP connections, for example 127.0.0.1/28. Using ident authentication for remote TCP connections is less secure because it requires you to trust the integrity of the ident service on the client's host.

This example shows how to edit the `pg_hba.conf` file of the master to allow remote client access to all databases from all roles using encrypted password authentication.

To edit `pg_hba.conf`:

1. Open the file `$MASTER_DATA_DIRECTORY/pg_hba.conf` in a text editor.
2. Add a line to the file for each type of connection you want to allow. Records are read sequentially, so the order of the records is significant. Typically, earlier records will have tight connection match parameters and weaker authentication methods, while later records will have looser match parameters and stronger authentication methods. For example:

```plaintext
# allow the gpadmin user local access to all databases
# using ident authentication
local   all   gpadmin   ident         sameuser
host   all   gpadmin   127.0.0.1/32  ident
host   all   gpadmin   ::1/128       ident
# allow the 'dba' role access to any database from any
# host with IP address 192.168.x.x and use md5 encrypted
# passwords to authenticate the user
# Note that to use SHA-256 encryption, replace md5 with
# password in the line below
host   all   dba   192.168.0.0/32  md5
```

### Authentication Methods

- **Basic Authentication**
- **Kerberos Authentication**
- **LDAP Authentication**
- **SSL Client Authentication**
- **PAM Based Authentication**
- **Radius Authentication**

### Basic Authentication

The following basic authentication methods are supported:

#### Password or MD5

Requires clients to provide a password, one of either:

- **Md5** – password transmitted as an MD5 hash.
- **Password** – A password transmitted in clear text. Always use SSL connections to prevent password sniffing during transit. This is configurable, see “Encrypting Passwords” in the *Greenplum Database Administrator Guide* for more information.

#### Reject

Reject the connections with the matching parameters. You should typically use this to restrict access from specific hosts or insecure connections.

#### Ident

Authenticates based on the client’s operating system user name. This is secure for local socket connections. Using ident for TCP connections from remote hosts requires that the client’s host is running an ident service. The ident authentication method should only be used with remote hosts on a trusted, closed network.
Following are some sample pg_hba.conf basic authentication entries:

```
hostnossl    all   all        0.0.0.0   reject
hostssl      all   testuser   0.0.0.0/0 md5
local        all   gpuser               ident
```

**Kerberos Authentication**

You can authenticate against a Kerberos server (RFC 2743, 1964).

The format for Kerberos authentication in the pg_hba.conf file is:

```
servicename/hostname@realm
```

The following options may be added to the entry:

- **Map**
  - Map system and database users.

- **Include_realm**
  - Option to specify realm name included in the system-user name in the ident map file.

- **Krb_realm**
  - Specify the realm name for matching the principals.

- **Krb_server_hostname**
  - The hostname of the service principal.

Following is an example pg_hba.conf entry for Kerberos:

```
host    all all 0.0.0.0/0   krb5
hostssl all all 0.0.0.0/0   krb5 map=krbmap
```

The following Kerberos server settings are specified in `postgresql.conf`:

- **krb_server_key file**
  - Sets the location of the Kerberos server key file.

- **krb_srvname string**
  - Kerberos service name.

- **krb_caseins_users boolean**
  - Case-sensitivity. The default is off.

The following client setting is specified as a connection parameter:

- **Krbsrvname**
  - The Kerberos service name to use for authentication.

**LDAP Authentication**

You can authenticate against an LDAP directory.

- LDAPS and LDAP over TLS options encrypt the connection to the LDAP server.
- The connection from the client to the server is not encrypted unless SSL is enabled. Configure client connections to use SSL to encrypt connections from the client.
- To configure or customize LDAP settings, set the `LDAPCONF` environment variable with the path to the `ldap.conf` file and add this to the `greenplum_path.sh` script.

Following are the recommended steps for configuring your system for LDAP authentication:

1. Set up the LDAP server with the database users/roles to be authenticated via LDAP.
2. On the database:
a. Verify that the database users to be authenticated via LDAP exist on the database. LDAP is only used for verifying username/password pairs, so the roles should exist in the database.

b. Update the pg_hba.conf file in the $MASTER_DATA_DIRECTORY to use LDAP as the authentication method for the respective users. Note that the first entry to match the user/role in the pg_hba.conf file will be used as the authentication mechanism, so the position of the entry in the file is important.

c. Reload the server for the pg_hba.conf configuration settings to take effect (gpstop -u).

Specify the following parameter auth-options.

**ldapserver**
Names or IP addresses of LDAP servers to connect to. Multiple servers may be specified, separated by spaces.

**ldapprefix**
String to prepend to the user name when forming the DN to bind as, when doing simple bind authentication.

**ldapsuffix**
String to append to the user name when forming the DN to bind as, when doing simple bind authentication.

**ldapport**
Port number on LDAP server to connect to. If no port is specified, the LDAP library's default port setting will be used.

**ldaptls**
Set to 1 to make the connection between PostgreSQL and the LDAP server use TLS encryption. Note that this only encrypts the traffic to the LDAP server — the connection to the client will still be unencrypted unless SSL is used.

**ldapbasedn**
Root DN to begin the search for the user in, when doing search+bind authentication.

**ldapbinddn**
DN of user to bind to the directory with to perform the search when doing search+bind authentication.

**ldapbindpasswd**
Password for user to bind to the directory with to perform the search when doing search+bind authentication.

**ldapsearchattribute**
Attribute to match against the user name in the search when doing search+bind authentication.

Example:

```plaintext
ldapserver=ldap.greenplum.com prefix="cn=" suffix=", dc=greenplum, dc=com"
```

Following are sample pg_hba.conf file entries for LDAP authentication:

```plaintext
host all testuser 0.0.0.0/0 ldap ldap
ldapserver=ldapserver.greenplum.com ldapsuffix=", ou=people, dc=greenplum, dc=com"
hostssl all ldaprole 0.0.0.0/0 ldaptls=1 ldapprefix="cn="
```

```plaintext
ldapserver=ldapserver.greenplum.com ldapprefix="cn="
```

SSL Client Authentication

SSL authentication compares the Common Name (cn) attribute of an SSL certificate provided by the connecting client during the SSL handshake to the requested database user name. The database user should exist in the database. A map file can be used for mapping between system and database user names.

SSL Authentication Parameters

Authentication method:

- Cert

Authentication options:

- Hostssl
  Connection type must be hostssl.

- map=mapping
  mapping.
  This is specified in the pg_ident.conf, or in the file specified in the ident_file server setting.

Following are sample pg_hba.conf entries for SSL client authentication:

```
Hostssl testdb certuser 192.168.0.0/16 cert
Hostssl testdb all 192.168.0.0/16 cert map=gpuser
```

OpenSSL Configuration

Greenplum Database reads the OpenSSL configuration file specified in $GP_HOME/etc/openssl.cnf by default. You can make changes to the default configuration for OpenSSL by modifying or updating this file and restarting the server.

Creating a Self-Signed Certificate

A self-signed certificate can be used for testing, but a certificate signed by a certificate authority (CA) (either one of the global CAs or a local one) should be used in production so that clients can verify the server's identity. If all the clients are local to the organization, using a local CA is recommended.

To create a self-signed certificate for the server:

1. Enter the following openssl command:

   ```
   openssl req -new -text -out server.req
   ```

2. Enter the requested information at the prompts.
   Make sure you enter the local host name for the Common Name. The challenge password can be left blank.

3. The program generates a key that is passphrase-protected; it does not accept a passphrase that is less than four characters long. To remove the passphrase (and you must if you want automatic start-up of the server), run the following command:

   ```
   openssl rsa -in privkey.pem -out server.key rm privkey.pem
   ```

4. Enter the old passphrase to unlock the existing key. Then run the following command:

   ```
   openssl req -x509 -in server.req -text -key server.key -out server.crt
   ```
This turns the certificate into a self-signed certificate and copies the key and certificate to where the server will look for them.

5. Finally, run the following command:

```bash
chmod og-rwx server.key
```

For more details on how to create your server private key and certificate, refer to the OpenSSL documentation.

### Configuring postgresql.conf for SSL Authentication

The following Server settings need to be specified in the `postgresql.conf` configuration file:

- `ssl boolean`. Enables SSL connections.
- `ssl_renegotiation_limit integer`. Specifies the data limit before key renegotiation.
- `ssl_ciphers string`. Lists SSL ciphers that are allowed.

The following SSL server files can be found in the Master Data Directory:

- `server.crt`. Server certificate.
- `server.key`. Server private key.
- `root.crt`. Trusted certificate authorities.
- `root.crl`. Certificates revoked by certificate authorities.

### Configuring the SSL Client Connection

SSL options:

- `require` Only use SSL connection. If a root CA file is present, verify the certificate in the same way as if `verify-ca` was specified.

- `verify-ca` Only use an SSL connection. Verify that the server certificate is issued by a trusted CA.

- `verify-full` Only use an SSL connection. Verify that the server certificate is issued by a trusted CA and that the server host name matches that in the certificate.

- `sslcert` The file name of the client SSL certificate. The default is `~/.postgresql/postgresql.crt`.

- `sslkey` The secret key used for the client certificate. The default is `~/.postgresql/postgresql.key`.

- `sslrootcert` The name of a file containing SSL Certificate Authority certificate(s). The default is `~/.postgresql/root.crt`.

- `sslcrl` The name of the SSL certificate revocation list. The default is `~/.postgresql/root.crl`.

The client connection parameters can be set using the following environment variables:

- `sslmode - PGSSLMODE`
- `sslkey - PGSSLKEY`
- `sslrootcert - PGSSLROOTCERT`
• sslcert – PGSSLCERT
• sslcrl – PGSSLCRL

**PAM Based Authentication**

"PAM" (Pluggable Authentication Modules) is used to validate username/password pairs, similar to basic authentication. PAM authentication only works if the users already exist in the database.

**Parameters**

**pamservice**

The default PAM service is `postgresql`. Note that if PAM is set up to read `/etc/shadow`, authentication will fail because the PostgreSQL server is started by a non-root user.

Following are sample `pg_hba.conf` entries for PAM client authentication:

```
local    all gpuser am pamservice=postgresql
```

**Radius Authentication**

RADIUS (Remote Authentication Dial In User Service) authentication works by sending an Access Request message of type 'Authenticate Only' to a configured RADIUS server. It includes parameters for user name, password (encrypted), and the Network Access Server (NAS) Identifier. The request is encrypted using the shared secret specified in the `radiussecret` option. The RADIUS server responds with either Access Accept or Access Reject.

**Note:** RADIUS accounting is not supported.

RADIUS authentication only works if the users already exist in the database.

The RADIUS encryption vector requires SSL to be enabled in order to be cryptographically strong.

**RADIUS Authentication Options**

**radiusserver**

The name of the RADIUS server.

**radiussecret**

The RADIUS shared secret.

**radiusport**

The port to connect to on the RADIUS server.

**radiusidentifier**

NAS identifier in RADIUS requests.

Following are sample `pg_hba.conf` entries for RADIUS client authentication:

```
hostssl  all all 0.0.0.0/0 radius radiusserver=servername radiussecret=sharedsecret
```

**Limiting Concurrent Connections**

To limit the number of active concurrent sessions to your Greenplum Database system, you can configure the `max_connections` server configuration parameter. This is a local parameter, meaning that you must set it in the `postgresql.conf` file of the master, the standby master, and each segment instance (primary and mirror). The value of `max_connections` on segments must be 5-10 times the value on the master.
When you set `max_connections`, you must also set the dependent parameter `max_prepared_transactions`. This value must be at least as large as the value of `max_connections` on the master, and segment instances should be set to the same value as the master.

In `$MASTER_DATA_DIRECTORY/postgresql.conf` (including standby master):

```
max_connections=100
max_prepared_transactions=100
```

In `$SEGMENT_DATA_DIRECTORY/postgresql.conf` for all segment instances:

```
max_connections=500
max_prepared_transactions=100
```

**Note:** Raising the values of these parameters may cause Greenplum Database to request more shared memory. To mitigate this effect, consider decreasing other memory-related parameters such as `gp_cached_segworkers_threshold`.

To change the number of allowed connections:

1. Stop your Greenplum Database system:

   ```
   $ gpstop
   ```

2. On the master host, edit `$MASTER_DATA_DIRECTORY/postgresql.conf` and change the following two parameters:
   - `max_connections` – the number of active user sessions you want to allow plus the number of `superuser_reserved_connections`.
   - `max_prepared_transactions` – must be greater than or equal to `max_connections`.

3. On each segment instance, edit `$SEGMENT_DATA_DIRECTORY/postgresql.conf` and change the following two parameters:
   - `max_connections` – must be 5-10 times the value on the master.
   - `max_prepared_transactions` – must be equal to the value on the master.

4. Restart your Greenplum Database system:

   ```
   $ gpstart
   ```

---

**Encrypting Client/Server Connections**

Greenplum Database has native support for SSL connections between the client and the master server. SSL connections prevent third parties from snooping on the packets, and also prevent man-in-the-middle attacks. SSL should be used whenever the client connection goes through an insecure link, and must be used whenever client certificate authentication is used.

**Note:** For information about encrypting data between the `gpfdist` server and Greenplum Database segment hosts, see *Encrypting gpfdist Connections*.

To enable SSL requires that OpenSSL be installed on both the client and the master server systems. Greenplum can be started with SSL enabled by setting the server configuration parameter `ssl=on` in the master `postgresql.conf`. When starting in SSL mode, the server will look for the files `server.key` (server private key) and `server.crt` (server certificate) in the master data directory. These files must be set up correctly before an SSL-enabled Greenplum system can start.

**Important:** Do not protect the private key with a passphrase. The server does not prompt for a passphrase for the private key, and the database startup fails with an error if one is required.

A self-signed certificate can be used for testing, but a certificate signed by a certificate authority (CA) should be used in production, so the client can verify the identity of the server. Either a global or local CA
can be used. If all the clients are local to the organization, a local CA is recommended. See *Creating a Self-Signed Certificate* for steps to create a self-signed certificate.
Configuring Database Authorization

Describes how to restrict authorization access to database data at the user level by using roles and permissions.

Access Permissions and Roles

Greenplum Database manages database access permissions using roles. The concept of roles subsumes the concepts of users and groups. A role can be a database user, a group, or both. Roles can own database objects (for example, tables) and can assign privileges on those objects to other roles to control access to the objects. Roles can be members of other roles, thus a member role can inherit the object privileges of its parent role.

Every Greenplum Database system contains a set of database roles (users and groups). Those roles are separate from the users and groups managed by the operating system on which the server runs. However, for convenience you may want to maintain a relationship between operating system user names and Greenplum Database role names, since many of the client applications use the current operating system user name as the default.

In Greenplum Database, users log in and connect through the master instance, which verifies their role and access privileges. The master then issues out commands to the segment instances behind the scenes using the currently logged in role.

Roles are defined at the system level, so they are valid for all databases in the system.

To bootstrap the Greenplum Database system, a freshly initialized system always contains one predefined superuser role (also referred to as the system user). This role will have the same name as the operating system user that initialized the Greenplum Database system. Customarily, this role is named `gpadmin`. To create more roles you first must connect as this initial role.

Managing Object Privileges

When an object (table, view, sequence, database, function, language, schema, or tablespace) is created, it is assigned an owner. The owner is normally the role that executed the creation statement. For most kinds of objects, the initial state is that only the owner (or a superuser) can do anything with the object. To allow other roles to use it, privileges must be granted. Greenplum Database supports the following privileges for each object type:

<table>
<thead>
<tr>
<th>Object Type</th>
<th>Privileges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tables, Views, Sequences</td>
<td>SELECT</td>
</tr>
<tr>
<td></td>
<td>INSERT</td>
</tr>
<tr>
<td></td>
<td>UPDATE</td>
</tr>
<tr>
<td></td>
<td>DELETE</td>
</tr>
<tr>
<td></td>
<td>RULE</td>
</tr>
<tr>
<td></td>
<td>ALL</td>
</tr>
<tr>
<td>External Tables</td>
<td>SELECT</td>
</tr>
<tr>
<td></td>
<td>RULE</td>
</tr>
<tr>
<td></td>
<td>ALL</td>
</tr>
</tbody>
</table>
Privileges must be granted for each object individually. For example, granting `ALL` on a database does not grant full access to the objects within that database. It only grants all of the database-level privileges (CONNECT, CREATE, TEMPORARY) to the database itself.

Use the `GRANT` SQL command to give a specified role privileges on an object. For example:

```sql
=# GRANT INSERT ON mytable TO jsmith;
```

To revoke privileges, use the `REVOKE` command. For example:

```sql
=# REVOKE ALL PRIVILEGES ON mytable FROM jsmith;
```

You can also use the `DROP OWNED` and `REASSIGN OWNED` commands for managing objects owned by deprecated roles. (Note: only an object's owner or a superuser can drop an object or reassign ownership.) For example:

```sql
=# REASSIGN OWNED BY sally TO bob;
=# DROP OWNED BY visitor;
```

### Using SSH-256 Encryption

Greenplum Database access control corresponds roughly to the Orange Book 'C2' level of security, not the 'B1' level. Greenplum Database currently supports access privileges at the object level. Row-level or column-level access is not supported, nor is labeled security.

Row-level and column-level access can be simulated using views to restrict the columns and/or rows that are selected. Row-level labels can be simulated by adding an extra column to the table to store sensitivity information, and then using views to control row-level access based on this column. Roles can then be granted access to the views rather than the base table. While these workarounds do not provide the same as "B1" level security, they may still be a viable alternative for many organizations.

To use SHA-256 encryption, you must set a parameter either at the system or the session level. This section outlines how to use a server parameter to implement SHA-256 encrypted password storage. Note that in order to use SHA-256 encryption for storage, the client authentication method must be set to password rather than the default, MD5. (See Configuring the SSL Client Connection for more details.) This means that the password is transmitted in clear text over the network, so we highly recommend that you set up SSL to encrypt the client server communication channel.

You can set your chosen encryption method system-wide or on a per-session basis. The available encryption methods are SHA-256 and MD5 (for backward compatibility).
Setting Encryption Method System-wide

To set the `password_hash_algorithm` server parameter on a complete Greenplum system (master and its segments):

1. Log in to your Greenplum Database instance as a superuser.
2. Execute `gpconfig` with the `password_hash_algorithm` set to SHA-256:

   ```
   $ gpconfig -c password_hash_algorithm -v 'SHA-256'
   ```

3. Verify the setting:

   ```
   $ gpconfig -s
   ```

   You will see:

   Master value: SHA-256
   Segment value: SHA-256

Setting Encryption Method for an Individual Session

To set the `password_hash_algorithm` server parameter for an individual session:

1. Log in to your Greenplum Database instance as a superuser.
2. Set the `password_hash_algorithm` to SHA-256:

   ```
   # set password_hash_algorithm = 'SHA-256'
   ```

3. Verify the setting:

   ```
   # show password_hash_algorithm;
   ```

   You will see:

   SHA-256

Following is an example of how the new setting works:

1. Log in as a super user and verify the password hash algorithm setting:

   ```
   # show password_hash_algorithm
   password_hash_algorithm
   ---------------------------
   SHA-256
   ```

2. Create a new role with password that has login privileges.

   ```
   create role testdb with password 'testdb12345#' LOGIN;
   ```

3. Change the client authentication method to allow for storage of SHA-256 encrypted passwords:

   Open the `pg_hba.conf` file on the master and add the following line:

   ```
   host all testdb 0.0.0.0/0 password
   ```

4. Restart the cluster.
5. Log in to the database as the user just created, testdb.

```
psql -U testdb
```

6. Enter the correct password at the prompt.
7. Verify that the password is stored as a SHA-256 hash.

```
Password hashes are stored in pg_authid.rolpassword.
```

8. Log in as the super user.
9. Execute the following query:

```
# SELECT rolpassword FROM pg_authid WHERE rolname = 'testdb';
Rolpassword
----------
sha256<64 hexadecimal characters>
```

## Restricting Access by Time

Greenplum Database enables the administrator to restrict access to certain times by role. Use the `CREATE ROLE` or `ALTER ROLE` commands to specify time-based constraints.

Access can be restricted by day or by day and time. The constraints are removable without deleting and recreating the role.

Time-based constraints only apply to the role to which they are assigned. If a role is a member of another role that contains a time constraint, the time constraint is not inherited.

Time-based constraints are enforced only during login. The `SET ROLE` and `SET SESSION AUTHORIZATION` commands are not affected by any time-based constraints.

Superuser or `CREATEROLE` privileges are required to set time-based constraints for a role. No one can add time-based constraints to a superuser.

There are two ways to add time-based constraints. Use the keyword `DENY` in the `CREATE ROLE` or `ALTER ROLE` command followed by one of the following.

- A day, and optionally a time, when access is restricted. For example, no access on Wednesdays.
- An interval—that is, a beginning and ending day and optional time—when access is restricted. For example, no access from Wednesday 10 p.m. through Thursday at 8 a.m.

You can specify more than one restriction; for example, no access Wednesdays at any time and no access on Fridays between 3:00 p.m. and 5:00 p.m.

There are two ways to specify a day. Use the word `DAY` followed by either the English term for the weekday, in single quotation marks, or a number between 0 and 6, as shown in the table below.

<table>
<thead>
<tr>
<th>English Term</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAY 'Sunday'</td>
<td>DAY 0</td>
</tr>
<tr>
<td>DAY 'Monday'</td>
<td>DAY 1</td>
</tr>
<tr>
<td>DAY 'Tuesday'</td>
<td>DAY 2</td>
</tr>
<tr>
<td>DAY 'Wednesday'</td>
<td>DAY 3</td>
</tr>
<tr>
<td>DAY 'Thursday'</td>
<td>DAY 4</td>
</tr>
<tr>
<td>DAY 'Friday'</td>
<td>DAY 5</td>
</tr>
<tr>
<td>DAY 'Saturday'</td>
<td>DAY 6</td>
</tr>
</tbody>
</table>
A time of day is specified in either 12- or 24-hour format. The word `TIME` is followed by the specification in single quotation marks. Only hours and minutes are specified and are separated by a colon (:``). If using a 12-hour format, add `AM` or `PM` at the end. The following examples show various time specifications.

```
TIME '14:00'     # 24-hour time implied
TIME '02:00 PM'  # 12-hour time specified by PM
TIME '02:00'     # 24-hour time implied. This is equivalent to TIME '02:00 AM'.
```

**Important:** Time-based authentication is enforced with the server time. Timezones are disregarded.

To specify an interval of time during which access is denied, use two day/time specifications with the words `BETWEEN` and `AND`, as shown. `DAY` is always required.

```
BETWEEN DAY 'Monday' AND DAY 'Tuesday'

BETWEEN DAY 'Monday' TIME '00:00' AND
DAY 'Monday' TIME '01:00'

BETWEEN DAY 'Monday' TIME '12:00 AM' AND
DAY 'Tuesday' TIME '02:00 AM'

BETWEEN DAY 'Monday' TIME '00:00' AND
DAY 'Tuesday' TIME '02:00'
DAY 2 TIME '02:00'
```

The last three statements are equivalent.

**Note:** Intervals of days cannot wrap past Saturday.

The following syntax is not correct:

```
DENY BETWEEN DAY 'Saturday' AND DAY 'Sunday'
```

The correct specification uses two `DENY` clauses, as follows:

```
DENY DAY 'Saturday'
DENY DAY 'Sunday'
```

The following examples demonstrate creating a role with time-based constraints and modifying a role to add time-based constraints. Only the statements needed for time-based constraints are shown. For more details on creating and altering roles see the descriptions of `CREATE ROLE` and `ALTER ROLE` in the Greenplum Database Reference Guide.

**Example 1 – Create a New Role with Time-based Constraints**

No access is allowed on weekends.

```
CREATE ROLE generaluser
DENY DAY 'Saturday'
DENY DAY 'Sunday'
...
```

**Example 2 – Alter a Role to Add Time-based Constraints**

No access is allowed every night between 2:00 a.m. and 4:00 a.m.

```
ALTER ROLE generaluser
DENY BETWEEN DAY 'Monday' TIME '02:00' AND DAY 'Monday' TIME '04:00'
```
DENY BETWEEN DAY 'Tuesday' TIME '02:00' AND DAY 'Tuesday' TIME '04:00'
DENY BETWEEN DAY 'Wednesday' TIME '02:00' AND DAY 'Wednesday' TIME '04:00'
DENY BETWEEN DAY 'Thursday' TIME '02:00' AND DAY 'Thursday' TIME '04:00'
DENY BETWEEN DAY 'Friday' TIME '02:00' AND DAY 'Friday' TIME '04:00'
DENY BETWEEN DAY 'Saturday' TIME '02:00' AND DAY 'Saturday' TIME '04:00'
DENY BETWEEN DAY 'Sunday' TIME '02:00' AND DAY 'Sunday' TIME '04:00'

Example 3 – Alter a Role to Add Time-based Constraints

No access is allowed Wednesdays or Fridays between 3:00 p.m. and 5:00 p.m.

ALTER ROLE generaluser
DENY DAY 'Wednesday'
DENY BETWEEN DAY 'Friday' TIME '15:00' AND DAY 'Friday' TIME '17:00'

Dropping a Time-based Restriction

To remove a time-based restriction, use the ALTER ROLE command. Enter the keywords DROP DENY FOR followed by a day/time specification to drop.

DROP DENY FOR DAY 'Sunday'

Any constraint containing all or part of the conditions in a DROP clause is removed. For example, if an existing constraint denies access on Mondays and Tuesdays, and the DROP clause removes constraints for Mondays, the existing constraint is completely dropped. The DROP clause completely removes all constraints that overlap with the constraint in the drop clause. The overlapping constraints are completely removed even if they contain more restrictions that the restrictions mentioned in the DROP clause.

Example 1 - Remove a Time-based Restriction from a Role

ALTER ROLE generaluser
DROP DENY FOR DAY 'Monday'

This statement would remove all constraints that overlap with a Monday constraint for the role generaluser in Example 2, even if there are additional constraints.
Greenplum Command Center Security

Greenplum Command Center (GPCC) is a web-based application for monitoring and managing Greenplum clusters. GPCC works with data collected by agents running on the segment hosts and saved to the gpperfmon database. The gpperfmon database is created by running the gpperfmon_install utility, which also creates the gpmon database role that GPCC uses to access the gpperfmon database.

The gpmon User

The gpperfmon_install utility creates the gpmon database role and adds the role to the pg_hba.conf file with the following entries:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>local</td>
<td>gpperfmon</td>
<td>gpmon</td>
<td>md5</td>
</tr>
<tr>
<td>host</td>
<td>all</td>
<td>gpmon</td>
<td>127.0.0.1/28</td>
</tr>
<tr>
<td>host</td>
<td>all</td>
<td>gpmon</td>
<td>::1/128</td>
</tr>
</tbody>
</table>

These entries allow gpmon to establish a local socket connection to the gpperfmon database and a TCP/IP connection to any database.

The gpmon database role is a superuser. In a secure or production environment, it may be desirable to restrict the gpmon user to just the gpperfmon database. Do this by editing the gpmon host entry in the pg_hba.conf file and changing all in the database field to gpperfmon:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>local</td>
<td>gpperfmon</td>
<td>gpmon</td>
<td>md5</td>
</tr>
<tr>
<td>host</td>
<td>gpperfmon</td>
<td>gpmon</td>
<td>127.0.0.1/28</td>
</tr>
<tr>
<td>host</td>
<td>gpperfmon</td>
<td>gpmon</td>
<td>::1/128</td>
</tr>
</tbody>
</table>

The password used to authenticate the gpmon user is set by the gpperfmon_install utility and is stored in the gpadmin home directory in the ~/.pgpass file. The ~/.pgpass file must be owned by the gpadmin user and be RW-accessible only by the gpadmin user. To change the gpmon password, use the ALTER ROLE command to change the password in the database, change the password in the ~/.pgpass file, and then restart GPCC with the gpcmdr --restart instance_name command.

Note: The GPCC web server can be configured to encrypt connections with SSL. Two-way authentication with public keys can also be enabled for GPCC users. However, the gpmon user always uses md5 authentication with the password saved in the ~/.pgpass file.

GPCC does not allow logins from any role configured with trust authentication, including the gpadmin user.

The gpmon user can log in to the Command Center Console and has access to all of the application’s features. You can allow other database roles access to GPCC so that you can secure the gpmon user and restrict other users’ access to GPCC features. Setting up other GPCC users is described in the next section.

Greenplum Command Center Users

GPCC has the following types of users:

- **Self Only** users can view metrics and view and cancel their own queries. Any Greenplum Database user successfully authenticated through the Greenplum Database authentication system can access Greenplum Command Center with Self Only permission. Higher permission levels are required to view and cancel other’s queries and to access the System and Admin Control Center features.
- **Basic** users can view metrics, view all queries, and cancel their own queries. Users with Basic permission are members of the Greenplum Database gpcc_basic group.
• **Operator Basic** users can view metrics, view their own and others’ queries, cancel their own queries, and view the System and Admin screens. Users with Operator Basic permission are members of the Greenplum Database `gpcc_operator_basic` group.

• **Operator** users can view their own and others’ queries, cancel their own and other’s queries, and view the System and Admin screens. Users with Operator permission are members of the Greenplum Database `gpcc_operator` group.

• **Admin** users can access all views and capabilities in the Command Center. Greenplum Database users with the **SUPERUSER** privilege have Admin permissions in Command Center.

To log in to the GPCC web application, a user must be allowed access to the gpperfmon database in `pg_hba.conf`. For example, to make `user1` a regular GPCC user, edit the `pg_hba.conf` file and either add or edit a line for the user so that the gpperfmon database is included in the database field. For example:

```
host     gpperfmon,accounts   user1     127.0.0.1/28    md5
```

To designate a user as an operator, grant the `gpcc_operator` role to the user:

```
=# GRANT gpcc_operator TO user;
```

You can also grant `gpcc_operator` to a group role to make all members of the group GPCC operators.

See the `gpperfmon_install` reference in *Greenplum Database Utility Guide* for more information about managing the gpperfmon database.

**Enabling SSL for Greenplum Command Center**

The GPCC web server can be configured to support SSL so that client connections are encrypted. A server certificate can be generated when the Command Center instance is created or you can supply an existing certificate.

Two-way authentication with public key encryption can also be enabled for GPCC. See the *Greenplum Command Center Administration Guide* for instructions.

**Enabling Kerberos Authentication for Greenplum Command Center Users**

If Kerberos authentication is enabled for Greenplum Database, Command Center users can also authenticate with Kerberos. Command Center supports three Kerberos authentication modes: **strict**, **normal**, and **gpmon-only**.

**Strict**

Command Center has a Kerberos keytab file containing the Command Center service principal and a principal for every Command Center user. If the principal in the client's connection request is in the keytab file, the web server grants the client access and the web server connects to Greenplum Database using the client's principal name. If the principal is not in the keytab file, the connection request fails.

**Normal**

The Command Center Kerberos keytab file contains the Command Center principal and may contain principals for Command Center users. If the principal in the client's connection request is in Command Center’s keytab file, it uses the client’s principal for database connections. Otherwise, Command Center uses the `gpmon` user for database connections.

**gpmon-only**

The Command Center uses the `gpmon` database role for all Greenplum Database connections. No client principals are needed in the Command Center's keytab file.
See the *Greenplum Command Center documentation* for instructions to enable Kerberos authentication with Greenplum Command Center.
Auditing

Describes Greenplum Database events that are logged and should be monitored to detect security threats.

Greenplum Database is capable of auditing a variety of events, including startup and shutdown of the system, segment database failures, SQL statements that result in an error, and all connection attempts and disconnections. Greenplum Database also logs SQL statements and information regarding SQL statements, and can be configured in a variety of ways to record audit information with more or less detail. The log_error_verbosity configuration parameter controls the amount of detail written in the server log for each message that is logged. Similarly, the log_min_error_statement parameter allows administrators to configure the level of detail recorded specifically for SQL statements, and the log_statement parameter determines the kind of SQL statements that are audited. Greenplum Database records the username for all auditable events, when the event is initiated by a subject outside the Greenplum Database.

Greenplum Database prevents unauthorized modification and deletion of audit records by only allowing administrators with an appropriate role to perform any operations on log files. Logs are stored in a proprietary format using comma-separated values (CSV). Each segment and the master stores its own log files, although these can be accessed remotely by an administrator. Greenplum Database also authorizes overwriting of old log files via the log_truncate_on_rotation parameter. This is a local parameter and must be set on each segment and master configuration file.

Greenplum provides an administrative schema called gp_toolkit that you can use to query log files, as well as system catalogs and operating environment for system status information. For more information, including usage, refer to The gp_toolkit Administrative Schema appendix in the Greenplum Database Reference Guide.

Viewing the Database Server Log Files

Every database instance in Greenplum Database (master and segments) is a running PostgreSQL database server with its own server log file. Daily log files are created in the pg_log directory of the master and each segment data directory.

The server log files are written in comma-separated values (CSV) format. Not all log entries will have values for all of the log fields. For example, only log entries associated with a query worker process will have the slice_id populated. Related log entries of a particular query can be identified by its session identifier (gp_session_id) and command identifier (gp_command_count).

<table>
<thead>
<tr>
<th>#</th>
<th>Field Name</th>
<th>Data Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>event_time</td>
<td>timestamp with time zone</td>
<td>Time that the log entry was written to the log</td>
</tr>
<tr>
<td>2</td>
<td>user_name</td>
<td>varchar(100)</td>
<td>The database user name</td>
</tr>
<tr>
<td>3</td>
<td>database_name</td>
<td>varchar(100)</td>
<td>The database name</td>
</tr>
<tr>
<td>4</td>
<td>process_id</td>
<td>varchar(10)</td>
<td>The system process id (prefixed with &quot;p&quot;)</td>
</tr>
<tr>
<td>5</td>
<td>thread_id</td>
<td>varchar(50)</td>
<td>The thread count (prefixed with &quot;th&quot;)</td>
</tr>
<tr>
<td>6</td>
<td>remote_host</td>
<td>varchar(100)</td>
<td>On the master, the hostname/address of the client machine. On the segment, the hostname/address of the master.</td>
</tr>
<tr>
<td>#</td>
<td>Field Name</td>
<td>Data Type</td>
<td>Description</td>
</tr>
<tr>
<td>----</td>
<td>---------------------</td>
<td>---------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>7</td>
<td>remote_port</td>
<td>varchar(10)</td>
<td>The segment or master port number</td>
</tr>
<tr>
<td>8</td>
<td>session_start_time</td>
<td>timestamp with time zone</td>
<td>Time session connection was opened</td>
</tr>
<tr>
<td>9</td>
<td>transaction_id</td>
<td>int</td>
<td>Top-level transaction ID on the master. This ID is the parent of any subtransactions.</td>
</tr>
<tr>
<td>10</td>
<td>gp_session_id</td>
<td>text</td>
<td>Session identifier number (prefixed with &quot;con&quot;)</td>
</tr>
<tr>
<td>11</td>
<td>gp_command_count</td>
<td>text</td>
<td>The command number within a session (prefixed with &quot;cmd&quot;)</td>
</tr>
<tr>
<td>12</td>
<td>gp_segment</td>
<td>text</td>
<td>The segment content identifier (prefixed with &quot;seg&quot; for primaries or &quot;mir&quot; for mirrors). The master always has a content id of -1.</td>
</tr>
<tr>
<td>13</td>
<td>slice_id</td>
<td>text</td>
<td>The slice id (portion of the query plan being executed)</td>
</tr>
<tr>
<td>14</td>
<td>distr_trxn_id</td>
<td>text</td>
<td>Distributed transaction ID</td>
</tr>
<tr>
<td>15</td>
<td>local_trxn_id</td>
<td>text</td>
<td>Local transaction ID</td>
</tr>
<tr>
<td>16</td>
<td>sub_trxn_id</td>
<td>text</td>
<td>Subtransaction ID</td>
</tr>
<tr>
<td>17</td>
<td>event_severity</td>
<td>varchar(10)</td>
<td>Values include: LOG, ERROR, FATAL, PANIC, DEBUG1, DEBUG2</td>
</tr>
<tr>
<td>18</td>
<td>sql_state_code</td>
<td>varchar(10)</td>
<td>SQL state code associated with the log message</td>
</tr>
<tr>
<td>19</td>
<td>event_message</td>
<td>text</td>
<td>Log or error message text</td>
</tr>
<tr>
<td>20</td>
<td>event_detail</td>
<td>text</td>
<td>Detail message text associated with an error or warning message</td>
</tr>
<tr>
<td>21</td>
<td>event_hint</td>
<td>text</td>
<td>Hint message text associated with an error or warning message</td>
</tr>
<tr>
<td>22</td>
<td>internal_query</td>
<td>text</td>
<td>The internally-generated query text</td>
</tr>
<tr>
<td>23</td>
<td>internal_query_pos</td>
<td>int</td>
<td>The cursor index into the internally-generated query text</td>
</tr>
<tr>
<td>24</td>
<td>event_context</td>
<td>text</td>
<td>The context in which this message gets generated</td>
</tr>
<tr>
<td>#</td>
<td>Field Name</td>
<td>Data Type</td>
<td>Description</td>
</tr>
<tr>
<td>----</td>
<td>---------------------</td>
<td>-----------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>25</td>
<td>debug_query_string</td>
<td>text</td>
<td>User-supplied query string with full detail for debugging. This string can be modified for internal use.</td>
</tr>
<tr>
<td>26</td>
<td>error_cursor_pos</td>
<td>int</td>
<td>The cursor index into the query string</td>
</tr>
<tr>
<td>27</td>
<td>func_name</td>
<td>text</td>
<td>The function in which this message is generated</td>
</tr>
<tr>
<td>28</td>
<td>file_name</td>
<td>text</td>
<td>The internal code file where the message originated</td>
</tr>
<tr>
<td>29</td>
<td>file_line</td>
<td>int</td>
<td>The line of the code file where the message originated</td>
</tr>
<tr>
<td>30</td>
<td>stack_trace</td>
<td>text</td>
<td>Stack trace text associated with this message</td>
</tr>
</tbody>
</table>

Greenplum provides a utility called `gplogfilter` that can be used to search through a Greenplum Database log file for entries matching the specified criteria. By default, this utility searches through the Greenplum master log file in the default logging location. For example, to display the last three lines of the master log file:

```
$ gplogfilter -n 3
```

You can also use `gplogfilter` to search through all segment log files at once by running it through the `gpssh` utility. For example, to display the last three lines of each segment log file:

```
$ gpssh -f seg_host_file
  => source /usr/local/greenplum-db/greenplum_path.sh
  => gplogfilter -n 3 /gpdata/gp*/pg_log/gpdb*.csv
```

The following are the Greenplum security-related audit (or logging) server configuration parameters that are set in the `postgresql.conf` configuration file:

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Value Range</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>log_connections</td>
<td>Boolean</td>
<td>off</td>
<td>This outputs a line to the server log detailing each successful connection. Some client programs, like <code>psql</code>, attempt to connect twice while determining if a password is required, so duplicate “connection received” messages do not always indicate a problem.</td>
</tr>
<tr>
<td>log_disconnections</td>
<td>Boolean</td>
<td>off</td>
<td>This outputs a line in the server log at termination of a client session, and includes the duration of the session.</td>
</tr>
<tr>
<td>Field Name</td>
<td>Value Range</td>
<td>Default</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------------</td>
<td>---------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>log_statement</td>
<td>NONE, DDL, MOD, ALL</td>
<td>ALL</td>
<td>Controls which SQL statements are logged. DDL logs all data definition commands like CREATE, ALTER, and DROP commands. MOD logs all DDL statements, plus INSERT, UPDATE, DELETE, TRUNCATE, and COPY FROM. PREPARE and EXPLAIN ANALYZE statements are also logged if their contained command is of an appropriate type.</td>
</tr>
<tr>
<td>log_hostname</td>
<td>Boolean</td>
<td>off</td>
<td>By default, connection log messages only show the IP address of the connecting host. Turning on this option causes logging of the host name as well. Note that depending on your host name resolution setup this might impose a non-negligible performance penalty.</td>
</tr>
<tr>
<td>log_duration</td>
<td>Boolean</td>
<td>off</td>
<td>Causes the duration of every completed statement which satisfies log_statement to be logged.</td>
</tr>
<tr>
<td>log_error_verbosity</td>
<td>TERSE, DEFAULT, VERBOSE</td>
<td>DEFAULT</td>
<td>Controls the amount of detail written in the server log for each message that is logged.</td>
</tr>
<tr>
<td>log_min_duration_statement</td>
<td>number of milliseconds, 0, -1</td>
<td>-1</td>
<td>Logs the statement and its duration on a single log line if its duration is greater than or equal to the specified number of milliseconds. Setting this to 0 will print all statements and their durations. -1 disables the feature. For example, if you set it to 250 then all SQL statements that run 250ms or longer will be logged. Enabling this option can be useful in tracking down unoptimized queries in your applications.</td>
</tr>
<tr>
<td>Field Name</td>
<td>Value Range</td>
<td>Default</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>---------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>log_min_messages</td>
<td>DEBUG5, DEBUG4, DEBUG3, DEBUG2, DEBUG1, INFO, NOTICE, WARNING, ERROR, LOG,</td>
<td>NOTICE</td>
<td>Controls which message levels are written to the server log. Each level includes all the levels that follow it. The later the level, the fewer messages are sent to the log.</td>
</tr>
<tr>
<td></td>
<td>FATAL, PANIC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>log_rotation_age</td>
<td>Any valid time expression (number and unit)</td>
<td>1d</td>
<td>Determines the maximum lifetime of an individual log file. After this time has elapsed, a new log file will be created. Set to zero to disable time-based creation of new log files.</td>
</tr>
<tr>
<td>log_statement_stats</td>
<td>Boolean</td>
<td>off</td>
<td>For each query, write total performance statistics of the query parser, planner, and executor to the server log. This is a crude profiling instrument.</td>
</tr>
<tr>
<td>log_truncate_on_rotation</td>
<td>Boolean</td>
<td>off</td>
<td>Truncates (overwrites), rather than appends to, any existing log file of the same name. Truncation will occur only when a new file is being opened due to time-based rotation. For example, using this setting in combination with a log_filename such as gpseg#-%H.log would result in generating twenty-four hourly log files and then cyclically overwriting them. When off, pre-existing files will be appended to in all cases.</td>
</tr>
</tbody>
</table>
Encrypting Data and Database Connections

Describes how to encrypt data at rest in the database or in transit over the network, to protect from eavesdroppers or man-in-the-middle attacks.

- Connections between clients and the master database can be encrypted with SSL. This is enabled with the `ssl` server configuration parameter, which is `off` by default. Setting the `ssl` parameter to `on` allows client communications with the master to be encrypted. The master database must be set up for SSL. See OpenSSL Configuration for more about encrypting client connections with SSL.
- Greenplum Database allows SSL encryption of data in transit between the Greenplum parallel file distribution server, `gpfdist`, and segment hosts. See Encrypting gpfdist Connections for more information.
- The `pgcrypto` module of encryption/decryptions functions protect data at rest in the database. Encryption at the column level protects sensitive information, such as social security numbers or credit card numbers. See Encrypting Data at Rest with `pgcrypto` for more information.

Encrypting gpfdist Connections

The `gpfdists` protocol is a secure version of the `gpfdist` protocol that securely identifies the file server and the Greenplum Database and encrypts the communications between them. Using `gpfdists` protects against eavesdropping and man-in-the-middle attacks.

The `gpfdists` protocol implements client/server SSL security with the following notable features:

- Client certificates are required.
- Multilingual certificates are not supported.
- A Certificate Revocation List (CRL) is not supported.
- The TLSv1 protocol is used with the `TLS_RSA_WITH_AES_128_CBC_SHA` encryption algorithm. These SSL parameters cannot be changed.
- SSL renegotiation is supported.
- The SSL ignore host mismatch parameter is set to false.
- Private keys containing a passphrase are not supported for the `gpfdist` file server (`server.key`) or for the Greenplum Database (`client.key`).
- It is the user’s responsibility to issue certificates that are appropriate for the operating system in use. Generally, converting certificates to the required format is supported, for example using the SSL Converter at https://www.sslshopper.com/ssl-converter.html.

A `gpfdist` server started with the `--ssl` option can only communicate with the `gpfdists` protocol. A `gpfdist` server started without the `--ssl` option can only communicate with the `gpfdist` protocol. For more detail about `gpfdist` refer to the Greenplum Database Administrator Guide.

There are two ways to enable the `gpfdists` protocol:

- Run `gpfdist` with the `--ssl` option and then use the `gpfdists` protocol in the `LOCATION` clause of a `CREATE EXTERNAL TABLE` statement.
- Use a YAML control file with the SSL option set to true and run `gpload`. Running `gpload` starts the `gpfdist` server with the `--ssl` option and then uses the `gpfdists` protocol.

When using `gpfdists`, the following client certificates must be located in the `$PGDATA/gpfdists` directory on each segment:

- The client certificate file, `client.crt`
- The client private key file, `client.key`
- The trusted certificate authorities, `root.crt`

**Important:** Do not protect the private key with a passphrase. The server does not prompt for a passphrase for the private key, and loading data fails with an error if one is required.
When using `gpload` with SSL you specify the location of the server certificates in the YAML control file. When using `gpfdist` with SSL, you specify the location of the server certificates with the `--ssl` option.

The following example shows how to securely load data into an external table. The example creates a readable external table named `ext_expenses` from all files with the `.txt` extension, using the `gpfdists` protocol. The files are formatted with a pipe (|) as the column delimiter and an empty space as null.

1. Run `gpfdist` with the `--ssl` option on the segment hosts.
2. Log into the database and execute the following command:

```sql
=# CREATE EXTERNAL TABLE ext_expenses
    ( name text, date date, amount float4, category text, desc1 text )
LOCATION ('gpfdists://etlhost-1:8081/*.txt', 'gpfdists://etlhost-2:8082/*.txt')
FORMAT 'TEXT' ( DELIMITER '|' NULL ' ');
```

## Encrypting Data at Rest with pgcrypto

The pgcrypto module for Greenplum Database provides functions for encrypting data at rest in the database. Administrators can encrypt columns with sensitive information, such as social security numbers or credit card numbers, to provide an extra layer of protection. Database data stored in encrypted form cannot be read by users who do not have the encryption key, and the data cannot be read directly from disk.

pgcrypto is installed by default when you install Greenplum Database. You must explicitly enable pgcrypto in each database in which you want to use the module.

pgcrypto allows PGP encryption using symmetric and asymmetric encryption. Symmetric encryption encrypts and decrypts data using the same key and is faster than asymmetric encryption. It is the preferred method in an environment where exchanging secret keys is not an issue. With asymmetric encryption, a public key is used to encrypt data and a private key is used to decrypt data. This is slower than symmetric encryption and it requires a stronger key.

Using pgcrypto always comes at the cost of performance and maintainability. It is important to use encryption only with the data that requires it. Also, keep in mind that you cannot search encrypted data by indexing the data.

Before you implement in-database encryption, consider the following PGP limitations.

- No support for signing. That also means that it is not checked whether the encryption sub-key belongs to the master key.
- No support for encryption key as master key. This practice is generally discouraged, so this limitation should not be a problem.
- No support for several subkeys. This may seem like a problem, as this is common practice. On the other hand, you should not use your regular GPG/PGP keys with pgcrypto, but create new ones, as the usage scenario is rather different.

Greenplum Database is compiled with zlib by default; this allows PGP encryption functions to compress data before encrypting. When compiled with OpenSSL, more algorithms will be available.

Because pgcrypto functions run inside the database server, the data and passwords move between pgcrypto and the client application in clear-text. For optimal security, you should connect locally or use SSL connections and you should trust both the system and database administrators.

pgcrypto configures itself according to the findings of the main PostgreSQL configure script.

When compiled with `zlib`, pgcrypto encryption functions are able to compress data before encrypting. Pgcrypto has various levels of encryption ranging from basic to advanced built-in functions. The following table shows the supported encryption algorithms.
Table 74: Pgcrypto Supported Encryption Functions

<table>
<thead>
<tr>
<th>Value Functionality</th>
<th>Built-in</th>
<th>With OpenSSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD5</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>SHA1</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>SHA224/256/384/512</td>
<td>yes</td>
<td>yes³</td>
</tr>
<tr>
<td>Other digest algorithms</td>
<td>no</td>
<td>yes⁴</td>
</tr>
<tr>
<td>Blowfish</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>AES</td>
<td>yes</td>
<td>yes⁵</td>
</tr>
<tr>
<td>DES/3DES/CAST5</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Raw Encryption</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>PGP Symmetric-Key</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>PGP Public Key</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

Creating PGP Keys

To use PGP asymmetric encryption in Greenplum Database, you must first create public and private keys and install them.

This section assumes you are installing Greenplum Database on a Linux machine with the Gnu Privacy Guard (gpg) command line tool. Use the latest version of GPG to create keys. Download and install Gnu Privacy Guard (GPG) for your operating system from [https://www.gnupg.org/download/](https://www.gnupg.org/download/). On the GnuPG website you will find installers for popular Linux distributions and links for Windows and Mac OS X installers.

1. As root, execute the following command and choose option 1 from the menu:

```
# gpg --gen-key
```

```
gpg (GnuPG) 2.0.14; Copyright (C) 2009 Free Software Foundation, Inc.
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.

gpg: directory '/root/.gnupg' created

gpg: new configuration file '/root/.gnupg/gpg.conf' created

gpg: WARNING: options in '/root/.gnupg/gpg.conf' are not yet active during this run

gpg: keyring '/root/.gnupg/secring.gpg' created

gpg: keyring '/root/.gnupg/pubring.gpg' created

Please select what kind of key you want:
(1) RSA and RSA (default)
(2) DSA and Elgamal
(3) DSA (sign only)
(4) RSA (sign only)
Your selection? 1
```

---

³ SHA2 algorithms were added to OpenSSL in version 0.9.8. For older versions, pgcrypto will use built-in code.

⁴ Any digest algorithm OpenSSL supports is automatically picked up. This is not possible with ciphers, which need to be supported explicitly.

⁵ AES is included in OpenSSL since version 0.9.7. For older versions, pgcrypto will use built-in code.
2. Respond to the prompts and follow the instructions, as shown in this example:

RSA keys may be between 1024 and 4096 bits long. What keysize do you want? (2048) Press enter to accept default key size
Requested keysize is 2048 bits
Please specify how long the key should be valid.
0 = key does not expire
<n> = key expires in n days
<n>w = key expires in n weeks
<n>m = key expires in n months
<n>y = key expires in n years
Key is valid for? (0) 365
Key expires at Wed 13 Jan 2016 10:35:39 AM PST
Is this correct? (y/N) y

GnuPG needs to construct a user ID to identify your key.

Real name: John Doe
Email address: jdoe@email.com
Comment:
You selected this USER-ID:
"John Doe <jdoe@email.com>"

Change (N)ame, (C)omment, (E)mail or (O)kay/(Q)uit? O
You need a Passphrase to protect your secret key.
(For this demo the passphrase is blank.)
can't connect to '/root/.gnupg/S.gpg-agent': No such file or directory
You don't want a passphrase - this is probably a *bad* idea!
I will do it anyway. You can change your passphrase at any time, using this program with the option "--edit-key".

We need to generate a lot of random bytes. It is a good idea to perform some other action (type on the keyboard, move the mouse, utilize the disks) during the prime generation; this gives the random number generator a better chance to gain enough entropy.
We need to generate a lot of random bytes. It is a good idea to perform some other action (type on the keyboard, move the mouse, utilize the disks) during the prime generation; this gives the random number generator a better chance to gain enough entropy.
gpg: /root/.gnupg/trustdb.gpg: trustdb created
gpg: key 2027CC30 marked as ultimately trusted
public and secret key created and signed.

gpg: checking the trustdb
3 marginal(s) needed, 1 complete(s) needed, PGP trust model
gpg: depth: 0 valid: 1 signed: 0 trust: 0-, 0q, 0n, 0m, 0f, 1u
gpg: next trustdb check due at 2016-01-13
pub 2048R/2027CC30 2015-01-13 [expires: 2016-01-13]
    Key fingerprint = 7EDA 6AD0 F5E0 400F 4D45 3259 077D 725E 2027 CC30
    uid John Doe <jdoe@email.com>
sub 2048R/4FD2EFBB 2015-01-13 [expires: 2016-01-13]

3. List the PGP keys by entering the following command:

gpg --list-secret-keys
/root/.gnupg/secring.gpg

sec 2048R/2027CC30 2015-01-13 [expires: 2016-01-13]
    John Doe <jdoe@email.com>
sub 2048R/4FD2EFBB 2015-01-13
2027CC30 is the public key and will be used to encrypt data in the database. 4FD2EFBB is the private (secret) key and will be used to decrypt data.

4. Export the keys using the following commands:

```bash
# gpg -a --export 4FD2EFBB > public.key
# gpg -a --export-secret-keys 2027CC30 > secret.key
```

See the `pgcrypto` documentation for more information about PGP encryption functions.

## Encrypting Data in Tables using PGP

This section shows how to encrypt data inserted into a column using the PGP keys you generated.

1. Dump the contents of the public.key file and then copy it to the clipboard:

```sql
# cat public.key
-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)
mQENBFs12f0BCADNw8vkl1V1C36KFcw3KpmdijPfrEyEwB6pQyA05jtW1ZTh2HslslojS6P1l0Sck1QMu9lALnccse2RhInBhuvGkL19Gsd9te2g2nSL9Adnq1k/yX55yVK9G+gcdWvuy29g0O0omeyjhc3n+kkbRTEMu3f1bMs8JwzovMvstCUVmuHUVvg5rJae8puYD5Jc7I46w7SOH38lR1c7ifi6xyYddV4213cd4b18/I71h2qy2uYaN2H/sjii2ymq7ttw3jSwa2gPns5Gdoq9Qdyo/o9nNcgBEg1i96ZFlmEnE6Pwbn+hi8CMd0iK5/GAI16HC0ZIFH6KEcaivrU1ikjNAEBBAAG0HHRlci3Qo2qAg2V5IDoXMN0a2V5GVtvYisLmnVsb7JATA4EewECAcfAaL12f0CgmFCQhM4AGCwk1BwMCMbUnCGkKqCwMQBAbAh4BHeaeAAAoJEd9c14qJ8wbwfh/3VysVskq1lowRJNvxFGti1y7BfrvUSy2k+PP2Yoses9UpdL3CMRK8qAM9bx5S08q2UXSL26fOpEw4UWgmYgYF8JRoC3oee2TkmcBw8IIIbUOgGetzVxopdXLUFPGC7hvWQe9HsmtITLxgov1Am07T AoaccXLbyu2h9RfsvLoqdKzcqCyOHh5lGqXaOQ1T0TeFepb9TIicwvctg3WCSUS5P0 DguOuAanJZD3KE8q7Pv74fhGIEZVzH8fPajR6C2XSHFKpqBiIxNtx0Kq45NbX0an4 eUXPSnwPi46qoAp9UQogsfGyBI1D0T82UqgutAMECAMA7VtePv7910/ZFevBe A9Q0EVLVL/QEINAAbFdQ+8QMCADOipM1bF/jRtq3Uoc4BTqICaxdyzAfozT0USF/7Zro2us9G1AlQ5wOq8Eojc1/xmfcJiZuyAm6aAzzoFXgNH5Y1sdtMTJ2dl5WeoJwc CGW/ZLu4wzxOFFzDiFv9RDw6e5MNLtJrSp4hS02apKdo04Ex8304mYnav/eR iDCCWU4T0lhz3hScpkceYcWzX/1lojoo+anM0P0ywfi4hr3UMP70+VlbePqW2J bVlzZ3lLLouHrgpC2a+PzzbEks16jq77Vg9kq2TCizXowALljuit1flkk3Ov99h0 v/8YAnkcAmowzrIbi2MK2BhznynM2Y2YUKAVEAAAYkB7QQYQAIADWxULCIVL1/Qib DAAUJeaEEqAACAARHxJc1CFMOMOHYCAcHfnIn2A9uAM3TC441+MrgMUJ3rW9izr048 WrdTsxR8WksNbx1JowXyYdPb/shc9k65huw2SDjks/0frs161FHPQNP5vz62 WHN2IasLouaJq2pGHLonFbtJuevkyBy1Rz+H/+8rjKc20qJkmk8GK0k8b5x/ HMMUC55Hq0q2qAQY0BnJNhGQ4Q56q3k2Z/7Debk5WJ6K1wURy51sNIGWE8pvqE Ex/UuZb+YqCwtvX0nnbUIKNcmK2AkEccFK3Y1iyicxomdOxhFov9AKjijhDyc65KJc Vp2lmKFS2fK0AgiR3LpMab8ZDDe14W3vckPQNRNynUtj6zoCxxv =X28J
-----END PGP PUBLIC KEY BLOCK-----
```

2. Create a table called `userson` and insert some sensitive data, social security numbers for Bob and Alice, in this example. Paste the public.key contents after "dearmor(".

```sql
CREATE TABLE userson ( ssn_id SERIAL PRIMARY KEY, username varchar(100), ssn bytea);

INSERT INTO userson(username, ssn) SELECT robotccs.username, pgp_pub_encrypt(robotccs.ssn, keys.pubkey) AS ssn FROM (VALUES ('Alice', '123-45-6788'), ('Bob', '123-45-6799')) AS robotccs(username, ssn) CROSS JOIN (SELECT dearmor("-----BEGIN PGP PUBLIC KEY BLOCK-----Version: GnuPG v2.0.14 (GNU/Linux)" ));
```
3. Verify that the `ssn` column is encrypted.

test_db=# select * from userssn;

<table>
<thead>
<tr>
<th>ssn_id</th>
<th>username</th>
<th>ssn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alice</td>
<td></td>
</tr>
</tbody>
</table>
4. Extract the public.key ID from the database:

```sql
SELECT pgp_key_id(dearmor('-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)
mQENBFS12f0BCADNw8kV1C36Kfcwd3Kpm/dijPfRyyEwB6pqyA05jtWiX2Th2HsiojSp6SLoCs6IQg9ALAnceeh2hRinhBhVgK1gS9d9teq2nnSL9AdmqkJ/yXR5syVKGqcdWuvy29o0Omateh3n+kkbRTEMuM3flbMs8hOw2MvstCuVMuHUCvG5rJe8PuY7DSJC7u416w7SOH3RIRc7rif6xYydV4213ctd44b18/1l1hq2UYy2//Hbsji2ymq7ttwjsWAXZg9PnnSgoyQQyD/Q/o9NgCE8Egllg962Fbn6Epewbhnc/ichMD0kIS/GA1R6Hc02ZIHF8KEacvrUY1kjenABEBAA0HRlC3Qg2aV5ID02X0N0aV25GQtYWrlsLmNvb76JAT4EewECACgFA1S12f0CGwMFCQHhM4ACGwIkBMBCMBUIAg5KcwcWAgMBAh4BAtaEAAoJEd9c14gJ8wbwfh/3vYVsPkm1lowjRNxvXGt7y78frvy52y+kPPPzyoese90pwdLC3MRK482a9M9x5S00g82UXZLS6F6OpEwWgyMgyfrjR3ocezTkcmBCWb110ug0QtetvXoqplXwFGE7hWWq9HcSntITLxGov1mJwAW07TAc0cXldbyuz2h9fr5vLoQdqCcyOh51gxAQT1O0TeFepb9TIiwcng3WCSUSP0DGoGU0aaujD2E8Bq97V4f1GElZvHb8BpAjR62CXSHKfqBpiXntv0KT45wXBDAn4ntETUXSwPn46q0Bp90qrgsqfgyB16D0Z2UQgutzwEMECAm7VtePv79102/Nfn6E3nOQ0EVLV1/DBIA3Od8Fq+6QMCDA0ipMibf/JrQt3uz0C4BtqICaxdzyAfz90tUSf7Zr0zuS99GlAQrg2wd8Ecqlj/xmcflvJiUam62z0hxog5H1slDMTjZwD5Po0wj/gcWzu/LU4wzx0FDFkI1vRt90w6s5MNltJsp4hH0s5oazKdpK0e8X304MyuA/rEuqD/DCw4U071hv53RCpke6IWcwsX7+1lozq+anM0PYPwf14h3UpUM70/+ViveFgw2J/blVr331LlQHr3pC2la+PzzBEKsl61j77vG9K2TClzXoWaLiJuiitR1fJKO3v09h0v/8yAnkcmAmowrzlv1lB9g2KBzhunymN2YvKUAEQEAyKbJQQYAIAEwUCV1L/VJ1/DbAUJaeEzgAAACRAHfXJeICfMMiOHYCACFhIn2A9uAM3TC441+MrgMU3r9W1izr408WtrKtsR8Wk5SwBnxloJwxyYuLyFbFshc9k65huw2SSDkJ/0FrRl61FPHQNP5vz62Wh+WN21ascUa0jB2kQGHLoNcFbJuevkyBy1Rzv+h/+8jJcKo2OjQkkmK8Hkh8bq5X/HMUC55h92qOqBpHJgh0Q4Q5q6p3G/7Dpek5W6J1wUrFy5Is1nlGE55bqgewPEx/UUZBd+YqCwtxVOnnBu1NKnmc2AAkEcFk3Vo1xOxHOvF9AKjojDyC65KJc1Pv2MkFseFk0Agi13lpmBzDEti4w3vckPGNRtQNHuUt7fj6z0Cvxw=X2J3
-----END PGP PUBLIC KEY BLOCK-----'));

pgp_key_id | 9D4D255F4F2D2EBB
```

This shows that the PGP key ID used to encrypt the `ssn` column is 9D4D255F4F2D2EBB. It is recommended to perform the PGP step whenever a new key is created and then store the ID for tracking.
You can use this key to see which key pair was used to encrypt the data:

```sql
SELECT username, pgp_key_id(ssn) As key_used
FROM userssn;

username | Bob
-----------+-----------------
key_used | 9D4D255F4FD2EFBB
username | Alice
key_used | 9D4D255F4FD2EFBB
```

**Note:** Different keys may have the same ID. This is rare, but is a normal event. The client application should try to decrypt with each one to see which fits — like handling ANYKEY. See `pgp_key_id()` in the pgcrypto documentation.

5. Decrypt the data using the private key.

```sql
SELECT username, pgp_pub_decrypt(ssn, keys.privkey) AS decrypted_ssn
FROM userssn
CROSS JOIN

---
```

5QYBFS12f0BcDAnW8qyk1V1C3kFcdw3Kpm/diJPFrywEw6pQyA05jtwIWiXZTh
2HislojSP6lIOcSDKiQ9MU9Luswce2h3HiRhBuVgKlG9sd9t6g2nnSN9Admqk/yX
R5syYKQ+gqcdwL1v029o00meyjyc3n+kbbRTEmu3f1bMs8shGwzMrVstCUMuHuV/H
vg5qsrje8aPyUSDYc7I4I6w7S0H3rlRc71fFl6xYddV42313tcd44b18/17lhqvUYN2
/hbsjia2ymq7ttw3jswAx92gl9Pnskqg0QyDy/o9mNqC8EG1lg96ZFnE6Pwbnh
ic8sm0D1K5/1AIlR6c01ZHf8KEecurvli1kjmABEBAEAEB/wNfjjv1bRffj1m/Q
XwH4nn+i4Vr7c94VTUkPgf617rvqcy2JucxVxrr2Bb1m6vlgEUIU7Y7BN8a
fe0Pam4Mw+yX9r4C2z2pbPwqawmNN3GQAqy41RLBvgWQY+kmdb871Tjwzid2NIMx
0zi2sra4r0l2t2xl4hkPfr6f7tmz0HoVlrs0BoW0vHueMy77tCwmdPe9HbQe0D1Pr
n9c1liUqbm4/acTtCLWajREzn0XAsNixttTFC1V+90nYmecMKxVhWfIPkHjYAM
OPFnwUz/Dz1rcC3HjHnb5162yUM5zDQuVvntkteq/0ENXsm0mfGmpchQoHgUmbDz
6uyBBADSCXHPfo/VFTvMm5yGrNOR2jJRr2U9j+p0zZd2gjtk5/xIKRlkBdQ4Q1
em27wrZ9dVEX7msOnvD5ibtqYd0JIuChMqSQR1luErb1B75VJ3hItimb1Pjn
4Jx6SWRXPUP6GKG18tU0uBoH0Lw1j7M2PW7l1aal+MLEA9ajJqWqQA+s9BKFL4Ya2
r5eN7gsbcCCL0wCrd1fRgtcbwYDmpyZo0ARJkJt0MG6rCJxfr6Lq1n8W/L
/gznItmch35MCq/M2za/bN4VMPEy1lwZkVJLs7qyyQ/XA7ac77BDHOKCexiEw
M5OAJhJmkXwl1Q1RRWn3cnYi8w3q7X40EAL/w54FVvPpgp3/scd66AAmpu0UO2R3
tIsuNVmVc1mBNVX08ASjz7VyveU5y4B8vHvCquJ1c7gean/LXhi8f Rs4c507l
Bf+i9cL/VNEV4k4u4d4b014g0EYy1fBw/cn/EnXEcZYINMna4aM4VQc/Rf7FH4
wkz/L9itc2/0HHHlric3q9aZiDx0Zo2a5QGgYTWLSmNvM6tJ6A7qEWEVw
ACgFal51sf0CwGMFCH04HAN4GcWkIBwMcbHUIAgkKwqAMGAb4AhAeAAo3EAd9
cl4J3wbfwbf/v3VsPoKqIl0w7RjnxXUt1by7Bfrvu52y+jz+PnPYYes9UpdJ3MRk
8gAm9bXs580q2U8X2SC6FO0PEW4uWmgYiF8jRoC0oeezTkmCBW81bU0qGe0zVx
opdKluPCGE7hWvOe9HcSntiTlXGovlMJA07TAoccCLYxBu2HR9fS5VoLqDkZcC5yOH
h5iQaAQT010TeFeEpb9TIIwctng3WCSUS0PDGouAOnjvD2K8E8q7P7f4UHlE1ZV
zhB8qfajR2C62CSHFKpQbg1NnxT0K4SNbXAD4eTXU3p5wPi46qopu9QOqgsyb1X
D0TB2UQohtAMCAm7vtePV43902/07/0n7IeAd5e5gEBLVL/QLEIAAbdpQ+8QCMACD0i
plMbh/FJRqtz3SoItOCx1TIcandyfa0tUs5f/7Z0r2usu99GAIagLWed8EgqJc1/xmF/cJ
izYum62AzzxFxCngh5YIstdMTJ2d5Pw0e0Wf70CW/2Lu4wzOPFZdkIPv9wDe6e5
MNnlTrsp4h502apKdb04Ex83040Mjy/nv/REiDDCwU4T01hv3shSKCpe6Lcsxs+7
llozp+a4MnP0Ywf14h3R3UMP07+VibLe2JW2Bl31LOUuHRgCz1a+PzbeEka16
jq77Vg9vZQ5hZCIxOwAltjSr1flJK03v9q0/h/8YsAncAm0cW2r1blFyGKBZbUNy
m2NYVkUAEQEAAGAH/A7r4HDrnmsX3Q6F6AzeP1R3n7tJE2iE8aUFF05Q2pzKU/
cl13E7wk/gqgMIAAyAsDKOCfhcanTnGufVYyggkT3es75m1RFPkRJXz2MoOzkdwy67B
Mu95V2K1u160CMs8d06+2fmmGx8qdc42sKj+yxjxtxK3H99yXMcd2vA2vC35N4TW3
Uc7t7c/z/k61boM67F7d7DX7NnQsMoOirtgPE8hgrDToonmTUonUdoyeJeqKyI
OIrswspn8R4g2CPSax8rEyUbH6BFx5Zw2ea1hQjGYLFOzO2RfOzVZq7Cn/7n+IhjupNc
Nd2aBDvx3y3qS3AmdxHzrFacz2jX311wvj0moF0kEOCZ1635KNNsnq1111RMjP
gao6/ux/z2MlmStzw2ou+I+kR8zG0GSAy1ZuOAB4tRFXEapozKAA42JKqjgQ0X
2zVulenfZaxrb9LiLd7zTDXKnGyGTWFD7FhavHJ4981McC711u1zhB59xM16p
dhFv0bdgy0JSLaFMPReJDA0fz3RhP7e6X12zdBgtg2hC/5O1kWBn6w6i2yx

586
If you created a key with passphrase, you may have to enter it here. However for the purpose of this example, the passphrase is blank.

Key Management

Whether you are using symmetric (single private key) or asymmetric (public and private key) cryptography, it is important to store the master or private key securely. There are many options for storing encryption keys, for example, on a file system, key vault, encrypted USB, trusted platform module (TPM), or hardware security module (HSM).

Consider the following questions when planning for key management:

- Where will the keys be stored?
- When should keys expire?
- How are keys protected?
- How are keys accessed?
- How can keys be recovered and revoked?

The Open Web Application Security Project (OWASP) provides a very comprehensive guide to securing encryption keys.
Enabling gphdfs Authentication with a Kerberos-secured Hadoop Cluster

Provides steps for configuring Greenplum Database to access external tables in a Hadoop cluster secured with Kerberos.

Using external tables and the gphdfs protocol, Greenplum Database can read files from and write files to a Hadoop File System (HDFS). Greenplum segments read and write files in parallel from HDFS for fast performance.

When a Hadoop cluster is secured with Kerberos ("Kerberized"), Greenplum Database must be configured to allow the Greenplum Database gpadmin role, which owns external tables in HDFS, to authenticate through Kerberos. This topic provides the steps for configuring Greenplum Database to work with a Kerberized HDFS, including verifying and troubleshooting the configuration.

- Prerequisites
- Configuring the Greenplum Cluster
- Creating and Installing Keytab Files
- Configuring gphdfs for Kerberos
- Testing Greenplum Database Access to HDFS
- Troubleshooting HDFS with Kerberos

Prerequisites

Make sure the following components are functioning and accessible on the network:

- Greenplum Database cluster
- Kerberos-secured Hadoop cluster. See the Greenplum Database Release Notes for supported Hadoop versions.
- Kerberos Key Distribution Center (KDC) server.

Configuring the Greenplum Cluster

The hosts in the Greenplum Cluster must have a Java JRE, Hadoop client files, and Kerberos clients installed.

Follow these steps to prepare the Greenplum Cluster.

1. Install a Java 1.6 or later JRE on all Greenplum cluster hosts.
   - Match the JRE version the Hadoop cluster is running. You can find the JRE version by running `java --version` on a Hadoop node.

2. (Optional) Confirm that Java Cryptography Extension (JCE) is present.
   - The default location of the JCE libraries is `JAVA_HOME/lib/security`. If a JDK is installed, the directory is `JAVA_HOME/jre/lib/security`. The files `local_policy.jar` and `US_export_policy.jar` should be present in the JCE directory.
   - The Greenplum cluster and the Kerberos server should, preferably, use the same version of the JCE libraries. You can copy the JCE files from the Kerberos server to the Greenplum cluster, if needed.

3. Set the `JAVA_HOME` environment variable to the location of the JRE in the `.bashrc` or `.bash_profile` file for the gpadmin account. For example:

   ```bash
   export JAVA_HOME=/usr/java/default
   ```
4. Source the `.bashrc` or `.bash_profile` file to apply the change to your environment. For example:

```
$ source ~/.bashrc
```

5. Install the Kerberos client utilities on all cluster hosts. Ensure the libraries match the version on the KDC server before you install them.

   For example, the following command installs the Kerberos client files on Red Hat or CentOS Linux:

```
$ sudo yum install krb5-libs krb5-workstation
```

   Use the `kinit` command to confirm the Kerberos client is installed and correctly configured.

6. Install Hadoop client files on all hosts in the Greenplum Cluster. Refer to the documentation for your Hadoop distribution for instructions.

7. Set the Greenplum Database server configuration parameters for Hadoop. The `gp_hadoop_target_version` parameter specifies the version of the Hadoop cluster. See the `Greenplum Database Release Notes` for the target version value that corresponds to your Hadoop distribution. The `gp_hadoop_home` parameter specifies the Hadoop installation directory.

   ```
   $ gpconfig -c gp_hadoop_target_version -v "hdp2"
   $ gpconfig -c gp_hadoop_home -v "/usr/lib/hadoop"
   ```

   See the `Greenplum Database Reference Guide` for more information.

8. Reload the updated `postgresql.conf` files for master and segments:

   ```
gpstop -u
   ```

   You can confirm the changes with the following commands:

   ```
   $ gpconfig -s gp_hadoop_target_version
   $ gpconfig -s gp_hadoop_home
   ```

9. Grant Greenplum Database gphdfs protocol privileges to roles that own external tables in HDFS, including `gpadmin` and other superuser roles. Grant `SELECT` privileges to enable creating readable external tables in HDFS. Grant `INSERT` privileges to enable creating writable external tables on HDFS.

   ```
   #= GRANT SELECT ON PROTOCOL gphdfs TO gpadmin;
   #= GRANT INSERT ON PROTOCOL gphdfs TO gpadmin;
   ```

10. Grant Greenplum Database external table privileges to external table owner roles:

   ```
   ALTER ROLE HDFS_USER CREATEEXTTABLE (type='readable');
   ALTER ROLE HDFS_USER CREATEEXTTABLE (type='writable');
   ```

   **Note:** It is best practice to review database privileges, including gphdfs external table privileges, at least annually.

### Creating and Installing Keytab Files

1. Log in to the KDC server as root.
2. Use the `kadmin.local` command to create a new principal for the `gpadmin` user:

   ```
   # kadmin.local -q "addprinc -randkey gpadmin@LOCAL.DOMAIN"
   ```

3. Use `kadmin.local` to generate a Kerberos service principal for each host in the Greenplum Database cluster. The service principal should be of the form `name/role@REALM`, where:

   - `name` is the gphdfs service user name. This example uses `gphdfs`. 

• **role** is the DNS-resolvable host name of a Greenplum cluster host (the output of the `hostname -f` command).
• **REALM** is the Kerberos realm, for example `LOCAL.DOMAIN`.

For example, the following commands add service principals for four Greenplum Database hosts, `mdw.example.com`, `smdw.example.com`, `sdw1.example.com`, and `sdw2.example.com`:

```
# kadmin.local -q "addprinc -randkey gphdfs/mdw.example.com@LOCAL.DOMAIN"
# kadmin.local -q "addprinc -randkey gphdfs/smdw.example.com@LOCAL.DOMAIN"
# kadmin.local -q "addprinc -randkey gphdfs/sdw1.example.com@LOCAL.DOMAIN"
# kadmin.local -q "addprinc -randkey gphdfs/sdw2.example.com@LOCAL.DOMAIN"
```

Create a principal for each Greenplum cluster host. Use the same principal name and realm, substituting the fully-qualified domain name for each host.

4. **Generate a keytab file for each principal that you created (gpadmin and each gphdfs service principal).** You can store the keytab files in any convenient location (this example uses the directory `/etc/security/keytabs`). You will deploy the service principal keytab files to their respective Greenplum host machines in a later step:

```
# kadmin.local -q "xst -k /etc/security/keytabs/gphdfs.service.keytab gpadmin@LOCAL.DOMAIN"
# kadmin.local -q "xst -k /etc/security/keytabs/mdw.service.keytab gpadmin/mdw gphdfs/mdw.example.com@LOCAL.DOMAIN"
# kadmin.local -q "xst -k /etc/security/keytabs/smdw.service.keytab gpadmin/smdw gphdfs/smdw.example.com@LOCAL.DOMAIN"
# kadmin.local -q "xst -k /etc/security/keytabs/sdw1.service.keytab gpadmin/sdw1 gphdfs/sdw1.example.com@LOCAL.DOMAIN"
# kadmin.local -q "xst -k /etc/security/keytabs/sdw2.service.keytab gpadmin/sdw2 gphdfs/sdw2.example.com@LOCAL.DOMAIN"
# kadmin.local -q "listprincs"
```

5. **Change the ownership and permissions on gphdfs.service.keytab as follows:**

```
# chown gpadmin:gpadmin /etc/security/keytabs/gphdfs.service.keytab
# chmod 440 /etc/security/keytabs/gphdfs.service.keytab
```

6. **Copy the keytab file for gpadmin@LOCAL.DOMAIN to the Greenplum master host:**

```
# scp /etc/security/keytabs/gphdfs.service.keytab mdw_fqdn:/home/gpadmin/gphdfs.service.keytab
```

7. **Copy the keytab file for each service principal to its respective Greenplum host:**

```
# scp /etc/security/keytabs/mdw.service.keytab mdw_fqdn:/home/gpadmin/mdw.service.keytab
# scp /etc/security/keytabs/smdw.service.keytab smdw_fqdn:/home/gpadmin/smdw.service.keytab
# scp /etc/security/keytabs/sdw1.service.keytab sdw1_fqdn:/home/gpadmin/sdw1.service.keytab
# scp /etc/security/keytabs/sdw2.service.keytab sdw2_fqdn:/home/gpadmin/sdw2.service.keytab
```

### Configuring gphdfs for Kerberos

1. **Edit the Hadoop core-site.xml client configuration file on all Greenplum cluster hosts.** Enable service-level authorization for Hadoop by setting the `hadoop.security.authorization` property to `true`. For example:

   ```xml
   <property>
   <name>hadoop.security.authorization</name>
   ```
2. Edit the `yarn-site.xml` client configuration file on all cluster hosts. Set the resource manager address and yarn Kerberos service principle. For example:

```xml
<property>
  <name>yarn.resourcemanager.address</name>
  <value>hostname:8032</value>
</property>
<property>
  <name>yarn.resourcemanager.principal</name>
  <value>yarn/hostname@DOMAIN</value>
</property>
```

3. Edit the `hdfs-site.xml` client configuration file on all cluster hosts. Set properties to identify the NameNode Kerberos principals, the location of the Kerberos keytab file, and the principal it is for:

- `dfs.namenode.kerberos.principal` - the Kerberos principal name the gphdfs protocol will use for the NameNode, for example `gpadmin@LOCAL.DOMAIN`.
- `dfs.namenode.https.principal` - the Kerberos principal name the gphdfs protocol will use for the NameNode's secure HTTP server, for example `gpadmin@LOCAL.DOMAIN`.
- `com.emc.greenplum.gpdb.hdfsconnector.security.user.keytab.file` - the path to the keytab file for the Kerberos HDFS service, for example `/home/gpadmin/mdw.service.keytab`.
- `com.emc.greenplum.gpdb.hdfsconnector.security.user.name` - the gphdfs service principal for the host, for example `gphdfs/mdw.example.com@LOCAL.DOMAIN`.

For example:

```xml
<property>
  <name>dfs.namenode.kerberos.principal</name>
  <value>gphdfs/gpadmin@LOCAL.DOMAIN</value>
</property>
<property>
  <name>dfs.namenode.https.principal</name>
  <value>gphdfs/gpadmin@LOCAL.DOMAIN</value>
</property>
<property>
  <name>com.emc.greenplum.gpdb.hdfsconnector.security.user.keytab.file</name>
  <value>/home/gpadmin/gpadmin.hdfs.keytab</value>
</property>
<property>
  <name>com.emc.greenplum.gpdb.hdfsconnector.security.user.name</name>
  <value>gpadmin/@LOCAL.DOMAIN</value>
</property>
```

**Testing Greenplum Database Access to HDFS**

Confirm that HDFS is accessible via Kerberos authentication on all hosts in the Greenplum cluster. For example, enter the following command to list an HDFS directory:

```bash
dfs dfs -ls hdfs://namenode:8020
```

**Create a Readable External Table in HDFS**

Follow these steps to verify that you can create a readable external table in a Kerberized Hadoop cluster.
1. Create a comma-delimited text file, test1.txt, with contents such as the following:

<table>
<thead>
<tr>
<th>Age</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Bill</td>
</tr>
<tr>
<td>19</td>
<td>Anne</td>
</tr>
<tr>
<td>32</td>
<td>Greg</td>
</tr>
<tr>
<td>27</td>
<td>Gloria</td>
</tr>
</tbody>
</table>

2. Persist the sample text file in HDFS:

   hdfs dfs -put test1.txt hdfs://namenode:8020/tmp

3. Log in to Greenplum Database and create a readable external table that points to the test1.txt file in Hadoop:

   ```sql
   CREATE EXTERNAL TABLE test_hdfs (age int, name text)
   LOCATION('gphdfs://namenode:8020/tmp/test1.txt')
   FORMAT 'text' (delimiter ',');
   ```

4. Read data from the external table:

   ```sql
   SELECT * FROM test_hdfs;
   ```

**Create a Writable External Table in HDFS**

Follow these steps to verify that you can create a writable external table in a Kerberized Hadoop cluster. The steps use the test_hdfs readable external table created previously.

1. Log in to Greenplum Database and create a writable external table pointing to a text file in HDFS:

   ```sql
   CREATE WRITABLE EXTERNAL TABLE test_hdfs2 (LIKE test_hdfs)
   LOCATION ('gphdfs://namenode:8020/tmp/test2.txt')
   FORMAT 'text' (DELIMITER ',');
   ```

2. Load data into the writable external table:

   ```sql
   INSERT INTO test_hdfs2
   SELECT * FROM test_hdfs;
   ```

3. Check that the file exists in HDFS:

   ```bash
   hdfs dfs -ls hdfs://namenode:8020/tmp/test2.txt
   ```

4. Verify the contents of the external file:

   ```bash
   hdfs dfs -cat hdfs://namenode:8020/tmp/test2.txt
   ```

**Troubleshooting HDFS with Kerberos**

**Forcing Classpaths**

If you encounter "class not found" errors when executing `SELECT` statements from gphdfs external tables, edit the `$GPHOME/lib/hadoop-env.sh` file and add the following lines towards the end of the file, before the `JAVA_LIBRARY_PATH` is set. Update the script on all of the cluster hosts.

```bash
if [ -d "/usr/hdp/current" ]; then
    for f in /usr/hdp/current/**/*.jar; do
        CLASSPATH=$CLASSPATH:$f;
    done
fi
```
Enabling Kerberos Client Debug Messages

To see debug messages from the Kerberos client, edit the $GPHOME/lib/hadoop-env.sh client shell script on all cluster hosts and set the HADOOP_OPTS variable as follows:

```
export HADOOP_OPTS="-Djava.net.preferredIPv4Stack=true -Dsun.security.krb5.debug=true ${HADOOP_OPTS}"
```

Adjusting JVM Process Memory on Segment Hosts

Each segment launches a JVM process when reading or writing an external table in HDFS. To change the amount of memory allocated to each JVM process, configure the GP_JAVA_OPTS environment variable.

Edit the $GPHOME/lib/hadoop-env.sh client shell script on all cluster hosts.

For example:

```
export GP_JAVA_OPTS=-Xmx1000m
```

Verify Kerberos Security Settings

Review the /etc/krb5.conf file:

- If AES256 encryption is not disabled, ensure that all cluster hosts have the JCE Unlimited Strength Jurisdiction Policy Files installed.
- Ensure all encryption types in the Kerberos keytab file match definitions in the krb5.conf file.

```
cat /etc/krb5.conf | egrep supported_enctypes
```

Test Connectivity on an Individual Segment Host

Follow these steps to test that a single Greenplum Database host can read HDFS data. This test method executes the Greenplum HDFSReader Java class at the command-line, and can help to troubleshoot connectivity problems outside of the database.

1. Save a sample data file in HDFS.

```
hdfs dfs -put test1.txt hdfs://namenode:8020/tmp
```

2. On the segment host to be tested, create an environment script, env.sh, like the following:

```
export JAVA_HOME=/usr/java/default
export HADOOP_HOME=/usr/lib/hadoop
export GP_HADOOP_CON_VERSION=hdp2
export GP_HADOOP_CON_JARDIR=/usr/lib/hadoop
```

3. Source all environment scripts:

```
source /usr/local/greenplum-db/greenplum_path.sh
source env.sh
source $GPHOME/lib/hadoop-env.sh
```

4. Test the Greenplum Database HDFS reader:

```
java com.emc.greenplum.gpdb.hdfsconnector.HDFSReader 0 32 TEXT hdp2 gphdfs://namenode:8020/tmp/test1.txt
```
Security Best Practices

Describes basic security best practices that you should follow to ensure the highest level of system security.

In the default Greenplum Database security configuration:

- Only local connections are allowed.
- Basic authentication is configured for the superuser (gpadmin).
- The superuser is authorized to do anything.
- Only database role passwords are encrypted.

System User (gpadmin)

Secure and limit access to the gpadmin system user.

Greenplum requires a UNIX user id to install and initialize the Greenplum Database system. This system user is referred to as gpadmin in the Greenplum documentation. The gpadmin user is the default database superuser in Greenplum Database, as well as the file system owner of the Greenplum installation and its underlying data files. The default administrator account is fundamental to the design of Greenplum Database. The system cannot run without it, and there is no way to limit the access of the gpadmin user id.

The gpadmin user can bypass all security features of Greenplum Database. Anyone who logs on to a Greenplum host with this user id can read, alter, or delete any data, including system catalog data and database access rights. Therefore, it is very important to secure the gpadmin user id and only allow essential system administrators access to it.

Administrators should only log in to Greenplum as gpadmin when performing certain system maintenance tasks (such as upgrade or expansion).

Database users should never log on as gpadmin, and ETL or production workloads should never run as gpadmin.

Superusers

Roles granted the SUPERUSER attribute are superusers. Superusers bypass all access privilege checks and resource queues. Only system administrators should be given superuser rights.

See "Altering Role Attributes" in the Greenplum Database Administrator Guide.

Login Users

Assign a distinct role to each user who logs in and set the LOGIN attribute.

For logging and auditing purposes, each user who is allowed to log in to Greenplum Database should be given their own database role. For applications or web services, consider creating a distinct role for each application or service. See "Creating New Roles (Users)" in the Greenplum Database Administrator Guide.

Each login role should be assigned to a single, non-default resource queue.

Groups

Use groups to manage access privileges.

Create a group for each logical grouping of object/access permissions.

Every login user should belong to one or more roles. Use the GRANT statement to add group access to a role. Use the REVOKE statement to remove group access from a role.
The **LOGIN** attribute should not be set for group roles.

See "Creating Groups (Role Membership)" in the *Greenplum Database Administrator Guide*.

**Object Privileges**

Only the owner and superusers have full permissions to new objects. Permission must be granted to allow other rules (users or groups) to access objects. Each type of database object has different privileges that may be granted. Use the **GRANT** statement to add a permission to a role and the **REVOKE** statement to remove the permission.

You can change the owner of an object using the **REASSIGN OWNED BY** statement. For example, to prepare to drop a role, change the owner of the objects that belong to the role. Use the **DROP OWNED BY** to drop objects, including dependent objects, that are owned by a role.

Schemas can be used to enforce an additional layer of object permissions checking, but schema permissions do not override object privileges set on objects contained within the schema.

**Operating System Users and File System**

To protect the network from intrusion, system administrators should verify the passwords used within an organization are sufficiently strong. The following recommendations can strengthen a password:

- **Minimum password length recommendation**: At least 9 characters. MD5 passwords should be 15 characters or longer.
- Mix upper and lower case letters.
- Mix letters and numbers.
- Include non-alphanumeric characters.
- Pick a password you can remember.

The following are recommendations for password cracker software that you can use to determine the strength of a password.

- **John The Ripper**. A fast and flexible password cracking program. It allows the use of multiple word lists and is capable of brute-force password cracking. It is available online at [http://www.openwall.com/john/](http://www.openwall.com/john/).
- **Crack**. Perhaps the most well-known password cracking software, Crack is also very fast, though not as easy to use as John The Ripper. It can be found online at [https://dropsafe.crypticide.com/alecm/software/crack/c50-faq.html](https://dropsafe.crypticide.com/alecm/software/crack/c50-faq.html).

The security of the entire system depends on the strength of the root password. This password should be at least 12 characters long and include a mix of capitalized letters, lowercase letters, special characters, and numbers. It should not be based on any dictionary word.

Password expiration parameters should be configured.

Ensure the following line exists within the file `/etc/libuser.conf` under the **[import]** section.

```
login_defs = /etc/login.defs
```

Ensure no lines in the **[userdefaults]** section begin with the following text, as these words override settings from `/etc/login.defs`:

- **LU_SHADOWMAX**
- **LU_SHADOWMIN**
- **LU_SHADOWWARNING**

Ensure the following command produces no output. Any accounts listed by running this command should be locked.

```
grep "^+:" /etc/passwd /etc/shadow /etc/group
```
Note: We strongly recommend that customers change their passwords after initial setup.

```bash
cd /etc
chown root:root passwd shadow group gshadow
chmod 644 passwd group
chmod 400 shadow gshadow
```

Find all the files that are world-writable and that do not have their sticky bits set.

```bash
find / -xdev -type d \( -perm -0002 -a ! -perm -1000 \) -print
```

Set the sticky bit (`chmod +t {dir}`) for all the directories that result from running the previous command.

Find all the files that are world-writable and fix each file listed.

```bash
find / -xdev -type f -perm -0002 -print
```

Set the right permissions (`chmod o-w {file}`) for all the files generated by running the aforementioned command.

Find all the files that do not belong to a valid user or group and either assign an owner or remove the file, as appropriate.

```bash
find / -xdev \( -nouser -o -nogroup \) -print
```

Find all the directories that are world-writable and ensure they are owned by either root or a system account (assuming only system accounts have a User ID lower than 500). If the command generates any output, verify the assignment is correct or reassign it to root.

```bash
find / -xdev -type d -perm -0002 -uid +500 -print
```

Authentication settings such as password quality, password expiration policy, password reuse, password retry attempts, and more can be configured using the Pluggable Authentication Modules (PAM) framework. PAM looks in the directory `/etc/pam.d` for application-specific configuration information. Running `authconfig` or `system-config-authentication` will re-write the PAM configuration files, destroying any manually made changes and replacing them with system defaults.

The default `pam_cracklib` PAM module provides strength checking for passwords. To configure `pam_cracklib` to require at least one uppercase character, lowercase character, digit, and special character, as recommended by the U.S. Department of Defense guidelines, edit the file `/etc/pam.d/system-auth` to include the following parameters in the line corresponding to password requisite `pam_cracklib.so try_first_pass`.

```plaintext
retry=3:
dcredit=-1. Require at least one digit
ucredit=-1. Require at least one uppercase character
ocredit=-1. Require at least one special character
lcredit=-1. Require at least one lowercase character
minlen-14. Require a minimum password length of 14.
```

For example:
password required pam_cracklib.so try_first_pass retry=3\minlen=14
dcredit=-1 ucredit=-1 ocredit=-1 lcredit=-1

These parameters can be set to reflect your security policy requirements. Note that the password restrictions are not applicable to the root password.

The `pam_tally2` PAM module provides the capability to lock out user accounts after a specified number of failed login attempts. To enforce password lockout, edit the file `/etc/pam.d/system-auth` to include the following lines:

- The first of the auth lines should include:
  ```
  auth required pam_tally2.so deny=5 onerr=fail unlock_time=900
  ```
- The first of the account lines should include:
  ```
  account required pam_tally2.so
  ```

Here, the deny parameter is set to limit the number of retries to 5 and the `unlock_time` has been set to 900 seconds to keep the account locked for 900 seconds before it is unlocked. These parameters may be configured appropriately to reflect your security policy requirements. A locked account can be manually unlocked using the `pam_tally2` utility:

```
/sbin/pam_tally2 --user {username} -reset
```

You can use PAM to limit the reuse of recent passwords. The remember option for the `pam_unix` module can be set to remember the recent passwords and prevent their reuse. To accomplish this, edit the appropriate line in `/etc/pam.d/system-auth` to include the remember option.

For example:

```
password sufficient pam_unix.so [ ... existing_options ...]
remember=5
```

You can set the number of previous passwords to remember to appropriately reflect your security policy requirements.

```
cd /etc
chown root:root passwd shadow group gshadow
chmod 644 passwd group
chmod 400 shadow gshadow
```
Chapter 11

Greenplum Database Best Practices

A best practice is a method or technique that has consistently shown results superior to those achieved with other means. Best practices are found through experience and are proven to reliably lead to a desired result. Best practices are a commitment to use any product correctly and optimally, by leveraging all the knowledge and expertise available to ensure success.

This document does not teach you how to use Greenplum Database features. Links are provided to other relevant parts of the Greenplum Database documentation for information on how to use and implement specific Greenplum Database features. This document addresses the most important best practices to follow when designing, implementing, and using Greenplum Database.

It is not the intent of this document to cover the entire product or compendium of features, but rather to provide a summary of what matters most in Greenplum Database. This document does not address edge use cases. While edge use cases can further leverage and benefit from Greenplum Database features, they require a proficient knowledge and expertise with these features, as well as a deep understanding of your environment, including SQL access, query execution, concurrency, workload, and other factors.

By mastering these best practices, you will increase the success of your Greenplum Database clusters in the areas of maintenance, support, performance, and scalability.
Best Practices Summary

A summary of best practices for Greenplum Database.

Data Model

Greenplum Database is an analytical MPP shared-nothing database. This model is significantly different from a highly normalized/transactional SMP database. Because of this, the following best practices are recommended.

• Greenplum Database performs best with a denormalized schema design suited for MPP analytical processing for example, Star or Snowflake schema, with large fact tables and smaller dimension tables.
• Use the same data types for columns used in joins between tables.

See Schema Design.

Heap vs. Append-Optimized Storage

• Use heap storage for tables and partitions that will receive iterative batch and singleton UPDATE, DELETE, and INSERT operations.
• Use heap storage for tables and partitions that will receive concurrent UPDATE, DELETE, and INSERT operations.
• Use append-optimized storage for tables and partitions that are updated infrequently after the initial load and have subsequent inserts only performed in large batch operations.
• Avoid performing singleton INSERT, UPDATE, or DELETE operations on append-optimized tables.
• Avoid performing concurrent batch UPDATE or DELETE operations on append-optimized tables. Concurrent batch INSERT operations are acceptable.

See Heap Storage or Append-Optimized Storage.

Row vs. Column Oriented Storage

• Use row-oriented storage for workloads with iterative transactions where updates are required and frequent inserts are performed.
• Use row-oriented storage when selects against the table are wide.
• Use row-oriented storage for general purpose or mixed workloads.
• Use column-oriented storage where selects are narrow and aggregations of data are computed over a small number of columns.
• Use column-oriented storage for tables that have single columns that are regularly updated without modifying other columns in the row.

See Row or Column Orientation.

Compression

• Use compression on large append-optimized and partitioned tables to improve I/O across the system.
• Set the column compression settings at the level where the data resides.
• Balance higher levels of compression with the time and CPU cycles needed to compress and uncompress data.

See Compression.

Distributions

• Explicitly define a column or random distribution for all tables. Do not use the default.
• Use a single column that will distribute data across all segments evenly.
• Do not distribute on columns that will be used in the WHERE clause of a query.
• Do not distribute on dates or timestamps.
• Never distribute and partition tables on the same column.
• Achieve local joins to significantly improve performance by distributing on the same column for large tables commonly joined together.
• To ensure there is no data skew, validate that data is evenly distributed after the initial load and after incremental loads.

See Distributions.

Resource Queue Memory Management

• Set vm.overcommit_memory to 2.
• Do not configure the OS to use huge pages.
• Use gp_vmem_protect_limit to set the maximum memory that the instance can allocate for all work being done in each segment database.
• You can use gp_vmem_protect_limit by calculating:

  \[ gp\_vmem = \frac{((SWAP + RAM) - (7.5GB + 0.05 \times RAM))}{1.7} \]

  where SWAP is the host's swap space in GB, and RAM is the host's RAM in GB

• max_acting_primary_segments – the maximum number of primary segments that could be running on a host when mirror segments are activated due to a host or segment failure
• gp_vmem_protect_limit

  \[ gp\_vmem\_protect\_limit = \frac{gp\_vmem}{acting\_primary\_segments} \]

  Convert to MB to set the value of the configuration parameter.

• In a scenario where a large number of workfiles are generated calculate the gp_vmem factor with this formulat to account for the workfiles:

  \[ gp\_vmem = \frac{((SWAP + RAM) - (7.5GB + 0.05 \times RAM - (300KB \times total\_#\_workfiles))}{1.7} \]

• Never set gp_vmem_protect_limit too high or larger than the physical RAM on the system.
• Use the calculated gp_vmem value to calculate the setting for the vm.overcommit_ratio operating system parameter:

  \[ vm\_overcommit\_ratio = \frac{(RAM - 0.026 \times gp\_vmem)}{RAM} \]

• Use statement_mem to allocate memory used for a query per segment db.
• Use resource queues to set both the numbers of active queries (ACTIVE_STATEMENTS) and the amount of memory (MEMORY_LIMIT) that can be utilized by queries in the queue.
• Associate all users with a resource queue. Do not use the default queue.
• Set PRIORITY to match the real needs of the queue for the workload and time of day. Avoid using MAX priority.
• Ensure that resource queue memory allocations do not exceed the setting for gp_vmem_protect_limit.
• Dynamically update resource queue settings to match daily operations flow.

See Memory and Resource Management with Resource Queues.

Partitioning

• Partition large tables only. Do not partition small tables.
• Use partitioning only if partition elimination (partition pruning) can be achieved based on the query criteria.
• Choose range partitioning over list partitioning.
• Partition the table based on a commonly-used column, such as a date column.
• Never partition and distribute tables on the same column.
• Do not use default partitions.
• Do not use multi-level partitioning; create fewer partitions with more data in each partition.
• Validate that queries are selectively scanning partitioned tables (partitions are being eliminated) by examining the query EXPLAIN plan.
• Do not create too many partitions with column-oriented storage because of the total number of physical files on every segment: physical files = segments x columns x partitions

See Partitioning.

Indexes
• In general indexes are not needed in Greenplum Database.
• Create an index on a single column of a columnar table for drill-through purposes for high cardinality tables that require queries with high selectivity.
• Do not index columns that are frequently updated.
• Consider dropping indexes before loading data into a table. After the load, re-create the indexes for the table.
• Create selective B-tree indexes.
• Do not create bitmap indexes on columns that are updated.
• Avoid using bitmap indexes for unique columns, very high or very low cardinality data. Bitmap indexes perform best when the column has a low cardinality—100 to 100,000 distinct values.
• Do not use bitmap indexes for transactional workloads.
• In general do not index partitioned tables. If indexes are needed, the index columns must be different than the partition columns.

See Indexes.

Resource Queues
• Use resource queues to manage the workload on the cluster.
• Associate all roles with a user-defined resource queue.
• Use the ACTIVE_STATEMENTS parameter to limit the number of active queries that members of the particular queue can run concurrently.
• Use the MEMORY_LIMIT parameter to control the total amount of memory that queries running through the queue can utilize.
• Alter resource queues dynamically to match the workload and time of day.

See Configuring Resource Queues.

Monitoring and Maintenance
• Implement the “Recommended Monitoring and Maintenance Tasks” in the Greenplum Database Administrator Guide.
• Run gpcheckperf at install time and periodically thereafter, saving the output to compare system performance over time.
• Use all the tools at your disposal to understand how your system behaves under different loads.
• Examine any unusual event to determine the cause.
• Monitor query activity on the system by running explain plans periodically to ensure the queries are running optimally.
- Review plans to determine whether indexing is being used and partition elimination is occurring as expected.
- Know the location and content of system log files and monitor them on a regular basis, not just when problems arise.

See System Monitoring and Maintenance, Query Profiling and Monitoring Greenplum Database Log Files.

**ANALYZE**

- Determine if analyzing the database is actually needed. Analyzing is not needed if `gp_autostats_mode` is set to `on_no_stats` (the default) and the table is not partitioned.
- Use `analyzedb` in preference to `ANALYZE` when dealing with large sets of tables, as it does not require analyzing the entire database. The `analyzedb` utility updates statistics data for the specified tables incrementally and concurrently. For append optimized tables, `analyzedb` updates statistics incrementally only if the statistics are not current. For heap tables, statistics are always updated. `ANALYZE` does not update the table metadata that the `analyzedb` utility uses to determine whether table statistics are up to date.
- Selectively run `ANALYZE` at the table level when needed.
- Always run `ANALYZE` after `INSERT`, `UPDATE`, and `DELETE` operations that significantly changes the underlying data.
- Always run `ANALYZE` after `CREATE INDEX` operations.
- If `ANALYZE` on very large tables takes too long, run `ANALYZE` only on the columns used in a join condition, `WHERE` clause, `SORT`, `GROUP BY`, or `HAVING` clause.
- When dealing with large sets of tables, use `analyzedb` instead of `ANALYZE`.

See Updating Statistics with `ANALYZE`.

**Vacuum**

- Run `VACUUM` after large `UPDATE` and `DELETE` operations.
- Do not run `VACUUM FULL`. Instead run a `CREATE TABLE ... AS` operation, then rename and drop the original table.
- Frequently run `VACUUM` on the system catalogs to avoid catalog bloat and the need to run `VACUUM FULL` on catalog tables.
- Never kill `VACUUM` on catalog tables.

See Managing Bloat in the Database.

**Loading**

- Maximize the parallelism as the number of segments increase.
- Spread the data evenly across as many ETL nodes as possible.
  - Split very large data files into equal parts and spread the data across as many file systems as possible.
  - Run two `gpfdist` instances per file system.
  - Run `gpfdist` on as many interfaces as possible.
  - Use `gp_external_max_segs` to control the number of segments that will request data from the `gpfdist` process.
  - Always keep `gp_external_max_segs` and the number of `gpfdist` processes an even factor.
- Always drop indexes before loading into existing tables and re-create the index after loading.
- Run `VACUUM` after load errors to recover space.

See Loading Data.
gptransfer

- Avoid using the --full or --schema-only options. Instead, copy schemas to the destination database using a different method, and then transfer the table data.
- Drop indexes before transferring tables and recreate them when the transfer is complete.
- Transfer smaller tables to the destination database using the SQL COPY command.
- Transfer larger tables in batches using gptransfer.
- Test running gptransfer before performing a production migration. Experiment with the --batch-size and --sub-batch-size options to obtain maximum parallelism. Determine proper batching of tables for iterative gptransfer runs.
- Use only fully qualified table names. Periods (.), whitespace, quotes (') and double quotes (") in table names may cause problems.
- If you use the --validation option to validate the data after transfer, be sure to also use the -x option to place an exclusive lock on the source table.
- Ensure any roles, functions, and resource queues are created in the destination database. These objects are not transferred when you use the gptransfer -t option.
- Copy the postgres.conf and pg_hba.conf configuration files from the source to the destination cluster.
- Install needed extensions in the destination database with gppkg.

See Migrating Data with Gptransfer.

Security

- Secure the gpadmin user id and only allow essential system administrators access to it.
- Administrators should only log in to Greenplum as gpadmin when performing certain system maintenance tasks (such as upgrade or expansion).
- Limit users who have the SUPERUSER role attribute. Roles that are superusers bypass all access privilege checks in Greenplum Database, as well as resource queuing. Only system administrators should be given superuser rights. See "Altering Role Attributes" in the Greenplum Database Administrator Guide.
- Database users should never log on as gpadmin, and ETL or production workloads should never run as gpadmin.
- Assign a distinct Greenplum Database role to each user, application, or service that logs in.
- For applications or web services, consider creating a distinct role for each application or service.
- Use groups to manage access privileges.
- Protect the root password.
- Enforce a strong password password policy for operating system passwords.
- Ensure that important operating system files are protected.

See Security.

Encryption

- Encrypting and decrypting data has a performance cost; only encrypt data that requires encryption.
- Do performance testing before implementing any encryption solution in a production system.
- Server certificates in a production Greenplum Database system should be signed by a certificate authority (CA) so that clients can authenticate the server. The CA may be local if all clients are local to the organization.
- Client connections to Greenplum Database should use SSL encryption whenever the connection goes through an insecure link.
- A symmetric encryption scheme, where the same key is used to both encrypt and decrypt, has better performance than an asymmetric scheme and should be used when the key can be shared safely.
• Use cryptographic functions to encrypt data on disk. The data is encrypted and decrypted in the database process, so it is important to secure the client connection with SSL to avoid transmitting unencrypted data.
• Use the gpfdists protocol to secure ETL data as it is loaded into or unloaded from the database.

See *Encrypting Data and Database Connections*

**High Availability**

Note: The following guidelines apply to actual hardware deployments, but not to public cloud-based infrastructure, where high availability solutions may already exist.

• Use a hardware RAID storage solution with 8 to 24 disks.
• Use RAID 1, 5, or 6 so that the disk array can tolerate a failed disk.
• Configure a hot spare in the disk array to allow rebuild to begin automatically when disk failure is detected.
• Protect against failure of the entire disk array and degradation during rebuilds by mirroring the RAID volume.
• Monitor disk utilization regularly and add additional space when needed.
• Monitor segment skew to ensure that data is distributed evenly and storage is consumed evenly at all segments.
• Set up a standby master instance to take over if the primary master fails.
• Plan how to switch clients to the new master instance when a failure occurs, for example, by updating the master address in DNS.
• Set up monitoring to send notifications in a system monitoring application or by email when the primary fails.
• Set up mirrors for all segments.
• Locate primary segments and their mirrors on different hosts to protect against host failure.
• Recover failed segments promptly, using the gprecoverseg utility, to restore redundancy and return the system to optimal balance.
• Configure Greenplum Database to send SNMP notifications to your network monitor.
• Set up email notification in the `$MASTER_DATA_DIRECTORY/postgresql.conf` configuration file so that the Greenplum system can email administrators when a critical issue is detected.
• Consider a Dual Cluster configuration to provide an additional level of redundancy and additional query processing throughput.
• Backup Greenplum databases regularly unless the data is easily restored from sources.
• Use incremental backups if heap tables are relatively small and few append-optimized or column-oriented partitions are modified between backups.
• If backups are saved to local cluster storage, move the files to a safe, off-cluster location when the backup is complete.
• If backups are saved to NFS mounts, use a scale-out NFS solution such as Dell EMC Isilon to prevent IO bottlenecks.
• Consider using Greenplum integration to stream backups to the Dell EMC Data Domain or Veritas NetBackup enterprise backup platforms.

See *High Availability.*
System Configuration

Requirements and best practices for system administrators who are configuring Greenplum Database cluster hosts.

Configuration of the Greenplum Database cluster is usually performed as root.

Configuring the Timezone

Greenplum Database selects a timezone to use from a set of internally stored PostgreSQL timezones. The available PostgreSQL timezones are taken from the Internet Assigned Numbers Authority (IANA) Time Zone Database, and Greenplum Database updates its list of available timezones as necessary when the IANA database changes for PostgreSQL.

Greenplum selects the timezone by matching a PostgreSQL timezone with the user specified time zone, or the host system time zone if no time zone is configured. For example, when selecting a default timezone, Greenplum uses an algorithm to select a PostgreSQL timezone based on the host system timezone files. If the system timezone includes leap second information, Greenplum Database cannot match the system timezone with a PostgreSQL timezone. In this case, Greenplum Database calculates a “best match” with a PostgreSQL timezone based on information from the host system.

As a best practice, configure the Greenplum Database and the host system to use a known, supported timezone. This prevents Greenplum Database from recalculating a "best match" timezone each time the cluster is restarted, using the current system timezone and Greenplum timezone files (which may have been updated from the IANA database since the last restart). Use the `gpconfig` utility to show and set the Greenplum Database timezone. For example, these commands show the Greenplum Database timezone and set the timezone to US/Pacific.

```
# gpconfig -s TimeZone
# gpconfig -c TimeZone 'US/Pacific'
```

You must restart Greenplum Database after changing the timezone. The command `gpstop -ra` restarts Greenplum Database. The catalog view `pg_timezone_names` provides Greenplum Database timezone information.

File System

XFS is the file system used for Greenplum Database data directories. XFS should be mounted with the following mount options:

```
    rw,nodev,noatime,nobarrier,inode64
```

Port Configuration

Set up `ip_local_port_range` so it does not conflict with the Greenplum Database port ranges. For example, setting this range in `/etc/sysctl.conf`:

```
    net.ipv4.ip_local_port_range = 10000   65535
```

you could set the Greenplum Database base port numbers to these values.

```
    PORT_BASE = 6000
    MIRROR_PORT_BASE = 7000
    REPLICATION_PORT_BASE = 8000
    MIRROR_REPLICATION_PORT_BASE = 9000
```
I/O Configuration

Set the blockdev read-ahead size to 16384 on the devices that contain data directories. This command sets the read-ahead size for /dev/sdb.

```
# /sbin/blockdev --setra 16384 /dev/sdb
```

This command returns the read-ahead size for /dev/sdb.

```
# /sbin/blockdev --getra /dev/sdb
16384
```

The deadline IO scheduler should be set for all data directory devices.

```
# cat /sys/block/sdb/queue/scheduler
noop anticipatory [deadline] cfq
```

The maximum number of OS files and processes should be increased in the /etc/security/limits.conf file.

```
* soft  nofile 65536  
* hard  nofile 65536  
* soft  nproc 131072 
* hard  nproc 131072
```

Enable core files output to a known location and make sure limits.conf allows core files.

```
kernel.core_pattern = /var/core/core.%h.%t
# grep core /etc/security/limits.conf
* soft  core unlimited
```

OS Memory Configuration

The Linux sysctl vm.overcommit_memory and vm.overcommit_ratio variables affect how the operating system manages memory allocation. These variables should be set as follows:

- `vm.overcommit_memory` determines the method the OS uses for determining how much memory can be allocated to processes. This should be always set to 2, which is the only safe setting for the database.

**Note:** For information on configuration of overcommit memory, refer to:

- [https://en.wikipedia.org/wiki/Memory_overcommitment](https://en.wikipedia.org/wiki/Memory_overcommitment)

- `vm.overcommit_ratio` is the percent of RAM that is used for application processes. The default is 50 on Red Hat Enterprise Linux. See Resource Queue Segment Memory Configuration for a formula to calculate an optimal value.

Do not enable huge pages in the operating system.

See also Memory and Resource Management with Resource Queues.

Shared Memory Settings

Greenplum Database uses shared memory to communicate between postgres processes that are part of the same postgres instance. The following shared memory settings should be set in sysctl and are rarely modified.

```
kernell.shmmax = 500000000
kernel.shmni = 4096
kernel.shmall = 4000000000
```
Validate the Operating System

Run `gpcheck` to validate the operating system configuration. See `gpcheck` in the Greenplum Database Utility Guide.

Number of Segments per Host

Determining the number of segments to execute on each segment host has immense impact on overall system performance. The segments share the host's CPU cores, memory, and NICs with each other and with other processes running on the host. Over-estimating the number of segments a server can accommodate is a common cause of suboptimal performance.

The factors that must be considered when choosing how many segments to run per host include the following:

- Number of cores
- Amount of physical RAM installed in the server
- Number of NICs
- Amount of storage attached to server
- Mixture of primary and mirror segments
- ETL processes that will run on the hosts
- Non-Greenplum processes running on the hosts

Resource Queue Segment Memory Configuration

The `gp_vmem_protect_limit` server configuration parameter specifies the amount of memory that all active postgres processes for a single segment can consume at any given time. Queries that exceed this amount will fail. Use the following calculations to estimate a safe value for `gp_vmem_protect_limit`.

1. Calculate `gp_vmem`, the host memory available to Greenplum Database, using this formula:

   \[ gp_vmem = \frac{(SWAP + RAM) - (7.5GB + 0.05 \times RAM)}{1.7} \]

   where `SWAP` is the host's swap space in GB and `RAM` is the RAM installed on the host in GB.

2. Calculate `max_acting_primary_segments`. This is the maximum number of primary segments that can be running on a host when mirror segments are activated due to a segment or host failure on another host in the cluster. With mirrors arranged in a 4-host block with 8 primary segments per host, for example, a single segment host failure would activate two or three mirror segments on each remaining host in the failed host's block. The `max_acting_primary_segments` value for this configuration is 11 (8 primary segments plus 3 mirrors activated on failure).

3. Calculate `gp_vmem_protect_limit` by dividing the total Greenplum Database memory by the maximum number of acting primaries:

   \[ gp_vmem_protect_limit = \frac{gp_vmem}{max_acting_primary_segments} \]

   Convert to megabytes to find the value to set for the `gp_vmem_protect_limit` system configuration parameter.

   For scenarios where a large number of workfiles are generated, adjust the calculation for `gp_vmem` to account for the workfiles:

   \[ gp_vmem = \frac{((SWAP + RAM) - (7.5GB + 0.05 \times RAM - (300KB \times total\_\#\_workfiles)))}{1.7} \]

   For information about monitoring and managing workfile usage, see the Greenplum Database Administrator Guide.
You can calculate the value of the `vm.overcommit_ratio` operating system parameter from the value of `gp_vmem`:

\[
vm.overcommit_ratio = \frac{(\text{RAM} - 0.026 \times \text{gp_vmem})}{\text{RAM}}
\]

See [OS Memory Configuration](#) for more about `vm.overcommit_ratio`.

See also [Memory and Resource Management with Resource Queues](#).

**Resource Queue Statement Memory Configuration**

The `statement_mem` server configuration parameter is the amount of memory to be allocated to any single query in a segment database. If a statement requires additional memory it will spill to disk. Calculate the value for `statement_mem` with the following formula:

\[
\frac{(\text{gp_vmem_protect_limit} \times 0.9)}{\text{max_expected_concurrent_queries}}
\]

For example, for 40 concurrent queries with `gp_vmem_protect_limit` set to 8GB (8192MB), the calculation for `statement_mem` would be:

\[
\frac{(8192\text{MB} \times 0.9)}{40} = 184\text{MB}
\]

Each query would be allowed 184MB of memory before it must spill to disk.

To increase `statement_mem` safely you must either increase `gp_vmem_protect_limit` or reduce the number of concurrent queries. To increase `gp_vmem_protect_limit`, you must add physical RAM and/or swap space, or reduce the number of segments per host.

Note that adding segment hosts to the cluster cannot help out-of-memory errors unless you use the additional hosts to decrease the number of segments per host.

Spill files are created when there is not enough memory to fit all the mapper output, usually when 80% of the buffer space is occupied.

Also, see [Resource Management](#) for best practices for managing query memory using resource queues.

**Resource Queue Spill File Configuration**

Greenplum Database creates spill files (also called workfiles) on disk if a query is allocated insufficient memory to execute in memory. A single query can create no more than 100,000 spill files, by default, which is sufficient for the majority of queries.

You can control the maximum number of spill files created per query and per segment with the configuration parameter `gp_workfile_limit_files_per_query`. Set the parameter to 0 to allow queries to create an unlimited number of spill files. Limiting the number of spill files permitted prevents runaway queries from disrupting the system.

A query could generate a large number of spill files if not enough memory is allocated to it or if data skew is present in the queried data. If a query creates more than the specified number of spill files, Greenplum Database returns this error:

```
ERROR: number of workfiles per query limit exceeded
```

Before raising the `gp_workfile_limit_files_per_query`, try reducing the number of spill files by changing the query, changing the data distribution, or changing the memory configuration.

The `gp_toolkit` schema includes views that allow you to see information about all the queries that are currently using spill files. This information can be used for troubleshooting and for tuning queries:

- The `gp_workfile_entries` view contains one row for each operator using disk space for workfiles on a segment at the current time. See [How to Read Explain Plans](#) for information about operators.
- The `gp_workfile_usage_per_query` view contains one row for each query using disk space for workfiles on a segment at the current time.
- The `gp_workfile_usage_per_segment` view contains one row for each segment. Each row displays the total amount of disk space used for workfiles on the segment at the current time.

See the *Greenplum Database Reference Guide* for descriptions of the columns in these views.

The `gp_workfile_compress_algorithm` configuration parameter specifies a compression algorithm to apply to spill files. It can have the value `none` (the default) or `zlib`. Setting this parameter to `zlib` can improve performance when spill files are used.
Schema Design
Best practices for designing Greenplum Database schemas.

Greenplum Database is an analytical, shared-nothing database, which is much different than a highly normalized, transactional SMP database. Greenplum Database performs best with a denormalized schema design suited for MPP analytical processing, a star or snowflake schema, with large centralized fact tables connected to multiple smaller dimension tables.

Data Types

Use Types Consistently
Use the same data types for columns used in joins between tables. If the data types differ, Greenplum Database must dynamically convert the data type of one of the columns so the data values can be compared correctly. With this in mind, you may need to increase the data type size to facilitate joins to other common objects.

Choose Data Types that Use the Least Space
You can increase database capacity and improve query execution by choosing the most efficient data types to store your data.

Use TEXT or VARCHAR rather than CHAR. There are no performance differences among the character data types, but using TEXT or VARCHAR can decrease the storage space used.

Use the smallest numeric data type that will accommodate your data. Using BIGINT for data that fits in INT or SMALLINT wastes storage space.

Storage Model
Greenplum Database provides an array of storage options when creating tables. It is very important to know when to use heap storage versus append-optimized (AO) storage, and when to use row-oriented storage versus column-oriented storage. The correct selection of heap versus AO and row versus column is extremely important for large fact tables, but less important for small dimension tables.

The best practices for determining the storage model are:

1. Design and build an insert-only model, truncating a daily partition before load.
2. For large partitioned fact tables, evaluate and use optimal storage options for different partitions. One storage option is not always right for the entire partitioned table. For example, some partitions can be row-oriented while others are column-oriented.
3. When using column-oriented storage, every column is a separate file on every Greenplum Database segment. For tables with a large number of columns consider columnar storage for data often accessed (hot) and row-oriented storage for data not often accessed (cold).
4. Storage options should be set at the partition level.
5. Compress large tables to improve I/O performance and to make space in the cluster.

Heap Storage or Append-Optimized Storage
Heap storage is the default model, and is the model PostgreSQL uses for all database tables. Use heap storage for tables and partitions that will receive iterative UPDATE, DELETE, and singleton INSERT operations. Use heap storage for tables and partitions that will receive concurrent UPDATE, DELETE, and INSERT operations.
Use append-optimized storage for tables and partitions that are updated infrequently after the initial load and have subsequent inserts performed only in batch operations. Avoid performing singleton INSERT, UPDATE, or DELETE operations on append-optimized tables. Concurrent batch INSERT operations are acceptable, but never perform concurrent batch UPDATE or DELETE operations.

The append-optimized storage model is inappropriate for frequently updated tables, because space occupied by rows that are updated and deleted in append-optimized tables is not recovered and reused as efficiently as with heap tables. Append-optimized storage is intended for large tables that are loaded once, updated infrequently, and queried frequently for analytical query processing.

**Row or Column Orientation**

Row orientation is the traditional way to store database tuples. The columns that comprise a row are stored on disk contiguously, so that an entire row can be read from disk in a single I/O.

Column orientation stores column values together on disk. A separate file is created for each column. If the table is partitioned, a separate file is created for each column and partition. When a query accesses only a small number of columns in a column-oriented table with many columns, the cost of I/O is substantially reduced compared to a row-oriented table; any columns not referenced do not have to be retrieved from disk.

Row-oriented storage is recommended for transactional type workloads with iterative transactions where updates are required and frequent inserts are performed. Use row-oriented storage when selects against the table are wide, where many columns of a single row are needed in a query. If the majority of columns in the SELECT list or WHERE clause is selected in queries, use row-oriented storage. Use row-oriented storage for general purpose or mixed workloads, as it offers the best combination of flexibility and performance.

Column-oriented storage is optimized for read operations but it is not optimized for write operations; column values for a row must be written to different places on disk. Column-oriented tables can offer optimal query performance on large tables with many columns where only a small subset of columns are accessed by the queries.

Another benefit of column orientation is that a collection of values of the same data type can be stored together in less space than a collection of mixed type values, so column-oriented tables use less disk space (and consequently less disk I/O) than row-oriented tables. Column-oriented tables also compress better than row-oriented tables.

Use column-oriented storage for data warehouse analytic workloads where selects are narrow or aggregations of data are computed over a small number of columns. Use column-oriented storage for tables that have single columns that are regularly updated without modifying other columns in the row. Reading a complete row in a wide columnar table requires more time than reading the same row from a row-oriented table. It is important to understand that each column is a separate physical file on every segment in Greenplum Database.

**Compression**

Greenplum Database offers a variety of options to compress append-optimized tables and partitions. Use compression to improve I/O across the system by allowing more data to be read with each disk read operation. The best practice is to set the column compression settings at the partition level.

Note that new partitions added to a partitioned table do not automatically inherit compression defined at the table level; you must specifically define compression when you add new partitions.

Run-length encoding (RLE) compression provides the best levels of compression. Higher levels of compression usually result in more compact storage on disk, but require additional time and CPU cycles when compressing data on writes and uncompressing on reads. Sorting data, in combination with the various compression options, can achieve the highest level of compression.

Data compression should never be used for data that is stored on a compressed file system.
Test different compression types and ordering methods to determine the best compression for your specific data. For example, you might start zlib compression at level 4 or 5 and adjust for best results. RLE compression works best with files that contain repetitive data.

**Distributions**

An optimal distribution that results in evenly distributed data is the most important factor in Greenplum Database. In an MPP shared nothing environment overall response time for a query is measured by the completion time for all segments. The system is only as fast as the slowest segment. If the data is skewed, segments with more data will take more time to complete, so every segment must have an approximately equal number of rows and perform approximately the same amount of processing. Poor performance and out of memory conditions may result if one segment has significantly more data to process than other segments.

Consider the following best practices when deciding on a distribution strategy:

- Explicitly define a column or random distribution for all tables. Do not use the default.
- Ideally, use a single column that will distribute data across all segments evenly.
- Do not distribute on columns that will be used in the `WHERE` clause of a query.
- Do not distribute on dates or timestamps.
- The distribution key column data should contain unique values or very high cardinality.
- If a single column cannot achieve an even distribution, use a multi-column distribution key with a maximum of two columns. Additional column values do not typically yield a more even distribution and they require additional time in the hashing process.
- If a two-column distribution key cannot achieve an even distribution of data, use a random distribution. Multi-column distribution keys in most cases require motion operations to join tables, so they offer no advantages over a random distribution.

Greenplum Database random distribution is not round-robin, so there is no guarantee of an equal number of records on each segment. Random distributions typically fall within a target range of less than ten percent variation.

Optimal distributions are critical when joining large tables together. To perform a join, matching rows must be located together on the same segment. If data is not distributed on the same join column, the rows needed from one of the tables are dynamically redistributed to the other segments. In some cases a broadcast motion, in which each segment sends its individual rows to all other segments, is performed rather than a redistribution motion, where each segment rehashes the data and sends the rows to the appropriate segments according to the hash key.

**Local (Co-located) Joins**

Using a hash distribution that evenly distributes table rows across all segments and results in local joins can provide substantial performance gains. When joined rows are on the same segment, much of the processing can be accomplished within the segment instance. These are called local or co-located joins. Local joins minimize data movement; each segment operates independently of the other segments, without network traffic or communications between segments.

To achieve local joins for large tables commonly joined together, distribute the tables on the same column. Local joins require that both sides of a join be distributed on the same columns (and in the same order) and that all columns in the distribution clause are used when joining tables. The distribution columns must also be the same data type—although some values with different data types may appear to have the same representation, they are stored differently and hash to different values, so they are stored on different segments.
Data Skew

Data skew is often the root cause of poor query performance and out of memory conditions. Skewed data affects scan (read) performance, but it also affects all other query execution operations, for instance, joins and group by operations.

It is very important to validate distributions to ensure that data is evenly distributed after the initial load. It is equally important to continue to validate distributions after incremental loads.

The following query shows the number of rows per segment as well as the variance from the minimum and maximum numbers of rows:

```
SELECT 'Example Table' AS "Table Name",
       max(c) AS "Max Seg Rows", min(c) AS "Min Seg Rows",
       (max(c)-min(c))*100.0/max(c) AS "Percentage Difference Between Max & Min"
FROM (SELECT count(*) c, gp_segment_id FROM facts GROUP BY 2) AS a;
```

The `gp_toolkit` schema has two views that you can use to check for skew.

- The view shows data distribution skew by calculating the coefficient of variation (CV) for the data stored on each segment. The `skccoeff` column shows the coefficient of variation (CV), which is calculated as the standard deviation divided by the average. It takes into account both the average and variability around the average of a data series. The lower the value, the better. Higher values indicate greater data skew.

- The view shows data distribution skew by calculating the percentage of the system that is idle during a table scan, which is an indicator of computational skew. The `siffraction` column shows the percentage of the system that is idle during a table scan. This is an indicator of uneven data distribution or query processing skew. For example, a value of 0.1 indicates 10% skew, a value of 0.5 indicates 50% skew, and so on. Tables that have more than 10% skew should have their distribution policies evaluated.

Processing Skew

Processing skew results when a disproportionate amount of data flows to, and is processed by, one or a few segments. It is often the culprit behind Greenplum Database performance and stability issues. It can happen with operations such as join, sort, aggregation, and various OLAP operations. Processing skew happens in flight while a query is executing and is not as easy to detect as data skew, which is caused by uneven data distribution due to the wrong choice of distribution keys. Data skew is present at the table level, so it can be easily detected and avoided by choosing optimal distribution keys.

If single segments are failing, that is, not all segments on a host, it may be a processing skew issue. Identifying processing skew is currently a manual process. First look for spill files. If there is skew, but not enough to cause spill, it will not become a performance issue. If you determine skew exists, then find the query responsible for the skew. Following are the steps and commands to use. (Change names like the host file name passed to `gpssh` accordingly):

1. Find the OID for the database that is to be monitored for skew processing:

```
SELECT oid, datname FROM pg_database;
```

Example output:

<table>
<thead>
<tr>
<th>oid</th>
<th>datname</th>
</tr>
</thead>
<tbody>
<tr>
<td>17088</td>
<td>gpadmin</td>
</tr>
<tr>
<td>10899</td>
<td>postgres</td>
</tr>
<tr>
<td>1</td>
<td>template1</td>
</tr>
<tr>
<td>10898</td>
<td>template0</td>
</tr>
<tr>
<td>38817</td>
<td>pws</td>
</tr>
<tr>
<td>39682</td>
<td>gpperfmon</td>
</tr>
</tbody>
</table>
2. Run a `gpssh` command to check file sizes across all of the segment nodes in the system. Replace `<OID>` with the OID of the database from the prior command:

```
[gpadmin@mdw kend]$ gpssh -f ~/hosts -e "du -b /data[1-2]/primary/gpseg*/base/<OID>/pgsql_tmp/*" | grep -v "du -b" | sort | awk -F" " '{ arr[$1] = arr[$1] + $2 ; tot = tot + $2 }; END { for ( i in arr ) print "Segment node" i, arr[i], "bytes (" arr[i]/(1024**3)" GB)"; print "Total", tot, "bytes (" tot/(1024**3)" GB)" }' -
```

Example output:

```
Segment node[sdw1] 2443370457 bytes (2.27557 GB)
Segment node[sdw2] 1766575328 bytes (1.64525 GB)
Segment node[sdw3] 1761686551 bytes (1.6407 GB)
Segment node[sdw4] 1780301617 bytes (1.65804 GB)
Segment node[sdw5] 1742543599 bytes (1.62287 GB)
Segment node[sdw6] 1830073754 bytes (1.70439 GB)
Segment node[sdw7] 1767310099 bytes (1.64594 GB)
Segment node[sdw8] 1765105802 bytes (1.64388 GB)
Total 14856967207 bytes (13.8366 GB)
```

If there is a **significant and sustained** difference in disk usage, then the queries being executed should be investigated for possible skew (the example output above does not reveal significant skew). In monitoring systems, there will always be some skew, but often it is **transient** and will be **short in duration**.

3. If significant and sustained skew appears, the next task is to identify the offending query.

The command in the previous step sums up the entire node. This time, find the actual segment directory. You can do this from the master or by logging into the specific node identified in the previous step. Following is an example run from the master.

This example looks specifically for sort files. Not all spill files or skew situations are caused by sort files, so you will need to customize the command:

```
$ gpssh -f ~/hosts -e "ls -l /data[1-2]/primary/gpseg*/base/19979/pgsql_tmp/*" | grep -i sort | awk '{sub(/base.*tmp//, ".../", $10); print $1,$6, $10} | sort -k2 -n
```

Here is output from this command:

```
[sdw1] 288718848 /data1/primary/gpseg2/.../pgsql_tmp_slice0_sort_17758_0001.0
291176448 /data2/primary/gpseg5/.../pgsql_tmp_slice0_sort_17764_0001.0
924581888 /data2/primary/gpseg45/.../pgsql_tmp_slice10_sort_15673_0010.9
980582400 /data1/primary/gpseg18/.../pgsql_tmp_slice10_sort_29425_0001.0
986447872 /data2/primary/gpseg35/.../pgsql_tmp_slice10_sort_29602_0001.0
[sdw5] 999620608 /data1/primary/gpseg2/.../pgsql_tmp_slice10_sort_28637_0001.0
999751680 /data2/primary/gpseg26/.../pgsql_tmp_slice10_sort_28637_0001.0
1000112128 /data2/primary/gpseg9/.../pgsql_tmp_slice10_sort_3969_0001.0
1000898560 /data1/primary/gpseg13/.../pgsql_tmp_slice10_sort_24723_0001.0
```
Scanning this output reveals that segment gpseg45 on host sdw8 is the culprit, as its sort files are larger than the others in the output.

4. Log in to the offending node with `ssh` and become root. Use the `lsof` command to find the PID for the process that owns one of the sort files:

```
[root@sdw8 ~]# lsof /data2/primary/gpseg45/base/19979/pgsql_tmp/
pgsql_tmp_slice10_sort_15673_0002.1
COMMAND PID USER    FD   TYPE DEVICE SIZE NODE        NAME
postgres 15673  gpadmin 11u  REG  8,48    1073741824  64424546751 /data2/
primary/gpseg45/base/19979/pgsql_tmp/pgsql_tmp_slice10_sort_15673_0002.1
```

The PID, 15673, is also part of the file name, but this may not always be the case.

5. Use the `ps` command with the PID to identify the database and connection information:

```
[root@sdw8 ~]# ps -eaf | grep 15673
gpadmin  15673 27471 28 12:05 ?        00:12:59 postgres: port 40003,
sbaskin bdw 172.28.12.250(21813) con699238 seg45 cmd32 slice10 MPPEXEC SELECT
root     29622 29566  0 12:50 pts/16   00:00:00 grep 15673
```

6. On the master, check the `pg_log` log file for the user in the previous command (sbaskin), connection (con699238, and command (cmd32). The line in the log file with these three values should be the line that contains the query, but occasionally, the command number may differ slightly. For example, the `ps` output may show cmd32, but in the log file it is cmd34. If the query is still running, the last query for the user and connection is the offending query.

The remedy for processing skew in almost all cases is to rewrite the query. Creating temporary tables can eliminate skew. Temporary tables can be randomly distributed to force a two-stage aggregation.

**Partitioning**

A good partitioning strategy reduces the amount of data to be scanned by reading only the partitions needed to satisfy a query.
Each partition is a separate physical file or set of tiles (in the case of column-oriented tables) on every segment. Just as reading a complete row in a wide columnar table requires more time than reading the same row from a heap table, reading all partitions in a partitioned table requires more time than reading the same data from a non-partitioned table.

Following are partitioning best practices:

• Partition large tables only, do not partition small tables.
• Use partitioning on large tables only when partition elimination (partition pruning) can be achieved based on query criteria and is accomplished by partitioning the table based on the query predicate. Whenever possible, use range partitioning instead of list partitioning.
• The query planner can selectively scan partitioned tables only when the query contains a direct and simple restriction of the table using immutable operators, such as =, <, <=, >, >=, and <>.
• Selective scanning recognizes **STABLE** and **IMMUTABLE** functions, but does not recognize **VOLATILE** functions within a query. For example, **WHERE** clauses such as
  
  ```
  date > CURRENT_DATE
  ```

  cause the query planner to selectively scan partitioned tables, but a **WHERE** clause such as

  ```
  time > TIMEOFDAY
  ```

do not. It is important to validate that queries are selectively scanning partitioned tables (partitions are being eliminated) by examining the query **EXPLAIN** plan.
• Do not use default partitions. The default partition is always scanned but, more importantly, in many environments they tend to overfill resulting in poor performance.
• Never partition and distribute tables on the same column.
• Do not use multi-level partitioning. While sub-partitioning is supported, it is not recommended because typically subpartitions contain little or no data. It is a myth that performance increases as the number of partitions or subpartitions increases; the administrative overhead of maintaining many partitions and subpartitions will outweigh any performance benefits. For performance, scalability and manageability, balance partition scan performance with the number of overall partitions.
• Beware of using too many partitions with column-oriented storage.
• Consider workload concurrency and the average number of partitions opened and scanned for all concurrent queries.

### Number of Partition and Columnar Storage Files

The only hard limit for the number of files Greenplum Database supports is the operating system's open file limit. It is important, however, to consider the total number of files in the cluster, the number of files on every segment, and the total number of files on a host. In an MPP shared nothing environment, every node operates independently of other nodes. Each node is constrained by its disk, CPU, and memory. CPU and I/O constraints are not common with Greenplum Database, but memory is often a limiting factor because the query execution model optimizes query performance in memory.

The optimal number of files per segment also varies based on the number of segments on the node, the size of the cluster, SQL access, concurrency, workload, and skew. There are generally six to eight segments per host, but large clusters should have fewer segments per host. When using partitioning and columnar storage it is important to balance the total number of files in the cluster, but it is more important to consider the number of files per segment and the total number of files on a node.

**Example DCA V2 64GB Memory per Node**

• Number of nodes: 16
• Number of segments per node: 8
• Average number of files per segment: 10,000
The total number of files per node is \( 8 \times 10,000 = 80,000 \) and the total number of files for the cluster is \( 8 \times 16 \times 10,000 = 1,280,000 \). The number of files increases quickly as the number of partitions and the number of columns increase.

As a general best practice, limit the total number of files per node to under 100,000. As the previous example shows, the optimal number of files per segment and total number of files per node depends on the hardware configuration for the nodes (primarily memory), size of the cluster, SQL access, concurrency, workload and skew.

**Indexes**

Indexes are not generally needed in Greenplum Database. Most analytical queries operate on large volumes of data, while indexes are intended for locating single rows or small numbers of rows of data. In Greenplum Database, a sequential scan is an efficient method to read data as each segment contains an equal portion of the data and all segments work in parallel to read the data.

If adding an index does not produce performance gains, drop it. Verify that every index you create is used by the optimizer.

For queries with high selectivity, indexes may improve query performance. Create an index on a single column of a columnar table for drill through purposes for high cardinality columns that are required for highly selective queries.

Do not index columns that are frequently updated. Creating an index on a column that is frequently updated increases the number of writes required on updates.

Indexes on expressions should be used only if the expression is used frequently in queries.

An index with a predicate creates a partial index that can be used to select a small number of rows from large tables.

Avoid overlapping indexes. Indexes that have the same leading column are redundant.

Indexes can improve performance on compressed append-optimized tables for queries that return a targeted set of rows. For compressed data, an index access method means only the necessary pages are uncompressed.

Create selective B-tree indexes. Index selectivity is a ratio of the number of distinct values a column has divided by the number of rows in a table. For example, if a table has 1000 rows and a column has 800 distinct values, the selectivity of the index is 0.8, which is considered good.

As a general rule, drop indexes before loading data into a table. The load will run an order of magnitude faster than loading data into a table with indexes. After the load, re-create the indexes.

Bitmap indexes are suited for querying and not updating. Bitmap indexes perform best when the column has a low cardinality—100 to 100,000 distinct values. Do not use bitmap indexes for unique columns, very high, or very low cardinality data. Do not use bitmap indexes for transactional workloads.

If indexes are needed on partitioned tables, the index columns must be different than the partition columns. A benefit of indexing partitioned tables is that because the b-tree performance degrades exponentially as the size of the b-tree grows, creating indexes on partitioned tables creates smaller b-trees that perform better than with non-partitioned tables.

**Column Sequence and Byte Alignment**

For optimum performance lay out the columns of a table to achieve data type byte alignment. Lay out the columns in heap tables in the following order:

1. Distribution and partition columns
2. Fixed numeric types
3. Variable data types
Lay out the data types from largest to smallest, so that \texttt{BIGINT} and \texttt{TIMESTAMP} come before \texttt{INT} and \texttt{DATE}, and all of these types come before \texttt{TEXT}, \texttt{VARCHAR}, or \texttt{NUMERIC}(x, y). For example, 8-byte types first (\texttt{BIGINT}, \texttt{TIMESTAMP}), 4-byte types next (\texttt{INT}, \texttt{DATE}), 2-byte types next (\texttt{SMALLINT}), and variable data type last (\texttt{VARCHAR}).

Instead of defining columns in this sequence:

\texttt{Int, Bigint, Timestamp, Bigint, Timestamp, Int (distribution key), Date (partition key), Bigint, Smallint}

define the columns in this sequence:

\texttt{Int (distribution key), Date (partition key), Bigint, Bigint, Timestamp, Bigint, Timestamp, Int, Smallint}
Memory and Resource Management with Resource Queues

Avoid memory errors and manage Greenplum Database resources.

Memory management has a significant impact on performance in a Greenplum Database cluster. The default settings are suitable for most environments. Do not change the default settings until you understand the memory characteristics and usage on your system.

- Resolving Out of Memory Errors
- Low Memory Queries
- Configuring Memory for Greenplum Database
- Example Memory Configuration Calculations
- Configuring Resource Queues

Resolving Out of Memory Errors

An out of memory error message identifies the Greenplum segment, host, and process that experienced the out of memory error. For example:

```
Out of memory (seg27 host.example.com pid=47093)
VM Protect failed to allocate 4096 bytes, 0 MB available
```

Some common causes of out-of-memory conditions in Greenplum Database are:

- Insufficient system memory (RAM) available on the cluster
- Improperly configured memory parameters
- Data skew at the segment level
- Operational skew at the query level

Following are possible solutions to out of memory conditions:

- Tune the query to require less memory
- Reduce query concurrency using a resource queue
- Validate the `gp_vmem_protect_limit` configuration parameter at the database level. See calculations for the maximum safe setting in Configuring Memory for Greenplum Database.
- Set the memory quota on a resource queue to limit the memory used by queries executed within the resource queue
- Use a session setting to reduce the `statement_mem` used by specific queries
- Decrease `statement_mem` at the database level
- Decrease the number of segments per host in the Greenplum Database cluster. This solution requires a re-initializing Greenplum Database and reloading your data.
- Increase memory on the host, if possible. (Additional hardware may be required.)

Adding segment hosts to the cluster will not in itself alleviate out of memory problems. The memory used by each query is determined by the `statement_mem` parameter and it is set when the query is invoked. However, if adding more hosts allows decreasing the number of segments per host, then the amount of memory allocated in `gp_vmem_protect_limit` can be raised.
Low Memory Queries

A low `statement_mem` setting (for example, in the 1-3MB range) has been shown to increase the performance of queries with low memory requirements. Use the `statement_mem` server configuration parameter to override the setting on a per-query basis. For example:

```
SET statement_mem='2MB';
```

Configuring Memory for Greenplum Database

Most out of memory conditions can be avoided if memory is thoughtfully managed.

It is not always possible to increase system memory, but you can prevent out-of-memory conditions by configuring memory use correctly and setting up resource queues to manage expected workloads.

It is important to include memory requirements for mirror segments that become primary segments during a failure to ensure that the cluster can continue when primary segments or segment hosts fail.

The following are recommended operating system and Greenplum Database memory settings:

- **Do not configure the OS to use huge pages.**

- **vm.overcommit_memory**
  
  This is a Linux kernel parameter, set in `/etc/sysctl.conf`. It should always be set to 2. It determines the method the OS uses for determining how much memory can be allocated to processes and 2 is the only safe setting for Greenplum Database.

- **vm.overcommit_ratio**
  
  This is a Linux kernel parameter, set in `/etc/sysctl.conf`. It is the percentage of RAM that is used for application processes. The remainder is reserved for the operating system. The default on Red Hat is 50.

  Setting `vm.overcommit_ratio` too high may result in not enough memory being reserved for the operating system, which can result in segment host failure or database failure. Setting the value too low reduces the amount of concurrency and query complexity that can be run by reducing the amount of memory available to Greenplum Database. When increasing the setting it is important to remember to always reserve some memory for operating system activities.

  See `Resource Queue Segment Memory Configuration` for instructions to calculate a value for `vm.overcommit_ratio`.

- **gp_vmem_protect_limit**
  
  Use `gp_vmem_protect_limit` to set the maximum memory that the instance can allocate for all work being done in each segment database. Never set this value larger than the physical RAM on the system. If `gp_vmem_protect_limit` is too high, it is possible for memory to become exhausted on the system and normal operations may fail, causing segment failures. If `gp_vmem_protect_limit` is set to a safe lower value, true memory exhaustion on the system is prevented; queries may fail for hitting the limit, but system disruption and segment failures are avoided, which is the desired behavior.

  See `Resource Queue Segment Memory Configuration` for instructions to calculate a safe value for `gp_vmem_protect_limit`.

- **runaway_detector_activation_percent**
  
  Runaway Query Termination, introduced in Greenplum Database 4.3.4, prevents out of memory conditions. The `runaway_detector_activation_percent` system parameter controls the percentage of `gp_vmem_protect_limit` memory utilized that triggers termination of queries. It is set on by default at 90%. If the percentage of `gp_vmem_protect_limit` memory that is utilized for a segment exceeds the specified value, Greenplum Database terminates queries based on memory usage, beginning with the query consuming the largest amount of memory. Queries are terminated until the utilized percentage of `gp_vmem_protect_limit` is below the specified percentage.

- **statement_mem**
Use `statement_mem` to allocate memory used for a query per segment database. If additional memory is required it will spill to disk. Set the optimal value for `statement_mem` as follows:

```
(vmprotect * .9) / max_expected_concurrent_queries
```

The default value of `statement_mem` is 125MB. For example, a query running on a Dell EMC DCA V2 system using the default `statement_mem` value will use 1GB of memory on each segment server (8 segments # 125MB). Set `statement_mem` at the session level for specific queries that require additional memory to complete. This setting works well to manage query memory on clusters with low concurrency. For clusters with high concurrency also use resource queues to provide additional control on what and how much is running on the system.

- **`gp_workfile_limit_files_per_query`**

  Set `gp_workfile_limit_files_per_query` to limit the maximum number of temporary spill files (workfiles) allowed per query. Spill files are created when a query requires more memory than it is allocated. When the limit is exceeded the query is terminated. The default is zero, which allows an unlimited number of spill files and may fill up the file system.

- **`gp_workfile_compress_algorithm`**

  If there are numerous spill files then set `gp_workfile_compress_algorithm` to compress the spill files. Compressing spill files may help to avoid overloading the disk subsystem with IO operations.

### Example Memory Configuration Calculations

- Total RAM = 256GB
- SWAP = 64GB
- 8 primary segments and 8 mirror segments per host, in blocks of 4 hosts
- Maximum number of primaries per host during failure is 11

#### `vm.overcommit_ratio` calculation

```
gp_vmem = ((SWAP + RAM) - (7.5GB + 0.05 * RAM)) / 1.7
       = ((64 + 256) - (7.5 + 0.05 * 256)) / 1.7
       = 176

vm.overcommit_ratio = (RAM - (0.026 * gp_vmem)) / RAM
                     = (256 - (0.026 * 176)) / 256
                     = .982
```

Set `vm.overcommit_ratio` to 98.

#### `gp_vmem_protect_limit` calculation

```
gp_vmem_protect_limit = gp_vmem / maximum_acting_primary_segments
                        = 176 / 11
                        = 16GB
                        = 16384MB
```

### Configuring Resource Queues

Greenplum Database resource queues provide a powerful mechanism for managing the workload of the cluster. Queues can be used to limit both the numbers of active queries and the amount of memory that can be used by queries in the queue. When a query is submitted to Greenplum Database, it is added to a resource queue, which determines if the query should be accepted and when the resources are available to execute it.

- Associate all roles with an administrator-defined resource queue.
Each login user (role) is associated with a single resource queue; any query the user submits is handled by the associated resource queue. If a queue is not explicitly assigned the user’s queries are handed by the default queue, `pg_default`.

- Do not run queries with the gpadmin role or other superuser roles.

Superusers are exempt from resource queue limits, therefore superuser queries always run regardless of the limits set on their assigned queue.

- Use the `ACTIVE_STATEMENTS` resource queue parameter to limit the number of active queries that members of a particular queue can run concurrently.
- Use the `MEMORY_LIMIT` parameter to control the total amount of memory that queries running through the queue can utilize. By combining the `ACTIVE_STATEMENTS` and `MEMORY_LIMIT` attributes an administrator can fully control the activity emitted from a given resource queue.

The allocation works as follows: Suppose a resource queue, `sample_queue`, has `ACTIVE_STATEMENTS` set to 10 and `MEMORY_LIMIT` set to 2000MB. This limits the queue to approximately 2 gigabytes of memory per segment. For a cluster with 8 segments per server, the total usage per server is 16 GB for `sample_queue` (2GB * 8 segments/server). If a segment server has 64GB of RAM, there could be no more than four of this type of resource queue on the system before there is a chance of running out of memory (4 queues * 16GB per queue).

Note that by using `STATEMENT_MEM`, individual queries running in the queue can allocate more than their “share” of memory, thus reducing the memory available for other queries in the queue.

- Resource queue priorities can be used to align workloads with desired outcomes. Queues with `MAX` priority throttle activity in all other queues until the `MAX` queue completes running all queries.
- Alter resource queues dynamically to match the real requirements of the queue for the workload and time of day. You can script an operational flow that changes based on the time of day and type of usage of the system and add `crontab` entries to execute the scripts.
- Use gptoolkit to view resource queue usage and to understand how the queues are working.
System Monitoring and Maintenance

Best practices for regular maintenance that will ensure Greenplum Database high availability and optimal performance.

Monitoring

Greenplum Database includes utilities that are useful for monitoring the system.

The `gp_toolkit` schema contains several views that can be accessed using SQL commands to query system catalogs, log files, and operating environment for system status information.

The `gp_stats_missing` view shows tables that do not have statistics and require `ANALYZE` to be run.

For additional information on `gpstate` and `gpcheckperf` refer to the `Greenplum Database Utility Guide`. For information about the `gp_toolkit` schema, see the `Greenplum Database Reference Guide`.

**gpstate**

The `gpstate` utility program displays the status of the Greenplum system, including which segments are down, master and segment configuration information (hosts, data directories, etc.), the ports used by the system, and mapping of primary segments to their corresponding mirror segments.

Run `gpstate -Q` to get a list of segments that are marked "down" in the master system catalog.

To get detailed status information for the Greenplum system, run `gpstate -s`.

**gpcheckperf**

The `gpcheckperf` utility tests baseline hardware performance for a list of hosts. The results can help identify hardware issues. It performs the following checks:

- disk I/O test – measures I/O performance by writing and reading a large file using the `dd` operating system command. It reports read and write rates in megabytes per second.
- memory bandwidth test – measures sustainable memory bandwidth in megabytes per second using the STREAM benchmark.
- network performance test – runs the `gpnetbench` network benchmark program (optionally `netperf`) to test network performance. The test is run in one of three modes: parallel pair test (`-r N`), serial pair test (`-r n`), or full-matrix test (`-r M`). The minimum, maximum, average, and median transfer rates are reported in megabytes per second.

To obtain valid numbers from `gpcheckperf`, the database system must be stopped. The numbers from `gpcheckperf` can be inaccurate even if the system is up and running with no query activity.

`gpcheckperf` requires a trusted host setup between the hosts involved in the performance test. It calls `gpssh` and `gpscp`, so these utilities must also be in your PATH. Specify the hosts to check individually (`-h host1 -h host2 ...`) or with `-f hosts_file`, where `hosts_file` is a text file containing a list of the hosts to check. If you have more than one subnet, create a separate host file for each subnet so that you can test the subnets separately.

By default, `gpcheckperf` runs the disk I/O test, the memory test, and a serial pair network performance test. With the disk I/O test, you must use the `-d` option to specify the file systems you want to test. The following command tests disk I/O and memory bandwidth on hosts listed in the `subnet_1_hosts` file:

```bash
$ gpcheckperf -f subnet_1_hosts -d /data1 -d /data2 -r ds
```

The `-r` option selects the tests to run: disk I/O (`d`), memory bandwidth (`s`), network parallel pair (`N`), network serial pair test (`n`), network full-matrix test (`t`). Only one network mode can be selected per execution. See the `Greenplum Database Reference Guide` for the detailed `gpcheckperf` reference.
Monitoring with Operating System Utilities

The following Linux/UNIX utilities can be used to assess host performance:

- `iostat` allows you to monitor disk activity on segment hosts.
- `top` displays a dynamic view of operating system processes.
- `vmstat` displays memory usage statistics.

You can use `gpssh` to run utilities on multiple hosts.

Best Practices

- Implement the “Recommended Monitoring and Maintenance Tasks” in the Greenplum Database Administrator Guide.
- Run `gpcheckperf` at install time and periodically thereafter, saving the output to compare system performance over time.
- Use all the tools at your disposal to understand how your system behaves under different loads.
- Examine any unusual event to determine the cause.
- Monitor query activity on the system by running explain plans periodically to ensure the queries are running optimally.
- Review plans to determine whether index are being used and partition elimination is occurring as expected.

Additional Information

- `gpcheckperf` reference in the Greenplum Database Utility Guide.
- "Recommended Monitoring and Maintenance Tasks” in the Greenplum Database Administrator Guide.
- [www.netperf.org](http://www.netperf.org) to use netperf, netperf must be installed on each host you test. See `gpcheckperf` reference for more information.

Updating Statistics with `ANALYZE`

The most important prerequisite for good query performance is to begin with accurate statistics for the tables. Updating statistics with the `ANALYZE` statement enables the query planner to generate optimal query plans. When a table is analyzed, information about the data is stored in the system catalog tables. If the stored information is out of date, the planner can generate inefficient plans.

Generating Statistics Selectively

Running `ANALYZE` with no arguments updates statistics for all tables in the database. This can be a very long-running process and it is not recommended. You should `ANALYZE` tables selectively when data has changed or use the `analyzedb` utility.

Running `ANALYZE` on a large table can take a long time. If it is not feasible to run `ANALYZE` on all columns of a very large table, you can generate statistics for selected columns only using `ANALYZE table(column, ...)`. Be sure to include columns used in joins, `WHERE` clauses, `SORT` clauses, `GROUP` clauses, or `HAVING` clauses.

For a partitioned table, you can run `ANALYZE` on just partitions that have changed, for example, if you add a new partition. Note that for partitioned tables, you can run `ANALYZE` on the parent (main) table, or on the leaf nodes—the partition files where data and statistics are actually stored. The intermediate files for sub-partitioned tables store no data or statistics, so running `ANALYZE` on them does not work. You can find the names of the partition tables in the `pg_partitions` system catalog:

```sql
SELECT partitiontablename from pg_partitions WHERE tablename='parent_table';
```
Improving Statistics Quality

There is a trade-off between the amount of time it takes to generate statistics and the quality, or accuracy, of the statistics.

To allow large tables to be analyzed in a reasonable amount of time, \texttt{ANALYZE} takes a random sample of the table contents, rather than examining every row. To increase the number of sample values for all table columns adjust the \texttt{default\_statistics\_target} configuration parameter. The target value ranges from 1 to 1000; the default target value is 100. The \texttt{default\_statistics\_target} variable applies to all columns by default, and specifies the number of values that are stored in the list of common values. A larger target may improve the quality of the query planner's estimates, especially for columns with irregular data patterns. \texttt{default\_statistics\_target} can be set at the master/session level and requires a reload.

The \texttt{gp\_analyze\_relative\_error} configuration parameter affects the sampling rate during statistics collection to determine cardinality in a column. For example, a value of .5 is equivalent to an acceptable error of 50%. The default is .25. Use the \texttt{gp\_analyze\_relative\_error} parameter to set the acceptable estimated relative error in the cardinality of a table. If statistics do not produce good estimates of cardinality for a particular table attribute, decreasing the relative error fraction (accepting less errors) tells the system to sample more rows. However, it is not recommended to reduce this below 0.1 as it will increase \texttt{ANALYZE} time substantially.

When to Run \texttt{ANALYZE}

Run \texttt{ANALYZE}:

- after loading data,
- after \texttt{CREATE INDEX} operations,
- and after \texttt{INSERT}, \texttt{UPDATE}, and \texttt{DELETE} operations that significantly change the underlying data.

\texttt{ANALYZE} requires only a read lock on the table, so it may be run in parallel with other database activity, but do not run \texttt{ANALYZE} while performing \texttt{LOADS}, \texttt{INSERT}, \texttt{UPDATE}, \texttt{DELETE}, and \texttt{CREATE INDEX} operations.

Configuring Automatic Statistics Collection

The \texttt{gp\_autostats\_mode} configuration parameter, together with the \texttt{gp\_autostats\_on\_change\_threshold} parameter, determines when an automatic analyze operation is triggered. When automatic statistics collection is triggered, the planner adds an \texttt{ANALYZE} step to the query.

By default, \texttt{gp\_autostats\_mode} is \texttt{on\_no\_stats}, which triggers statistics collection for \texttt{CREATE TABLE AS SELECT}, \texttt{INSERT}, or \texttt{COPY} operations on any table that has no existing statistics.

Setting \texttt{gp\_autostats\_mode} to \texttt{on\_change} triggers statistics collection only when the number of rows affected exceeds the threshold defined by \texttt{gp\_autostats\_on\_change\_threshold}, which has a default value of 2147483647. Operations that can trigger automatic statistics collection with \texttt{on\_change} are: \texttt{CREATE TABLE AS SELECT}, \texttt{UPDATE}, \texttt{DELETE}, \texttt{INSERT}, and \texttt{COPY}.

Setting \texttt{gp\_autostats\_mode} to \texttt{none} disables automatic statistics collection.

For partitioned tables, automatic statistics collection is not triggered if data is inserted from the top-level parent table of a partitioned table. But automatic statistics collection \texttt{is} triggered if data is inserted directly in a leaf table (where the data is stored) of the partitioned table.

Managing Bloat in the Database

Greenplum Database heap tables use the PostgreSQL Multiversion Concurrency Control (MVCC) storage implementation. A deleted or updated row is logically deleted from the database, but a non-visible image of the row remains in the table. These deleted rows, also called expired rows, are tracked in a free space
Running VACUUM marks the expired rows as free space that is available for reuse by subsequent inserts.

If the free space map is not large enough to accommodate all of the expired rows, the VACUUM command is unable to reclaim space for expired rows that overflowed the free space map. The disk space may only be recovered by running VACUUM FULL, which locks the table, copies rows one-by-one to the beginning of the file, and truncates the file. This is an expensive operation that can take an exceptional amount of time to complete with a large table. It should be used only on smaller tables. If you attempt to kill a VACUUM FULL operation, the system can be disrupted.

**Important:**

It is very important to run VACUUM after large UPDATE and DELETE operations to avoid the necessity of ever running VACUUM FULL.

If the free space map overflows and it is necessary to recover the space it is recommended to use the CREATE TABLE...AS SELECT command to copy the table to a new table, which will create a new compact table. Then drop the original table and rename the copied table.

It is normal for tables that have frequent updates to have a small or moderate amount of expired rows and free space that will be reused as new data is added. But when the table is allowed to grow so large that active data occupies just a small fraction of the space, the table has become significantly “bloated.” Bloated tables require more disk storage and additional I/O that can slow down query execution.

Bloat affects heap tables, system catalogs, and indexes.

Running the VACUUM statement on tables regularly prevents them from growing too large. If the table does become significantly bloated, the VACUUM FULL statement (or an alternative procedure) must be used to compact the file. If a large table becomes significantly bloated, it is better to use one of the alternative methods described in Removing Bloat from Database Tables to remove the bloat.

**Caution:** Never run VACUUM FULL <database_name> and do not run VACUUM FULL on large tables in a Greenplum Database.

**Sizing the Free Space Map**

Expired rows in heap tables are added to a shared free space map when you run VACUUM. The free space map must be adequately sized to accommodate these rows. If the free space map is not large enough, any space occupied by rows that overflow the free space map cannot be reclaimed by a regular VACUUM statement. You will have to use VACUUM FULL or an alternative method to recover the space.

You can avoid overflowing the free space map by running the VACUUM statement regularly. The more bloated a table becomes, the more rows that must be tracked in the free space map. For very large databases with many objects, you may need to increase the size of the free space map to prevent overflow.

The `max_fsm_pages` configuration parameter sets the maximum number of disk pages for which free space will be tracked in the shared free-space map. Each page slot consumes six bytes of shared memory. The default value for `max_fsm_pages` is 200,000.

The `max_fsm_relations` configuration parameter sets the maximum number of relations for which free space will be tracked in the shared memory free-space map. It should be set to a value larger than the total number of tables, indexes, and system tables in the database. It costs about 60 bytes of memory for each relation per segment instance. The default value is 1000.

See the Greenplum Database Reference Guide for detailed information about these configuration parameters.

**Detecting Bloat**

The statistics collected by the ANALYZE statement can be used to calculate the expected number of disk pages required to store a table. The difference between the expected number of pages and the actual number of pages is a measure of bloat. The `gp_toolkit` schema provides a `gp_bloat_diag` view that
identifies table bloat by comparing the ratio of expected to actual pages. To use it, make sure statistics are up to date for all of the tables in the database, then run the following SQL:

```sql
gpadmin=# SELECT * FROM gp_toolkit.gp_bloat_diag;
  bdirelid | bdinspname | bdirelname | bdirelpages | bdiexppages | bdidiag
----------+------------+------------+-------------+-------------
        +---------------------------------------
        21488 | public     | t1         |          97 |           1 | significant amount of bloat suspected
(1 row)
```

The results include only tables with moderate or significant bloat. Moderate bloat is reported when the ratio of actual to expected pages is greater than four and less than ten. Significant bloat is reported when the ratio is greater than ten.

The `gp_toolkit.gp_bloat_expected_pages` view lists the actual number of used pages and expected number of used pages for each database object.

```sql
gpadmin=# SELECT * FROM gp_toolkit.gp_bloat_expected_pages LIMIT 5;
  btdrelid | btdrelpages | btdexppages
----------+-------------+-------------
        10789 |            1 |            1
        10794 |            1 |            1
        10799 |            1 |            1
        5004  |            1 |            1
        7175  |            1 |            1
(5 rows)
```

The `btdrelid` is the object ID of the table. The `btdrelpages` column reports the number of pages the table uses; the `btdexppages` column is the number of pages expected. Again, the numbers reported are based on the table statistics, so be sure to run `ANALYZE` on tables that have changed.

### Removing Bloat from Database Tables

The `VACUUM` command adds expired rows to the shared free space map so that the space can be reused. When `VACUUM` is run regularly on a table that is frequently updated, the space occupied by the expired rows can be promptly reused, preventing the table file from growing larger. It is also important to run `VACUUM` before the free space map is filled. For heavily updated tables, you may need to run `VACUUM` at least once a day to prevent the table from becoming bloated.

**Warning:** When a table is significantly bloated, it is better to run `ANALYZE` before running `VACUUM`. Because `ANALYZE` uses block-level sampling, a table with a high ratio of blocks containing no valid rows can cause `ANALYZE` to set the `reltuples` column of the `pg_class` system catalog to an inaccurate value or 0, which can lead to poorly optimized queries. The `VACUUM` command produces a more accurate count and when run after `ANALYZE` will correct an inaccurate row count estimate.

When a table accumulates significant bloat, running the `VACUUM` command is insufficient. For small tables, running `VACUUM FULL <table_name>` can reclaim space used by rows that overflowed the free space map and reduce the size of the table file. However, a `VACUUM FULL` statement is an expensive operation that requires an `ACCESS EXCLUSIVE` lock and may take an exceptionally long and unpredictable amount of time to finish. Rather than run `VACUUM FULL` on a large table, an alternative method is required to remove bloat from a large file. Note that every method for removing bloat from large tables is resource intensive and should be done only under extreme circumstances.

The first method to remove bloat from a large table is to create a copy of the table excluding the expired rows, drop the original table, and rename the copy. This method uses the `CREATE TABLE <table_name> AS SELECT * FROM mytable` statement to create the new table, for example:

```sql
gpadmin=# CREATE TABLE mytable_tmp AS SELECT * FROM mytable;
gpadmin=# DROP TABLE mytable;
```
A second way to remove bloat from a table is to redistribute the table, which rebuilds the table without the expired rows. Follow these steps:

1. Make a note of the table’s distribution columns.
2. Change the table’s distribution policy to random:

   ```sql
   ALTER TABLE mytable SET WITH (REORGANIZE=false)
   DISTRIBUTED randomly;
   ```

   This changes the distribution policy for the table, but does not move any data. The command should complete instantly.

3. Change the distribution policy back to its initial setting:

   ```sql
   ALTER TABLE mytable SET WITH (REORGANIZE=true)
   DISTRIBUTED BY (<original distribution columns>);
   ```

   This step redistributes the data. Since the table was previously distributed with the same distribution key, the rows are simply rewritten on the same segment, excluding expired rows.

### Removing Bloat from Indexes

The `VACUUM` command only recovers space from tables. To recover the space from indexes, recreate them using the `REINDEX` command.

To rebuild all indexes on a table run `REINDEX table_name;`. To rebuild a particular index, run `REINDEX index_name;`. `REINDEX` does not update the `reltuples` and `replpages` statistics for the index, so it is important to `ANALYZE` the table to update these statistics after reindexing.

### Removing Bloat from System Catalogs

Greenplum Database system catalogs are also heap tables and can become bloated over time. As database objects are created, altered, or dropped, expired rows are left in the system catalogs. Using `gpload` to load data contributes to the bloat since `gpload` creates and drops external tables. (Rather than use `gpload`, it is recommended to use `gpfdist` to load data.)

Bloat in the system catalogs increases the time require to scan the tables, for example, when creating explain plans. System catalogs are scanned frequently and if they become bloated, overall system performance is degraded.

It is recommended to run `VACUUM` on the system catalog nightly and at least weekly. At the same time, running `REINDEX SYSTEM` removes bloat from the indexes. Alternatively, you can reindex system tables using the `reindexdb` utility with the `-s (--system)` option. After reindexing, it is also important to run `ANALYZE`, because the `REINDEX` command rebuilds indexes with empty statistics.

The following script runs `VACUUM`, `REINDEX`, and `ANALYZE` on the system catalogs.

```bash
#!/bin/bash
DBNAME="<database_name>"
SYSTABLES="' pg_catalog.' || relname || ' ' from pg_class a, pg_namespace b |
where a.relnamespace=b.oid and b.nspname='pg_catalog' and a.relkind='r'"
psql -tc "$SYSTABLES" $DBNAME | psql -a $DBNAME
reindexdb -s -d $DBNAME
analyzedb -s $DBNAME
```

If the system catalogs become significantly bloated, you must perform an intensive system catalog maintenance procedure. The `CREATE TABLE AS SELECT` and redistribution key methods for removing bloat cannot be used with system catalogs. You must instead run `VACUUM FULL` during a scheduled downtime period. During this period, stop all catalog activity on the system; `VACUUM FULL` takes exclusive
locks against the system catalog. Running VACUUM regularly can prevent the need for this more costly procedure.

Removing Bloat from Append-Optimized Tables

Append-optimized tables are handled much differently than heap tables. Although append-optimized tables allow updates, inserts, and deletes, they are not optimized for these operations and it is recommended to not use them with append-optimized tables. If you heed this advice and use append-optimized for load-once/read-many workloads, VACUUM on an append-optimized table runs almost instantaneously.

If you do run UPDATE or DELETE commands on an append-optimized table, expired rows are tracked in an auxiliary bitmap instead of the free space map. VACUUM is the only way to recover the space. Running VACUUM on an append-optimized table with expired rows compacts a table by rewriting the entire table without the expired rows. However, no action is performed if the percentage of expired rows in the table exceeds the value of the gp_appendonly_compaction_threshold configuration parameter, which is 10 (10%) by default. The threshold is checked on each segment, so it is possible that a VACUUM statement will compact an append-only table on some segments and not others. Compacting append-only tables can be disabled by setting the gp_appendonly_compaction parameter to no.

Monitoring Greenplum Database Log Files

Know the location and content of system log files and monitor them on a regular basis and not just when problems arise.

The following table shows the locations of the various Greenplum Database log files. In file paths, date is a date in the format YYYYMMDD, instance is the current instance name, and n is the segment number.

<table>
<thead>
<tr>
<th>Path</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>/var/gpadmin/gpadminlogs/*</td>
<td>Many different types of log files, directory on each server</td>
</tr>
<tr>
<td>/var/gpadmin/gpadminlogs/gpstart_date.log</td>
<td>start log</td>
</tr>
<tr>
<td>/var/gpadmin/gpadminlogs/gpstop_date.log</td>
<td>stop log</td>
</tr>
<tr>
<td>/var/gpadmin/gpadminlogs/gpsegstart.py_idb*gpadmin_date.log</td>
<td>segment start log</td>
</tr>
<tr>
<td>/var/gpadmin/gpadminlogs/gpsegstop.py_idb*gpadmin_date.log</td>
<td>segment stop log</td>
</tr>
<tr>
<td>/var/gpdb/instance/datamaster/gpseg-1/pg_log/startup.log</td>
<td>instance start log</td>
</tr>
<tr>
<td>/var/gpdb/instance/datamaster/gpseg-1/gpperfmon/logs/gpmon.*.log</td>
<td>gpperfmon logs</td>
</tr>
<tr>
<td>/var/gpdb/instance/datamirror/gpseg-n/pg_log/*.csv</td>
<td>mirror segment logs</td>
</tr>
<tr>
<td>/var/gpdb/instance/dataprimary/gpseg-n/pg_log/*.csv</td>
<td>primary segment logs</td>
</tr>
<tr>
<td>/var/log/messages</td>
<td>Global Linux system messages</td>
</tr>
</tbody>
</table>

Use gplogfilter -t (--trouble) first to search the master log for messages beginning with ERROR:, FATAL:, or PANIC:. Messages beginning with WARNING may also provide useful information.
To search log files on the segment hosts, use the Greenplum `gplogfilter` utility with `gpssh` to connect to segment hosts from the master host. You can identify corresponding log entries in segment logs by the `statement_id`.

The `log_rotation_age` configuration parameter specifies when a new log file is automatically created while a database instance is running. By default, a new log file is created every day.
Loading Data

Description of the different ways to add data to Greenplum Database.

**INSERT Statement with Column Values**

A singleton `INSERT` statement with values adds a single row to a table. The row flows through the master and is distributed to a segment. This is the slowest method and is not suitable for loading large amounts of data.

**COPY Statement**

The PostgreSQL `COPY` statement copies data from an external file into a database table. It can insert multiple rows more efficiently than an `INSERT` statement, but the rows are still passed through the master. All of the data is copied in one command; it is not a parallel process.

Data input to the `COPY` command is from a file or the standard input. For example:

```
COPY table FROM '/data/mydata.csv' WITH CSV HEADER;
```

Use `COPY` to add relatively small sets of data, for example dimension tables with up to ten thousand rows, or one-time data loads.

Use `COPY` when scripting a process that loads small amounts of data, less than 10 thousand rows.

Since `COPY` is a single command, there is no need to disable autocommit when you use this method to populate a table.

You can run multiple concurrent `COPY` commands to improve performance.

**External Tables**

External tables provide access to data in sources outside of Greenplum Database. They can be accessed with `SELECT` statements and are commonly used with the Extract, Load, Transform (ELT) pattern, a variant of the Extract, Transform, Load (ETL) pattern that takes advantage of Greenplum Database's fast parallel data loading capability.

With ETL, data is extracted from its source, transformed outside of the database using external transformation tools, such as Informatica or Datastage, and then loaded into the database.

With ELT, Greenplum external tables provide access to data in external sources, which could be read-only files (for example, text, CSV, or XML files), Web servers, Hadoop file systems, executable OS programs, or the Greenplum `gpfdist` file server, described in the next section. External tables support SQL operations such as select, sort, and join so the data can be loaded and transformed simultaneously, or loaded into a load table and transformed in the database into target tables.

The external table is defined with a `CREATE EXTERNAL TABLE` statement, which has a `LOCATION` clause to define the location of the data and a `FORMAT` clause to define the formatting of the source data so that the system can parse the input data. Files use the `file:///` protocol, and must reside on a segment host in a location accessible by the Greenplum superuser. The data can be spread out among the segment hosts with no more than one file per primary segment on each host. The number of files listed in the `LOCATION` clause is the number of segments that will read the external table in parallel.

**External Tables with Gpfdist**

The fastest way to load large fact tables is to use external tables with `gpdist`. `gpdist` is a file server program using an HTTP protocol that serves external data files to Greenplum Database segments.
in parallel. A gpfdist instance can serve 200 MB/second and many gpfdist processes can run simultaneously, each serving up a portion of the data to be loaded. When you begin the load using a statement such as `INSERT INTO <table> SELECT * FROM <external_table>`, the INSERT statement is parsed by the master and distributed to the primary segments. The segments connect to the gpfdist servers and retrieve the data in parallel, parse and validate the data, calculate a hash from the distribution key data and, based on the hash key, send the row to its destination segment. By default, each gpfdist instance will accept up to 64 connections from segments. With many segments and gpfdist servers participating in the load, data can be loaded at very high rates.

Primary segments access external files in parallel when using gpfdist up to the value of `gp_external_max_segments`. When optimizing gpfdist performance, maximize the parallelism as the number of segments increase. Spread the data evenly across as many ETL nodes as possible. Split very large data files into equal parts and spread the data across as many file systems as possible.

Run two gpfdist instances per file system. gpfdist tends to be CPU bound on the segment nodes when loading. But if, for example, there are eight racks of segment nodes, there is lot of available CPU on the segments to drive more gpfdist processes. Run gpfdist on as many interfaces as possible. Be aware of bonded NICs and be sure to start enough gpfdist instances to work them.

It is important to keep the work even across all these resources. The load is as fast as the slowest node. Skew in the load file layout will cause the overall load to bottleneck on that resource.

The `gp_external_max_segs` configuration parameter controls the number of segments each gpfdist process serves. The default is 64. You can set a different value in the `postgresql.conf` configuration file on the master. Always keep `gp_external_max_segs` and the number of gpfdist processes an even factor; that is, the `gp_external_max_segs` value should be a multiple of the number of gpfdist processes. For example, if there are 12 segments and 4 gpfdist processes, the planner round robin the segment connections as follows:

| Segment 1 | gpfdist 1 |
| Segment 2 | gpfdist 2 |
| Segment 3 | gpfdist 3 |
| Segment 4 | gpfdist 4 |
| Segment 5 | gpfdist 1 |
| Segment 6 | gpfdist 2 |
| Segment 7 | gpfdist 3 |
| Segment 8 | gpfdist 4 |
| Segment 9 | gpfdist 1 |
| Segment 10 | gpfdist 2 |
| Segment 11 | gpfdist 3 |
| Segment 12 | gpfdist 4 |

Drop indexes before loading into existing tables and re-create the index after loading. Creating an index on pre-existing data is faster than updating it incrementally as each row is loaded.

Run `ANALYZE` on the table after loading. Disable automatic statistics collection during loading by setting `gp_autostats_mode` to `NONE`. Run `VACUUM` after load errors to recover space.

Performing small, high frequency data loads into heavily partitioned column-oriented tables can have a high impact on the system because of the number of physical files accessed per time interval.

**Gpload**

`gpload` is a data loading utility that acts as an interface to the Greenplum external table parallel loading feature.

Beware of using `gpload` as it can cause catalog bloat by creating and dropping external tables. Use `gpfdist` instead, since it provides the best performance.

`gpload` executes a load using a specification defined in a YAML-formatted control file. It performs the following operations:
• Invokes gpfdist processes
• Creates a temporary external table definition based on the source data defined
• Executes an INSERT, UPDATE, or MERGE operation to load the source data into the target table in the database
• Drops the temporary external table
• Cleans up gpfdist processes

The load is accomplished in a single transaction.

**Best Practices**

• Drop any indexes on an existing table before loading data and recreate the indexes after loading. Newly creating an index is faster than updating an index incrementally as each row is loaded.
• Disable automatic statistics collection during loading by setting the gp_autostats_mode configuration parameter to NONE.
• External tables are not intended for frequent or ad hoc access.
• External tables have no statistics to inform the optimizer. You can set rough estimates for the number of rows and disk pages for the external table in the pg_class system catalog with a statement like the following:

```
UPDATE pg_class SET reltuples=400000, relpages=400
WHERE relname='myexttable';
```
• When using gpfdist, maximize network bandwidth by running one gpfdist instance for each NIC on the ETL server. Divide the source data evenly between the gpfdist instances.
• When using gpload, run as many simultaneous gpload instances as resources allow. Take advantage of the CPU, memory, and networking resources available to increase the amount of data that can be transferred from ETL servers to the Greenplum Database.
• Use the SEGMENT REJECT LIMIT clause of the COPY statement to set a limit for the number or percentage of rows that can have errors before the COPY FROM command is aborted. The reject limit is per segment; when any one segment exceeds the limit, the command is aborted and no rows are added. Use the LOG ERRORS clause to save error rows. If a row has errors in the formatting—for example missing or extra values, or incorrect data types—Greenplum Database stores the error information and row internally. Use the \texttt{gp_read_error_log()} built-in SQL function to access this stored information.
• If the load has errors, run VACUUM on the table to recover space.
• After you load data into a table, run VACUUM on heap tables, including system catalogs, and ANALYZE on all tables. It is not necessary to run VACUUM on append-optimized tables. If the table is partitioned, you can vacuum and analyze just the partitions affected by the data load. These steps clean up any rows from aborted loads, deletes, or updates and update statistics for the table.
• Recheck for segment skew in the table after loading a large amount of data. You can use a query like the following to check for skew:

```
SELECT segment, reltuples
FROM pg_class
WHERE relname='myexttable';
```

• By default, gpfdist assumes a maximum record size of 32K. To load data records larger than 32K, you must increase the maximum row size parameter by specifying the \texttt{-m <bytes>} option on the gpfdist command line. If you use gpload, set the MAX_LINE_LENGTH parameter in the gpload control file.

**Note:** Integrations with Informatica Power Exchange are currently limited to the default 32K record length.

**Additional Information**

See the *Greenplum Database Reference Guide* for detailed instructions for loading data using gpfdist and gpload.
**Migrating Data with Gptransfer**

Information about the `gptransfer` migration utility, which transfers Greenplum Database metadata and data from one Greenplum database to another.

`gptransfer` enables you to migrate the entire contents of a database, or just selected tables, to another database. The source and destination databases may be in the same or a different cluster. `gptransfer` moves data in parallel across all the segments, using the `gpfdist` data loading utility to attain the highest transfer rates.

`gptransfer` handles the setup and execution of the data transfer. Participating clusters must already exist, have network access between all hosts in both clusters, and have certificate-authenticated ssh access between all hosts in both clusters.

The `gptransfer` interface includes options to transfer one or more full databases, or one or more database tables. A full database transfer includes the database schema, table data, indexes, views, roles, user-defined functions, and resource queues. Configuration files, including `postgres.conf` and `pg_hba.conf`, must be transferred manually by an administrator. Extensions installed in the database with `gppkg`, such as MADlib and programming language extensions, must be installed in the destination database by an administrator.

**What gptransfer Does**

`gptransfer` uses writable and readable external tables, the Greenplum `gpfdist` parallel data-loading utility, and named pipes to transfer data from the source database to the destination database. Segments on the source cluster select from the source database table and insert into a writable external table. Segments in the destination cluster select from a readable external table and insert into the destination database table. The writable and readable external tables are backed by named pipes on the source cluster’s segment hosts, and each named pipe has a `gpfdist` process serving the pipe’s output to the readable external table on the destination segments.

`gptransfer` orchestrates the process by processing the database objects to be transferred in batches. For each table to be transferred, it performs the following tasks:

- creates a writable external table in the source database
- creates a readable external table in the destination database
- creates named pipes and `gpfdist` processes on segment hosts in the source cluster
- executes a `SELECT INTO` statement in the source database to insert the source data into the writable external table
- executes a `SELECT INTO` statement in the destination database to insert the data from the readable external table into the destination table
- optionally validates the data by comparing row counts or MD5 hashes of the rows in the source and destination
- cleans up the external tables, named pipes, and `gpfdist` processes

**Prerequisites**

- The `gptransfer` utility can only be used with Greenplum Database, including the Dell EMC DCA appliance. Pivotal HAWQ is not supported as a source or destination.
- The source and destination Greenplum clusters must both be version 4.2 or higher.
- At least one Greenplum instance must include the `gptransfer` utility in its distribution. The utility is included with Greenplum Database version 4.2.8.1 and higher and 4.3.2.0 and higher. If neither the source or destination includes `gptransfer`, you must upgrade one of the clusters to use `gptransfer`.
- The `gptransfer` utility can be run from the cluster with the source or destination database.
• The number of segments in the destination cluster must be greater than or equal to the number of hosts in the source cluster. The number of segments in the destination may be smaller than the number of segments in the source, but the data will transfer at a slower rate.
• The segment hosts in both clusters must have network connectivity with each other.
• Every host in both clusters must be able to connect to every other host with certificate-authenticated SSH. You can use the gpssh_exkeys utility to exchange public keys between the hosts of both clusters.

Fast Mode and Slow Mode

gptransfer sets up data transfer using the gpfdist parallel file serving utility, which serves the data evenly to the destination segments. Running more gpfdist processes increases the parallelism and the data transfer rate. When the destination cluster has the same or a greater number of segments than the source cluster, gptransfer sets up one named pipe and one gpfdist process for each source segment. This is the configuration for optimal data transfer rates and is called fast mode.

The configuration of the input end of the named pipes differs when there are fewer segments in the destination cluster than in the source cluster. gptransfer handles this alternative setup automatically. The difference in configuration means that transferring data into a destination cluster with fewer segments than the source cluster is not as fast as transferring into a destination cluster of the same or greater size. It is called slow mode because there are fewer gpfdist processes serving the data to the destination cluster, although the transfer is still quite fast with one gpfdist per segment host.

When the destination cluster is smaller than the source cluster, there is one named pipe per segment host and all segments on the host send their data through it. The segments on the source host write their data to a writable external web table connected to a gpfdist process on the input end of the named pipe. This consolidates the table data into a single named pipe. A gpfdist process on the output of the named pipe serves the consolidated data to the destination cluster.

On the destination side, gptransfer defines a readable external table with the gpfdist server on the source host as input and selects from the readable external table into the destination table. The data is distributed evenly to all the segments in the destination cluster.

Batch Size and Sub-batch Size

The degree of parallelism of a gptransfer execution is determined by two command-line options: --batch-size and --sub-batch-size. The --batch-size option specifies the number of tables to transfer in a batch. The default batch size is 2, which means that two table transfers are in process at any time. The minimum batch size is 1 and the maximum is 10. The --sub-batch-size parameter specifies the maximum number of parallel sub-processes to start to do the work of transferring a table. The default is 25 and the maximum is 50. The product of the batch size and sub-batch size is the amount of parallelism. If set to the defaults, for example, gptransfer can perform 50 concurrent tasks. Each thread is a Python process and consumes memory, so setting these values too high can cause a Python Out of Memory error. For this reason, the batch sizes should be tuned for your environment.

Preparing Hosts for gptransfer

When you install a Greenplum Database cluster, you set up all the master and segment hosts so that the Greenplum Database administrative user (gpadmin) can connect with ssh from every host in the cluster to any other host in the cluster without providing a password. The gptransfer utility requires this capability between every host in the source and destination clusters. First, ensure that the clusters have network connectivity with each other. Then, prepare a hosts file containing a list of all the hosts in both clusters, and use the gpssh-exkeys utility to exchange keys. See the reference for gpssh-exkeys in the Greenplum Database Utility Guide.

The host map file is a text file that lists the segment hosts in the source cluster. It is used to enable communication between the hosts in Greenplum clusters. The file is specified on the gptransfer command line with the --source-map-file=host_map_file command option. It is a required option when using gptransfer to copy data between two separate Greenplum clusters.
The file contains a list in the following format:

```
host1_name,host1_ip_addr
host2_name,host2_ipaddr
...
```

The file uses IP addresses instead of host names to avoid any problems with name resolution between the clusters.

**Limitations**

gptransfer transfers data from user databases only; the postgres, template0, and template1 databases cannot be transferred. Administrators must transfer configuration files manually and install extensions into the destination database with gppkg.

The destination cluster must have at least as many segments as the source cluster has segment hosts. Transferring data to a smaller cluster is not as fast as transferring data to a larger cluster.

Transferring small or empty tables can be unexpectedly slow. There is significant fixed overhead in setting up external tables and communications processes for parallel data loading between segments that occurs whether or not there is actual data to transfer.

When transferring data between databases, you can run only one instance of gptransfer at a time. Running multiple, concurrent instances of gptransfer is not supported.

**Full Mode and Table Mode**

When run with the `--full` option, gptransfer copies all tables, views, indexes, roles, user-defined functions, and resource queues in the source database to the destination database. Databases to be transferred must not already exist on the destination cluster. If gptransfer finds the database on the destination it fails with a message like the following:

```
[ERROR]:- gptransfer: error: --full option specified but tables exist on destination system
```

To copy tables individually, specify the tables using either the `-t` command-line option (one option per table) or by using the `-f` command-line option to specify a file containing a list of tables to transfer. Tables are specified in the fully-qualified format `database.schema.table`. The table definition, indexes, and table data are copied. The database must already exist on the destination cluster.

By default, gptransfer fails if you attempt to transfer a table that already exists in the destination database:

```
[INFO]:-Validating transfer table set...
[CRITICAL]:- gptransfer failed. (Reason='Table database.schema.table exists in database database .') exiting...
```

Override this behavior with the `--skip-existing`, `--truncate`, or `--drop` options.

The following table shows the objects that are copied in full mode and table mode.

<table>
<thead>
<tr>
<th>Object</th>
<th>Full Mode</th>
<th>Table Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Indexes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Roles</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Functions</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Resource Queues</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
The **--full** option and the **--schema-only** option can be used together if you want to copy a database in phases, for example, during scheduled periods of downtime or low activity. Run `gptransfer --full --schema-only ...` to create the full database schema on the destination cluster, but with no data. You can then transfer the tables in stages during scheduled down times or periods of low activity. Be sure to include the **--truncate** or **--drop** option when you later transfer tables to prevent the transfer from failing because the table already exists at the destination.

**Locking**

The **-x** option enables table locking. An exclusive lock is placed on the source table until the copy and validation, if requested, are complete.

**Validation**

By default, `gptransfer` does not validate the data transferred. You can request validation using the **--validate=type** option. The validation type can be one of the following:

- **count** – Compares the row counts for the tables in the source and destination databases.
- **md5** – Sorts tables on both source and destination, and then performs a row-by-row comparison of the MD5 hashes of the sorted rows.

If the database is accessible during the transfer, be sure to add the **-x** option to lock the table. Otherwise, the table could be modified during the transfer, causing validation to fail.

**Failed Transfers**

A failure on a table does not end the `gptransfer` job. When a transfer fails, `gptransfer` displays an error message and adds the table name to a failed transfers file. At the end of the `gptransfer` session, `gptransfer` writes a message telling you there were failures, and providing the name of the failed transfer file. For example:

```
[WARNING]:-Some tables failed to transfer. A list of these tables
[WARNING]:-has been written to the file
   failed transfer tables 20140808 101813.txt
[WARNING]:-This file can be used with the -f option to continue
```

The failed transfers file is in the format required by the **-f** option, so you can use it to start a new `gptransfer` session to retry the failed transfers.

**Best Practices**

`gptransfer` creates a configuration that allows transferring large amounts of data at very high rates. For small or empty tables, however, the `gptransfer` set up and clean up are too expensive. The best practice is to use `gptransfer` for large tables and to use other methods for copying smaller tables.

1. Before you begin to transfer data, replicate the schema or schemas from the source cluster to the destination cluster. Options for copying the schema include:
   - Use the `gpsd` (Greenplum Statistics Dump) support utility. This method includes statistics, so be sure to run `ANALYZE` after creating the schema on the destination cluster.
   - Use the PostgreSQL `pg_dump` or `pg_dumpall` utility with the **--schema-only** option.
   - DDL scripts, or any other method for recreating schema in the destination database.
2. Divide the non-empty tables to be transferred into large and small categories, using criteria of your own choice. For example, you could decide large tables have more than one million rows or a raw data size greater than 1GB.

3. Transfer data for small tables using the SQL COPY command. This eliminates the warm-up/cool-down time each table incurs when using the gptransfer utility.
   - Optionally, write or reuse existing shell scripts to loop through a list of table names to copy with the COPY command.

4. Use gptransfer to transfer the large table data in batches of tables.
   - It is best to transfer to the same size cluster or to a larger cluster so that gptransfer runs in fast mode.
   - If any indexes exist, drop them before starting the transfer process.
   - Use the gptransfer table (-t) or file (-f) options to execute the migration in batches of tables. Do not run gptransfer using the full mode; the schema and smaller tables have already been transferred.
   - Perform test runs of the gptransfer process before the production migration. This ensures tables can be transferred successfully. You can experiment with the --batch-size and --sub-batch-size options to obtain maximum parallelism. Determine proper batching of tables for iterative gptransfer runs.
   - Include the --skip-existing option because the schema already exists on the destination cluster.
   - Use only fully qualified table names. Be aware that periods (.), whitespace, quotes ('), and double quotes (") in table names may cause problems.
   - If you decide to use the --validation option to validate the data after transfer, be sure to also use the -x option to place an exclusive lock on the source table.

5. After all tables are transferred, perform the following tasks:
   - Check for and correct any failed transfers.
   - Recreate the indexes that were dropped before the transfer.
   - Ensure any roles, functions, and resource queues are created in the destination database. These objects are not transferred when you use the gptransfer -t option.
   - Copy the postgres.conf and pg_hba.conf configuration files from the source to the destination cluster.
   - Install needed extensions in the destination database with gppkg.
Security

Best practices to ensure the highest level of system security.

Basic Security Best Practices

- Secure the `gpadmin` system user. Greenplum requires a UNIX user id to install and initialize the Greenplum Database system. This system user is referred to as `gpadmin` in the Greenplum documentation. The `gpadmin` user is the default database superuser in Greenplum Database, as well as the file system owner of the Greenplum installation and its underlying data files. The default administrator account is fundamental to the design of Greenplum Database. The system cannot run without it, and there is no way to limit the access of the `gpadmin` user id. This `gpadmin` user can bypass all security features of Greenplum Database. Anyone who logs on to a Greenplum host with this user id can read, alter, or delete any data, including system catalog data and database access rights. Therefore, it is very important to secure the `gpadmin` user id and only allow essential system administrators access to it. Administrators should only log in to Greenplum as `gpadmin` when performing certain system maintenance tasks (such as upgrade or expansion). Database users should never log on as `gpadmin`, and ETL or production workloads should never run as `gpadmin`.

- Assign a distinct role to each user who logs in. For logging and auditing purposes, each user who is allowed to log in to Greenplum Database should be given their own database role. For applications or web services, consider creating a distinct role for each application or service. See "Creating New Roles (Users)" in the Greenplum Database Administrator Guide.

- Use groups to manage access privileges. See "Creating Groups (Role Membership)" in the Greenplum Database Administrator Guide.

- Limit users who have the `SUPERUSER` role attribute. Roles that are superusers bypass all access privilege checks in Greenplum Database, as well as resource queuing. Only system administrators should be given superuser rights. See "Altering Role Attributes" in the Greenplum Database Administrator Guide.

Password Strength Guidelines

To protect the network from intrusion, system administrators should verify the passwords used within an organization are strong ones. The following recommendations can strengthen a password:

- Minimum password length recommendation: At least 9 characters. MD5 passwords should be 15 characters or longer.
- Mix upper and lower case letters.
- Mix letters and numbers.
- Include non-alphanumeric characters.
- Pick a password you can remember.

The following are recommendations for password cracker software that you can use to determine the strength of a password.

- John The Ripper. A fast and flexible password cracking program. It allows the use of multiple word lists and is capable of brute-force password cracking. It is available online at [http://www.openwall.com/john/](http://www.openwall.com/john/).

- Crack. Perhaps the most well-known password cracking software, Crack is also very fast, though not as easy to use as John The Ripper. It can be found online at [http://www.crypticide.com/alecm/security/crack/c50-faq.html](http://www.crypticide.com/alecm/security/crack/c50-faq.html).

The security of the entire system depends on the strength of the root password. This password should be at least 12 characters long and include a mix of capitalized letters, lowercase letters, special characters, and numbers. It should not be based on any dictionary word.

Password expiration parameters should be configured.
Ensure the following line exists within the file `/etc/libuser.conf` under the `[import]` section.

```bash
login_defs = /etc/login.defs
```

Ensure no lines in the `[userdefaults]` section begin with the following text, as these words override settings from `/etc/login.defs`:

- LU_SHADOWMAX
- LU_SHADOWMIN
- LU_SHADOWWARNING

Ensure the following command produces no output. Any accounts listed by running this command should be locked.

```bash
grep "^+:" /etc/passwd /etc/shadow /etc/group
```

Note: We strongly recommend that customers change their passwords after initial setup.

```bash
cd /etc
chown root:root passwd shadow group gshadow
chmod 644 passwd group
chmod 400 shadow gshadow
```

Find all the files that are world-writable and that do not have their sticky bits set.

```bash
find / -xdev -type d \( -perm -0002 -a ! -perm -1000 \) -print
```

Set the sticky bit (`# chmod +t {dir}`) for all the directories that result from running the previous command.

Find all the files that are world-writable and fix each file listed.

```bash
find / -xdev -type f -perm -0002 -print
```

Set the right permissions (`# chmod o-w {file}`) for all the files generated by running the aforementioned command.

Find all the files that do not belong to a valid user or group and either assign an owner or remove the file, as appropriate.

```bash
find / -xdev \( -nouser -o nogroup \) -print
```

Find all the directories that are world-writable and ensure they are owned by either root or a system account (assuming only system accounts have a User ID lower than 500). If the command generates any output, verify the assignment is correct or reassign it to root.

```bash
find / -xdev -type d -perm -0002 -uid +500 -print
```

Authentication settings such as password quality, password expiration policy, password reuse, password retry attempts, and more can be configured using the Pluggable Authentication Modules (PAM) framework. PAM looks in the directory `/etc/pam.d` for application-specific configuration information. Running `authconfig` or `system-config-authentication` will re-write the PAM configuration files, destroying any manually made changes and replacing them with system defaults.
The default pam_cracklib PAM module provides strength checking for passwords. To configure pam_cracklib to require at least one uppercase character, lowercase character, digit, and special character, as recommended by the U.S. Department of Defense guidelines, edit the file /etc/pam.d/system-auth to include the following parameters in the line corresponding to password requisite pam_cracklib.so try_first_pass.

- retry=3:
  - dcredit=-1. Require at least one digit
  - ucredit=-1. Require at least one upper case character
  - ocredit=-1. Require at least one special character
  - lcredit=-1. Require at least one lower case character

For example:

```
password required pam_cracklib.so try_first_pass retry=3\minlen=14
dcredit=-1 ucredit=-1 ocredit=-1 lcredit=-1
```

These parameters can be set to reflect your security policy requirements. Note that the password restrictions are not applicable to the root password.

The pam_tally2 PAM module provides the capability to lock out user accounts after a specified number of failed login attempts. To enforce password lockout, edit the file /etc/pam.d/system-auth to include the following lines:

- The first of the auth lines should include:
  ```
  auth required pam_tally2.so deny=5 onerr=fail unlock_time=900
  ```
- The first of the account lines should include:
  ```
  account required pam_tally2.so
  ```

Here, the deny parameter is set to limit the number of retries to 5 and the unlock_time has been set to 900 seconds to keep the account locked for 900 seconds before it is unlocked. These parameters may be configured appropriately to reflect your security policy requirements. A locked account can be manually unlocked using the pam_tally2 utility:

```
/sbin/pam_tally2 --user {username} -reset
```

You can use PAM to limit the reuse of recent passwords. The remember option for the pam_unix module can be set to remember the recent passwords and prevent their reuse. To accomplish this, edit the appropriate line in /etc/pam.d/system-auth to include the remember option.

For example:

```
password sufficient pam_unix.so [ ... existing_options ...]
remember=5
```

You can set the number of previous passwords to remember to appropriately reflect your security policy requirements.

```
cd /etc
chown root:root passwd shadow group gshadow
chmod 644 passwd group
chmod 400 shadow gshadow
```
Encrypting Data and Database Connections

Best practices for implementing encryption and managing keys.

Encryption can be used to protect data in a Greenplum Database system in the following ways:

• Connections between clients and the master database can be encrypted with SSL. This is enabled by setting the `ssl` server configuration parameter to `on` and editing the `pg_hba.conf` file. See "Encrypting Client/Server Connections" in the Greenplum Database Administrator Guide for information about enabling SSL in Greenplum Database.

• Greenplum Database 4.2.1 and above allow SSL encryption of data in transit between the Greenplum parallel file distribution server, `gpfdist`, and segment hosts. See Encrypting gpfdist Connections for more information.

• Network communications between hosts in the Greenplum Database cluster can be encrypted using IPsec. An authenticated, encrypted VPN is established between every pair of hosts in the cluster. Check your operating system documentation for IPsec support, or consider a third-party solution such as that provided by Zettaset.

• The `pgcrypto` module of encryption/decryption functions protects data at rest in the database. Encryption at the column level protects sensitive information, such as passwords, Social Security numbers, or credit card numbers. See Encrypting Data in Tables using PGP for an example.

Best Practices

• Encryption ensures that data can be seen only by users who have the key required to decrypt the data.

• Encrypting and decrypting data has a performance cost; only encrypt data that requires encryption.

• Do performance testing before implementing any encryption solution in a production system.

• Server certificates in a production Greenplum Database system should be signed by a certificate authority (CA) so that clients can authenticate the server. The CA may be local if all clients are local to the organization.

• Client connections to Greenplum Database should use SSL encryption whenever the connection goes through an insecure link.

• A symmetric encryption scheme, where the same key is used to both encrypt and decrypt, has better performance than an asymmetric scheme and should be used when the key can be shared safely.

• Use functions from the `pgcrypto` module to encrypt data on disk. The data is encrypted and decrypted in the database process, so it is important to secure the client connection with SSL to avoid transmitting unencrypted data.

• Use the `gpfdists` protocol to secure ETL data as it is loaded into or unloaded from the database. See Encrypting gpfdist Connections.

Key Management

Whether you are using symmetric (single private key) or asymmetric (public and private key) cryptography, it is important to store the master or private key securely. There are many options for storing encryption keys, for example, on a file system, key vault, encrypted USB, trusted platform module (TPM), or hardware security module (HSM).

Consider the following questions when planning for key management:

• Where will the keys be stored?

• When should keys expire?

• How are keys protected?

• How are keys accessed?

• How can keys be recovered and revoked?
The Open Web Application Security Project (OWASP) provides a very comprehensive guide to securing encryption keys.

## Encrypting Data at Rest with pgcrypto

The pgcrypto module for Greenplum Database provides functions for encrypting data at rest in the database. Administrators can encrypt columns with sensitive information, such as social security numbers or credit card numbers, to provide an extra layer of protection. Database data stored in encrypted form cannot be read by users who do not have the encryption key, and the data cannot be read directly from disk.

pgcrypto is installed by default when you install Greenplum Database. You must explicitly enable pgcrypto in each database in which you want to use the module.

pgcrypto allows PGP encryption using symmetric and asymmetric encryption. Symmetric encryption encrypts and decrypts data using the same key and is faster than asymmetric encryption. It is the preferred method in an environment where exchanging secret keys is not an issue. With asymmetric encryption, a public key is used to encrypt data and a private key is used to decrypt data. This is slower than symmetric encryption and it requires a stronger key.

Using pgcrypto always comes at the cost of performance and maintainability. It is important to use encryption only with the data that requires it. Also, keep in mind that you cannot search encrypted data by indexing the data.

Before you implement in-database encryption, consider the following PGP limitations.

- No support for signing. That also means that it is not checked whether the encryption sub-key belongs to the master key.
- No support for encryption key as master key. This practice is generally discouraged, so this limitation should not be a problem.
- No support for several subkeys. This may seem like a problem, as this is common practice. On the other hand, you should not use your regular GPG/PGP keys with pgcrypto, but create new ones, as the usage scenario is rather different.

Greenplum Database is compiled with zlib by default; this allows PGP encryption functions to compress data before encrypting. When compiled with OpenSSL, more algorithms will be available.

Because pgcrypto functions run inside the database server, the data and passwords move between pgcrypto and the client application in clear-text. For optimal security, you should connect locally or use SSL connections and you should trust both the system and database administrators.

pgcrypto configures itself according to the findings of the main PostgreSQL configure script.

When compiled with zlib, pgcrypto encryption functions are able to compress data before encrypting.

Pgcrypto, has various levels of encryption ranging from basic to advanced built-in functions. The following table shows the supported encryption algorithms.

### Table 75: Pgcrypto Supported Encryption Functions

<table>
<thead>
<tr>
<th>Value</th>
<th>Functionality</th>
<th>Built-in</th>
<th>With OpenSSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD5</td>
<td></td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>SHA1</td>
<td></td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>SHA224/256/384/512</td>
<td>yes</td>
<td></td>
<td>yes&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>6</sup> SHA2 algorithms were added to OpenSSL in version 0.9.8. For older versions, pgcrypto will use built-in code
<table>
<thead>
<tr>
<th>Value Functionality</th>
<th>Built-in</th>
<th>With OpenSSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other digest algorithms</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Blowfish</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>AES</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>DES/3DES/CAST5</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Raw Encryption</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>PGP Symmetric-Key</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>PGP Public Key</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

### Creating PGP Keys

To use PGP asymmetric encryption in Greenplum Database, you must first create public and private keys and install them.

This section assumes you are installing Greenplum Database on a Linux machine with the Gnu Privacy Guard (gpg) command line tool. Pivotal recommends using the latest version of GPG to create keys.

Download and install Gnu Privacy Guard (GPG) for your operating system from [https://www.gnupg.org/download/](https://www.gnupg.org/download/). On the GnuPG website you will find installers for popular Linux distributions and links for Windows and Mac OS X installers.

1. As root, execute the following command and choose option 1 from the menu:

   ```bash
   # gpg --gen-key
   gpg (GnuPG) 2.0.14; Copyright (C) 2009 Free Software Foundation, Inc.
   This is free software: you are free to change and redistribute it.
   There is NO WARRANTY, to the extent permitted by law.
   gpg: directory `/root/.gnupg' created
   gpg: new configuration file `/root/.gnupg/gpg.conf' created
   gpg: WARNING: options in `/root/.gnupg/gpg.conf' are not yet active during this run
   gpg: keyring `/root/.gnupg/secring.gpg' created
   gpg: keyring `/root/.gnupg/pubring.gpg' created
   Please select what kind of key you want:
   (1) RSA and RSA (default)
   (2) DSA and Elgamal
   (3) DSA (sign only)
   (4) RSA (sign only)
   Your selection? 1
   ```

2. Respond to the prompts and follow the instructions, as shown in this example:

   ```bash
   RSA keys may be between 1024 and 4096 bits long.
   What keysize do you want? (2048) Press enter to accept default key size
   Requested keysize is 2048 bits
   Please specify how long the key should be valid.
   0 = key does not expire
   <n> = key expires in n days
   <n>w = key expires in n weeks
   <n>m = key expires in n months
   <n>y = key expires in n years
   Key is valid for? (0) 365
   ```

---

7 Any digest algorithm OpenSSL supports is automatically picked up. This is not possible with ciphers, which need to be supported explicitly.

8 AES is included in OpenSSL since version 0.9.7. For older versions, pgcrypto will use built-in code.
Key expires at Wed 13 Jan 2016 10:35:39 AM PST
Is this correct? (y/N) **y**

GnuPG needs to construct a user ID to identify your key.

Real name: **John Doe**
Email address: **jdoe@email.com**
Comment:
You selected this USER-ID:
"John Doe <jdoe@email.com>"

Change (N)ame, (C)omment, (E)mail or (O)kay/(Q)uit? **O**
You need a Passphrase to protect your secret key.
(For this demo the passphrase is blank.)
can't connect to `/root/.gnupg/S.gpg-agent': No such file or directory
You don't want a passphrase - this is probably a *bad* idea!
I will do it anyway. You can change your passphrase at any time,
using this program with the option "--edit-key".

We need to generate a lot of random bytes. It is a good idea to perform
some other action (type on the keyboard, move the mouse, utilize the
disks) during the prime generation; this gives the random number
generator a better chance to gain enough entropy.
We need to generate a lot of random bytes. It is a good idea to perform
some other action (type on the keyboard, move the mouse, utilize the
disks) during the prime generation; this gives the random number
generator a better chance to gain enough entropy.
gpg: /root/.gnupg/trustdb.gpg: trustdb created
gpg: key 2027CC30 marked as ultimately trusted
public and secret key created and signed.
gpg: checking the trustdb
3 marginal(s) needed, 1 complete(s) needed, PGP trust model
gpg: depth: 0 valid: 1 signed: 0 trust: 0-, 0q, 0n, 0m, 0f, 1u
gpg: next trustdb check due at 2016-01-13
pub  2048R/2027CC30 2015-01-13 [expires: 2016-01-13]
    Key fingerprint = 7EDA 6AD0 F5E0 400F 4D45   3259 077D 725E 2027
    CC30
    uid                  John Doe <jdoe@email.com>
sub  2048R/4FD2EFBB 2015-01-13 [expires: 2016-01-13]

3. List the PGP keys by entering the following command:

    gpg --list-secret-keys
      /root/.gnupg/secring.gpg
      ------------------------
    sec  2048R/2027CC30 2015-01-13 [expires: 2016-01-13]
    uid                  John Doe <jdoe@email.com>
    ssb  2048R/4FD2EFBB 2015-01-13

    2027CC30 is the public key and will be used to encrypt data in the database. 4FD2EFBB is the private
    (secret) key and will be used to decrypt data.

4. Export the keys using the following commands:

    # gpg -a --export 4FD2EFBB > public.key
    # gpg -a --export-secret-keys 2027CC30 > secret.key

See the **pgcrypto** documentation for more information about PGP encryption functions.
Encrypting Data in Tables using PGP

This section shows how to encrypt data inserted into a column using the PGP keys you generated.

1. Dump the contents of the `public.key` file and then copy it to the clipboard:

```bash
# cat public.key
-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)
mQENBF5ZfoBCADnWqv1k1C36Kfcwd3Kpm/dijPfRyyEywb6qKyA05jtWixZTh
2Hslsojsp6L10cSkIqM9LaNcez2HrHbuvGkJG9d9texg2nSL9Admynk/yX
R5syvK5g+qcdWuvy29g00omeyjhc3n+kkbRTEMuM3flbMs8sh0zwMvstCUVmHU/V

...WH+N2lasoUaoJjb2kQGhLOnFbJuevkyBYlRz+hi/+8rJkc20jQkmmK8HkK8qb5x/
HMUC55H0q2qQAy0BpnJHg0O4Q56p3G2/7Dbe55WJ6K1urFy5lsNlGWE8pvqvEx
/UVZB+dYqCwDvX0nnBu1KNCmk2AkeEcF3Yo1iCxm0dOxhF0v9AMkJjojDyC65KJCi
Pv2M1kFS2fK0Ag1R3lpMa8zDEt14w3vckPQNrQNNyyUtjf6zoCxx
=X8J3
-----END PGP PUBLIC KEY BLOCK-----
```

2. Create a table called `userssn` and insert some sensitive data, social security numbers for Bob and Alice, in this example. Paste the public.key contents after "dearmor(".

```sql
CREATE TABLE userssn (ssn_id SERIAL PRIMARY KEY, username varchar(100), ssn bytea);

INSERT INTO userssn(username, ssn)
SELECT robotccs.username, pgp_pub_encrypt(robotccs.ssn, keys.pubkey) AS ssn
FROM (
VALUES ('Alice', '123-45-6788'), ('Bob', '123-45-6799'))
AS robotccs(username, ssn)
CROSS JOIN (SELECT dearmor('-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)
mQENBF5ZfoBCADnWqv1k1C36Kfcwd3Kpm/dijPfRyyEywb6qKyA05jtWixZTh
2Hslsojsp6L10cSkIqM9LaNcez2HrHbuvGkJG9d9texg2nSL9Admynk/yX
R5syvK5g+qcdWuvy29g00omeyjhc3n+kkbRTEMuM3flbMs8sh0zwMvstCUVmHU/V

...WH+N2lasoUaoJjb2kQGhLOnFbJuevkyBYlRz+hi/+8rJkc20jQkmmK8HkK8qb5x/
HMUC55H0q2qQAy0BpnJHg0O4Q56p3G2/7Dbe55WJ6K1urFy5lsNlGWE8pvqvEx
/UVZB+dYqCwDvX0nnBu1KNCmk2AkeEcF3Yo1iCxm0dOxhF0v9AMkJjojDyC65KJCi
Pv2M1kFS2fK0Ag1R3lpMa8zDEt14w3vckPQNrQNNyyUtjf6zoCxx
=X8J3
-----END PGP PUBLIC KEY BLOCK-----' AS pubkey) AS keys;
```

3. Verify that the `ssn` column is encrypted.

```sql
test_db=# select * from userssn;
ssn_id | 1
username | Alice
ssn     | 301\300L\003\235M\_0\322\357\273\010\000\272\227\010\341\216\360\217C\020\261\_367
\[\237\034\313\C\354d\201\330\275\021\375\232\f\015\004\242\231\222\225\032\271\005\035\277\021\375X\232\304\305/\340\334\013\031\325\344\_\362\0
\[\237\336\303\340\377\011\275\301\MY\334\343\245\244\372y\257S\374\230\346\277\373\W\346\230\276\017\f\226Q\307\012\326\364\000\326\005\E\364W\252=zz\010\004\343Y\237\257i\032\365\0v0\362\327\350\0
```
4. Extract the public.key ID from the database:

```sql
SELECT pgp_key_id(dearmor('-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)
mQENBFS12f0BCADnW8Qvk1V1C36Kfcwd3Kpm/dijPfRyyEwB6PqKya05jtWixZH
2HislojSP6LIcSKiqMU9LA1ncce2hRhBuVgK1SG9d9texg2nnSL9Admqik/yX
R5syVKG+qcDWuy29go0Oomnyhj3cn+kkkRTEmuM3f1bMs8shOwzMvstCVMuHU/V
... 
WH+N2lasoUaoJjb2kQGHOlONbJuevkyBy1rZ+h/4+ SrKc20jQkmrK8Hkk8q5b5x/
HMUC55Hoq2qQA0BpnJHGQOQ456p3G27Dbek5WJ6KUrFyF51sN1GWE8pvqEx
/UUZB+YqCtwtXOnnBiKNCmK2AKeEcFK3Yo1lCxomDFV89AKjjojDyc65KJC1
Pv2MikPSfKOAg1R3lpMa8zdET14w3vckPQNRQnYuU7fj6ZoCv
=X2B3
-----END PGP PUBLIC KEY BLOCK-----'));
p gp_key_id | 9D4D255F4FD2EFBB
```

This shows that the PGP key ID used to encrypt the `ssn` column is `9D4D255F4FD2EFBB`. It is recommended to perform this step whenever a new key is created and then store the ID for tracking.
You can use this key to see which key pair was used to encrypt the data:

```
SELECT username, pgp_key_id(ssn) As key_used
FROM userssn;
```

<table>
<thead>
<tr>
<th>username</th>
<th>key_used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bob</td>
<td>9D4D255F4FD2EFBB</td>
</tr>
<tr>
<td>Alice</td>
<td>9D4D255F4FD2EFBB</td>
</tr>
</tbody>
</table>

Note: Different keys may have the same ID. This is rare, but is a normal event. The client application should try to decrypt with each one to see which fits — like handling `ANYKEY`. See `pgp_key_id()` in the pgcrypto documentation.

5. Decrypt the data using the private key.

```
SELECT username, pgp_pub_decrypt(ssn, keys.privkey) AS decrypted_ssn FROM userssn
CROSS JOIN (SELECT dearmor('-----BEGIN PGP PRIVATE KEY BLOCK-----
Version: GnuPG v2.0.14 (GNU/Linux)
lQOYBFS12f0BCADNW8qkv1V1C36Kfcwd3Kp/mjDFprYywEb6PqkyA05jtWixZTh
2HislojSP6I10cSkiqM9U9ALiaceehRIBhuVgKLGSgd9txeq2nnLS9Admqjik/yX
R5syVKG+qcDluyvZGB900OMMe3f1bMs8shOWzMvstCVUmuHU/v
vg5rjJae8uPyUYsDJC74I6w7S0H3rIeC7IffLxYyxd4V213td44b17/ihq8UvN2
/Hbsjii2ym7tw3jwsXAx2gp9nsWqoYQdy/o9nMqBEG1li9G6ZFnE6Pwbnhn
/ic8SM01IKS/GAR1t6Hoc1ZlHF8Kecavruv1bknjvABEBAAEAB/wNfjvlPbfjJjm1/j
XwUNn+1i4v2ur7zC9FPGf67lvqyc7JzUqcvvz2b8l6mu165xEU1ZYy7BNA8
fe0paM4WMy+x94c2z2pBpgawq延伸NN33AQY4r1BTqvqQYw/kmpbd87I7jw2idZNNm
02iSa3q41Rto02xz1JhrkFp67ftmzOH0vlrSb0WolHVHeMY7tCwmdPe99HbQeDiPr
n9CL1UqBn4/aCTTCCICLWaJRE2n0zXAsnixTFTC1v+9n09yEcMKwV9nFIIpHyAM
OPFnuz/D1crhUNb5156yUM5dZqvUVnnezktxqrOENXsm0fgMCpsqHPqQoUMzb7c
6uyBBDASCXHFpc/VpV7mm5yGrNOR2jR2rUj9+jpo2Zd2gjkt5g/xIKR1kb4uoQ1
emu27wr9v9DEx7msOnvDq5flburtQ4d0jID1clHmeSRQ2luErblB7V5J3htIb1pJpn
4Jx6SWRXUPJGkXGB17u0uB0H1Wlj7MW2P711ao+MLEA9jAjQwQa+s9BKL4yA2
r5nE72gsCBCCLowk0rn4Dv11bctwYDMpmy2oArkjK0TMG6rCJXrfF6lqini8/w/L
/gnZtniMch35MCq/M2za/bN4VMvPE11wzvKX7JlsQyqY/A7ac7B7DHIKZriEXW
M50AOJhMmk1W1Q1RRNw3cyYi8w3Q7x4OAE/l5f4FvVpap3sCid65AaAM4UO2R3
tIsUnVemiMwDnvXxwK8A57vReeV5uyZ4B8hvCuqj1C7gea LHxt1S8fR3cJC0s7n
Bf+iHC/VNEv4k4uDb410qNHJYYy1fBwC+cnn/EnXCZ2YIQINia14M6VqC/RfFh4
nwkzt/820/HH1ricja2O2Xr1n02X0nA2V5QCVrtYLtSrmnVbT6JAT4eEWEC
ACgfPAlS12f0CGwMFCQHHm4AGCwk1BmC84BHUKaH4BagAhAAaAOeJEd9
cl14j3w8bwvhf/5lyVsPkJl0wLNxVxt1iyb7BfrvU5y2k/PYyZoses9UpdC3MrK
8gAm9bx55k0q2UxiousLC6F0p EW4UwgmGYf8JRoc3oeezTkmCBW811buB0ugetVx
opdXLuPGCE7hVWqeH9cStiTlxGov1mAju07AaoccXLbyu2h9f5vLoQdKzcOYH
h5rgXaQoQT09teFpe9b9T1iwCn34WSCSU5P0DGOuA0anjD2BKE88q7v4hfE1EZV
zhB8PajR62CSXSHFKpqBg1nXnT0k45NbXAdn4eUTXP5npi46gq0Ap9QUGsGqyB1X
OTT2lZGquhCRMvAMCv7Te9v02JfNbenAd5gEvLV1/QEIANaFpD+q8MCADCoi
pmBlBF/Jrtq3sUb04B1tCaydzyf20Usf/7zo2u99G1AqrlWd8EaqLc1/xmfcj
izyUam62AzfZFXCgnH5YsidTTMDJTzd25Pwe0jwCGW/2/LZu4wzOFF2kpiy9R9Dw6e5
MNLJrSp4h5s0z2apKd04Ex8304mYJyan/reIdDCWUt4Itv3hSKCpke6LcwSx7+7
liopz+aNmOCYywfi4hr3UUMP70/vbbeFwQz2bV12H0urHgpcCZla+pzzbEks16
j7q7v9G9kgZC1tCwzLiJit1lKjoksV9h9Ov/ByAnkAcmow2r1BlFYg2KBzhuy
GmN2YvkUAEQEAQAQAH/A74hrDrmmxZ3Q16F6Jafe1P1Rb7nJe2I2E8N8uFF05Q2pZKU
/c1TS2tWjqltMAIAgYAsD0kHfchxanTenGufVgy8kJT3se5m1RFPkRjX22m0zKdvy67B
mu952V0k1uE0Cm80d6jz2fMKGxGqC4zbs/KyJxtX3SH18yMXC0dVAc2V5CNgTwi
Uct7z/h/K61bmaLd7fD7DXT7Hn7Qsm08I1lrtgPE8qRTm0udTmoyEeqkYi
OIrWsp8n8s2CPsAsXERyU6HByFXY5X2ea1hQJXYLF0z2D0MrZtVZQcn/7n/IhupnDC
Nd2aAVDvX3yQ35AmvLzhFacd3jX13i1vWjo0mFOKEAOcZ1e63SKNN9sniQ11RMp
gaov6UX/zGLMstwTznouIk+Kr8/dboG1SAy123u0Ab4tfQXEApoX9A4AJ2Kq9jQoX
```
If you created a key with passphrase, you may have to enter it here. However for the purpose of this example, the passphrase is blank.

Encrypting gpfdist Connections

The gpfdists protocol is a secure version of the gpfdist protocol that securely identifies the file server and the Greenplum Database and encrypts the communications between them. Using gpfdists protects against eavesdropping and man-in-the-middle attacks.

The gpfdists protocol implements client/server SSL security with the following notable features:

- Client certificates are required.
- Multilingual certificates are not supported.
- A Certificate Revocation List (CRL) is not supported.
- The TLSv1 protocol is used with the TLS_RSA_WITH_AES_128_CBC_SHA encryption algorithm. These SSL parameters cannot be changed.
- SSL renegotiation is supported.
- The SSL ignore host mismatch parameter is set to false.
- Private keys containing a passphrase are not supported for the gpfdist file server (server.key) or for the Greenplum Database (client.key).
- It is the user's responsibility to issue certificates that are appropriate for the operating system in use. Generally, converting certificates to the required format is supported, for example using the SSL Converter at https://www.sslshopper.com/ssl-converter.html.

A gpfdist server started with the --ssl option can only communicate with the gpfdists protocol. A gpfdist server started without the --ssl option can only communicate with the gpfdist protocol. For more detail about gpfdist refer to the Greenplum Database Administrator Guide.

There are two ways to enable the gpfdists protocol:

- Run gpfdist with the --ssl option and then use the gpfdists protocol in the LOCATION clause of a CREATE EXTERNAL TABLE statement.
- Use a YAML control file with the SSL option set to true and run gpload. Running gpload starts the gpfdist server with the --ssl option and then uses the gpfdists protocol.

When using gpfdists, the following client certificates must be located in the $PGDATA/gpfdists directory on each segment:
- The client certificate file, `client.crt`
- The client private key file, `client.key`
- The trusted certificate authorities, `root.crt`

**Important:** Do not protect the private key with a passphrase. The server does not prompt for a passphrase for the private key, and loading data fails with an error if one is required.

When using `gpload` with SSL you specify the location of the server certificates in the YAML control file. When using `gpfdist` with SSL, you specify the location of the server certificates with the `--ssl` option.

The following example shows how to securely load data into an external table. The example creates a readable external table named `ext_expenses` from all files with the `txt` extension, using the `gpfdists` protocol. The files are formatted with a pipe (`|`) as the column delimiter and an empty space as null.

1. Run `gpfdist` with the `--ssl` option on the segment hosts.
2. Log into the database and execute the following command:

   ```sql
   =# CREATE EXTERNAL TABLE ext_expenses
    ( name text, date date, amount float4, category text, descr text )
   LOCATION ('gpfdists://etlhost-1:8081/*.txt', 'gpfdists://etlhost-2:8082/*.txt')
   FORMAT 'TEXT' ( DELIMITER '|' NULL ' ') ;
   ```
Accessing a Kerberized Hadoop Cluster

Using external tables and the gphdfs protocol, Greenplum Database can read files from and write files to a Hadoop File System (HDFS). Greenplum segments read and write files in parallel from HDFS for fast performance.

When a Hadoop cluster is secured with Kerberos ("Kerberized"), Greenplum Database must be configured to allow the Greenplum Database gpadmin role, which owns external tables in HDFS, to authenticate through Kerberos. This topic provides the steps for configuring Greenplum Database to work with a Kerberized HDFS, including verifying and troubleshooting the configuration.

• Prerequisites
• Configuring the Greenplum Cluster
• Creating and Installing Keytab Files
• Configuring gphdfs for Kerberos
• Testing Greenplum Database Access to HDFS
• Troubleshooting HDFS with Kerberos

Prerequisites

Make sure the following components are functioning and accessible on the network:

• Greenplum Database cluster—either a Pivotal Greenplum Database software-only cluster, or a Dell EMC Data Computing Appliance (DCA).
• Kerberos-secured Hadoop cluster. See the Greenplum Database Release Notes for supported Hadoop versions.
• Kerberos Key Distribution Center (KDC) server.

Configuring the Greenplum Cluster

The hosts in the Greenplum Cluster must have a Java JRE, Hadoop client files, and Kerberos clients installed.

Follow these steps to prepare the Greenplum Cluster.

1. Install a Java 1.6 or later JRE on all Greenplum cluster hosts.

Match the JRE version the Hadoop cluster is running. You can find the JRE version by running `java --version` on a Hadoop node.

2. (Optional) Confirm that Java Cryptography Extension (JCE) is present.

The default location of the JCE libraries is `JAVA_HOME/lib/security`. If a JDK is installed, the directory is `JAVA_HOME/jre/lib/security`. The files `local_policy.jar` and `US_export_policy.jar` should be present in the JCE directory.

The Greenplum cluster and the Kerberos server should, preferably, use the same version of the JCE libraries. You can copy the JCE files from the Kerberos server to the Greenplum cluster, if needed.

3. Set the JAVA_HOME environment variable to the location of the JRE in the .bashrc or .bash_profile file for the gpadmin account. For example:

```bash
export JAVA_HOME=/usr/java/default
```

4. Source the .bashrc or .bash_profile file to apply the change to your environment. For example:

```bash
$ source ~/.bashrc
```
5. Install the Kerberos client utilities on all cluster hosts. Ensure the libraries match the version on the KDC server before you install them.

For example, the following command installs the Kerberos client files on Red Hat or CentOS Linux:

```
$ sudo yum install krb5-libs krb5-workstation
```

Use the `kinit` command to confirm the Kerberos client is installed and correctly configured.

6. Install Hadoop client files on all hosts in the Greenplum Cluster. Refer to the documentation for your Hadoop distribution for instructions.

7. Set the Greenplum Database server configuration parameters for Hadoop. The `gp_hadoop_target_version` parameter specifies the version of the Hadoop cluster. See the Greenplum Database Release Notes for the target version value that corresponds to your Hadoop distribution. The `gp_hadoop_home` parameter specifies the Hadoop installation directory.

```
$ gpconfig -c gp_hadoop_target_version -v "hdp2"
$ gpconfig -c gp_hadoop_home -v "/usr/lib/hadoop"
```

See the Greenplum Database Reference Guide for more information.

8. Reload the updated `postgresql.conf` files for master and segments:

```
gpstop -u
```

You can confirm the changes with the following commands:

```
$ gpconfig -s gp_hadoop_target_version
$ gpconfig -s gp_hadoop_home
```

9. Grant Greenplum Database `gphdfs` protocol privileges to roles that own external tables in HDFS, including `gpadmin` and other superuser roles. Grant `SELECT` privileges to enable creating readable external tables in HDFS. Grant `INSERT` privileges to enable creating writable external tables on HDFS.

```
#= GRANT SELECT ON PROTOCOL gphdfs TO gpadmin;
#= GRANT INSERT ON PROTOCOL gphdfs TO gpadmin;
```

10. Grant Greenplum Database external table privileges to external table owner roles:

```
ALTER ROLE HDFS_USER CREATEEXTTABLE (type='readable');
ALTER ROLE HDFS_USER CREATEEXTTABLE (type='writable');
```

**Note:** It is best practice to review database privileges, including `gphdfs` external table privileges, at least annually.

### Creating and Installing Keytab Files

1. Log in to the KDC server as root.
2. Use the `kadmin.local` command to create a new principal for the `gpadmin` user:

```
# kadmin.local -q "addprinc -randkey gpadmin@LOCAL.DOMAIN"
```

3. Use `kadmin.local` to generate a Kerberos service principal for each host in the Greenplum Database cluster. The service principal should be of the form `name\role@REALM`, where:

   - `name` is the `gphdfs` service user name. This example uses `gphdfs`.
   - `role` is the DNS-resolvable host name of a Greenplum cluster host (the output of the `hostname -f` command).
   - `REALM` is the Kerberos realm, for example `LOCAL.DOMAIN`. 
For example, the following commands add service principals for four Greenplum Database hosts, mdw.example.com, smdw.example.com, sdw1.example.com, and sdw2.example.com:

```
# kadmin.local -q "addprinc -randkey gphdfs/mdw.example.com@LOCAL.DOMAIN"
# kadmin.local -q "addprinc -randkey gphdfs/smdw.example.com@LOCAL.DOMAIN"
# kadmin.local -q "addprinc -randkey gphdfs/sdw1.example.com@LOCAL.DOMAIN"
# kadmin.local -q "addprinc -randkey gphdfs/sdw2.example.com@LOCAL.DOMAIN"
```

Create a principal for each Greenplum cluster host. Use the same principal name and realm, substituting the fully-qualified domain name for each host.

4. **Generate a keytab file for each principal that you created (gpadmin and each gphdfs service principal).** You can store the keytab files in any convenient location (this example uses the directory `/etc/security/keytabs`). You will deploy the service principal keytab files to their respective Greenplum host machines in a later step:

```
# kadmin.local -q "xst -k /etc/security/keytabs/gphdfs.service.keytab gpadmin@LOCAL.DOMAIN"
# kadmin.local -q "xst -k /etc/security/keytabs/mdw.service.keytab gpadmin/mdw gphdfs/mdw.example.com@LOCAL.DOMAIN"
# kadmin.local -q "xst -k /etc/security/keytabs/smdw.service.keytab gpadmin/smdw gphdfs/smdw.example.com@LOCAL.DOMAIN"
# kadmin.local -q "xst -k /etc/security/keytabs/sdw1.service.keytab gpadmin/sdw1 gphdfs/sdw1.example.com@LOCAL.DOMAIN"
# kadmin.local -q "xst -k /etc/security/keytabs/sdw2.service.keytab gpadmin/sdw2 gphdfs/sdw2.example.com@LOCAL.DOMAIN"
# kadmin.local -q "listprincs"
```

5. **Change the ownership and permissions on gphdfs.service.keytab as follows:**

```
# chown gpadmin:gpadmin /etc/security/keytabs/gphdfs.service.keytab
# chmod 440 /etc/security/keytabs/gphdfs.service.keytab
```

6. **Copy the keytab file for gpadmin@LOCAL.DOMAIN to the Greenplum master host:**

```
# scp /etc/security/keytabs/gphdfs.service.keytab mdw_fqdn:/home/gpadmin/gphdfs.service.keytab
```

7. **Copy the keytab file for each service principal to its respective Greenplum host:**

```
# scp /etc/security/keytabs/mdw.service.keytab mdw_fqdn:/home/gpadmin/mdw.service.keytab
# scp /etc/security/keytabs/smdw.service.keytab smdw_fqdn:/home/gpadmin/smdw.service.keytab
# scp /etc/security/keytabs/sdw1.service.keytab sdw1_fqdn:/home/gpadmin/sdw1.service.keytab
# scp /etc/security/keytabs/sdw2.service.keytab sdw2_fqdn:/home/gpadmin/sdw2.service.keytab
```

### Configuring gphdfs for Kerberos

1. **Edit the Hadoop core-site.xml client configuration file on all Greenplum cluster hosts.** Enable service-level authorization for Hadoop by setting the `hadoop.security.authorization` property to true. For example:

```
<pROPERTY>
  <name>hadoop.security.authorization</name>
  <value>true</value>
</PROPERTY>
```
2. Edit the yarn-site.xml client configuration file on all cluster hosts. Set the resource manager address and yarn Kerberos service principle. For example:

```xml
<property>
    <name>yarn.resourcemanager.address</name>
    <value>hostname:8032</value>
</property>
<property>
    <name>yarn.resourcemanager.principal</name>
    <value>yarn/hostname@DOMAIN</value>
</property>
```

3. Edit the hdfs-site.xml client configuration file on all cluster hosts. Set properties to identify the NameNode Kerberos principals, the location of the Kerberos keytab file, and the principal it is for:

- `dfs.namenode.kerberos.principal` - the Kerberos principal name the gphdfs protocol will use for the NameNode, for example `gpadmin@LOCAL.DOMAIN`.
- `dfs.namenode.https.principal` - the Kerberos principal name the gphdfs protocol will use for the NameNode's secure HTTP server, for example `gpadmin@LOCAL.DOMAIN`.
- `com.emc.greenplum.gpdb.hdfsconnector.security.user.keytab.file` - the path to the keytab file for the Kerberos HDFS service, for example `/home/gpadmin/mdw.service.keytab`.
- `com.emc.greenplum.gpdb.hdfsconnector.security.user.name` - the gphdfs service principal for the host, for example `gphdfs/mdw.example.com@LOCAL.DOMAIN`.

For example:

```xml
<property>
    <name>dfs.namenode.kerberos.principal</name>
    <value>gphdfs/gpadmin@LOCAL.DOMAIN</value>
</property>
<property>
    <name>dfs.namenode.https.principal</name>
    <value>gphdfs/gpadmin@LOCAL.DOMAIN</value>
</property>
<property>
    <name>com.emc.greenplum.gpdb.hdfsconnector.security.user.keytab.file</name>
    <value>/home/gpadmin/gpadmin.hdfs.keytab</value>
</property>
<property>
    <name>com.emc.greenplum.gpdb.hdfsconnector.security.user.name</name>
    <value>gpadmin@LOCAL.DOMAIN</value>
</property>
```

**Testing Greenplum Database Access to HDFS**

Confirm that HDFS is accessible via Kerberos authentication on all hosts in the Greenplum cluster. For example, enter the following command to list an HDFS directory:

```
hdfs dfs -ls hdfs://namenode:8020
```

**Create a Readable External Table in HDFS**

Follow these steps to verify that you can create a readable external table in a Kerberized Hadoop cluster.

1. Create a comma-delimited text file, `test1.txt`, with contents such as the following:

```
25, Bill
19, Anne
32, Greg
```
27, Gloria

2. Persist the sample text file in HDFS:

```bash
hdfs dfs -put test1.txt hdfs://namenode:8020/tmp
```

3. Log in to Greenplum Database and create a readable external table that points to the `test1.txt` file in Hadoop:

```sql
CREATE EXTERNAL TABLE test_hdfs (age int, name text)
LOCATION('gphdfs://namenode:8020/tmp/test1.txt')
FORMAT 'text' (delimiter ',');
```

4. Read data from the external table:

```sql
SELECT * FROM test_hdfs;
```

Create a Writable External Table in HDFS

Follow these steps to verify that you can create a writable external table in a Kerberized Hadoop cluster. The steps use the `test_hdfs` readable external table created previously.

1. Log in to Greenplum Database and create a writable external table pointing to a text file in HDFS:

```sql
CREATE WRITABLE EXTERNAL TABLE test_hdfs2 (LIKE test_hdfs)
LOCATION ('gphdfs://namenode:8020/tmp/test2.txt')
FORMAT 'text' (DELIMITER ',');
```

2. Load data into the writable external table:

```sql
INSERT INTO test_hdfs2
SELECT * FROM test_hdfs;
```

3. Check that the file exists in HDFS:

```bash
hdfs dfs -ls hdfs://namenode:8020/tmp/test2.txt
```

4. Verify the contents of the external file:

```bash
hdfs dfs -cat hdfs://namenode:8020/tmp/test2.txt
```

Troubleshooting HDFS with Kerberos

Forcing Classpaths

If you encounter "class not found" errors when executing `SELECT` statements from `gphdfs` external tables, edit the `$GPHOME/lib/hadoop-env.sh` file and add the following lines towards the end of the file, before the `JAVA_LIBRARY_PATH` is set. Update the script on all of the cluster hosts.

```bash
if [ -d "/usr/hdp/current" ]; then
  for f in /usr/hdp/current/**/*.jar; do
    CLASSPATH=${CLASSPATH}:${f};
  done
fi
```
Enabling Kerberos Client Debug Messages
To see debug messages from the Kerberos client, edit the $GPHOME/lib/hadoop-env.sh client shell script on all cluster hosts and set the HADOOP_OPTS variable as follows:

```bash
export HADOOP_OPTS="-Djava.net.prefIPv4Stack=true -Dsun.security.krb5.debug=true ${HADOOP_OPTS}"
```

Adjusting JVM Process Memory on Segment Hosts
Each segment launches a JVM process when reading or writing an external table in HDFS. To change the amount of memory allocated to each JVM process, configure the GP_JAVA_OPT environment variable.

Edit the $GPHOME/lib/hadoop-env.sh client shell script on all cluster hosts.

For example:

```bash
export GP_JAVA_OPT=-Xmx1000m
```

Verify Kerberos Security Settings
Review the /etc/krb5.conf file:

- If AES256 encryption is not disabled, ensure that all cluster hosts have the JCE Unlimited Strength Jurisdiction Policy Files installed.
- Ensure all encryption types in the Kerberos keytab file match definitions in the krb5.conf file.

```bash
cat /etc/krb5.conf | egrep supported_enctypes
```

Test Connectivity on an Individual Segment Host
Follow these steps to test that a single Greenplum Database host can read HDFS data. This test method executes the Greenplum HDFSReader Java class at the command-line, and can help to troubleshoot connectivity problems outside of the database.

1. Save a sample data file in HDFS.

```bash
hdfs dfs -put test1.txt hdfs://namenode:8020/tmp
```

2. On the segment host to be tested, create an environment script, env.sh, like the following:

```bash
export JAVA_HOME=/usr/java/default
export HADOOP_HOME=/usr/lib/hadoop
export GP_HADOOP_CON_VERSION=hdp2
export GP_HADOOP_CON_JARDIR=/usr/lib/hadoop
```

3. Source all environment scripts:

```bash
source /usr/local/greenplum-db/greenplum_path.sh
source env.sh
source $GPHOME/lib/hadoop-env.sh
```

4. Test the Greenplum Database HDFS reader:

```bash
java com.emc.greenplum.gpdb.hdfsconnector.HDFSReader 0 32 TEXT hdp2 gphdfs://namenode:8020/tmp/test1.txt
```
Tuning SQL Queries

The Greenplum Database cost-based optimizer evaluates many strategies for executing a query and chooses the least costly method.

Like other RDBMS optimizers, the Greenplum optimizer takes into account factors such as the number of rows in tables to be joined, availability of indexes, and cardinality of column data when calculating the costs of alternative execution plans. The optimizer also accounts for the location of the data, preferring to perform as much of the work as possible on the segments and to minimize the amount of data that must be transmitted between segments to complete the query.

When a query runs slower than you expect, you can view the plan the optimizer selected as well as the cost it calculated for each step of the plan. This will help you determine which steps are consuming the most resources and then modify the query or the schema to provide the optimizer with more efficient alternatives. You use the SQL `EXPLAIN` statement to view the plan for a query.

The optimizer produces plans based on statistics generated for tables. It is important to have accurate statistics to produce the best plan. See Updating Statistics with `ANALYZE` in this guide for information about updating statistics.

How to Generate Explain Plans

The `EXPLAIN` and `EXPLAIN ANALYZE` statements are useful tools to identify opportunities to improve query performance. `EXPLAIN` displays the query plan and estimated costs for a query, but does not execute the query. `EXPLAIN ANALYZE` executes the query in addition to displaying the query plan. `EXPLAIN ANALYZE` discards any output from the `SELECT` statement; however, other operations in the statement are performed (for example, `INSERT`, `UPDATE`, or `DELETE`). To use `EXPLAIN ANALYZE` on a DML statement without letting the command affect the data, explicitly use `EXPLAIN ANALYZE` in a transaction (`BEGIN; EXPLAIN ANALYZE ...; ROLLBACK;`).

`EXPLAIN ANALYZE` runs the statement in addition to displaying the plan with additional information as follows:

- Total elapsed time (in milliseconds) to run the query
- Number of workers (segments) involved in a plan node operation
- Maximum number of rows returned by the segment (and its segment ID) that produced the most rows for an operation
- The memory used by the operation
- Time (in milliseconds) it took to retrieve the first row from the segment that produced the most rows, and the total time taken to retrieve all rows from that segment.

How to Read Explain Plans

An explain plan is a report detailing the steps the Greenplum Database optimizer has determined it will follow to execute a query. The plan is a tree of nodes, read from bottom to top, with each node passing its result to the node directly above. Each node represents a step in the plan, and one line for each node identifies the operation performed in that step—for example, a scan, join, aggregation, or sort operation. The node also identifies the method used to perform the operation. The method for a scan operation, for example, may be a sequential scan or an index scan. A join operation may perform a hash join or nested loop join.

Following is an explain plan for a simple query. This query finds the number of rows in the contributions table stored at each segment.
This plan has seven nodes – Dynamic Table Scan, Function Scan, Result, Sequence, Redistribute Motion, HashAggregate, and finally Gather Motion. Each node contains three cost estimates: cost (in sequential page reads), the number of rows, and the width of the rows.

The cost is a two-part estimate. A cost of 1.0 is equal to one sequential disk page read. The first part of the estimate is the start-up cost, which is the cost of getting the first row. The second estimate is the total cost, the cost of getting all of the rows.

The rows estimate is the number of rows output by the plan node. The number may be lower than the actual number of rows processed or scanned by the plan node, reflecting the estimated selectivity of WHERE clause conditions. The total cost assumes that all rows will be retrieved, which may not always be the case (for example, if you use a LIMIT clause).

The width estimate is the total width, in bytes, of all the columns output by the plan node.

The cost estimates in a node include the costs of all its child nodes, so the top-most node of the plan, usually a Gather Motion, has the estimated total execution costs for the plan. This is this number that the query planner seeks to minimize.

Scan operators scan through rows in a table to find a set of rows. There are different scan operators for different types of storage. They include the following:

- Seq Scan on heap tables — scans all rows in the table.
- Append-only Scan — scans rows in row-oriented append-only tables.
- Append-only Columnar Scan — scans rows in column-oriented append-only tables.
- Index Scan — traverses a B-tree index to fetch the rows from the table.
- Bitmap Append-only Row-oriented Scan — gathers pointers to rows in an append-only table from an index and sorts by location on disk.
- Dynamic Table Scan — chooses partitions to scan using a partition selection function. The Function Scan node contains the name of the partition selection function, which can be one of the following:
  - `gp_partition_expansion` — selects all partitions in the table. No partitions are eliminated.
  - `gp_partition_selection` — chooses a partition based on an equality expression.
  - `gp_partition_inversion` — chooses partitions based on a range expression.

  The Function Scan node passes the dynamically selected list of partitions to the Result node which is passed to the Sequence node.

Join operators include the following:

- Hash Join – builds a hash table from the smaller table with the join column(s) as hash key. Then scans the larger table, calculating the hash key for the join column(s) and probing the hash table to find the rows with the same hash key. Hash joins are typically the fastest joins in Greenplum Database. The Hash Cond in the explain plan identifies the columns that are joined.
- Nested Loop – iterates through rows in the larger dataset, scanning the rows in the smaller dataset on each iteration. The Nested Loop join requires the broadcast of one of the tables so that all rows in one table can be compared to all rows in the other table. It performs well for small tables or tables that are limited by using an index. It is also used for Cartesian joins and range joins. There are performance implications when using a Nested Loop join with large tables. For plan nodes that contain a Nested Loop join operator, validate the SQL and ensure that the results are what is intended. Set the `enable_nestloop` server configuration parameter to OFF (default) to favor Hash Join.
- Merge Join – sorts both datasets and merges them together. A merge join is fast for pre-ordered data, but is very rare in the real world. To favor Merge Joins over Hash Joins, set the `enable_mergejoin` system configuration parameter to ON.

Some query plan nodes specify motion operations. Motion operations move rows between segments when required to process the query. The node identifies the method used to perform the motion operation. Motion operators include the following:

- Broadcast motion – each segment sends its own, individual rows to all other segments so that every segment instance has a complete local copy of the table. A Broadcast motion may not be as optimal
as a Redistribute motion, so the optimizer typically only selects a Broadcast motion for small tables. A Broadcast motion is not acceptable for large tables. In the case where data was not distributed on the join key, a dynamic redistribution of the needed rows from one of the tables to another segment is performed.

- Redistribute motion – each segment rehashes the data and sends the rows to the appropriate segments according to hash key.
- Gather motion – result data from all segments is assembled into a single stream. This is the final operation for most query plans.

Other operators that occur in query plans include the following:

- Materialize – the planner materializes a subselect once so it does not have to repeat the work for each top-level row.
- InitPlan – a pre-query, used in dynamic partition elimination, performed when the values the planner needs to identify partitions to scan are unknown until execution time.
- Sort – sort rows in preparation for another operation requiring ordered rows, such as an Aggregation or Merge Join.
- Group By – groups rows by one or more columns.
- Group/Hash Aggregate – aggregates rows using a hash.
- Append – concatenates data sets, for example when combining rows scanned from partitions in a partitioned table.
- Filter – selects rows using criteria from a WHERE clause.
- Limit – limits the number of rows returned.

**Optimizing Greenplum Queries**

This topic describes Greenplum Database features and programming practices that can be used to enhance system performance in some situations.

To analyze query plans, first identify the plan nodes where the estimated cost to perform the operation is very high. Determine if the estimated number of rows and cost seems reasonable relative to the number of rows for the operation performed.

If using partitioning, validate that partition elimination is achieved. To achieve partition elimination the query predicate (WHERE clause) must be the same as the partitioning criteria. Also, the WHERE clause must not contain an explicit value and cannot contain a subquery.

Review the execution order of the query plan tree. Review the estimated number of rows. You want the execution order to build on the smaller tables or hash join result and probe with larger tables. Optimally, the largest table is used for the final join or probe to reduce the number of rows being passed up the tree to the topmost plan nodes. If the analysis reveals that the order of execution builds and/or probes is not optimal ensure that database statistics are up to date. Running `ANALYZE` will likely address this and produce an optimal query plan.

Look for evidence of computational skew. Computational skew occurs during query execution when execution of operators such as Hash Aggregate and Hash Join cause uneven execution on the segments. More CPU and memory are used on some segments than others, resulting in less than optimal execution. The cause could be joins, sorts, or aggregations on columns that have low cardinality or non-uniform distributions. You can detect computational skew in the output of the `EXPLAIN ANALYZE` statement for a query. Each node includes a count of the maximum rows processed by any one segment and the average rows processed by all segments. If the maximum row count is much higher than the average, at least one segment has performed much more work than the others and computational skew should be suspected for that operator.

Identify plan nodes where a Sort or Aggregate operation is performed. Hidden inside an Aggregate operation is a Sort. If the Sort or Aggregate operation involves a large number of rows, there is an opportunity to improve query performance. A HashAggregate operation is preferred over Sort and Aggregate operations when a large number of rows are required to be sorted. Usually a Sort operation is
chosen by the optimizer due to the SQL construct; that is, due to the way the SQL is written. Most Sort operations can be replaced with a HashAggregate if the query is rewritten. To favor a HashAggregate operation over a Sort and Aggregate operation ensure that the enable_groupagg server configuration parameter is set to ON.

When an explain plan shows a broadcast motion with a large number of rows, you should attempt to eliminate the broadcast motion. One way to do this is to use the gp_segments_for_planner server configuration parameter to increase the cost estimate of the motion so that alternatives are favored. The gp_segments_for_planner variable tells the query planner how many primary segments to use in its calculations. The default value is zero, which tells the planner to use the actual number of primary segments in estimates. Increasing the number of primary segments increases the cost of the motion, thereby favoring a redistribute motion over a broadcast motion. For example, setting gp_segments_for_planner = 100000 tells the planner that there are 100,000 segments. Conversely, to influence the optimizer to broadcast a table and not redistribute it, set gp_segments_for_planner to a low number, for example 2.

Greenplum Grouping Extensions

Greenplum Database aggregation extensions to the GROUP BY clause can perform some common calculations in the database more efficiently than in application or procedure code:

- GROUP BY ROLLUP(col1, col2, col3)
- GROUP BY CUBE(col1, col2, col3)
- GROUP BY GROUPING SETS((col1, col2), (col1, col3))

A ROLLUP grouping creates aggregate subtotals that roll up from the most detailed level to a grand total, following a list of grouping columns (or expressions). ROLLUP takes an ordered list of grouping columns, calculates the standard aggregate values specified in the GROUP BY clause, then creates progressively higher-level subtotals, moving from right to left through the list. Finally, it creates a grand total.

A CUBE grouping creates subtotals for all of the possible combinations of the given list of grouping columns (or expressions). In multidimensional analysis terms, CUBE generates all the subtotals that could be calculated for a data cube with the specified dimensions.

You can selectively specify the set of groups that you want to create using a GROUPING SETS expression. This allows precise specification across multiple dimensions without computing a whole ROLLUP or CUBE.

Refer to the Greenplum Database Reference Guide for details of these clauses.

Window Functions

Window functions apply an aggregation or ranking function over partitions of the result set—for example, sum(population) over (partition by city). Window functions are powerful and, because they do all of the work in the database, they have performance advantages over front-end tools that produce similar results by retrieving detail rows from the database and reprocessing them.

- The row_number() window function produces row numbers for the rows in a partition, for example, row_number() over (order by id).
- When a query plan indicates that a table is scanned in more than one operation, you may be able to use window functions to reduce the number of scans.
- It is often possible to eliminate self joins by using window functions.
High Availability

Greenplum Database supports highly available, fault-tolerant database services when you enable and properly configure Greenplum high availability features. To guarantee a required level of service, each component must have a standby ready to take its place if it should fail.

Disk Storage

With the Greenplum Database "shared-nothing" MPP architecture, the master host and segment hosts each have their own dedicated memory and disk storage, and each master or segment instance has its own independent data directory. For both reliability and high performance, Pivotal recommends a hardware RAID storage solution with from 8 to 24 disks. A larger number of disks improves I/O throughput when using RAID 5 (or 6) because striping increases parallel disk I/O. The RAID controller can continue to function with a failed disk because it saves parity data on each disk in a way that it can reconstruct the data on any failed member of the array. If a hot spare is configured (or an operator replaces the failed disk with a new one) the controller rebuilds the failed disk automatically.

RAID 1 exactly mirrors disks, so if a disk fails, a replacement is immediately available with performance equivalent to that before the failure. With RAID 5 each I/O for data on the failed array member must be reconstructed from data on the remaining active drives until the replacement disk is rebuilt, so there is a temporary performance degradation. If the Greenplum master and segments are mirrored, you can switch any affected Greenplum instances to their mirrors during the rebuild to maintain acceptable performance.

A RAID disk array can still be a single point of failure, for example, if the entire RAID volume fails. At the hardware level, you can protect against a disk array failure by mirroring the array, using either host operating system mirroring or RAID controller mirroring, if supported.

It is important to regularly monitor available disk space on each segment host. Query the `gp_disk_free` external table in the `gptoolkit` schema to view disk space available on the segments. This view runs the Linux `df` command. Be sure to check that there is sufficient disk space before performing operations that consume large amounts of disk, such as copying a large table.

See `gp_toolkit.gp_disk_free` in the Greenplum Database Reference Guide.

Best Practices

- Use a hardware RAID storage solution with 8 to 24 disks.
- Use RAID 1, 5, or 6 so that the disk array can tolerate a failed disk.
- Configure a hot spare in the disk array to allow rebuild to begin automatically when disk failure is detected.
- Protect against failure of the entire disk array and degradation during rebuilds by mirroring the RAID volume.
- Monitor disk utilization regularly and add additional space when needed.
- Monitor segment skew to ensure that data is distributed evenly and storage is consumed evenly at all segments.

Master Mirroring

The Greenplum Database master instance is clients' single point of access to the system. The master instance stores the global system catalog, the set of system tables that store metadata about the database instance, but no user data. If an unmirrored master instance fails or becomes inaccessible, the Greenplum instance is effectively off-line, since the entry point to the system has been lost. For this reason, a standby master must be ready to take over if the primary master fails.

Master mirroring uses two processes, a sender on the active master host and a receiver on the mirror host, to synchronize the mirror with the master. As changes are applied to the master system catalogs,
the active master streams its write-ahead log (WAL) to the mirror so that each transaction applied on the master is applied on the mirror.

The mirror is a warm standby. If the primary master fails, switching to the standby requires an administrative user to run the `gpactivatestandby` utility on the standby host so that it begins to accept client connections. Clients must reconnect to the new master and will lose any work that was not committed when the primary failed.

See "Enabling High Availability Features" in the *Greenplum Database Administrator Guide* for more information.

**Best Practices**

- Set up a standby master instance—a mirror—to take over if the primary master fails.
- The standby can be on the same host or on a different host, but it is best practice to place it on a different host from the primary master to protect against host failure.
- Plan how to switch clients to the new master instance when a failure occurs, for example, by updating the master address in DNS.
- Set up monitoring to send notifications in a system monitoring application or by email when the primary fails.

**Segment Mirroring**

Greenplum Database segment instances each store and manage a portion of the database data, with coordination from the master instance. If any unmirrored segment fails, the database may have to be shutdown and recovered, and transactions occurring after the most recent backup could be lost. Mirroring segments is, therefore, an essential element of a high availability solution.

A segment mirror is a hot standby for a primary segment. Greenplum Database detects when a segment is unavailable and automatically activates the mirror. During normal operation, when the primary segment instance is active, data is replicated from the primary to the mirror in two ways:

- The transaction commit log is replicated from the primary to the mirror before the transaction is committed. This ensures that if the mirror is activated, the changes made by the last successful transaction at the primary are present at the mirror. When the mirror is activated, transactions in the log are applied to tables in the mirror.
- Second, segment mirroring uses physical file replication to update heap tables. Greenplum Server stores table data on disk as fixed-size blocks packed with tuples. To optimize disk I/O, blocks are cached in memory until the cache fills and some blocks must be evicted to make room for newly updated blocks. When a block is evicted from the cache it is written to disk and replicated over the network to the mirror. Because of the caching mechanism, table updates at the mirror can lag behind the primary. However, because the transaction log is also replicated, the mirror remains consistent with the primary. If the mirror is activated, the activation process updates the tables with any unapplied changes in the transaction commit log.

When the acting primary is unable to access its mirror, replication stops and state of the primary changes to "Change Tracking." The primary saves changes that have not been replicated to the mirror in a system table to be replicated to the mirror when it is back on-line.

The master automatically detects segment failures and activates the mirror. Transactions in progress at the time of failure are restarted using the new primary. Depending on how mirrors are deployed on the hosts, the database system may be unbalanced until the original primary segment is recovered. For example, if each segment host has four primary segments and four mirror segments, and a mirror is activated on one host, that host will have five active primary segments. Queries are not complete until the last segment has finished its work, so performance can be degraded until the balance is restored by recovering the original primary.

Administrators perform the recovery while Greenplum Database is up and running by running the `gprecoverseg` utility. This utility locates the failed segments, verifies they are valid, and compares the
transactional state with the currently active segment to determine changes made while the segment was offline. `gprecoverseg` synchronizes the changed database files with the active segment and brings the segment back online.

It is important to reserve enough memory and CPU resources on segment hosts to allow for increased activity from mirrors that assume the primary role during a failure. The formulas provided in Configuring Memory for Greenplum Database for configuring segment host memory include a factor for the maximum number of primary hosts on any one segment during a failure. The arrangement of mirrors on the segment hosts affects this factor and how the system will respond during a failure. See Segment Mirroring Configuration for a discussion of segment mirroring options.

**Best Practices**

- Set up mirrors for all segments.
- Locate primary segments and their mirrors on different hosts to protect against host failure.
- Mirrors can be on a separate set of hosts or co-located on hosts with primary segments.
- Set up monitoring to send notifications in a system monitoring application or by email when a primary segment fails.
- Recover failed segments promptly, using the `gprecoverseg` utility, to restore redundancy and return the system to optimal balance.

**Dual Clusters**

For some use cases, an additional level of redundancy can be provided by maintaining two Greenplum Database clusters that store the same data. The decision to implement dual clusters should be made with business requirements in mind.

There are two recommended methods for keeping the data synchronized in a dual cluster configuration. The first method is called Dual ETL. ETL (extract, transform, and load) is the common data warehousing process of cleansing, transforming, validating, and loading data into a data warehouse. With Dual ETL, the ETL processes are performed twice, in parallel on each cluster, and validated each time. Dual ETL provides for a complete standby cluster with the same data. It also provides the capability to query the data on both clusters, doubling the processing throughput. The application can take advantage of both clusters as needed and also ensure that the ETL is successful and validated on both sides.

The second mechanism for maintaining dual clusters is backup and restore. The data is backedup on the primary cluster, then the backup is replicated to and restored on the second cluster. The backup and restore mechanism has higher latency than Dual ETL, but requires less application logic to be developed. Backup and restore is ideal for use cases where data modifications and ETL are done daily or less frequently.

**Best Practices**

- Consider a Dual Cluster configuration to provide an additional level of redundancy and additional query processing throughput.

**Backup and Restore**

Backups are recommended for Greenplum Database databases unless the data in the database can be easily and cleanly regenerated from source data. Backups protect from operational, software, or hardware errors.

The `gpcrondump` utility makes backups in parallel across the segments, so that backups scale as the cluster grows in hardware size.

Incremental backups can significantly reduce backup sizes in some cases. An incremental backup saves all heap tables, but only the append-optimized and column-oriented partitions that have changed since the previous backup. When the database has large fact tables with many partitions and modifications are
confined to one or a few partitions in a time period, incremental backups can save a large amount of disk space. Conversely, a database with large, unpartitioned fact tables is a poor application for incremental backups.

A backup strategy must consider where the backups will be written and where they will be stored. Backups can be taken to the local cluster disks, but they should not be stored there permanently. If the database and its backup are on the same storage, they can be lost simultaneously. The backup also occupies space that could be used for database storage or operations. After performing a local backup, the files should be copied to a safe, off-cluster location.

An alternative is to back up directly to an NFS mount. If each host in the cluster has an NFS mount, ghe backups can be written directly to NFS storage. A scale-out NFS solution is recommended to ensure that backups do not bottleneck on the IO throughput of the NFS device. Dell EMC Isilon is an example of this type of solution and can scale alongside the Greenplum cluster.

Finally, through native API integration, Greenplum Database can stream backups directly to Dell EMC Data Domain or Veritas NetBackup enterprise backup platforms.

**Best Practices**

- Back up Greenplum databases regularly unless the data is easily restored from sources.
- Use the `gpcrondump -s, -S, -t, or -T` options to specify only the schema and tables that need to be backed up. See the `gpcrondump` reference in the *Greenplum Database Utility Reference Guide* for more information.
- Back up one schema at a time to reduce the length of time the `pg_class` table is locked.
  
  At the start of the backup, `gpcrondump` places an EXCLUSIVE lock on the `pg_class` table, which prevents creating, altering, or dropping tables. This lock is held while `gpcrondump` computes the set of tables to back up and then places SHARED ACCESS locks on the tables. Once the tables are locked and backup processes started on the segments, the EXCLUSIVE lock on `pg_class` is released. In a database with many objects the duration of the EXCLUSIVE lock may be disruptive. Backing up one schema at a time can reduce the duration of the EXCLUSIVE lock. Backups with fewer tables are also more efficient for selectively restoring schemas and tables, since `gpdbrestore` does not have to search through the entire database. See *Backup Process and Locks* for more information.
- Use incremental backups when heap tables are relatively small and few append-optimized or column-oriented partitions are modified between backups.
- If backups are saved to local cluster storage, move the files to a safe, off-cluster location when the backup is complete. Backup files and database files that reside on the same storage can be lost simultaneously.
- If your operating system supports direct I/O, set the `gp_backup_directIO` configuration parameter to reduce CPU usage during backups. See *Using Direct I/O* for more information.
- If backups are saved to NFS mounts, use a scale-out NFS solution such as Dell EMC Isilon to prevent IO bottlenecks.
- Consider using Pivotal Greenplum Database integration to stream backups to the Dell EMC Data Domain or Veritas NetBackup enterprise backup platforms.

**Detecting Failed Master and Segment Instances**

Recovering from system failures requires intervention from a system administrator, even when the system detects a failure and activates a standby for the failed component. In each case, the failed component must be replaced or recovered to restore full redundancy. Until the failed component is recovered, the active component lacks a standby, and the system may not be executing optimally. For these reasons, it is important to perform recovery operations promptly. Constant system monitoring and automated fault notifications through SNMP and email ensure that administrators are aware of failures that demand their attention.

The Greenplum Database server `ftsprobe` subprocess handles fault detection. `ftsprobe` connects to and scans all segments and database processes at intervals that you can configure with the
gp_fts_probe_interval configuration parameter. If ftsprobe cannot connect to a segment, it marks the segment “down” in the Greenplum Database system catalog. The segment remains down until an administrator runs the gprecoverseg recovery utility.

You can configure a Greenplum Database system to trigger SNMP (Simple Network Management Protocol) alerts or send email notifications to system administrators if certain database events occur. See "Using SNMP with a Greenplum Database System" in the Pivotal Greenplum Database Administrator Guide for instructions to set up SNMP.

**Best Practices**

- Run the gpstate utility to see the overall state of the Greenplum system.
- Configure Greenplum Database to send SNMP notifications to your network monitor.
- Set up email notification in the $MASTER_DATA_DIRECTORY/postgresql.conf configuration file so that the Greenplum system can email administrators when a critical issue is detected.

**Additional Information**

*Greenplum Database Administrator Guide:*

- Monitoring a Greenplum System
- Recovering a Failed Segment
- Using SNMP with a Greenplum System
- Enabling Email Notifications

*Greenplum Database Utility Guide:*

- gpstate—view state of the Greenplum system
- gprecoverseg—recover a failed segment
- gpactivatestandby—make the standby master the active master

*RDBMS MIB Specification*

**Segment Mirroring Configuration**

Segment mirroring allows database queries to fail over to a backup segment if the primary segment fails or becomes unavailable. Pivotal requires mirroring for supported production Greenplum Database systems.

A primary segment and its mirror must be on different hosts to ensure high availability. Each host in a Greenplum Database system has the same number of primary segments and mirror segments. Multi-homed hosts should have the same numbers of primary and mirror segments on each interface. This ensures that segment hosts and network resources are equally loaded when all primary segments are operational and brings the most resources to bear on query processing.

When a segment becomes unavailable, its mirror segment on another host becomes the active primary and processing continues. The additional load on the host creates skew and degrades performance, but should allow the system to continue. A database query is not complete until all segments return results, so a single host with an additional active primary segment has the same effect as adding an additional primary segment to every host in the cluster.

The least amount of performance degradation in a failover scenario occurs when no host has more than one mirror assuming the primary role. If multiple segments or hosts fail, the amount of degradation is determined by the host or hosts with the largest number of mirrors assuming the primary role. Spreading a host's mirrors across the remaining hosts minimizes degradation when any single host fails.

It is important, too, to consider the cluster's tolerance for multiple host failures and how to maintain a mirror configuration when expanding the cluster by adding hosts. There is no mirror configuration that is ideal for every situation.

You can allow Greenplum Database to arrange mirrors on the hosts in the cluster using one of two standard configurations, or you can design your own mirroring configuration.
The two standard mirroring arrangements are *group mirroring* and *spread mirroring*:

- **Group mirroring** — Each host mirrors another host’s primary segments. This is the default for `gpinit` and `gpaddmirrors`.
- **Spread mirroring** — Mirrors are spread across the available hosts. This requires that the number of hosts in the cluster is greater than the number of segments per host.

You can design a custom mirroring configuration and use the Greenplum `gpaddmirrors` or `gpmovemirrors` utilities to set up the configuration.

*Block mirroring* is a custom mirror configuration that divides hosts in the cluster into equally sized blocks and distributes mirrors evenly to hosts within the block. If a primary segment fails, its mirror on another host within the same block becomes the active primary. If a segment host fails, mirror segments on each of the other hosts in the block become active.

The following sections compare the group, spread, and block mirroring configurations.

**Group Mirroring**

Group mirroring is easiest to set up and is the default Greenplum mirroring configuration. It is least expensive to expand, since it can be done by adding as few as two hosts. There is no need to move mirrors after expansion to maintain a consistent mirror configuration.

The following diagram shows a group mirroring configuration with eight primary segments on four hosts.
Unless both the primary and mirror of the same segment instance fail, up to half of your hosts can fail and the cluster will continue to run as long as resources (CPU, memory, and IO) are sufficient to meet the needs.

Any host failure will degrade performance by half or more because the host with the mirrors will have twice the number of active primaries. If your resource utilization is normally greater than 50%, you will have to adjust your workload until the failed host is recovered or replaced. If you normally run at less than 50% resource utilization the cluster can continue to operate at a degraded level of performance until the failure is corrected.

**Spread Mirroring**

With spread mirroring, mirrors for each host's primary segments are spread across as many hosts as there are segments per host. Spread mirroring is easy to set up when the cluster is initialized, but requires that the cluster have at least one more host than there are segments per host.

The following diagram shows the spread mirroring configuration for a cluster with three primaries on four hosts.
Expanding a cluster with spread mirroring requires more planning and may take more time. You must either add a set of hosts equal to the number of primaries per host plus one, or you can add two nodes in a group mirroring configuration and, when the expansion is complete, move mirrors to recreate the spread mirror configuration.

Spread mirroring has the least performance impact for a single failed host because each host's mirrors are spread across the maximum number of hosts. Load is increased by $1/N$, where $N$ is the number of primaries per host. Spread mirroring is, however, the most likely configuration to suffer catastrophic failure if two or more hosts fail simultaneously.

**Block Mirroring**

With block mirroring, nodes are divided into blocks, for example a block of four or eight hosts, and the mirrors for segments on each host are placed on other hosts within the block. Depending on the number of hosts in the block and the number of primary segments per host, each host maintains more than one mirror for each other host's segments.

The following diagram shows a single block mirroring configuration for a block of four hosts, each with eight primary segments:
If there are eight hosts, an additional four-host block is added with the mirrors for primary segments 32 through 63 set up in the same pattern.

A cluster with block mirroring is easy to expand because each block is a self-contained primary mirror group. The cluster is expanded by adding one or more blocks. There is no need to move mirrors after expansion to maintain a consistent mirror setup. This configuration is able to survive multiple host failures as long as the failed hosts are in different blocks.

Because each host in a block has multiple mirror instances for each other host in the block, block mirroring has a higher performance impact for host failures than spread mirroring, but a lower impact than group mirroring. The expected performance impact varies by block size and primary segments per node. As with group mirroring, if the resources are available, performance will be negatively impacted but the cluster will remain available. If resources are insufficient to accommodate the added load you must reduce the workload until the failed node is replaced.

**Implementing Block Mirroring**

Block mirroring is not one of the automatic options Greenplum Database offers when you set up or expand a cluster. To use it, you must create your own configuration.
For a new Greenplum system, you can initialize the cluster without mirrors, and then run `gpaddmirrors -i mirror_config_file` with a custom mirror configuration file to create the mirrors for each block. You must create the file system locations for the mirror segments before you run `gpaddmirrors`. See the `gpaddmirrors` reference page in the Greenplum Database Management Utility Guide for details.

If you expand a system that has block mirroring or you want to implement block mirroring at the same time you expand a cluster, it is recommended that you complete the expansion first, using the default grouping mirror configuration, and then use the `gpmovemirrors` utility to move mirrors into the block configuration.

To implement block mirroring with an existing system that has a different mirroring scheme, you must first determine the desired location for each mirror according to your block configuration, and then determine which of the existing mirrors must be relocated. Follow these steps:

1. Run the following query to find the current locations of the primary and mirror segments:

   ```sql
   SELECT dbid, content, address, port, replication_port, fselocation as datadir
   FROM gp_segment_configuration, pg_filespace_entry
   WHERE dbid=fsedbid AND content > -1
   ORDER BY dbid;
   ```

   The `gp_segment_configuration`, `pg_filespace`, and `pg_filespace_entry` system catalog tables contain the current segment configuration.

2. Create a list with the current mirror location and the desired block mirroring location, then remove any mirrors from the list that are already on the correct host.

3. Create an input file for the `gpmovemirrors` utility with an entry for each mirror that must be moved.

   The `gpmovemirrors` input file has the following format:

   ```
   filespaceOrder=[filespace1_fsname[:filespace2_fsname:...]
   old_address:port:fselocation
   new_address:port:replication_port:fselocation[:fselocation:...]
   ```

   The first non-comment line must be a line beginning with `filespaceOrder=`. Do not include the default `pg_system` filespace in the list of filespaces. Leave the list empty if you are using only the `pg_system` filespace.

   The following example `gpmovemirrors` input file specifies three mirror segments to move.

   ```
   filespaceOrder=
   sdw2:50001:/data2/mirror/gpseg1 sdw3:50000:51000:/data/mirror/gpseg1
   sdw2:50001:/data2/mirror/gpseg2 sdw4:50000:51000:/data/mirror/gpseg2
   sdw3:50001:/data2/mirror/gpseg3 sdw1:50000:51000:/data/mirror/gpseg3
   ```

4. Run `gpmovemirrors` with a command like the following:

   ```
   gpmovemirrors -i mirror_config_file
   ```

   The `gpmovemirrors` utility validates the input file, calls `gp_recoverseg` to relocate each specified mirror, and removes the original mirror. It creates a backout configuration file which can be used as input to `gpmovemirrors` to undo the changes that were made. The backout file has the same name as the input file, with the suffix `_backout_timestamp` added.

   See the Greenplum Database Management Utility Reference for complete information about the `gpmovemirrors` utility.
Chapter 13

Greenplum Database Utility Guide

Reference information for command-line utilities, client programs, and Oracle compatibility functions.
Managing Utility Reference

Describes the command-line management utilities provided with Greenplum Database.

Greenplum Database uses the standard PostgreSQL client and server programs and provides additional
management utilities for administering a distributed Greenplum Database DBMS. Greenplum Database
management utilities reside in $GPHOME/bin.

Note: When referencing IPv6 addresses in gpfdist URLs or when using numeric IP addresses
instead of hostnames in any management utility, always enclose the IP address in brackets. For
command prompt use, the best practice is to escape any brackets or put them inside quotation
marks. For example, use either:

```
gpdbname -R \[2620:0:170:610::11\]
gpdbname -R '[2620:0:170:610::11]'
```

The following are the Greenplum Database management utilities.

<table>
<thead>
<tr>
<th>analyzedb</th>
<th>gpmfr</th>
</tr>
</thead>
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<td>gpmoveMmirrors</td>
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<td>gpaddmirrors</td>
<td>gpperfmon_install</td>
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<td>gpbackup</td>
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<td>gprebuildsystem</td>
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<td>gmapreduce</td>
<td>gprebuildsystem</td>
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</tbody>
</table>

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**Backend Server Programs**

The following standard PostgreSQL server management programs are provided with Greenplum Database and reside in `$GPHOME/bin`. They are modified to handle the parallelism and distribution of a Greenplum Database system. You access these programs only through the Greenplum Database management tools and utilities.

**Table 76: Greenplum Database Backend Server Programs**

<table>
<thead>
<tr>
<th>Program Name</th>
<th>Description</th>
<th>Use Instead</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>initdb</code></td>
<td>This program is called by <code>gpinitsystem</code> when initializing a Greenplum Database array. It is used internally to create the individual segment instances and the master instance.</td>
<td><code>gpinitsystem</code></td>
</tr>
<tr>
<td><code>ipcclean</code></td>
<td>Not used in Greenplum Database</td>
<td>N/A</td>
</tr>
<tr>
<td><code>gpsyncmaster</code></td>
<td>This is the Greenplum program that starts the <code>gpsyncagent</code> process on the standby master host. Administrators do not call this program directly, but do so through the management scripts that initialize and/or activate a standby master for a Greenplum Database system. This process is responsible for keeping the standby master up to date with the primary master via a transaction log replication process.</td>
<td><code>gpinitstandby</code>, <code>gpactivatestandby</code></td>
</tr>
<tr>
<td><code>pg_controldata</code></td>
<td>Not used in Greenplum Database</td>
<td><code>gpstate</code></td>
</tr>
<tr>
<td><code>pg_ctl</code></td>
<td>This program is called by <code>gpstart</code> and <code>gpstop</code> when starting or stopping a Greenplum Database array. It is used internally to stop and start the individual segment instances and the master instance in parallel and with the correct options.</td>
<td><code>gpstart</code>, <code>gpstop</code></td>
</tr>
</tbody>
</table>
| `pg_resetxlog`   | DO NOT USE

**Warning:** This program might cause data loss or cause data to become unavailable. If this program is used, the Pivotal Greenplum Database cluster is not supported. The cluster must be reinitialized and restored by the customer. | N/A                          |
### Program Name | Description | Use Instead
--- | --- | ---
**postgres** | The `postgres` executable is the actual PostgreSQL server process that processes queries. | The main `postgres` process (postmaster) creates other `postgres` subprocesses and `postgres` session as needed to handle client connections.
**postmaster** | `postmaster` starts the `postgres` database server listener process that accepts client connections. In Greenplum Database, a `postgres` database listener process runs on the Greenplum master Instance and on each Segment Instance. | In Greenplum Database, you use `gpstart` and `gpstop` to start all postmasters (`postgres` processes) in the system at once in the correct order and with the correct options.

---

### analyzedb

A utility that performs `ANALYZE` operations on tables incrementally and concurrently. For append optimized tables, `analyzedb` updates statistics only if the statistics are not current.

#### Synopsis

```
analyzedb -d dbname
  { -s schema | -t schema.table
    [ -i col1[, col2, ...] | -x col1[, col2, ...] ] } |
  { -f | --file} config-file
  [ -l | --list ]
  [ --gen_profile_only ]
  [ -p parallel-level ]
  [ --full ]
  [ --skip_root_stats ]
  [ -v | --verbose ]
  [ --debug ]
  [ -a ]

analyzedb { --clean_last | --clean_all }
analyzedb --version
analyzedb { -? | -h | --help }
```

#### Description

The `analyzedb` utility updates statistics on table data for the specified tables in a Greenplum database incrementally and concurrently.

While performing `ANALYZE` operations, `analyzedb` creates a snapshot of the table metadata and stores it on disk on the master host. An `ANALYZE` operation is performed only if the table has been modified. If a table or partition has not been modified since the last time it was analyzed, `analyzedb` automatically skips the table or partition because it already contains up-to-date statistics.

- For append optimized tables, `analyzedb` updates statistics incrementally, if the statistics are not current. For example, if table data is changed after statistics were collected for the table. If there are no statistics for the table, statistics are collected.
- For heap tables, statistics are always updated.
Specify the `--full` option to update append-optimized table statistics even if the table statistics are current.

By default, `analyzedb` creates a maximum of 5 concurrent sessions to analyze tables in parallel. For each session, `analyzedb` issues an `ANALYZE` command to the database and specifies different table names. The `-p` option controls the maximum number of concurrent sessions.

**Partitioned Append-Optimized Tables**

For a partitioned, append-optimized table, `analyzedb` checks the partitioned table root partition and leaf partitions. If needed, the utility updates statistics for non-current partitions and the root partition.

The root partition statistics is required by GPORCA. By default, the `analyzedb` utility collects statistics on the root partition of a partitioned table if the statistics do not exist. If any of the leaf partitions have stale statistics, `analyzedb` also refreshes the root partition statistics. The cost of refreshing the root level statistics is comparable to analyzing one leaf partition. You can specify the option `--skip_root_stats` to disable collection of statistics on the root partition of a partitioned table.

**Notes**

The `analyzedb` utility updates append optimized table statistics if the table has been modified by DML or DDL commands, including INSERT, DELETE, UPDATE, CREATE TABLE, ALTER TABLE and TRUNCATE.

The utility determines if a table has been modified by comparing catalog metadata of tables with the previous snapshot of metadata taken during a previous `analyzedb` operation. The snapshots of table metadata are stored as state files in the directory `db_analyze/<db_name>/<timestamp>` in the Greenplum Database master data directory.

The utility does not automatically remove old snapshot information. Over time, the snapshots can consume a large amount of disk space. To recover disk space, you can keep the most recent snapshot information and remove the older snapshots. You can also specify the `--clean_last` or `--clean_all` option to remove state files generated by `analyzedb`.

If you do not specify a table, set of tables, or schema, the `analyzedb` utility collects the statistics as needed on all system catalog tables and user-defined tables in the database.

External tables are not affected by `analyzedb`.

Table names that contain spaces are not supported.

Running the `ANALYZE` command on a table, not using the `analyzedb` utility, does not update the table metadata that the `analyzedb` utility uses to determine whether table statistics are up to date.

**Options**

`--clean_last`

Remove the state files generated by last `analyzedb` operation. All other options except `-d` are ignored.

`--clean_all`

Remove all the state files generated by `analyzedb`. All other options except `-d` are ignored.

`-d dbname`

Specifies the name of the database that contains the tables to be analyzed. If this option is not specified, the database name is read from the environment variable `PGDATABASE`. If `PGDATABASE` is not set, the user name specified for the connection is used.

`--debug`

If specified, sets the logging level to debug. During command execution, debug level information is written to the log file and to the command line. The information includes the commands executed by the utility and the duration of each `ANALYZE` operation.

`-f config-file | --file config-file`
Text file that contains a list of tables to be analyzed. A relative file path from current
directory can be specified.

The file lists one table per line. Table names must be qualified with a schema name.
 Optionally, a list of columns can be specified using the -i or -x. No other options are
allowed in the file. Other options such as --full must be specified on the command line.

Only one of the options can be used to specify the files to be analyzed: -f or --file, -t,
or -s.

When performing ANALYZE operations on multiple tables, analyzedb creates concurrent
sessions to analyze tables in parallel. The -p option controls the maximum number of
concurrent sessions.

In the following example, the first line performs an ANALYZE operation on the table
public.nation, the second line performs an ANALYZE operation only on the columns
l_shipdate and l_receiptdate in the table public.lineitem.

```
public.nation
public.lineitem -i l_shipdate, l_receiptdate
```

--full

Perform an ANALYZE operation on all the specified tables. The operation is performed
even if the statistics are up to date.

--gen_profile_only

Update the analyzedb snapshot of table statistics information without performing any
ANALYZE operations. If other options specify tables or a schema, the utility updates the
snapshot information only for the specified tables.

Specify this option if the ANALYZE command was run on database tables and you want to
update the analyzedb snapshot for the tables.

-i col1, col2, ...

Optional. Must be specified with the -t option. For the table specified with the -t option,
collect statistics only for the specified columns.

Only -i, or -x can be specified. Both options cannot be specified.

-l | --list

Lists the tables that would have been analyzed with the specified options. The ANALYZE
operations are not performed.

-p parallel-level

The number of tables that are analyzed in parallel. parallel level can be an integer between
1 and 10, inclusive. Default value is 5.

--skip_root_stats

Skip refreshing root partition statistics if any of the leaf partitions that are also analyzed
require updating.

Do not specify this option if you use GPORCA to execute queries against partitioned tables
(the default).

-s schema

Specify a schema to analyze. All tables in the schema will be analyzed. Only a single
schema name can be specified on the command line.

Only one of the options can be used to specify the files to be analyzed: -f or --file, -t,
or -s.

-t schema.table
Collect statistics only on `schema.table`. The table name must be qualified with a schema name. Only a single table name can be specified on the command line. You can specify the `-f` option to specify multiple tables in a file or the `-s` option to specify all the tables in a schema.

Only one of these options can be used to specify the files to be analyzed: `-f` or `--file`, `-t`, or `-s`.

`-x col1, col2, ...`  
Optional. Must be specified with the `-t` option. For the table specified with the `-t` option, exclude statistics collection for the specified columns. Statistics are collected only on the columns that are not listed.

Only `-i`, or `-x` can be specified. Both options cannot be specified.

`-a`  
Quiet mode. Do not prompt for user confirmation.

`-h | -? | --help`  
Displays the online help.

`-v | --verbose`  
If specified, sets the logging level to verbose to write additional information the log file and to the command line during command execution. The information includes a list of all the tables to be analyzed (including child leaf partitions of partitioned tables). Output also includes the duration of each `ANALYZE` operation.

`--version`  
Displays the version of this utility.

Examples

An example that collects statistics only on a set of table columns. In the database `mytest`, collect statistics on the columns `shipdate` and `receiptdate` in the table `public.orders`:

```
analyzedb -d mytest -t public.orders -i shipdate, receiptdate
```

An example that collects statistics on a table and exclude a set of columns. In the database `mytest`, collect statistics on the table `public.foo`, and do not collect statistics on the columns `bar` and `test2`.

```
analyzedb -d mytest -t public.foo -x bar, test2
```

An example that specifies a file that contains a list of tables. This command collect statistics on the tables listed in the file `analyze-tables` in the database named `mytest`.

```
analyzedb -d mytest -f analyze-tables
```

If you do not specify a table, set of tables, or schema, the `analyzedb` utility collects the statistics as needed on all catalog tables and user-defined tables in the specified database. This command refreshes table statistics on the system catalog tables and user-defined tables in the database `mytest`.

```
analyzedb -d mytest
```

You can create a PL/Python function to run the `analyzedb` utility as a Greenplum Database function. This example `CREATE FUNCTION` command creates a user defined PL/Python function that runs the `analyzedb` utility and displays output on the command line. Specify `analyzedb` options as the function parameter.

```
CREATE OR REPLACE FUNCTION analyzedb(params TEXT) 
RETURNS VOID AS
```
When this `SELECT` command is run by the `gpadmin` user, the `analyzedb` utility performs an analyze operation on the table `public.mytable` that is in the database `mytest`.

```sql
SELECT analyzedb('-d mytest -t public.mytable') ;
```

**Note:** To create a PL/Python function, the PL/Python procedural language must be registered as a language in the database. For example, this `CREATE LANGUAGE` command run as `gpadmin` registers PL/Python as an untrusted language:

```sql
CREATE LANGUAGE plpythonu;
```

### See Also

`ANALYZE` in the *Greenplum Database Reference Guide*

### `gpactivatestandby`

Activates a standby master host and makes it the active master for the Greenplum Database system.

#### Synopsis

```bash
gpactivatestandby [-d standby_master_datadir] [-f] [-a] [-q]
[-l logfile_directory]
gpactivatestandby -v
gpactivatestandby -? | -h | --help
```

#### Description

The `gpactivatestandby` utility activates a backup, standby master host and brings it into operation as the active master instance for a Greenplum Database system. The activated standby master effectively becomes the Greenplum Database master, accepting client connections on the master port.

When you initialize a standby master, the default is to use the same port as the active master. For information about the master port for the standby master, see `gpinitstandby`.

You must run this utility from the master host you are activating, not the failed master host you are disabling. Running this utility assumes you have a standby master host configured for the system (see `gpinitstandby`).

The utility will perform the following steps:

- Stops the synchronization process (`walreceiver`) on the standby master
- Updates the system catalog tables of the standby master using the logs
• Activates the standby master to be the new active master for the system
• Restarts the Greenplum Database system with the new master host

A backup, standby Greenplum master host serves as a 'warm standby' in the event of the primary Greenplum master host becoming non-operational. The standby master is kept up to date by transaction log replication processes (the `walsender` and `walreceiver`), which run on the primary master and standby master hosts and keep the data between the primary and standby master hosts synchronized.

If the primary master fails, the log replication process is shutdown, and the standby master can be activated in its place by using the `gpactivatestandby` utility. Upon activation of the standby master, the replicated logs are used to reconstruct the state of the Greenplum master host at the time of the last successfully committed transaction.

In order to use `gpactivatestandby` to activate a new primary master host, the master host that was previously serving as the primary master cannot be running. The utility checks for a `postmaster.pid` file in the data directory of the disabled master host, and if it finds it there, it will assume the old master host is still active. In some cases, you may need to remove the `postmaster.pid` file from the disabled master host data directory before running `gpactivatestandby` (for example, if the disabled master host process was terminated unexpectedly).

After activating a standby master, run `ANALYZE` to update the database query statistics. For example:

```
psql dbname -c 'ANALYZE;'
```

After you activate the standby master as the primary master, the Greenplum Database system no longer has a standby master configured. You might want to specify another host to be the new standby with the `gpinitstandby` utility.

**Options**

- `-a` (do not prompt)
  Do not prompt the user for confirmation.

- `-d standby_master_datadir`
  The absolute path of the data directory for the master host you are activating.
  If this option is not specified, `gpactivatestandby` uses the value of the `MASTER_DATA_DIRECTORY` environment variable setting on the master host you are activating. If this option is specified, it overrides any setting of `MASTER_DATA_DIRECTORY`.
  If a directory cannot be determined, the utility returns an error.

- `-f` (force activation)
  Use this option to force activation of the backup master host. Use this option only if you are sure that the standby and primary master hosts are consistent.

- `-l logfile_directory`
  The directory to write the log file. Defaults to `~/gpAdminLogs`.

- `-q` (no screen output)
  Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

- `-v` (show utility version)
  Displays the version, status, last updated date, and check sum of this utility.

- `?` | `-h` | `--help` (help)
  Displays the online help.
Example
Activate the standby master host and make it the active master instance for a Greenplum Database system (run from backup master host you are activating):

```
bpactivatestandby -d /gpdata
```

See Also
`gpinitsystem`, `gpinitstandby`

**gpaddmirrors**

Adds mirror segments to a Greenplum Database system that was initially configured without mirroring.

**Synopsis**

```
gpaddmirrors [-p port_offset] [-m datadir_config_file [-a]] [-s]
[-d master_data_directory] [-B parallel_processes] [-l logfile_directory]
[-v]

gpaddmirrors -i mirror_config_file [-s] [-a] [-d master_data_directory]
[-B parallel_processes] [-l logfile_directory] [-v]

gpaddmirrors -o output_sample_mirror_config [-m datadir_config_file]

gpaddmirrors -?

gpaddmirrors --version
```

**Description**

The **gpaddmirrors** utility configures mirror segment instances for an existing Greenplum Database system that was initially configured with primary segment instances only. The utility will create the mirror instances and begin the online replication process between the primary and mirror segment instances. Once all mirrors are synchronized with their primaries, your Greenplum Database system is fully data redundant.

**Important:** During the online replication process, Greenplum Database should be in a quiescent state, workloads and other queries should not be running.

By default, the utility will prompt you for the file system location(s) where it will create the mirror segment data directories. If you do not want to be prompted, you can pass in a file containing the file system locations using the `-m` option.

The mirror locations and ports must be different than your primary segment data locations and ports. If you have created additional filespaces, you will also be prompted for mirror locations for each of your filespaces.

The utility creates a unique data directory for each mirror segment instance in the specified location using the predefined naming convention. There must be the same number of file system locations declared for mirror segment instances as for primary segment instances. It is OK to specify the same directory name multiple times if you want your mirror data directories created in the same location, or you can enter a different data location for each mirror. Enter the absolute path. For example:

```
Enter mirror segment data directory location 1 of 2 > /gpdb/mirror
Enter mirror segment data directory location 2 of 2 > /gpdb/mirror
```
Alternatively, you can run the `gpaddmirrors` utility and supply a detailed configuration file using the `-i` option. This is useful if you want your mirror segments on a completely different set of hosts than your primary segments. The format of the mirror configuration file is:

```
filespaceOrder=[filespace1_fsname[:filespace2_fsname:...]
mirror[content]=content:address:port:mir_replication_port:pri_replication_port:fselocation[:fselocation:...]
```

For example (if you do not have additional filespaces configured besides the default `pg_system` filespace):

```
filespaceOrder=
mirror0=0:sdw1-1:60000:61000:62000:/gpdata/mir1/gp0
mirror1=1:sdw1-1:60001:61001:62001:/gpdata/mir2/gp1
```

The `gp_segment_configuration`, `pg_filespace`, and `pg_filespace_entry` system catalog tables can help you determine your current primary segment configuration so that you can plan your mirror segment configuration. For example, run the following query:

```
=# SELECT dbid, content, address as host_address, port, replication_port, fselocation as datadir
    FROM gp_segment_configuration, pg_filespace_entry
    WHERE dbid=fsedbid
    ORDER BY dbid;
```

If creating your mirrors on alternate mirror hosts, the new mirror segment hosts must be pre-installed with the Greenplum Database software and configured exactly the same as the existing primary segment hosts.

You must make sure that the user who runs `gpaddmirrors` (the `gpadmin` user) has permissions to write to the data directory locations specified. You may want to create these directories on the segment hosts and `chown` them to the appropriate user before running `gpaddmirrors`.

**Note:** This utility uses secure shell (SSH) connections between systems to perform its tasks. In large Greenplum Database deployments, cloud deployments, or deployments with a large number of segments per host, this utility may exceed the host's maximum threshold for unauthenticated connections. Consider updating the SSH `MaxStartups` configuration parameter to increase this threshold. For more information about SSH configuration options, refer to the SSH documentation for your Linux distribution.

**Options**
- `-a (do not prompt)`
  - Run in quiet mode - do not prompt for information. Must supply a configuration file with either `-m` or `-i` if this option is used.
- `-B parallel_processes`
  - The number of mirror setup processes to start in parallel. If not specified, the utility will start up to 10 parallel processes depending on how many mirror segment instances it needs to set up.
- `-d master_data_directory`
  - The master data directory. If not specified, the value set for `$MASTER_DATA_DIRECTORY` will be used.
- `-i mirror_config_file`
A configuration file containing one line for each mirror segment you want to create. You must have one mirror segment listed for each primary segment in the system. The format of this file is as follows (as per attributes in the gp_segment_configuration, pg_filespace, and pg_filespace_entry catalog tables):

```
filespaceOrder=[filespace1_fsname[:filespace2_fsname:...]]
mirror[content]=content:address:port:mir_replication_port:pri_replication_port:fselocation[:fselocation:...]
```

Note that you only need to specify a name for filespaceOrder if your system has multiple filespaces configured. If your system does not have additional filespaces configured besides the default pg_system filespace, this file will only have one location (for the default data directory filespace, pg_system). pg_system does not need to be listed in the filespaceOrder line. It will always be the first fselocation listed after replication_port.

`-l logfile_directory`
The directory to write the log file. Defaults to `~/gpAdminLogs`.

`-m datadir_config_file`
A configuration file containing a list of file system locations where the mirror data directories will be created. If not supplied, the utility prompts you for locations. Each line in the file specifies a mirror data directory location. For example:

```
/gpdata/m1
/gpdata/m2
/gpdata/m3
/gpdata/m4
```

If your system has additional filespaces configured in addition to the default pg_system filespace, you must also list file system locations for each filespace as follows:

```
filespace filespace1
/gpfs1/m1
/gpfs1/m2
/gpfs1/m3
/gpfs1/m4
```

`-o output_sample_mirror_config`
If you are not sure how to lay out the mirror configuration file used by the `-i` option, you can run gpaddmirrors with this option to generate a sample mirror configuration file based on your primary segment configuration. The utility will prompt you for your mirror segment data directory locations (unless you provide these in a file using `-m`). You can then edit this file to change the host names to alternate mirror hosts if necessary.

`-p port_offset`
Optional. This number is used to calculate the database ports and replication ports used for mirror segments. The default offset is 1000. Mirror port assignments are calculated as follows:

- primary port + offset = mirror database port
- primary port + (2 * offset) = mirror replication port
- primary port + (3 * offset) = primary replication port

For example, if a primary segment has port 50001, then its mirror will use a database port of 51001, a mirror replication port of 52001, and a primary replication port of 53001 by default.

`-s (spread mirrors)`
Spreads the mirror segments across the available hosts. The default is to group a set of mirror segments together on an alternate host from their primary segment set. Mirror spreading will place each mirror on a different host within the Greenplum Database array. Spreading is only allowed if there is a sufficient number of hosts in the array (number of hosts is greater than the number of segment instances per host).

- **-v (verbose)**
  Sets logging output to verbose.

- **--version (show utility version)**
  Displays the version of this utility.

- **-? (help)**
  Displays the online help.

**Examples**

Add mirroring to an existing Greenplum Database system using the same set of hosts as your primary data. Calculate the mirror database and replication ports by adding 100 to the current primary segment port numbers:

```
$ gpaddmirrors -p 100
```

Add mirroring to an existing Greenplum Database system using a different set of hosts from your primary data:

```
$ gpaddmirrors -i mirror_config_file
```

Where `mirror_config_file` looks something like this (if you do not have additional filesystems configured besides the default `pg_system` filesystem):

```
filespaceOrder=
mirror0=0:sdw1-1:52001:53001:54001:/gpdata/mir1/gp0
mirror1=1:sdw1-2:52002:53002:54002:/gpdata/mir2/gp1
mirror2=2:sdw2-1:52001:53001:54001:/gpdata/mir1/gp2
```

Output a sample mirror configuration file to use with `gpaddmirrors -i`:

```
$ gpaddmirrors -o /home/gpadmin/sample_mirror_config
```

**See Also**

`gpinitsystem`, `gpinitstandby`, `gpactivatestandby`

**gpbackup**

Create a Greenplum Database backup for use with the `gprestore` utility.

**Synopsis**

```
gpbackup --dbname database_name
  [--backup-dir directory]
  [--compression-level level]
  [--data-only]
  [--debug]
  [--exclude-schema schema_name]
  [--exclude-table schema.table]
```
gpbackup --help

**Description**

The `gpbackup` utility backs up the contents of a database into a collection of metadata files and data files that can be used to restore the database at a later time using `gprestore`. When you back up a database, you can specify table level and schema level filter options to back up specific tables. For example, you can combine schema level and table level options to back up all the tables in a schema except for a single table.

By default, `gpbackup` backs up objects in the specified database as well as global Greenplum Database system objects. You can optionally supply the `--with-globals` option with `gprestore` to restore global objects. See [Objects Included in a Backup or Restore](#) for additional information.

`gpbackup` stores the object metadata files and DDL files for a backup in the Greenplum Database master data directory by default. Greenplum Database segments use the `COPY ... ON SEGMENT` command to store their data for backed-up tables in compressed CSV data files, located in each segment's data directory. See [Understanding Backup Files](#) for additional information.

You can add the `--backup-dir` option to copy all backup files from the Greenplum Database master and segment hosts to an absolute path for later use. Additional options are provided to filter the backup set in order to include or exclude specific tables.

Each `gpbackup` task uses a single transaction on the Greenplum Database master host. The `COPY ... ON SEGMENT` command performs the backup task in parallel on each segment host. The backup process acquires an `ACCESS SHARE` lock on each table that is backed up.

When a back up operation completes, `gpbackup` returns a status code. See [Return Codes](#).

`gpbackup` can send status email notifications after a back up operation completes. You specify when the utility sends the mail and the email recipients in a configuration file. See [Configuring Email Notifications](#).

**Options**

`--dbname database_name`

Required. Specifies the database to back up.

`--backup-dir directory`

Optional. Copies all required backup files (metadata files and data files) to the specified directory. You must specify `directory` as an absolute path (not relative). If you do not supply this option, metadata files are created on the Greenplum Database master host in the `$MASTER_DATA_DIRECTORY/backups/YYYYMMDD/YYYYMMDDhhmmss/` directory. Segment hosts create CSV data files in the `<seg_dir>/backups/YYYYMMDD/YYYYMMDDhhmmss/` directory. When you specify a custom backup directory, files are copied to these paths in subdirectories of the backup directory.

`--compression-level level`
Optional. Specifies the gzip compression level (from 1 to 9) used to compress data files. The default is 1. Note that gpbackup uses compression by default.

`--data-only`
Optional. Backs up only the table data into CSV files, but does not backup metadata files needed to recreate the tables and other database objects.

`--debug`
Optional. Displays verbose debug messages during operation.

`--exclude-schema schema_name`
Optional. Specifies a database schema to exclude from the backup. You can specify this option multiple times to exclude multiple schemas. You cannot combine this option with the option `--include-schema`, or a table filtering option such as `--include-table`. See Filtering the Contents of a Backup or Restore for more information.

`--exclude-table schema.table`
Optional. Specifies a table to exclude from the backup. The table must be in the format `<schema-name>.<table-name>`. If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. You can specify this option multiple times. You cannot combine this option with the option `--exclude-schema`, or another a table filtering option such as `--include-table`.

You cannot use this option in combination with `--leaf-partition-data`. Although you can specify leaf partition names, gpbackup ignores the partition names.

See Filtering the Contents of a Backup or Restore for more information.

`--exclude-table-file file_name`
Optional. Specifies a text file containing a list of tables to exclude from the backup. Each line in the text file must define a single table using the format `<schema-name>.<table-name>`. The file must not include trailing lines. If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. You cannot combine this option with the option `--exclude-schema`, or another a table filtering option such as `--include-table`.

You cannot use this option in combination with `--leaf-partition-data`. Although you can specify leaf partition names in a file specified with `--exclude-table-file`, gpbackup ignores the partition names.

See Filtering the Contents of a Backup or Restore for more information.

`--include-schema schema_name`
Optional. Specifies a database schema to include in the backup. You can specify this option multiple times to include multiple schemas. If you specify this option, any schemas that are not included in subsequent `--include-schema` options are omitted from the backup set. You cannot combine this option with the options `--exclude-schema`, `--include-table`, or `--include-table-file`. See Filtering the Contents of a Backup or Restore for more information.

`--include-table schema.table`
Optional. Specifies a table to include in the backup. The table must be in the format `<schema-name>.<table-name>`. If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. You can specify this option multiple times. You cannot combine this option with a schema filtering option such as `--include-schema`, or another table filtering option such as `--exclude-table-file`.

You can optionally specify a table leaf partition name in place of the table name, to include only specific leaf partitions in a backup with the `--leaf-partition-data` option. When
a leaf partition is backed up, the leaf partition data is backed up along with the metadata for the partitioned table.

See Filtering the Contents of a Backup or Restore for more information.

`--include-table-file file_name`
Optional. Specifies a text file containing a list of tables to include in the backup. Each line in the text file must define a single table using the format `<schema-name>.<table-name>`. The file must not include trailing lines. If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. Any tables not listed in this file are omitted from the backup set. You cannot combine this option with a schema filtering option such as `--include-schema`, or another table filtering option such as `--exclude-table-file`.

You can optionally specify a table leaf partition name in place of the table name, to include only specific leaf partitions in a backup with the `--leaf-partition-data` option. When a leaf partition is backed up, the leaf partition data is backed up along with the metadata for the partitioned table.

See Filtering the Contents of a Backup or Restore for more information.

`--leaf-partition-data`
Optional. For partitioned tables, creates one data file per leaf partition instead of one data file for the entire table (the default). Using this option also enables you to specify individual leaf partitions to include in a backup, with the `--include-table-file` option. You cannot use this option in combination with `--exclude-table-file` or `--exclude-table`.

`--metadata-only`
Optional. Creates only the metadata files (DDL) needed to recreate the database objects, but does not back up the actual table data.

`--no-compression`
Optional. Do not compress the table data CSV files.

`--plugin-config config-file_location`
Specify the location of the `gpbackup` plugin configuration file, a YAML-formatted text file. The file contains configuration information for the plugin application that `gpbackup` uses during the backup operation.

This option is supported only with `--single-data-file` or `--metadata-only`.

If you specify the `--plugin-config` option when you back up a database, you must specify this option with configuration information for a corresponding plugin application when you restore the database from the backup.

For information about using the S3 storage plugin application, see Using the S3 Storage Plugin with `gpbackup` and `gprestore`.

`--quiet`
Optional. Suppress all non-warning, non-error log messages.

`--single-data-file`
Optional. Create a single data file on each segment host for all tables backed up on that segment. By default, each `gpbackup` creates one compressed CSV file for each table that is backed up on the segment.

**Note:** If you use the `--single-data-file` option to combine table backups into a single file per segment, you cannot set the `gprestore` option `--jobs` to a value higher than 1 to perform a parallel restore operation.

`--verbose`
Optional. Print verbose log messages.
--version
Optional. Print the version number and exit.

--with-stats
Optional. Include query plan statistics in the backup set.

--help
Displays the online help.

Return Codes
One of these codes is returned after gpbackup completes.

- 0 – Backup completed with no problems.
- 1 – Backup completed with non-fatal errors. See log file for more information.
- 2 – Backup failed with a fatal error. See log file for more information.

Examples
Backup all schemas and tables in the "demo" database, including global Greenplum Database system objects statistics:

$ gpbackup --dbname demo

Backup all schemas and tables in the "demo" database except for the "twitter" schema:

$ gpbackup --dbname demo --exclude-schema twitter

Backup only the "twitter" schema in the "demo" database:

$ gpbackup --dbname demo --include-schema twitter

Backup all schemas and tables in the "demo" database, including global Greenplum Database system objects and query statistics, and copy all backup files to the /home/gpadmin/backup directory:

$ gpbackup --dbname demo --with-stats --backup-dir /home/gpadmin/backup

This example uses --include-schema with --exclude-table to back up a schema except for a single table.

$ gpbackup --dbname demo --include-schema mydata --exclude-table mydata.addresses

You cannot use the option --exclude-schema with a table filtering option such as --include-table.

See Also
gprestore, Parallel Backup with gpbackup and gprestore and Using the S3 Storage Plugin with gpbackup and gprestore

gpcheck
Verifies and validates Greenplum Database platform settings.

Synopsis
gpcheck {(--f | --file) hostfile_gpcheck | (-h | --host) host_ID| --local} [-m master_host] [-s standby_master_host] [--stdout | --zipout]
Description

The `gpcheck` utility determines the platform on which you are running Greenplum Database and validates various platform-specific configuration settings. `gpcheck` can use a host file or a file previously created with the `--zipout` option to validate platform settings. At the end of a successful validation process, `GPCHECK_NORMAL` message displays. If `GPCHECK_ERROR` displays, one or more validation checks failed. You can use also `gpcheck` to gather and view platform settings on hosts without running validation checks.

You should run `gpcheck` as `root`. If you do not run `gpcheck` as `root`, the utility displays a warning message and will not be able to validate all configuration settings; Only some of these settings will be validated.

Options

`--config config_file`  
The name of a configuration file to use instead of the default file `$GPHOME/etc/gpcheck.cnf` (or `~/gpconfigs/gpcheck_dca_config` on the Dell EMC Greenplum Data Computing Appliance). This file specifies the OS-specific checks to run.

`{-f | --file} hostfile_gpcheck`  
The name of a file that contains a list of hosts that `gpcheck` uses to validate platform-specific settings. This file should contain a single host name for all hosts in your Greenplum Database system (master, standby master, and segments). `gpcheck` uses SSH to connect to the hosts.

`{-h | --host} host_ID`  
Checks platform-specific settings on the host in your Greenplum Database system specified by `host_ID`. `gpcheck` uses SSH to connect to the host.

`--local`  
Checks platform-specific settings on the segment host where `gpcheck` is run. This option does not require SSH authentication.

`-m master_host`  
This option is deprecated and will be removed in a future release.

`-s standby_master_host`  
This option is deprecated and will be removed in a future release.

`--stdout`  
Display collected host information from `gpcheck`. No checks or validations are performed.

`--zipout`  
Save all collected data to a `.zip` file in the current working directory. `gpcheck` automatically creates the `.zip` file and names it `gpcheck_timestamp.tar.gz`. No checks or validations are performed.

`--zipin gpcheck_zipfile`  
Use this option to decompress and check a `.zip` file created with the `--zipout` option. `gpcheck` performs validation tasks against the file you specify in this option.

`-?` (Help)
Displays the online help.

```
--version
```

Displays the version of this utility.

**Examples**

Verify and validate the Greenplum Database platform settings by entering a host file:

```
# gpcheck -f hostfile_gpcheck
```

Save Greenplum Database platform settings to a zip file:

```
# gpcheck -f hostfile_gpcheck --zipout
```

Verify and validate the Greenplum Database platform settings using a zip file created with the `--zipout` option:

```
# gpcheck --zipin gpcheck_timestamp.tar.gz
```

View collected Greenplum Database platform settings:

```
# gpcheck -f hostfile_gpcheck --stdout
```

**See Also**

`gpssh`, `gpscp`, `gpcheckperf`

**gpcheckcat**

The `gpcheckcat` utility tests Greenplum Database catalog tables for inconsistencies.

The utility is in `$GPHOME/bin/lib`.

**Synopsis**

```
gpcheckcat [ options] [ dbname]
```

Options:

- `-g` dir
- `-p` port
- `-P` password
- `-U` user_name
- `-S` {none | only}
- `-O`
- `-R` test_name
- `-C` catalog_name
- `-B` parallel_processes
- `-v`
- `-A`

```
gpcheckcat -l
```

```
gpcheckcat -?
```
Description

The gpcheckcat utility runs multiple tests that check for database catalog inconsistencies. Some of the tests cannot be run concurrently with other workload statements or the results will not be usable. Restart the database in restricted mode when running gpcheckcat, otherwise gpcheckcat might report inconsistencies due to ongoing database operations rather than the actual number of inconsistencies. If you run gpcheckcat without stopping database activity, run it with -O option.

Note: Any time you run the utility, it checks for and deletes orphaned, temporary database schemas (temporary schemas without a session ID) in the specified databases. The utility displays the results of the orphaned, temporary schema check on the command line and also logs the results.

Catalog inconsistencies are inconsistencies that occur between Greenplum Database system tables. In general, there are three types of inconsistencies:

- Inconsistencies in system tables at the segment level. For example, an inconsistency between a system table that contains table data and a system table that contains column data. As another, a system table that contains duplicates in a column that should to be unique.

- Inconsistencies between same system table across segments. For example, a system table is missing row on one segment, but other segments have this row. As another example, the values of specific row column data are different across segments, such as table owner or table access privileges.

- Persistent Table inconsistencies are inconsistencies in persistence object state and file system objects on a segment. For example, there are no running transactions, all transactions are complete, but there is object that is marked as creation incomplete in persistent tables. As another example, a file exists in database directory, but there is no corresponding object existing in the database system tables.

Options

-A

Run gpcheckcat on all databases in the Greenplum Database installation.

-B parallel_processes

The number of processes to run in parallel.

The gpcheckcat utility attempts to determine the number of simultaneous processes (the batch size) to use. The utility assumes it can use a buffer with a minimum of 20MB for each process. The maximum number of parallel processes is the number of Greenplum Database segment instances. The utility displays the number of parallel processes that it uses when it starts checking the catalog.

Note: The utility might run out of memory if the number of errors returned exceeds the buffer size. If an out of memory error occurs, you can lower the batch size with the -B option. For example, if the utility displays a batch size of 936 and runs out of memory, you can specify -B 468 to run 468 processes in parallel.

-C catalog_table

Run cross consistency, foreign key, and ACL tests for the specified catalog table.

-g data_directory

Generate SQL scripts to fix catalog inconsistencies. The scripts are placed in data_directory.

-l

List the gpcheckcat tests.

-O

Run only the gpcheckcat tests that can be run in online (not restricted) mode.
-p port
   This option specifies the port that is used by the Greenplum Database.

-P password
   The password of the user connecting to Greenplum Database.

-R test_name
   Specify a test to run. Some tests can be run only when Greenplum Database is in restricted mode.
   These are the tests that can be performed:
   acl - Cross consistency check for access control privileges
   duplicate - Check for duplicate entries
   duplicate_persistent - Check for duplicate gp_persistent_relation_node entries
   foreign_key - Check foreign keys
   inconsistent - Cross consistency check for master segment inconsistency
   mirroring_matching - Checks if mirroring is consistent (either enabled or disabled) for the cluster and segments.
   missing_extraneous - Cross consistency check for missing or extraneous entries
   owner - Check table ownership that is inconsistent with the master database
   part_integrity - Check pg_partition branch integrity, partition with OIDs, partition distribution policy
   part_constraint - Check constraints on partitioned tables
   unique_index_violation - Check tables that have columns with the unique index constraint for duplicate entries
   dependency - Check for dependency on non-existent objects (restricted mode only)
   distribution_policy - Check constraints on randomly distributed tables (restricted mode only)
   namespace - Check for schemas with a missing schema definition (restricted mode only)
   persistent - Check persistent tables (restricted mode only)
   pgclass - Check pg_class entry that does not have any corresponding pg_attribute entry (restricted mode only)

-S {none | only}
   Specify this option to control the testing of catalog tables that are shared across all databases in the Greenplum Database installation, such as pg_database.
   The value none disables testing of shared catalog tables. The value only tests only the shared catalog tables.

-U user_name
   The user connecting to Greenplum Database.

-? (help)
   Displays the online help.

-v (verbose)
   Displays detailed information about the tests that are performed.
Notes
The utility identifies tables with missing attributes and displays them in various locations in the output and in a non-standardized format. The utility also displays a summary list of tables with missing attributes in the format `database.schema.table.segment_id` after the output information is displayed.

If `gpcheckcat` detects inconsistent OID (Object ID) information, it generates one or more verification files that contain an SQL query. You can run the SQL query to see details about the OID inconsistencies and investigate the inconsistencies. The files are generated in the directory where `gpcheckcat` is invoked.

This is the format of the file:
```
gpcheckcat.verify.dbname.catalog_table_name.test_name.TIMESTAMP.sql
```

This is an example verification filename created by `gpcheckcat` when it detects inconsistent OID (Object ID) information in the catalog table `pg_type` in the database `mydb`:
```
gpcheckcat.verify.mydb.pg_type.missing_extraneous.20150420102715.sql
```

This is an example query from a verification file:
```
SELECT *
FROM (SELECT relname, oid FROM pg_class WHERE reltype IN (1305822,1301043,1301069,1301095)
UNION ALL SELECT relname, oid FROM gp_dist_random('pg_class') WHERE reltype IN (1305822,1301043,1301069,1301095)
) alltyprelids
GROUP BY relname, oid ORDER BY count(*) desc;
```

`gpcheckperf`
Verifies the baseline hardware performance of the specified hosts.

Synopsis
```
gpcheckperf -d test_directory [-d test_directory ...]
[-f hostfile_gpcheckperf | -h hostname [-h hostname ...]]
[-r ds] [-B block_size] [-S file_size] [-D] [-v|-V]
gpcheckperf -d temp_directory
[-f hostfile_gpchecknet | -h hostname [-h hostname ...]]
[-r n|N|M [--duration time] [--netperf] ] [-D] [-v | -V]
gpcheckperf -?
gpcheckperf --version
```

Description
The `gpcheckperf` utility starts a session on the specified hosts and runs the following performance tests:

- **Disk I/O Test (dd test)** — To test the sequential throughput performance of a logical disk or file system, the utility uses the `dd` command, which is a standard UNIX utility. It times how long it takes to write and read a large file to and from disk and calculates your disk I/O performance in megabytes (MB) per second. By default, the file size that is used for the test is calculated at two times the total random access memory (RAM) on the host. This ensures that the test is truly testing disk I/O and not using the memory cache.

- **Memory Bandwidth Test (stream)** — To test memory bandwidth, the utility uses the STREAM benchmark program to measure sustainable memory bandwidth (in MB/s). This tests that your system is not limited in performance by the memory bandwidth of the system in relation to the computational...
performance of the CPU. In applications where the data set is large (as in Greenplum Database), low memory bandwidth is a major performance issue. If memory bandwidth is significantly lower than the theoretical bandwidth of the CPU, then it can cause the CPU to spend significant amounts of time waiting for data to arrive from system memory.

- **Network Performance Test (gpnetbench)** — To test network performance (and thereby the performance of the Greenplum Database interconnect), the utility runs a network benchmark program that transfers a 5 second stream of data from the current host to each remote host included in the test. The data is transferred in parallel to each remote host and the minimum, maximum, average and median network transfer rates are reported in megabytes (MB) per second. If the summary transfer rate is slower than expected (less than 100 MB/s), you can run the network test serially using the `-r n` option to obtain per-host results. To run a full-matrix bandwidth test, you can specify `-r M` which will cause every host to send and receive data from every other host specified. This test is best used to validate if the switch fabric can tolerate a full-matrix workload.

To specify the hosts to test, use the `-f` option to specify a file containing a list of host names, or use the `-h` option to name single host names on the command-line. If running the network performance test, all entries in the host file must be for network interfaces within the same subnet. If your segment hosts have multiple network interfaces configured on different subnets, run the network test once for each subnet.

You must also specify at least one test directory (with `-d`). The user who runs `gpcheckperf` must have write access to the specified test directories on all remote hosts. For the disk I/O test, the test directories should correspond to your segment data directories (primary and/or mirrors). For the memory bandwidth and network tests, a temporary directory is required for the test program files.

Before using `gpcheckperf`, you must have a trusted host setup between the hosts involved in the performance test. You can use the utility `gpssh-exkeys` to update the known host files and exchange public keys between hosts if you have not done so already. Note that `gpcheckperf` calls to `gpssh` and `gpscp`, so these Greenplum utilities must also be in your `$PATH`.

**Options**

- `-B block_size`
  Specifies the block size (in KB or MB) to use for disk I/O test. The default is 32KB, which is the same as the Greenplum Database page size. The maximum block size is 1 MB.

- `-d test_directory`
  For the disk I/O test, specifies the file system directory locations to test. You must have write access to the test directory on all hosts involved in the performance test. You can use the `-d` option multiple times to specify multiple test directories (for example, to test disk I/O of your primary and mirror data directories).

- `-d temp_directory`
  For the network and stream tests, specifies a single directory where the test program files will be copied for the duration of the test. You must have write access to this directory on all hosts involved in the test.

- `-D (display per-host results)`
  Reports performance results for each host for the disk I/O tests. The default is to report results for just the hosts with the minimum and maximum performance, as well as the total and average performance of all hosts.

- `--duration time`
  Specifies the duration of the network test in seconds (s), minutes (m), hours (h), or days (d). The default is 15 seconds.

- `-f hostfile_gpcheckperf`
  For the disk I/O and stream tests, specifies the name of a file that contains one host name per host that will participate in the performance test. The host name is required, and you
can optionally specify an alternate user name and/or SSH port number per host. The syntax of the host file is one host per line as follows:

\[
[\text{username}@]\text{hostname}[:\text{ssh_port}]
\]

- `f hostfile_gpchecknet`

For the network performance test, all entries in the host file must be for host addresses within the same subnet. If your segment hosts have multiple network interfaces configured on different subnets, run the network test once for each subnet. For example (a host file containing segment host address names for interconnect subnet 1):

```plaintext
sdw1-1
sdw2-1
sdw3-1
```

- `h hostname`

Specifies a single host name (or host address) that will participate in the performance test. You can use the `-h` option multiple times to specify multiple host names.

--netperf

Specifies that the `netperf` binary should be used to perform the network test instead of the Greenplum network test. To use this option, you must download netperf from [http://www.netperf.org](http://www.netperf.org) and install it into `$GPHOME/bin/lib` on all Greenplum hosts (master and segments).

- `r ds{n|N|M}`

Specifies which performance tests to run. The default is `dsn`:

- Disk I/O test (`d`)
- Stream test (`s`)
- Network performance test in sequential (`n`), parallel (`N`), or full-matrix (`M`) mode. The optional `--duration` option specifies how long (in seconds) to run the network test. To use the parallel (`N`) mode, you must run the test on an even number of hosts.

If you would rather use `netperf` ([http://www.netperf.org](http://www.netperf.org)) instead of the Greenplum network test, you can download it and install it into `$GPHOME/bin/lib` on all Greenplum hosts (master and segments). You would then specify the optional `--netperf` option to use the `netperf` binary instead of the default `gpnetbench*` utilities.

- `S file_size`

Specifies the total file size to be used for the disk I/O test for all directories specified with `-d`. `file_size` should equal two times total RAM on the host. If not specified, the default is calculated at two times the total RAM on the host where `gpcheckperf` is executed. This ensures that the test is truly testing disk I/O and not using the memory cache. You can specify sizing in KB, MB, or GB.

- `v (verbose) | -V (very verbose)`

Verbose mode shows progress and status messages of the performance tests as they are run. Very verbose mode shows all output messages generated by this utility.

--version

Displays the version of this utility.

- `? (help)`

Displays the online help.
**Examples**

Run the disk I/O and memory bandwidth tests on all the hosts in the file `host_file` using the test directory of `/data1` and `/data2`:

```
$ gpcheckperf -f hostfile_gpcheckperf -d /data1 -d /data2 -r ds
```

Run only the disk I/O test on the hosts named `sdw1` and `sdw2` using the test directory of `/data1`. Show individual host results and run in verbose mode:

```
$ gpcheckperf -h sdw1 -h sdw2 -d /data1 -r d -D -v
```

Run the parallel network test using the test directory of `/tmp`, where `hostfile_gpcheck_ic*` specifies all network interface host address names within the same interconnect subnet:

```
$ gpcheckperf -f hostfile_gpchecknet_ic1 -r N -d /tmp
$ gpcheckperf -f hostfile_gpchecknet_ic2 -r N -d /tmp
```

Run the same test as above, but use `netperf` instead of the Greenplum network test (note that `netperf` must be installed in `$GPHOME/bin/lib` on all Greenplum hosts):

```
$ gpcheckperf -f hostfile_gpchecknet_ic1 -r N --netperf -d /tmp
$ gpcheckperf -f hostfile_gpchecknet_ic2 -r N --netperf -d /tmp
```

**See Also**

`gpssh`, `gpscp`, `gpcheck`

**gpconfig**

Sets server configuration parameters on all segments within a Greenplum Database system.

**Synopsis**

```
gpconfig -c param_name -v value [ -m master_value | --masteronly]  
   | -r param_name [--masteronly] | -l  
   [--skipvalidation] [--verbose] [--debug] 

gpconfig -s param_name [--file | --file-compare] [--verbose] [--debug] 

gpconfig --help
```

**Description**

The `gpconfig` utility allows you to set, unset, or view configuration parameters from the `postgresql.conf` files of all instances (master, segments, and mirrors) in your Greenplum Database system. When setting a parameter, you can also specify a different value for the master if necessary. For example, parameters such as `max_connections` require a different setting on the master than what is used for the segments. If you want to set or unset a global or master only parameter, use the `--masteronly` option.

`gpconfig` can only be used to manage certain parameters. For example, you cannot use it to set parameters such as `port`, which is required to be distinct for every segment instance. Use the `-l` (list) option to see a complete list of configuration parameters supported by `gpconfig`.

When `gpconfig` sets a configuration parameter in a segment `postgresql.conf` file, the new parameter setting always displays at the bottom of the file. When you use `gpconfig` to remove a configuration parameter setting, `gpconfig` comments out the parameter in all segment `postgresql.conf` files,
thereby restoring the system default setting. For example, if you use `gpconfig` to remove (comment out) a parameter and later add it back (set a new value), there will be two instances of the parameter; one that is commented out, and one that is enabled and inserted at the bottom of the `postgresql.conf` file.

After setting a parameter, you must restart your Greenplum Database system or reload the `postgresql.conf` files in order for the change to take effect. Whether you require a restart or a reload depends on the parameter.

For more information about the server configuration parameters, see the *Greenplum Database Reference Guide*.

To show the currently set values for a parameter across the system, use the `-s` option.

`gpconfig` uses the following environment variables to connect to the Greenplum Database master instance and obtain system configuration information:

- `PGHOST`
- `PGPORT`
- `PGUSER`
- `PGPASSWORD`
- `PGDATABASE`

### Options

#### `-c` | `--change param_name`
Changes a configuration parameter setting by adding the new setting to the bottom of the `postgresql.conf` files.

#### `-v` | `--value value`
The value to use for the configuration parameter you specified with the `-c` option. By default, this value is applied to all segments, their mirrors, the master, and the standby master.

Parameter values that are not simple identifiers or numbers must be enclosed in single quotes ('). For example, values that contain spaces or special characters must be enclosed in single quotes. To embed a single quote in a parameter value, enter either two single quotes or backslash and quote (\').

The utility encloses the value in single quotes when adding the setting to the `postgresql.conf` files.

#### `-m` | `--mastervalue master_value`
The master value to use for the configuration parameter you specified with the `-c` option. If specified, this value only applies to the master and standby master. This option can only be used with `-v`.

#### `--masteronly`
When specified, `gpconfig` will only edit the master `postgresql.conf` file.

#### `-r` | `--remove param_name`
Removes a configuration parameter setting by commenting out the entry in the `postgresql.conf` files.

#### `-l` | `--list`
Lists all configuration parameters supported by the `gpconfig` utility.

#### `-s` | `--show param_name`
Shows the value for a configuration parameter used on all instances (master and segments) in the Greenplum Database system. If there is a difference in a parameter value among the instances, the utility displays an error message. Running `gpconfig` with the `-s` option reads parameter values directly from the database, and not the `postgresql.conf` file. If you are using `gpconfig` to set configuration parameters...
across all segments, then running `gpconfig -s` to verify the changes, you might still see the previous (old) values. You must reload the configuration files (gpstop -u) or restart the system (gpstop -r) for changes to take effect.

--file
For a configuration parameter, shows the value from the `postgresql.conf` file on all instances (master and segments) in the Greenplum Database system. If there is a difference in a parameter value among the instances, the utility displays a message. Must be specified with the -s option.

For example, the configuration parameter `statement_mem` is set to 64MB for a user with the `ALTER ROLE` command, and the value in the `postgresql.conf` file is 128MB. Running the command `gpconfig -s statement_mem --file` displays 128MB. The command `gpconfig -s statement_mem` run by the user displays 64MB.

Not valid with the --file-compare option.

--file-compare
For a configuration parameter, compares the current Greenplum Database value with the value in the `postgresql.conf` files on hosts (master and segments). The values in the `postgresql.conf` files represent the value when Greenplum Database is restarted.

If the values are not the same, the utility displays the values from all hosts. If all hosts have the same value, the utility displays a summary report.

Not valid with the --file option.

--skipvalidation
Overrides the system validation checks of `gpconfig` and allows you to operate on any server configuration parameter, including hidden parameters and restricted parameters that cannot be changed by `gpconfig`. When used with the -l option (list), it shows the list of restricted parameters.

Warning: Use extreme caution when setting configuration parameters with this option.

--verbose
Displays additional log information during `gpconfig` command execution.

--debug
Sets logging output to debug level.

-? | -h | --help
Displays the online help.

Examples
Set the `gp_snmp_community` parameter to `testenv` in the master host file only:

```
$ gpconfig -c gp_snmp_community -v testenv --masteronly
```

Set the `max_connections` setting to 100 on all segments and 10 on the master:

```
$ gpconfig -c max_connections -v 100 -m 10
```

Set the server configuration parameters `gp_email_to` and `gp_email_from`. These parameters require single quotes around the values.

```
$ gpconfig -c gp_email_from -v 'gpdb-server@example.com'
$ gpconfig -c gp_email_to -v 'gpdb-admin@example.com'
```
In the `postgresql.conf` file, the parameters are set correctly, with single quotes around the values:

```plaintext
gp_email_from='gpdb-server@example.com'
gp_email_to='gpdb-admin@example.com'
```

These examples shows the syntax required due to bash shell string processing.

```plaintext
gpconfig -c search_path -v '"$user",public'
gpconfig -c dynamic_library_path -v '$libdir'
```

The configuration parameters are added to the `postgresql.conf` file.

```plaintext
search_path='$user',public'
dynamic_library_path='$libdir'
```

Comment out all instances of the `default_statistics_target` configuration parameter, and restore the system default:

```plaintext
gpconfig -r default_statistics_target
```

List all configuration parameters supported by `gpconfig`:

```plaintext
gpconfig -l
```

Show the values of a particular configuration parameter across the system:

```plaintext
gpconfig -s max_connections
```

### See Also

`gpstop`

**gpcrondump**

Writes out a database to SQL script files. The script files can be used to restore the database using the `gpdbrestore` utility. The `gpcrondump` utility can be called directly or from a `crontab` entry.

**Note:** This utility is deprecated and will not be supported after the end of Greenplum Database 5.x Support Life.

#### Synopsis

```plaintext
gpcrondump -x database_name
[-s schema | -S schema | -t schema.table | -T schema.table]
[--table-file=filename | --exclude-table-file=filename]
[--schema-file=filename | --exclude-schema-file=filename]
[--dump-stats]
[-u backup_directory] [-R post_dump_script] [--incremental]
[-K timestamp | --list-backup-files]
[--prefix prefix_string | --list-filter-tables]
[-c [-cleanup-date yyyyMMdd | --cleanup-total n] ]
[-z] [-r]
[-d master_data_directory] [-B parallel_processes] [-a] [-q]
[-y reportfile] [-l logfile_directory]
[--email-file path_to_file] [-v]
{ [-E encoding] [--inserts | --column-inserts] [--oids]
  [--no-owner | --use-set-session-authorization] [--no-privileges]
```
Description

The `gpcrondump` utility dumps the contents of a database into SQL script files, which can then be used to restore the database schema and user data at a later time using `gpdbrestore`. During a dump operation, users will still have full access to the database.

By default, dump files are created in their respective master and segment data directories in a directory named `db_dumps/YYYYMMDD`. The data dump files are compressed by default using `gzip`.

The utility backs up the database-level settings for the server configuration parameters `gp_default_storage_options`, `optimizer`, and `search_path`. The settings are restored when you restore the database with the `gpdbrestore` utility and specify the `-e` option to create an empty target database before performing a restore operation.

If you specify an option to back up schemas, such as `-s`, or `-S`, all procedural languages that are defined in the database are also backed up even though they are not schema specific. The languages are backed up to support any functions that might be backed up. External items such as shared libraries that are used by a language are not backed up. Also, languages are not backed up if you specify an option to back up only tables, such as `-t`, `-T`.

After a backup operation completes, the utility checks the `gpcrondump` status file for SQL execution errors and displays a warning if an error is found. The default location of the backup status files are in the `db_dumps/date/` directory.

If you specify an option that includes or excludes tables or schemas, such as `-t`, `-T`, `-s`, or `-S`, the schema qualified names of the tables that are backed up are listed in the file `gp_dump_timestamp_table`. The file is stored in the backup directory of the master segment.

`gpcrondump` allows you to schedule routine backups of a Greenplum database using `cron` (a scheduling utility for UNIX operating systems). Cron jobs that call `gpcrondump` should be scheduled on the master host.

**Warning:** Backing up a database with `gpcrondump` while simultaneously running `ALTER TABLE` might cause `gpcrondump` to fail.

Backing up a database with `gpcrondump` while simultaneously running DDL commands might cause issues with locks. You might see either the DDL command or `gpcrondump` waiting to acquire locks.
About Database, Schema, and Table Names

You can specify names of databases, schemas, and tables that contain these special characters.
" ' ` ~ # $ % ^ & * ( ) _ - + [ ] { } > < \ | ; : / ? and the space character.

Note: The characters !, comma (,), and period (.) are not supported. Also, the tab (\t) and newline (\n) characters are not supported.

When the name contains special characters and is specified on the command line, the name must be enclosed in double quotes ("). Double quotes are optional for names that do not contain special characters. For example, either use of quotes is valid on the command line "my#1schema"."mytable or "my#1schema"."mytable". Within the name, these special characters must be escaped with a backslash (\):
" ` $ \

When the name is specified in an input file, the name must not be enclosed in double quotes. Special characters do not require escaping.

Backup Filenames

The utility creates backup files with this file name format.

prefix_gp_dump_content_dbid_timestamp

The content and dbid are identifiers for the Greenplum Database segment instances that are assigned by Greenplum Database. For information about the identifiers, see the Greenplum Database system catalog table gp_segment_configuration in the Greenplum Database Reference Guide.

Using Data Domain Boost

The gpcrondump utility is used to schedule Data Domain Boost (DD Boost) backup operations. The utility is also used to set, change, or remove one-time credentials and storage unit ID for DD Boost. The gpcrondump, gpdbrstore, and gpmfr utilities use the DD Boost credentials to access Data Domain systems. DD Boost information is stored in these files.

- DDBOOST_CONFIG is used by gpdbrstore and gpcrondump for backup and restore operations with the Data Domain system. The gpdbrstore utility creates or updates the file when you specify Data Domain information with the --ddboost-host option.
- DDBOOST_MFR_CONFIG is used by gpmfr for remote replication operations with the remote Data Domain system. The gpdbrstore utility creates or updates the file when you specify Data Domain information with the --ddboost-host option and the --ddboost-remote option.

The configuration files are created in the current user (gpadmin) home directory on the Greenplum Database master and segment hosts. The path and file name cannot be changed.

When you use DD Boost to perform a backup operation, the operation uses a storage unit on a Data Domain system. You can specify the storage unit ID when you perform these operations:

- When you set the DD Boost credentials with the --ddboost-host option. If you specify the --ddboost-storage-unit option, the storage unit ID is written to the Greenplum Database DD Boost configuration file DDBOOST_CONFIG. If the storage unit ID is not specified, the default value is GPDB.
- When you perform a backup operation with the --ddboost option. When you specify the --ddboost-storage-unit option, the utility uses the specified Data Domain storage unit for the operation. The value in the configuration file is not changed.

When performing a full backup operation (not an incremental backup), the storage unit is created on the Data Domain system if it does not exist.

A storage unit is not created if these gpcrondump options are specified: --incremental, --list-backup-file, --list-filter-tables, -o, or --ddboost-config-remove.

A storage unit is not created if these gpcrondump options are specified: --incremental, --list-backup-file, --list-filter-tables, -o, or --ddboost-config-remove.
Use the `gpcrondump` option `--ddboost-show-config` to display the current DD Boost configuration information from the master configuration file. Specify the `--remote` option to display the configuration information for the remote Data Domain system.

For information about using DD Boost and Data Domain systems with Greenplum Database, see "Backing Up and Restoring Databases" in the *Greenplum Database Administrator Guide*.

### Using NetBackup

Veritas NetBackup integration is included with Pivotal Greenplum Database. Greenplum Database must be configured to communicate with the Veritas NetBackup master server that is used to backup the database.

When backing up a large amount of data, set the NetBackup `CLIENT_READ_TIMEOUT` option to a value that is at least twice the expected duration of the operation (in seconds). The `CLIENT_READ_TIMEOUT` default value is 300 seconds (5 minutes).

See the *Greenplum Database Administrator Guide* for information on configuring Greenplum Database and NetBackup and backing up and restoring with NetBackup.

### About Return Codes

The following is a list of the codes that `gpcrondump` returns.

- **0** – Dump completed with no problems
- **1** – Dump completed, but one or more warnings were generated
- **2** – Dump failed with a fatal error

### Email Notifications

To have `gpcrondump` send out status email notifications after a back up operation completes, you must place a file named `mail_contacts` in the home directory of the Greenplum superuser (`gpadmin`) or in the same directory as the `gpcrondump` utility (`$GPHOME/bin`). This file should contain one email address per line. `gpcrondump` will issue a warning if it cannot locate a `mail_contacts` file in either location. If both locations have a `mail_contacts` file, then the one in `$HOME` takes precedence.

You can customize the email Subject and From lines of the email notifications that `gpcrondump` sends after a back up completes for a database. You specify the option `--email-file` with the location of a YAML file that contains email Subject and From lines that `gpcrondump` uses. For information about the format of the YAML file, see *File Format for Customized Emails*.

**Note:** The UNIX mail utility must be running on Greenplum Database host and must be configured to allow the Greenplum superuser (`gpadmin`) to send email.

### Limitations

Dell EMC DD Boost is integrated with Pivotal Greenplum Database and requires a DD Boost license. Open source Greenplum Database cannot use the DD Boost software, but can back up to a Dell EMC Data Domain system mounted as an NFS share on the Greenplum master and segment hosts.

NetBackup is not compatible with DD Boost. Both NetBackup and DD Boost cannot be used in a single back up operation.

For incremental back up sets, a full backup and associated incremental backups, the backup set must be on a single device. For example, a backup set must all be on a file system. The backup set cannot have some backups on the local file system and others on a Data Domain system or a NetBackup system.

For external tables, the table definition is backed up, however the data is not backed up. For leaf child partition of a partitioned table that is a readable external table, the leaf child partition data is not backed up.

### Options

- **-a** (do not prompt)
  Do not prompt the user for confirmation.
- **-b** (bypass disk space check)
Bypass disk space check. The default is to check for available disk space, unless --ddboost is specified. When using Data Domain Boost, this option is always enabled.

**Note:** Bypassing the disk space check generates a warning message. With a warning message, the return code for gpcrondump is 1 if the dump is successful. (If the dump fails, the return code is 2, in all cases.)

-B parallel_processes

The number of segments to check in parallel for pre/post-dump validation. If not specified, the utility will start up to 60 parallel processes depending on how many segment instances it needs to dump.

-c (clear old dump files first)

Specify this option to delete old backups before performing a backup. In the db_dumps directory, the directory where the name is the oldest date is deleted. If the directory name is the current date, the directory is not deleted. The default is to not delete old backup files.

The deleted directory might contain files from one or more backups.

**Warning:** Before using this option, ensure that incremental backups required to perform the restore are not deleted. The gpdbrestore utility option --list-backup lists the backup sets required to perform a backup.

If --ddboost is specified, only the old files on Data Domain Boost are deleted.

You can specify the option --cleanup-date or --cleanup-total to specify backup sets to delete.

This option is not supported with the -u option.

-C (clean catalog before restore)

Clean out the catalog schema prior to restoring database objects. gpcrondump adds the DROP command to the SQL script files when creating the backup files. When the script files are used by the gpdbrestore utility to restore database objects, the DROP commands remove existing database objects before restoring them.

If --incremental is specified and the files are on NFS storage, the -C option is not supported. The database objects are not dropped if the -C option is specified.

--cleanup-date=yyyyymmdd

Remove backup sets for the date yyyy-mm-dd. The date format is yyyyymmdd. If multiple backup sets were created on the date, all the backup sets for that date are deleted. If no backup sets are found, gpcrondump returns a warning message and no backup sets are deleted. If the -c option is specified, the backup process continues.

Valid only with the -c or -o option.

**Warning:** Before using this option, ensure that incremental backups required to perform the restore are not deleted. The gpdbrestore utility option --list-backup lists the backup sets required to perform a backup.

--cleanup-total=n

Remove the n oldest backup sets based on the backup timestamp.

If there are fewer than n backup sets, gpcrondump returns a warning message and no backup sets are deleted. If the -c option is specified, the backup process continues.

Valid only with the -c or -o option.

**Warning:** Before using this option, ensure that incremental backups required to perform the restore are not deleted. The gpdbrestore utility option --list-backup lists the backup sets required to perform a backup.

--column-inserts
Dump data as \texttt{INSERT} commands with column names.

If \texttt{--incremental} is specified, this option is not supported.

\texttt{-d master_data_directory}

The master host data directory. If not specified, the value set for \$\texttt{MASTER\_DATA\_DIRECTORY} will be used.

\texttt{--ddboost \[\texttt{--replicate --max-streams max\_IO\_streams \]} \[\texttt{--ddboost-skip-ping}\]}

Use Data Domain Boost for this backup. Before using Data Domain Boost, set up the Data Domain Boost credential with the \texttt{--ddboost-host} option. Also, see \textit{Using Data Domain Boost}.

If \texttt{--ddboost} is specified, the \texttt{-z} option (uncompressed) is recommended.

Backup compression (turned on by default) should be turned off with the \texttt{-z} option. Data Domain Boost will deduplicate and compress the backup data before sending it to the Data Domain system.

\texttt{--replicate --max-streams max\_IO\_streams} is optional. If you specify this option, \texttt{gpcrondump} replicates the backup on the remote Data Domain server after the backup is complete on the primary Data Domain server. \texttt{max\_IO\_streams} specifies the maximum number of Data Domain I/O streams that can be used when replicating the backup set on the remote Data Domain server from the primary Data Domain server.

You can use \texttt{gpmfr} to replicate a backup if replicating a backup with \texttt{gpcrondump} takes a long time and prevents other backups from occurring. Only one instance of \texttt{gpcrondump} can be running at a time. While \texttt{gpcrondump} is being used to replicate a backup, it cannot be used to create a backup.

You can run a mixed backup that writes to both a local disk and Data Domain. If you want to use a backup directory on your local disk other than the default, use the \texttt{-u} option. Mixed backups are not supported with incremental backups. For more information about mixed backups and Data Domain Boost, see "Backing Up and Restoring Databases" in the \textit{Greenplum Database Administrator Guide}.

\textbf{Important:} Never use the Greenplum Database default backup options with Data Domain Boost.

To maximize Data Domain deduplication benefits, retain at least 30 days of backups.

\textbf{Note:} The \texttt{-b}, \texttt{-c}, \texttt{-f}, \texttt{-G}, \texttt{-g}, \texttt{-R}, and \texttt{-u} options change if \texttt{--ddboost} is specified. See the options for details.

The DDBoost backup options are not supported if the NetBackup options are specified.

\texttt{--ddboost-host ddboost\_hostname \[\texttt{--ddboost-host ddboost\_hostname \} ...\]} \texttt{\[\texttt{--ddboost-remote\]}} \texttt{\[\texttt{--ddboost-skip-ping}\]}

Sets the Data Domain Boost credentials. Do not combine this options with any other \texttt{gpcrondump} options. Do not enter just one part of this option.

\texttt{ddboost\_hostname} is the IP address (or hostname associated to the IP) of the host. There is a 30-character limit. If you use two or more network connections to connect to the Data Domain system, specify each connection with the \texttt{--ddboost-host} option.

\texttt{ddboost\_user} is the Data Domain Boost user name. There is a 30-character limit.

\texttt{backup\_directory} is the location for the backup files, configuration files, and global objects on the Data Domain system. The location on the system is \texttt{GPDB/backup\_directory}.

\texttt{--ddboost-remote} is optional. It indicates that the configuration parameters are for the remote Data Domain system used for backup replication and Data Domain Boost managed
file replication. Credentials for the remote Data Domain system must be configured to use the --replicate option or the gpmfr management utility.

For example:

```
gpcrondump --ddboost-host 192.0.2.230 --ddboost-user ddboostusername --ddboost-backupdir gp_production
```

**Note:** When setting Data Domain Boost credentials, the --ddboost-backupdir option is ignored if the --ddboost-remote option is specified for a Data Domain system that is used for the replication of backups. The --ddboost-backupdir value is for backup operations with a Data Domain system, not for backup replication.

After running gpcrondump with these options, the system verifies the limits on the host and user names and prompts for the Data Domain Boost password. Enter the password when prompted; the password is not echoed on the screen. There is a 40-character limit on the password that can include lowercase letters (a-z), uppercase letters (A-Z), numbers (0-9), and special characters ($, %, #, +, etc.).

The system verifies the password. After the password is verified, the system creates encrypted DDBOOST_CONFIG files in the user's home directory.

In the example, the --ddboost-backupdir option specifies the backup directory gp_production in the Data Domain Storage Unit GPDB.

**Note:** If there is more than one operating system user using Data Domain Boost for backup and restore operations, repeat this configuration process for each of those users.

**Important:** Set up the Data Domain Boost credential before running any Data Domain Boost backups with the --ddboost option, described above.

```
--ddboost-config-remove
```

Removes all Data Domain Boost credentials from the master and all segments on the system. Do not enter this option with any other gpcrondump option.

```
--ddboost-show-config [--remote]
```

Optional. Displays the DD Boost configuration file information for the Data Domain server. Specify this option with the --remote option to display the configuration file information for remote Data Domain server. No backup is performed.

```
--ddboost-skip-ping
```

Specify this option to skip the ping of a Data Domain system. When working with a Data Domain system, ping is used to ensure that the Data Domain system is reachable. If the Data Domain system is configured to block ICMP ping probes, specify this option.

```
--ddboost-storage-unit=unit-ID
```

Optional. Specify a valid storage unit name for the Data Domain system that is used for backup and restore operations. The default storage unit ID is GPDB. See Using Data Domain Boost.

- Specify this option with the --ddboost-host option to create or update the storage unit ID in the DD Boost credentials file.
- Specify this option with the --ddboost option to override the storage unit ID in the DD Boost credentials file when performing a backup operation.

When performing a full backup operation (not an incremental backup), the storage unit is created on the Data Domain system if it does not exist.

A replication operation uses the same storage unit ID on both local and remote Data Domain systems.
--dump-stats

Specify this option to back up database statistics. The data is written to an SQL file and can be restored manually or with gpdbrestore utility.

The statistics are written in the master data directory to
`db_dumps/YYYYMMDD/prefix_string_gp_statistics_-l_1_timestamp`

If this option is specified with options that include or exclude tables or schemas, the utility backs up only the statistics for the tables that are backed up.

-E encoding

Character set encoding of dumped data. Defaults to the encoding of the database being dumped. See the Greenplum Database Reference Guide for the list of supported character sets.

-email-file path_to_file

Specify the fully-qualified location of the YAML file that contains the customized Subject and From lines that are used when gpcrondump sends notification emails about a database back up.

For information about the format of the YAML file, see File Format for Customized Emails.

-f free_space_percent

When checking that there is enough free disk space to create the dump files, specifies a percentage of free disk space that should remain after the dump completes. The default is 10 percent.

This option is not supported if --ddboost or --incremental is specified.

-g (copy config files)

Secure a copy of the master and segment configuration files `postgresql.conf`, `pg_ident.conf`, and `pg_hba.conf`. These configuration files are dumped in the master or segment data directory to `db_dumps/YYYYMMDD/config_files_{timestamp}.tar`

If --ddboost is specified, the backup is located on the default storage unit in the directory specified by --ddboost-backupdir when the Data Domain Boost credentials were set.

-G (dump global objects)

Back up database metadata information that is not associated with any particular schema or table such as roles and tablespaces. Global objects are dumped in the master data directory to `db_dumps/YYYYMMDD/prefix_string_gp_global_-l_1_timestamp`

If --ddboost is specified, the backup is located on the default storage unit in the directory specified by --ddboost-backupdir when the Data Domain Boost credentials were set.

-h (record dump details)

Record details of the database dump in database table `public.gpcrondump_history` in the database supplied via -x option. The gpcrondump utility will create the table if it does not currently exist. The public schema must exist in the database so that gpcrondump can create the public.gpcrondump_history table. The default is to record the database dump details.

This option will be deprecated in a future release.

-H (disable recording dump details)

Disable recording details of database dump in database table `public.gpcrondump_history` in the database supplied via -x option. If not specified, the utility will create/update the history table. The -H option cannot be selected with the -h option.

Note: The gpcrondump utility creates the public.gpcrondump_history table by default. If the public schema has been deleted from the database,
you must specify the `-H` option to prevent `gpcrondump` from returning an error when it attempts to create the table.

**--incremental (backup changes to append-optimized tables)**

Adds an incremental backup to a backup set. When performing an incremental backup, the complete backup set created prior to the incremental backup must be available. The complete backup set includes the following backup files:

- The last full backup before the current incremental backup
- All incremental backups created between the time of the full backup and the current incremental backup

An incremental backup is similar to a full backup except for append-optimized tables, including column-oriented tables. An append-optimized table is backed up only if one of the following operations was performed on the table after the last backup:

```
ALTER TABLE
INSERT
DELETE
UPDATE
TRUNCATE
DROP and then re-create the table
```

For partitioned append-optimized tables, only the changed table partitions are backed up.

The `-u` option must be used consistently within a backup set that includes a full and incremental backups. If you use the `-u` option with a full backup, you must use the `-u` option when you create incremental backups that are part of the backup set that includes the full backup.

You can create an incremental backup for a full backup of a set of database tables. When you create the full backup, specify the `--prefix` option to identify the backup. To include a set of tables in the full backup, use either the `-t` option or `--table-file` option. To exclude a set of tables, use either the `-T` option or the `--exclude-table-file` option. See the description of the option for more information on its use.

To create an incremental backup based on the full backup of the set of tables, specify the option `--incremental` and the `--prefix` option with the string specified when creating the full backup. The incremental backup is limited to only the tables in the full backup.

*Warning:* `gpcrondump` does not check for available disk space prior to performing an incremental backup.

*Important:* An incremental back up set, a full backup and associated incremental backups, must be on a single device. For example, a the backups in a backup set must all be on a file system or must all be on a Data Domain system.

**--inserts**

Dump data as `INSERT`, rather than `COPY` commands.

If `--incremental` is specified, this option is not supported.

**--j (vacuum before dump)**

Run `VACUUM` before the dump starts.

**-K timestamp [--list-backup-files]**

Specify the `timestamp` that is used when creating a backup. The `timestamp` is 14-digit string that specifies a date and time in the format `yyyyMMddhhmmss`. The date is used for backup directory name. The date and time is used in the backup file names. If `-K` `timestamp` is not specified, a timestamp is generated based on the system time.
When adding a backup to set of backups, `gpcrondump` returns an error if the timestamp does not specify a date and time that is more recent than all other backups in the set.

`--list-backup-files` is optional. When you specify both this option and the `-K timestamp` option, `gpcrondump` does not perform a backup. `gpcrondump` creates two text files that contain the names of the files that will be created when `gpcrondump` backs up a Greenplum database. The text files are created in the same location as the backup files.

The file names use the `timestamp` specified by the `-K timestamp` option and have the suffix `_pipes` and `_regular_files`. For example:

```
gp_dump_20130514093000_pipes
gp_dump_20130514093000_regular_files
```

The `pipes` file contains a list of file names that be can be created as named pipes. When `gpcrondump` performs a backup, the backup files will generate into the named pipes. The `regular_files` file contains a list of backup files that must remain regular files. `gpcrondump` and `gpdbrestore` use the information in the regular files during backup and restore operations. To backup a complete set of Greenplum Database backup files, the files listed in the `regular_files` file must also be backed up after the completion of the backup job.

To use named pipes for a backup, you need to create the named pipes on all the Greenplum Database hosts and make them writable before running `gpcrondump`.

If `--ddboost` is specified, `-K timestamp` `[--list-backup-files]` is not supported.

```
-k (vacuum after dump)
```

Run VACUUM after the dump has completed successfully.

```
-l logfile_directory
```

The directory to write the log file. Defaults to `~/gpAdminLogs`.

```
--netbackup-block-size size
```

Specify the block size, in bytes, of data being transferred to the Veritas NetBackup server. The default is 512 bytes.

NetBackup options are not supported if DDBoost backup options are specified.

```
--netbackup-keyword keyword
```

Specify a `keyword` for the backup that is transferred to the Veritas NetBackup server. NetBackup adds the keyword property and the specified keyword value to the NetBackup .img files that are created for the backup.

The maximum length of this parameter is 127 characters.

NetBackup options are not supported if DDBoost backup options are specified.

```
--netbackup-policy netbackup_policy
```

The name of the NetBackup policy created for backing up Greenplum Database. NetBackup options are not supported if DDBoost backup options are specified.

The maximum length of this parameter is 127 characters.

```
--netbackup-service-host netbackup_server
```

The NetBackup master server that Greenplum Database connects to when backing up to NetBackup.

NetBackup options are not supported if DDBoost backup options are specified.

The maximum length of this parameter is 127 characters.

```
--netbackup-schedule netbackup_schedule
```

The name of the NetBackup schedule created for backing up Greenplum Database.

NetBackup options are not supported if DDBoost backup options are specified

The maximum length of this parameter is 127 characters.

--no-owner
Do not output commands to set object ownership.

--no-privileges
Do not output commands to set object privileges (GRANT/REVOKE commands).

-o (clear old dump files only)
Clear out old dump files only, but do not run a dump. This will remove the oldest dump directory except the current date’s dump directory. All dump sets within that directory will be removed.

Warning: Before using this option, ensure that incremental backups required to perform the restore are not deleted. The gpdbrestore utility option --list-backup lists the backup sets required to perform a backup.

If --ddboost is specified, only the old files on Data Domain Boost are deleted.

You can specify the option --cleanup-date or --cleanup-total to specify backup sets to delete.

If --incremental is specified, this option is not supported.

--oids
Include object identifiers (oid) in dump data.

If --incremental is specified, this option is not supported.

--prefix prefix_string [--list-filter-tables]
Prepends prefix_string followed by an underscore character (_) to the names of all the backup files created during a backup.

--list-filter-tables is optional. When you specify both options, gpcrondump does not perform a backup. For the full backup created by gpcrondump that is identified by the prefix-string, the tables that were included or excluded for the backup are listed. You must also specify the --incremental option if you specify the --list-filter-tables option.

If --ddboost is specified, --prefix prefix_string [--list-filter-tables] is not supported.

-q (no screen output)
Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

-r (rollback on failure)
Rollback the dump files (delete a partial dump) if a failure is detected. The default is to not rollback.

Note: This option is not supported if --ddboost is specified.

-R post_dump_script
The absolute path of a script to run after a successful dump operation. For example, you might want a script that moves completed dump files to a backup host. This script must reside in the same location on the master and all segment hosts.

--rsyncable
Passes the --rsyncable flag to the gzip utility to synchronize the output occasionally, based on the input during compression. This synchronization increases the file size by less than 1% in most cases. When this flag is passed, the rsync(1) program can synchronize
compressed files much more efficiently. The `gunzip` utility cannot differentiate between a compressed file created with this option, and one created without it.

`-s schema_name`
Dump all the tables that are qualified by the specified schema in the database. The `-s` option can be specified multiple times. System catalog schemas are not supported. If you want to specify multiple schemas, you can also use the `--schema-file=filename` option in order not to exceed the maximum token limit.

Only a set of tables or set of schemas can be specified. For example, the `-s` option cannot be specified with the `-t` option.

If `--incremental` is specified, this option is not supported.

`-S schema_name`
A schema name to **exclude** from the database dump. The `-S` option can be specified multiple times. If you want to specify multiple schemas, you can also use the `--exclude-schema-file=filename` option in order not to exceed the maximum token limit.

Only a set of tables or set of schemas can be specified. For example, this option cannot be specified with the `-t` option.

If `--incremental` is specified, this option is not supported.

`-t schema.table_name`
Dump only the named table in this database. The `-t` option can be specified multiple times. If you want to specify multiple tables, you can also use the `--table-file=filename` option in order not to exceed the maximum token limit.

Only a set of tables or set of schemas can be specified. For example, this option cannot be specified with the `-s` option.

If `--incremental` is specified, this option is not supported.

`-T schema.table_name`
A table name to **exclude** from the database dump. The `-T` option can be specified multiple times. If you want to specify multiple tables, you can also use the `--exclude-table-file=filename` option in order not to exceed the maximum token limit.

Only a set of tables or set of schemas can be specified. For example, this option cannot be specified with the `-s` option.

If `--incremental` is specified, this option is not supported.

`--exclude-schema-file=filename`
Excludes all the tables that are qualified by the specified schemas listed in the `filename` from the database dump. The file `filename` contains any number of schemas, listed one per line.

Only a set of tables or set of schemas can be specified. For example, this option cannot be specified with the `-t` option.

If `--incremental` is specified, this option is not supported.

`--exclude-table-file=filename`
Excludes all tables listed in the `filename` from the database dump. The file `filename` contains any number of tables, listed one per line.

Only a set of tables or set of schemas can be specified. For example, this cannot be specified with the `-s` option.

If `--incremental` is specified, this option is not supported.

`--schema-file=filename`
Dumps only the tables that are qualified by the schemas listed in the `filename`. The file `filename` contains any number of schemas, listed one per line.

Only a set of tables or set of schemas can be specified. For example, this option cannot be specified with the `--t` option.

If `--incremental` is specified, this option is not supported.

---

`--table-file=filename`

Dumps only the tables listed in the `filename`. The file `filename` contains any number of tables, listed one per line.

Only a set of tables or set of schemas can be specified. For example, this cannot be specified with the `--s` option.

If `--incremental` is specified, this option is not supported.

---

`-u backup_directory`

Specifies the absolute path where the backup files will be placed on each host. If the path does not exist, it will be created, if possible. If not specified, defaults to the data directory of each instance to be backed up. Using this option may be desirable if each segment host has multiple segment instances as it will create the dump files in a centralized location rather than the segment data directories.

**Note:** This option is not supported if `--ddboost` is specified.

---

`--use-set-session-authorization`

Use `SET SESSION AUTHORIZATION` commands instead of `ALTER OWNER` commands to set object ownership.

---

`-v | --verbose`

Specifies verbose mode.

---

`--version (show utility version)`

Displays the version of this utility.

---

`-x database_name`

Required. The name of the Greenplum database to dump.

---

`-y reportfile`

This option is deprecated and will be removed in a future release. If specified, a warning message is returned stating that the `-y` option is deprecated.

Specifies the full path name where a copy of the backup job log file is placed on the master host. The job log file is created in the master data directory or if running remotely, the current working directory.

---

`-z (no compression)`

Do not use compression. Default is to compress the dump files using `gzip`.

Use this option (`-z`) for NFS and Data Domain Boost backups.

---

`-? (help)`

Displays the online help.

---

**File Format for Customized Emails**

You can configure `gpcrondump` to send an email notification after a back up operation completes for a database. To customize the From and Subject lines of the email that are sent for a database, you create a YAML file and specify the location of the file with the option `--email-file`. In the YAML file, you can
specify a different From and Subject line for each database that gpcrondump backs up. This is the format of the YAML file to specify a custom From and Subject line for a database:

```
EMAIL_DETAILS:
  - DBNAME: database_name
    FROM: from_user
    SUBJECT: subject_text
```

When email notification is configured for gpcrondump, the `from_user` and the `subject_text` are the strings that gpcrondump uses in the email notification after completing the back up for `database_name`.

This example YAML file specifies different From and Subject lines for the databases testdb100 and testdb200.

```
EMAIL_DETAILS:
  - DBNAME: testdb100
    FROM: RRP_MPE2_1
    SUBJECT: backup completed for Database 'testdb100'
  - DBNAME: testdb200
    FROM: Report_from_DCDDEV_host
    SUBJECT: Completed backup for database 'testdb200'
```

Examples

Call gpcrondump directly and dump mydatabase (and global objects):

```
gpcrondump -x mydatabase -c -g -G
```

A `crontab` entry that runs a backup of the sales database (and global objects) nightly at one past midnight:

```
01 0 * * * /home/gpadmin/gpdump.sh >> gpdump.log
```

The content of dump script `gpdump.sh` is:

```
#!/bin/bash
export GPHOME=/usr/local/greenplum-db
export MASTER_DATA_DIRECTORY=/data/gpdb_p1/gp-1
. $GPHOME/greenplum_path.sh
gpcrondump -x sales -c -g -G -a -q
```

This example creates two text files, one with the suffix `_pipes` and the other with `_regular_files`. The `_pipes` file contain the file names that can be named pipes when you backup the Greenplum database mytestdb.

```
gpcrondump -x mytestdb -K 20131030140000 --list-backup-files
```

To use incremental backup with a set of database tables, you must create a full backup of the set of tables and specify the `--prefix` option to identify the backup set. The following example uses the `--table-file` option to create a full backup of the set of files listed in the file `user-tables`. The prefix `user_backup` identifies the backup set.

```
gpcrondump -x mydatabase --table-file=user-tables
  --prefix user_backup
```
To create an incremental backup for the full backup created in the previous example, specify the --incremental option and the option --prefix user_backup to identify backup set. This example creates an incremental backup.

```bash
gpcrondump -x mydatabase --incremental --prefix user_backup
```

This command lists the tables that were included or excluded for the full backup.

```bash
gpcrondump -x mydatabase --incremental --prefix user_backup
--list-filter-tables
```

This command backs up the database `customer` and specifies a NetBackup policy and schedule that are defined on the NetBackup master server `nbu_server1`. A block size of 1024 bytes is used to transfer data to the NetBackup server.

```bash
gpcrondump -x customer --netbackup-service-host=nbu_server1
--netbackup-policy=gpdb_cust --netbackup-schedule=gpdb_backup
--netbackup-block-size=1024
```

**See Also**

`gpdbrestore`

**gpdbrestore**

Restores a database from a set of dump files generated by `gpcrondump`.

**Note:** This utility is deprecated and will not be supported after the end of Greenplum Database 5.x Support Life.

**Synopsis**

```bash
gpdbrestore { -t timestamp_key { [-L] | [-b YYYYMMDD | -R hostname:path_to_dumpset | -s database_name ]
[---netbackup-service-host netbackup_server
[---netbackup-block-size size] } ]
[-m]
[---restore-stats [include | only]]
[---G [include | only]] [--change-schema schema_name]
[---B parallel_processes] [--d master_data_directory] [-a] [-q]
[-l logfile_directory] [-v]
[--ddboost [--ddboost-storage-unit=unit-ID] ]
[---redirect database_name ]
```

**Description**

The `gpdbrestore` utility recreates the data definitions (schema) and user data in a Greenplum database using the script files created by `gpcrondump` operations.

When you restore from an incremental backup, the `gpdbrestore` utility assumes the complete backup set is available. The complete backup set includes the following backup files:
The last full backup before the specified incremental backup
All incremental backups created between the time of the full backup and the specified incremental backup

The `gpdbrestore` utility provides the following functionality:

- Automatically reconfigures for compression.
- Validates the number of dump files are correct (for primary only, mirror only, primary and mirror, or a subset consisting of some mirror and primary segment dump files).
- If a failed segment is detected, restores to active segment instances.
- Except when restoring data from a NetBackup server, you do not need to know the complete timestamp key (`-t`) of the backup set to restore. Additional options are provided to instead give just a date (`-b`), backup set directory location (`-R`), or database name (`-s`) to restore.
- The `--R` option allows the ability to restore from a backup set located on a host outside of the Greenplum Database array (archive host). Ensures that the correct dump file goes to the correct segment instance.
- Identifies the database name automatically from the backup set.
- Allows you to restore particular tables only (`-T` option) instead of the entire database. Note that single tables are not automatically dropped or truncated prior to restore.
- Performs an **ANALYZE** operation on the tables that are restored.
- Can restore global objects such as roles and tablespaces (`-G` option).
- Detects if the backup set is primary segments only or primary and mirror segments and performs the appropriate restore operation.
- Allows you to drop the target database before a restore in a single operation.

The backups contain the database-level settings for the server configuration parameters `gp_default_storage_options`, `optimizer`, and `search_path`, the settings are restored when you perform a restore operation and specify the `--e` option to create an empty target database before performing a restore operation.

**Important:** When restoring table data to an existing table, the utility assumes that the database table definition is the same as the table that was backed up. The utility does not check the table definitions.

**Database, Schema, and Table Names**

You can specify names of databases, schemas, and tables that contain these special characters.

```
" ' ` ~ # $ % & * ( ) _ - + [ ] { } > < \ | ; : / ?
```

**Note:** The characters `!`, comma (`,`), and period (`.`) are not supported. Also, the tab (`\t`) and newline (`\n`) characters are not supported.

When the name contains special characters and is specified on the command line, the name must be enclosed in double quotes (`"`). Double quotes are optional for names that do not contain special characters. For example, either use of quotes is valid on the command line "my\#1schema".mytable or "my\#1schema"."mytable". Within the name, these special characters must be escaped with a backslash (`\`).

When the name is specified in an input file, the name must **not** be enclosed in double quotes. Special characters do not require escaping.

**Restoring from a Data Domain System with DD Boost**

When you create a backup with `gpcrondump` using DD Boost, the backup is stored on a Data Domain system storage unit. When restore the backup, you must use the same storage unit ID that was used when you backed up the data. You can use the `gpcrondump option --ddboost-show-config` to display the current DD Boost configuration information that includes the storage unit ID.

For information about using DD Boost and Data Domain systems with Greenplum Database, see "Backing Up and Restoring Databases" in the *Greenplum Database Administrator Guide*. 
NetBackup is not compatible with DD Boost. Both NetBackup and DD Boost cannot be used in a single backup operation.

**Restoring a Database from NetBackup**

Greenplum Database must be configured to communicate with the Veritas NetBackup master server that is used to restore database data. See the Greenplum Database System Administrator Guide for information about configuring Greenplum Database and NetBackup.

When restoring from NetBackup server, you must specify the timestamp of the backup with the `-t` option.

When restoring a large amount of data, set the NetBackup `CLIENT_READ_TIMEOUT` option to a value that is at least twice the expected duration of the operation (in seconds). The `CLIENT_READ_TIMEOUT` default value is 300 seconds (5 minutes).

NetBackup is not compatible with DD Boost. Both NetBackup and DD Boost cannot be used in a single backup operation.

**Restoring a Database with Named Pipes**

If you used named pipes when you backed up a database with `gpcrondump`, named pipes with the backup data must be available when restoring the database from the backup.

**Error Reporting**

After a restore operation completes, the utility checks the `gpdbrestore` status file for SQL execution errors and displays a warning if an error is found. The default location of the restore status files are in the `db_dumps/date/` directory.

**Options**

- **-a (do not prompt)**
  Do not prompt the user for confirmation.

- **-b YYYYMMDD**
  Looks for dump files in the segment data directories on the Greenplum Database array of hosts in `db_dumps/YYYYMMDD`. If `--ddboost` is specified, the systems looks for dump files on the Data Domain Boost host.

- **-B parallel_processes**
  The number of segments to check in parallel for pre/post-restore validation. If not specified, the utility will start up to 60 parallel processes depending on how many segment instances it needs to restore.

- **--change-schema=schema_name**
  Optional. Restores tables from a backup created with `gpcrondump` to a different schema. The `schema_name` must exist in the database. If the schema does not exist, the utility returns an error. System catalog schemas are not supported.

  You must specify tables to restore with the `-T` and `--table-file` options. If a table that is being restored exists in `schema-name`, the utility returns a warning and attempts to append the data to the table from the backup. You can specify the `--truncate` option to truncate table data before restoring data to the table from the backup.

  This option is not supported if `-S` is specified.

- **-d master_data_directory**
  Optional. The master host data directory. If not specified, the value set for `$MASTER_DATA_DIRECTORY` will be used.

- **--ddboost [--ddboost-storage-unit=unit-ID ]**
  Use Data Domain Boost for this restore operation, if the `--ddboost` option was specified when the data was backed up with the `gpcrondump` utility. Before using Data Domain Boost, make sure the one-time Data Domain Boost credential setup is complete.
The --ddboost-storage-unit option is optional. When restoring a backup from a Data Domain server, you must use the same storage unit that was used when you backed up the data.

See *Restoring from a Data Domain System with DD Boost*.

If you backed up Greenplum Database configuration files with the gpcrondump option -g and specified the --ddboost option, you must manually restore the backup from the Data Domain system. The configuration files must be restored for the Greenplum Database master and all the hosts and segments. The backup location on the Data Domain system is the directory unit_ID/backup_directory/date. The backup_directory is set when you specify the Data Domain credentials with gpcrondump. The unit_ID is the Data Domain system storage unit that was used when you backed up the database.

This option is not supported if --netbackup-service-host is specified.

-e (create target database before restore)

Creates the target database and then performs a restore operation. If the target database exists, drops the existing database before creating the database and performing a restore operation.

The utility restores database-level settings for the server configuration parameters gp_default_storage_options, optimizer, and search_path.

-G [include | only] (restore global objects)

Restores database metadata information that is not associated with a specific schema or table, such as roles and tablespaces, if the global object dump file db_dumps/date/prefix_string_gp_global_-1_1_1_timestamp is found in the master data directory. The global object file is created with the gpcrondump option -G.

- The keyword *include* restores global objects in addition to performing a restore. This is the default if no keyword is specified.
- The keyword *only* restores only global objects. No other database objects or database table data are restored.

The -m option restores metadata associated with schemas or tables.

-l logfile_directory

The directory to write the log file. Defaults to ~/gpAdminLogs.

--list-backup

Lists the set of full and incremental backup sets required to perform a restore based on the timestamp_key specified with the -t option and the location of the backup set.

This option is supported only if the timestamp_key is for an incremental backup.

-L (list tablenames in backup set)

When used with the -t option, lists the table names that exist in the named backup set and exits. Does not perform a restore.

-m (restore metadata only)

Restores database metadata information such schema and table definitions and information created by SET statements. This option does not restore database table data. All table and schema metadata is restored unless options are specified that include or exclude tables or schemas. If table or schema filters are specified, the utility restores the schema and table metadata only for the schemas and tables that are specified to be restored.

Database information that is not associated with a specific schema or table, such as roles and tablespaces, is not restored. You can specify the -G option with this option to restore global metadata that was backed up with the gpcrondump utility.
Database statistics are not restored. You can specify the --restore-stats option to restore statistics that were backed up with the gpcrondump utility.

Not supported with the --noplan or --noanalyze options.

`--netbackup-block-size size`
Specify the block size, in bytes, of data being transferred from the Veritas NetBackup server. The default is 512 bytes.

NetBackup options are not supported if DDBoost backup options are specified.

`--netbackup-service-host netbackup_server`
The NetBackup master server that Greenplum Database connects to when backing up to NetBackup. If you specify this option, you must specify the timestamp of the backup with the -t option.

The maximum length for the this parameter is 127 characters.
This option is not supported with any of the these options: -R, -s, -b, -L, or --ddboost.

NetBackup options are not supported if DDBoost backup options are specified.

`--noanalyze`
The ANALYZE command is not run after a successful restore. The default is to run the ANALYZE command on restored tables. This option is useful if running ANALYZE on tables in your database requires a significant amount of time.

If this option is specified, you should run ANALYZE manually on restored tables. Failure to run ANALYZE following a restore might result in poor database performance.
Not supported with the -m option.

`--noplan`
Restores only the data backed up during the incremental backup specified by the timestamp_key. No other data from the complete backup set are restored. The full backup set containing the incremental backup must be available.

The --noplan option does not truncate existing tables prior to restoration. To avoid loading duplicate data into existing tables, you can truncate the tables before performing an incremental restore with the --noplan option.
If the timestamp_key specified with the -t option does not reference an incremental backup, an error is returned.
Not supported with the -m option.

`--prefix prefix_string`
If you specified the gpcrondump option --prefix prefix_string to create the backup, you must specify this option with the prefix_string when restoring the backup.

If you created a full backup of a set of tables with gpcrondump and specified a prefix, you can use gpcrondump with the options --list-filter-tables and --prefix prefix_string to list the tables that were included or excluded for the backup.

-q (no screen output)
Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

-R hostname:path_to_dumpset
Allows you to provide a hostname and full path to a set of dump files. The host does not have to be in the Greenplum Database array of hosts, but must be accessible from the Greenplum master.

`--redirect database_name`
Specify the name of the database where the data is restored. Specify this option to restore data to a database that is different than the database specified during back up. If `database_name` does not exist, it is created.

`--report-status-dir` `report_directory`

Specifies the absolute path to the directory on the each Greenplum Database host (master and segment hosts) where `gpdbrestore` writes report status files for a restore operation. If `report_directory` does not exist or is not writable, `gpdbrestore` returns an error and stops.

If this option is not specified and the `-u` option is specified, report status files are written to the location specified by the `-u` option if the `-u` location is writable. If the location specified by `-u` option is not writable, the report status files are written to segment data directories.

`--restore-stats` [include | only]

Specify this option to restore database statistics that were backed up with the `gpcrondump` utility option `--dump-stats`.

- The keyword `include` restores the statistics that were backed up in addition to performing a restore. This is the default if no keyword is specified.
- The keyword `only` restores only the statistics that were backed up. No other database objects or database data are restored.

If this option is specified with other options that include or exclude tables or schemas to restore, the utility restores statistics only for the tables specified to be restored.

If statistics would be restored for a table that does not exist in the database, the utility displays a warning. The statistics are not restored.

`-s` `database_name`

Looks for latest set of dump files for the given database name in the segment data directories `db_dumps` directory on the Greenplum Database array of hosts.

`-S` `schema_name`

Restore all the tables, views, indexes, functions, and sequences qualified by the specified schema from the backup. The `-S` option can be specified multiple times. System catalog schemas are not supported. The schema name must exist in the backup set of the database being restored. To replace the data in the schema tables with the data from backup, you can specify the `--truncate` option. The schema tables are truncated before the data is restored.

To support functions that might be restored, all procedural languages that are in the backup are also restored even though they are not schema specific. External items such as shared libraries that are used by a language are not included in a backup.

The `-S` option cannot be specified with the `--change-schema` option.

`-t` `timestamp_key`

The 14 digit timestamp key that uniquely identifies a backup set of data to restore. It is of the form `YYYYMMDDHHMMSS`. Looks for dump files matching this timestamp key in the segment data directories `db_dumps` directory on the Greenplum Database array of hosts.

`-T` `schema.table_name`

The name of a table to restore. The `-T` option can be specified multiple times. The named table(s) must exist in the backup set of the database being restored. Existing tables are not automatically truncated before data is restored from backup. To replace existing data in the table from backup, you can specify the `--truncate` option.

Wildcard characters are not supported.

`--table-file` `file_name`
Specify a file `file_name` that contains a list of table names to restore. The file contains any number of table names, listed one per line. See the `-T` option for information about restoring specific tables.

**--truncate**

Truncate table data before restoring data to the table from the backup. If this option is not specified, existing table data is not removed before data is restored to the table.

This option is supported only when restoring a set of tables with the option `-S`, `-T` or `--table-file`. If a table to be restored does not exist in the database, the table is restored and the utility returns a warning message stating that the table did not exist in the database.

This option is not supported with the `-e` option.

**-u backup_directory**

Specifies the absolute path to the directory containing the `db_dumps` directory on each host. If not specified, defaults to the data directory of each instance to be backed up.

Specify this option if you specified a backup directory with the `gpcrondump` option `-u` when creating a backup set.

If `backup_directory` is not writable, backup operation report status files are written to segment data directories. You can specify a different location where report status files are written with the `--report-status-dir` option.

*Note:* This option is not supported if `--ddboost` is specified.

**-v | --verbose**

Specifies verbose mode.

**--version (show utility version)**

Displays the version of this utility.

**-? (help)**

Displays the online help.

**Examples**

Restore the `sales` database from the latest backup files generated by `gpcrondump` (assumes backup files are in the segment data directories in `db_dumps`):

```
gpdbrestore -s sales
```

Restore a database from backup files that reside on an archive host outside the Greenplum Database array (command issued on the Greenplum master host):

```
gpdbrestore -R archivehostname:/data_pl/db_dumps/20160214
```

Restore global objects only (roles and tablespaces):

```
gpdbrestore -G
```

*Note:* The `-R` option is not supported when restoring a backup set that includes incremental backups.

If you restore from a backup set that contains an incremental backup, all the files in the backup set must be available to `gpdbrestore`. For example, the following timestamp keys specify a backup set. `20160514054532` is the full backup and the others are incremental.

```
20160514054532
20160714095512
20150914081205
```
The following `gbdbrestore` command specifies the timestamp key 20161114064330. The incremental backup with the timestamps 20160714095512 and 20160914081205 and the full backup must be available to perform a restore.

```bash
gpdbrestore -t 20161114064330
```

The following `gbdbrestore` command uses the `--noplan` option to restore only the data that was backed up during the incremental backup with the timestamp key 20161114064330. Data in the previous incremental backups and the data in the full backup are not restored. The `--noplan` option does not truncate existing tables prior to restoration. To avoid loading duplicate data into existing tables, you can truncate the tables before performing an incremental restore with the `--noplan` option.

```bash
gpdbrestore -t 20161114064330 --noplan
```

This `gbdbrestore` command restores Greenplum Database data from the data managed by NetBackup master server `nbu_server1`. The option `-t 20170530090000` specifies the timestamp generated by `gpcrondump` when the backup was created. The `-e` option specifies that the target database is dropped before it is restored.

```bash
gpdbrestore -t 20170530090000 -e --netbackup-service-host=nbu_server1
```

### See Also

`gpcrondump`

### gpdeletesystem

Deletes a Greenplum Database system that was initialized using `gpinitdb`.

#### Synopsis

```

  gpdeletesystem -?
  gpdeletesystem -v
```

#### Description

The `gpdeletesystem` utility performs the following actions:

- Stop all `postgres` processes (the segment instances and master instance).
- Deletes all data directories.

Before running `gpdeletesystem`:

- Move any backup files out of the master and segment data directories.
- Make sure that Greenplum Database is running.
- If you are currently in a segment data directory, change directory to another location. The utility fails with an error when run from within a segment data directory.

This utility will not uninstall the Greenplum Database software.
Options
-d master_data_directory
    Specifies the master host data directory. If this option is not specified, the setting for the environment variable MASTER_DATA_DIRECTORY is used. If this option is specified, it overrides any setting of MASTER_DATA_DIRECTORY. If master_data_directory cannot be determined, the utility returns an error.

-B parallel_processes
    The number of segments to delete in parallel. If not specified, the utility will start up to 60 parallel processes depending on how many segment instances it needs to delete.

-f (force)
    Force a delete even if backup files are found in the data directories. The default is to not delete Greenplum Database instances if backup files are present.

-l logfile_directory
    The directory to write the log file. Defaults to ~/gpAdminLogs.

-D (debug)
    Sets logging level to debug.

-? (help)
    Displays the online help.

-v (show utility version)
    Displays the version, status, last updated date, and check sum of this utility.

Examples
Delete a Greenplum Database system:

    gpdeletesystem -d /gpdata/gp-1

Delete a Greenplum Database system even if backup files are present:

    gpdeletesystem -d /gpdata/gp-1 -f

See Also
gpinit

gpexpand

Expands an existing Greenplum Database across new hosts in the array.

Synopsis

gpexpand [{-f|--hosts-file} hosts_file]
    [{-i|--input} input_file [-B batch_size] [-V|--novacuum]
    [{-d|--duration} hh:mm:ss | {-e|--end} 'YYYY-MM-DD hh:mm:ss']
    [-a|--analyze]
    [-n parallel_processes]
    [{-r|--rollback}]
    [{-c|--clean}]
    [-D database_name] [-V|--verbose] [-s|--silent]
    [{-t|--tardir} directory ]
    [-S|--simple-progress ]

gpexpand -? | -h | --help
gpexpand --version

Prerequisites

- You are logged in as the Greenplum Database superuser (gpadmin).
- The new segment hosts have been installed and configured as per the existing segment hosts. This involves:
  - Configuring the hardware and OS
  - Installing the Greenplum software
  - Creating the gpadmin user account
  - Exchanging SSH keys.
- Enough disk space on your segment hosts to temporarily hold a copy of your largest table.
- When redistributing data, Greenplum Database must be running in production mode. Greenplum Database cannot be restricted mode or in master mode. The gpstart options -R or -m cannot be specified to start Greenplum Database.

Description

The gpexpand utility performs system expansion in two phases: segment initialization and then table redistribution.

In the initialization phase, gpexpand runs with an input file that specifies data directories, dbid values, and other characteristics of the new segments. You can create the input file manually, or by following the prompts in an interactive interview.

If you choose to create the input file using the interactive interview, you can optionally specify a file containing a list of expansion hosts. If your platform or command shell limits the length of the list of hostnames that you can type when prompted in the interview, specifying the hosts with -f may be mandatory.

In addition to initializing the segments, the initialization phase performs these actions:

- Creates an expansion schema to store the status of the expansion operation, including detailed status for tables.
- Changes the distribution policy for all tables to DISTRIBUTED RANDOMLY. The original distribution policies are later restored in the redistribution phase.

  **Note:** Data redistribution should be performed during low-use hours. Redistribution can divided into batches over an extended period.

To begin the redistribution phase, you must run gpexpand with either the -d (duration) or -e (end time) options. Until the specified end time or duration is reached, the utility will redistribute tables in the expansion schema. Each table is reorganized using ALTER TABLE commands to rebalance the tables across new segments, and to set tables to their original distribution policy. If gpexpand completes the reorganization of all tables before the specified duration, it displays a success message and ends.

  **Note:** This utility uses secure shell (SSH) connections between systems to perform its tasks. In large Greenplum Database deployments, cloud deployments, or deployments with a large number of segments per host, this utility may exceed the host's maximum threshold for unauthenticated connections. Consider updating the SSH MaxStartups configuration parameter to increase this threshold. For more information about SSH configuration options, refer to the SSH documentation for your Linux distribution.

Options

- **-a | --analyze**
  
  Run ANALYZE to update the table statistics after expansion. The default is to not run ANALYZE.
-B batch_size
  Batch size of remote commands to send to a given host before making a one-second pause. Default is 16. Valid values are 1-128.

  The gpexpand utility issues a number of setup commands that may exceed the host's maximum threshold for unauthenticated connections as defined by MaxStartups in the SSH daemon configuration. The one-second pause allows authentications to be completed before gpexpand issues any more commands.

  The default value does not normally need to be changed. However, it may be necessary to reduce the maximum number of commands if gpexpand fails with connection errors such as 'ssh_exchange_identification: Connection closed by remote host.'

-c | --clean
  Remove the expansion schema.

-d | --duration hh:mm:ss
  Duration of the expansion session from beginning to end.

-D database_name
  Specifies the database in which to create the expansion schema and tables. If this option is not given, the setting for the environment variable PGDATABASE is used. The database templates template1 and template0 cannot be used.

-e | --end 'YYYY-MM-DD hh:mm:ss'
  Ending date and time for the expansion session.

-f | --hosts-file filename
  Specifies the name of a file that contains a list of new hosts for system expansion. Each line of the file must contain a single host name.

  This file can contain hostnames with or without network interfaces specified. The gpexpand utility handles either case, adding interface numbers to end of the hostname if the original nodes are configured with multiple network interfaces.

  Note: The Greenplum Database segment host naming convention is sdwN where sdw is a prefix and N is an integer. For example, sdw1, sdw2 and so on. For hosts with multiple interfaces, the convention is to append a dash (-) and number to the host name. For example, sdw1-1 and sdw1-2 are the two interface names for host sdw1.

-i | --input input_file
  Specifies the name of the expansion configuration file, which contains one line for each segment to be added in the format of:

  hostname:address:port:fselocation:dbid:content:preferred_role:replication_port

  If your system has filesystems, gpexpand will expect a filesystem configuration file (input_file_name.fs) to exist in the same directory as your expansion configuration file. The filesystem configuration file is in the format of:

  filesystemOrder=filesystem1_name:filesystem2_name: ...  
dbid:/path/for/filespace1:/path/for/filespace2: ...  
dbid:/path/for/filespace1:/path/for/filespace2: ...  
...

-n parallel_processes
  The number of tables to redistribute simultaneously. Valid values are 1 - 96.

  Each table redistribution process requires two database connections: one to alter the table, and another to update the table's status in the expansion schema. Before increasing −n,
check the current value of the server configuration parameter `max_connections` and make sure the maximum connection limit is not exceeded.

-r | --rollback
Roll back a failed expansion setup operation. If the rollback command fails, attempt again using the `-D` option to specify the database that contains the expansion schema for the operation that you want to roll back.

-s | --silent
Runs in silent mode. Does not prompt for confirmation to proceed on warnings.

-S | --simple-progress
If specified, the `gpexpand` utility records only the minimum progress information in the Greenplum Database table `gpexpand.expansion_progress`. The utility does not record the relation size information and status information in the table `gpexpand.status_detail`.

Specifying this option can improve performance by reducing the amount of progress information written to the `gpexpand` tables.

[-t | --tardir] directory
The fully qualified path to a directory on segment hosts were the `gpexpand` utility copies a temporary tar file. The file contains Greenplum Database files that are used to create segment instances. The default directory is the user home directory.

-v | --verbose
Verbose debugging output. With this option, the utility will output all DDL and DML used to expand the database.

--version
Display the utility's version number and exit.

-V | --novacuum
Do not vacuum catalog tables before creating schema copy.

-? | -h | --help
Displays the online help.

Examples
Run `gpexpand` with an input file to initialize new segments and create the expansion schema in the default database:

```
$ gpexpand -i input_file
```

Run `gpexpand` for sixty hours maximum duration to redistribute tables to new segments:

```
$ gpexpand -d 60:00:00
```

See Also
`gpssh-exkeys`, *Expanding a Greenplum System* in the *Greenplum Database Administrator Guide*

### gpfdist

Serves data files to or writes data files out from Greenplum Database segments.

**Synopsis**

```
```
gpfdist -? | --help

gpfdist --version

**Description**

*gpfdist* is Greenplum Database parallel file distribution program. It is used by readable external tables and *gpload* to serve external table files to all Greenplum Database segments in parallel. It is used by writable external tables to accept output streams from Greenplum Database segments in parallel and write them out to a file.

In order for *gpfdist* to be used by an external table, the **LOCATION** clause of the external table definition must specify the external table data using the *gpfdist://* protocol (see the Greenplum Database command CREATE EXTERNAL TABLE).

**Note:** If the --ssl option is specified to enable SSL security, create the external table with the *gpfdists://* protocol.

The benefit of using *gpfdist* is that you are guaranteed maximum parallelism while reading from or writing to external tables, thereby offering the best performance as well as easier administration of external tables.

For readable external tables, *gpfdist* parses and serves data files evenly to all the segment instances in the Greenplum Database system when users `SELECT` from the external table. For writable external tables, *gpfdist* accepts parallel output streams from the segments when users `INSERT` into the external table, and writes to an output file.

For readable external tables, if load files are compressed using *gzip* or *bzip2* (have a .gz or .bz2 file extension), *gpfdist* uncompressed the files automatically before loading provided that *gunzip* or *bunzip2* is in your path.

**Note:** Currently, readable external tables do not support compression on Windows platforms, and writable external tables do not support compression on any platforms.

When reading or writing data with the *gpfdist* or *gpfdists* protocol, Greenplum Database includes `X-GP-PROTO` in the HTTP request header to indicate that the request is from Greenplum Database. The utility rejects HTTP requests that do not include `X-GP-PROTO` in the request header.

Most likely, you will want to run *gpfdist* on your ETL machines rather than the hosts where Greenplum Database is installed. To install *gpfdist* on another host, simply copy the utility over to that host and add *gpfdist* to your $PATH.

**Note:** When using IPv6, always enclose the numeric IP address in brackets.

**Options**

- **-d directory**
  
The directory from which *gpfdist* will serve files for readable external tables or create output files for writable external tables. If not specified, defaults to the current directory.

- **-l log_file**
  
The fully qualified path and log file name where standard output messages are to be logged.

- **-p http_port**
  
The HTTP port on which *gpfdist* will serve files. Defaults to 8080.

- **-P last_http_port**
The last port number in a range of HTTP port numbers (http_port to last_http_port, inclusive) on which gpfdist will attempt to serve files. gpfdist serves the files on the first port number in the range to which it successfully binds.

-t timeout
Sets the time allowed for Greenplum Database to establish a connection to a gpfdist process. Default is 5 seconds. Allowed values are 2 to 7200 seconds (2 hours). May need to be increased on systems with a lot of network traffic.

-m max_length
Sets the maximum allowed data row length in bytes. Default is 32768. Should be used when user data includes very wide rows (or when line too long error message occurs). Should not be used otherwise as it increases resource allocation. Valid range is 32K to 256MB. (The upper limit is 1MB on Windows systems.)

Note: Memory issues might occur if you specify a large maximum row length and run a large number of gpfdist concurrent connections. For example, setting this value to the maximum of 256MB with 96 concurrent gpfdist processes requires approximately 24GB of memory \((96 + 1) \times 246MB\).

-s
Enables simplified logging. When this option is specified, only messages with WARN level and higher are written to the gpfdist log file. INFO level messages are not written to the log file. If this option is not specified, all gpfdist messages are written to the log file.

You can specify this option to reduce the information written to the log file.

-S (use O_SYNC)
Opens the file for synchronous I/O with the O_SYNC flag. Any writes to the resulting file descriptor block gpfdist until the data is physically written to the underlying hardware.

-w time
Sets the number of seconds that Greenplum Database delays before closing a target file such as a named pipe. The default value is 0, no delay. The maximum value is 7200 seconds (2 hours).

For a Greenplum Database with multiple segments, there might be a delay between segments when writing data from different segments to the file. You can specify a time to wait before Greenplum Database closes the file to ensure all the data is written to the file.

--ssl certificate_path
Adds SSL encryption to data transferred with gpfdist. After executing gpfdist with the --ssl certificate_path option, the only way to load data from this file server is with the gpfdist:// protocol. For information on the gpfdist:// protocol, see "Loading and Unloading Data" in the Greenplum Database Administrator Guide.

The location specified in certificate_path must contain the following files:

- The server certificate file, server.crt
- The server private key file, server.key
- The trusted certificate authorities, root.crt

The root directory (/) cannot be specified as certificate_path.

--sslclean wait_time
When the utility is run with the --ssl option, sets the number of seconds that the utility delays before closing an SSL session and cleaning up the SSL resources after it completes writing data to or from a Greenplum Database segment. The default value is 0, no delay. The maximum value is 500 seconds. If the delay is increased, the transfer speed decreases.
In some cases, this error might occur when copying large amounts of data: gpfdist server closed connection. To avoid the error, you can add a delay, for example --sslclean 5.

-c config.yaml
   Specifies rules that gpfdist uses to select a transform to apply when loading or extracting data. The gpfdist configuration file is a YAML 1.1 document.
   
   For information about the file format, see Configuration File Format in the Greenplum Database Administrator Guide. For information about configuring data transformation with gpfdist, see Transforming External Data with gpfdist and gpload in the Greenplum Database Administrator Guide.
   
   This option is not available on Windows platforms.

-v (verbose)
   Verbose mode shows progress and status messages.

-V (very verbose)
   Verbose mode shows all output messages generated by this utility.

-? (help)
   Displays the online help.

--version
   Displays the version of this utility.

Notes
The server configuration parameter verify_gpfdisrts_cert controls whether SSL certificate authentication is enabled when Greenplum Database communicates with the gpfdist utility to either read data from or write data to an external data source. You can set the parameter value to false to disable authentication when testing the communication between the Greenplum Database external table and the gpfdist utility that is serving the external data. If the value is false, these SSL exceptions are ignored:

- The self-signed SSL certificate that is used by gpfdist is not trusted by Greenplum Database.
- The host name contained in the SSL certificate does not match the host name that is running gpfdist.

Warning: Disabling SSL certificate authentication exposes a security risk by not validating the gpfdists SSL certificate.

If the gpfdist utility hangs with no read or write activity occurring, you can generate a core dump the next time a hang occurs to help debug the issue. Set the environment variable GPFDIST_WATCHDOG_TIMER to the number of seconds of no activity to wait before gpfdist is forced to exit. When the environment variable is set and gpfdist hangs, the utility aborts after the specified number of seconds, creates a core dump, and sends abort information to the log file.

This example sets the environment variable on a Linux system so that gpfdist exits after 300 seconds (5 minutes) of no activity.

   export GPFDIST_WATCHDOG TIMER=300

Examples
To serve files from a specified directory using port 8081 (and start gpfdist in the background):

gpfdist -d /var/load_files -p 8081&

To start gpfdist in the background and redirect output and errors to a log file:

gpfdist -d /var/load_files -p 8081 -l /home/gpadmin/log &
To stop gpfdist when it is running in the background:
--First find its process id:

```
ps ax | grep gpfdist
```

--Then kill the process, for example:

```
kil 3456
```

**See Also**
gpload, CREATE EXTERNAL TABLE in the *Greenplum Database Reference Guide*

**gpfilespace**

Creates a filespace using a configuration file that defines per-segment file system locations. Filespaces describe the physical file system resources to be used by a tablespace.

**Synopsis**

```
gpfilespace [connection_option ...] [-l logfile_directory] [-o output_file_name]
gpfilespace [connection_option ...] [-l logfile_directory] [-c fs_config_file]
gpfilespace --movetempfilespace {filespace_name | default}
gpfilespace --movetransfilespace {filespace_name | default}
gpfilespace --showtempfilespace
gpfilespace --showtransfilespace
gpfilespace -v
gpfilespace -?
```

**Description**

A tablespace requires a file system location to store its database files. In Greenplum Database, the master and each segment (primary and mirror) needs its own distinct storage location. This collection of file system locations for all components in a Greenplum system is referred to as a *filespace*. Once a filespace is defined, it can be used by one or more tablespaces.

When used with the `-o` option, the `gpfilespace` utility looks up your system configuration information in the Greenplum Database catalog tables and prompts you for the appropriate file system locations needed to create the filespace. It then outputs a configuration file that can be used to create a filespace. If a file name is not specified, a `gpfilespace_config_#` file will be created in the current directory by default.

Once you have a configuration file, you can run `gpfilespace` with the `-c` option to create the filespace in Greenplum Database.

You will need to create a filespace before you can use the `gpfilespace --movetempfilespace` or `--movetransfilespace` option to move your temporary or transaction files to the new location.

Use either `gpfilespace --showtempfilespace` or `--showtransfilespace` options to show the name of the filespace currently associated with temporary or transaction files.
Note: If segments are down due to a power or nic failure, you may see inconsistencies during filespace creation. You may not be able to bring up the Greenplum Database.

Options
-\-config fs_config_file
  A configuration file containing:
  • An initial line denoting the new filespace name. For example:
    filespace:myfs
  • One line each for the master, the primary segments, and the mirror segments. A line describes a file system location that a particular segment database instance should use as its data directory location to store database files associated with a tablespace. Each line is in the format of:

    hostname:dbid:/filesystem_dir/seg_datadir_name

-\-logdir logfile_directory
  The directory to write the log file. Defaults to `~/gpAdminLogs`.

-\-output output_file_name
  The directory location and file name to output the generated filespace configuration file. You will be prompted to enter a name for the filespace, a master file system location, the primary segment file system locations, and the mirror segment file system locations. For example, if your configuration has 2 primary and 2 mirror segments per host, you will be prompted for a total of 5 locations (including the master). The file system locations must exist on all hosts in your system prior to running the gpfilespace utility. The utility will designate segment-specific data directories within the location(s) you specify, so it is possible to use the same location for multiple segments. However, primaries and mirrors cannot use the same location. After the utility creates the configuration file, you can manually edit the file to make any required changes to the filespace layout before creating the filespace in Greenplum Database.

--movetempfilespace {filespace_name | default}
  Moves temporary files to a new filespace or to the default location.

--movetransfilespace {filespace_name | default}
  Moves transaction files to a new filespace or to the default location.

--showtempfilespace
  Show the name of the filespace currently associated with temporary files. This option checks that all primary and mirror segments, master and master standby are using the same filespace or temporary files. You will receive a warning message and an email if any inconsistencies exist.

--showtransfilespace
  Show the name of the filespace currently associated with transaction files. This option checks that all primary and mirror segments, master and master standby are using the same filespace or transaction files. You will receive a warning message and an email if any inconsistencies exist.

-\-version (show utility version)
  Displays the version of this utility.

-? | --help (help)
  Displays the utility usage and syntax.

Connection Options
-\-host host
The host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to localhost.

- **p** port | --port port
  The TCP port on which the Greenplum master database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to 5432.

- **U** username | --username superuser_name
  The database superuser role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system user name. Only database superusers are allowed to create filespaces.

- **W** | --password
  Force a password prompt.

**Examples**

Create a filespace configuration file. You will be prompted to enter a name for the filespace, a master file system location, the primary segment file system locations, and the mirror segment file system locations. For example, if your configuration has 2 primary and 2 mirror segments per host, you will be prompted for a total of 5 locations (including the master). The file system locations must exist on all hosts in your system prior to running the `gpfilespace` utility:

$ gpfilespace -o .
Enter a name for this filespace
> fastdisk

Checking your configuration:

Your system has 2 hosts with 2 primary and 2 mirror segments per host.

Configuring hosts: [sdw1, sdw2]

Please specify 2 locations for the primary segments, one per line:
primary location 1> /gp_pri_filespc
primary location 2> /gp_pri_filespc

Please specify 2 locations for the mirror segments, one per line:
mirror location 1> /gp_mir_filespc
mirror location 2> /gp_mir_filespc

Enter a file system location for the master:
master location> /gp_master_filespc

Example filespace configuration file:

```
filespace:fastdisk
mdw:1:/gp_master_filespc/gp-1
sdw1:2:/gp_pri_filespc/gp0
sdw1:3:/gp_mir_filespc/gp1
sdw2:4:/gp_mir_filespc/gp0
sdw2:5:/gp_pri_filespc/gp1
```

Execute the configuration file to create the filespace in Greenplum Database:

$ gpfilespace -c gpfilespace_config_1
gpinitstandby

Adds and/or initializes a standby master host for a Greenplum Database system.

Synopsis

```
gpinitstandby { -s standby_hostname [-P port]
    [-F list_of_filesaces] | -r | -n }
[-a] [-q] [-D] [-l logfile_directory]
gpinitstandby -v

gpinitstandby -?
```

Description

The gpinitstandby utility adds a backup, standby master host to your Greenplum Database system. If your system has an existing standby master host configured, use the -r option to remove it before adding the new standby master host.

Before running this utility, make sure that the Greenplum Database software is installed on the standby master host and that you have exchanged SSH keys between the hosts. It is recommended that the master port is set to the same port number on the master host and the backup master host.

This utility should be run on the currently active primary master host. See the Greenplum Database Installation Guide for instructions.

The utility performs the following steps:

- Updates the Greenplum Database system catalog to remove the existing standby master host information (if the -r option is supplied)
- Updates the Greenplum Database system catalog to add the new standby master host information
- Edits the pg_hba.conf file of the Greenplum Database master to allow access from the newly added standby master.
- Sets up the standby master instance on the alternate master host
- Starts the synchronization process

A backup, standby master host serves as a 'warm standby' in the event of the primary master host becoming non-operational. The standby master is kept up to date by transaction log replication processes (the walsender and walreceiver), which run on the primary master and standby master hosts and keep the data between the primary and standby master hosts synchronized. If the primary master fails, the log replication process is shut down, and the standby master can be activated in its place by using the gpactivatestandby utility. Upon activation of the standby master, the replicated logs are used to reconstruct the state of the master host at the time of the last successfully committed transaction.

The activated standby master effectively becomes the Greenplum Database master, accepting client connections on the master port and performing normal master operations such as SQL command processing and resource management.

**Important:** If the gpinitstandby utility previously failed to initialize the standby master, you must delete the files in the standby master data directory before running gpinitstandby again. The standby master data directory is not cleaned up after an initialization failure because it contains log files that can help in determining the reason for the failure.

If an initialization failure occurs, a summary report file is generated in the standby host directory /tmp. The report file lists the directories on standby host that require clean up.
Options

-a (do not prompt)
   Do not prompt the user for confirmation.

-D (debug)
   Sets logging level to debug.

-F list_of_filespaces
   A list of filesystem names and the associated locations. Each filesystem name and its
   location is separated by a colon. If there is more than one filesystem name, each pair
   (name and location) is separated by a comma. For example:

   filesystem1_name:fs1_location,filesystem2_name:fs2_location

   If this option is not specified, gpinitstandby prompts the user for the filesystem names
   and locations.

   If the list is not formatted correctly or number of filesystems do not match the number of
   filesystems already created in the system, gpinitstandby returns an error.

-l logfile_directory
   The directory to write the log file. Defaults to ~/gpAdminLogs.

-n (restart standby master)
   Specify this option to start a Greenplum Database standby master that has been
   configured but has stopped for some reason.

-P port
   This option specifies the port that is used by the Greenplum Database standby master.
   The default is the same port used by the active Greenplum Database master.

   If the Greenplum Database standby master is on the same host as the active master, the
   ports must be different. If the ports are the same for the active and standby master and the
   host is the same, the utility returns an error.

-q (no screen output)
   Run in quiet mode. Command output is not displayed on the screen, but is still written to
   the log file.

-r (remove standby master)
   Removes the currently configured standby master host from your Greenplum Database
   system.

-s standby_hostname
   The host name of the standby master host.

-v (show utility version)
   Displays the version, status, last updated date, and check sum of this utility.

-? (help)
   Displays the online help.

Examples

Add a standby master host to your Greenplum Database system and start the synchronization process:

   gpinitstandby -s host09
Start an existing standby master host and synchronize the data with the current primary master host:

```
gpinitstandby -n
```

**Note:** Do not specify the `-n` and `-s` options in the same command.

Add a standby master host to your Greenplum Database system specifying a different port:

```
gpinitstandby -s myhost -P 2222
```

If you specify the same host name as the active Greenplum Database master, the installed Greenplum Database software that is used as a standby master must be in a separate location from the active Greenplum Database master. Also, filesystem locations that are used by the standby master must be different than the filesystem locations used by the active Greenplum Database master.

Remove the existing standby master from your Greenplum system configuration:

```
gpinitstandby -r
```

**See Also**

`gpinitsystem`, `gpaddmirrors`, `gpactivatestandby`

---

**gpinitsystem**

Initializes a Greenplum Database system using configuration parameters specified in the `gpinitsystem_config` file.

**Synopsis**

```
gpinitsystem -c cluster_configuration_file
    [-h hostfile_gpinitsystem]
    [-B parallel_processes]
    [-p postgresql_conf_param_file]
    [-s standby_master_host [-P standby_master_port]
        [-F standby_master_filespaces]]
    [-m number | --max_connections=number]
    [-b size | --shared_buffers=size]
    [-n locale | --locale=locale] [-lc-collate=locale]
    [-lc-type=locale] [-lc-messages=locale]
    [-lc-monetary=locale] [-lc-numeric=locale]
    [-lc-time=locale] [-e password | --su_password=password]
    [-I input_configuration_file]
    [-O output_configuration_file]
```

**Description**

The `gpinitsystem` utility creates a Greenplum Database instance or writes an input configuration file using the values defined in a cluster configuration file and any command-line options that you provide. See *Initialization Configuration File Format* for more information about the configuration file. Before running this utility, make sure that you have installed the Greenplum Database software on all the hosts in the array.

With the `-O output_configuration_file` option, `gpinitsystem` does not create a new database instance but instead writes all provided configuration information to the specified output file. This file uses the `QD_PRIMARY_ARRAY` and `PRIMARY_ARRAY` parameters to define each member using its hostname,
port, data directory, segment prefix, segment ID, and content ID. Details of the array configuration can be modified as necessary to match values available in a Greenplum Database backup, or can simply be used to recreate the same cluster configuration at a later time. Configuration files that use QD_PRIMARY_ARRAY and PRIMARY_ARRAY must be passed into gpinitsystem using the -I input_configuration_file option. See Initialization Configuration File Format for more information.

In a Greenplum Database DBMS, each database instance (the master and all segments) must be initialized across all of the hosts in the system in such a way that they can all work together as a unified DBMS. The gpinitsystem utility takes care of initializing the Greenplum master and each segment instance, and configuring the system as a whole.

Before running gpinitsystem, you must set the $GPHOME environment variable to point to the location of your Greenplum Database installation on the master host and exchange SSH keys between all host addresses in the array using gpssh-exkeys.

This utility performs the following tasks:

- Verifies that the parameters in the configuration file are correct.
- Ensures that a connection can be established to each host address. If a host address cannot be reached, the utility will exit.
- Verifies the locale settings.
- Displays the configuration that will be used and prompts the user for confirmation.
- Initializes the master instance.
- Initializes the standby master instance (if specified).
- Initializes the primary segment instances.
- Initializes the mirror segment instances (if mirroring is configured).
- Configures the Greenplum Database system and checks for errors.
- Starts the Greenplum Database system.

**Note:** This utility uses secure shell (SSH) connections between systems to perform its tasks. In large Greenplum Database deployments, cloud deployments, or deployments with a large number of segments per host, this utility may exceed the host's maximum threshold for unauthenticated connections. Consider updating the SSH MaxStartups configuration parameter to increase this threshold. For more information about SSH configuration options, refer to the SSH documentation for your Linux distribution.

**Options**

-a

Do not prompt the user for confirmation.

-B parallel_processes

The number of segments to create in parallel. If not specified, the utility will start up to 4 parallel processes at a time.

-c cluster_configuration_file

Required. The full path and filename of the configuration file, which contains all of the defined parameters to configure and initialize a new Greenplum Database system. See Initialization Configuration File Format for a description of this file. You must provide either the -c cluster_configuration_file option or the -I input_configuration_file option to gpinitsystem.

-D

Sets log output level to debug.

-h hostfile_gpinitsystem

Optional. The full path and filename of a file that contains the host addresses of your segment hosts. If not specified on the command line, you can specify the host file using the MACHINE_LIST_FILE parameter in the gpinitsystem_config file.
The full path and filename of an input configuration file, which defines the Greenplum Database members and segments using the QD_PRIMARY_ARRAY and PRIMARY_ARRAY parameters. The input configuration file is typically created by using gpinitsystem with the -O output_configuration_file option. You must provide either the -c cluster_configuration_file option or the -I input_configuration_file option to gpinitsystem.

--locale=locale | -n locale
Sets the default locale used by Greenplum Database. If not specified, the LC_ALL, LC_COLLATE, or LANG environment variable of the master host determines the locale. If these are not set, the default locale is C (POSIX). A locale identifier consists of a language identifier and a region identifier, and optionally a character set encoding. For example, sv_SE is Swedish as spoken in Sweden, en_US is U.S. English, and fr_CA is French Canadian. If more than one character set can be useful for a locale, then the specifications look like this: en_US.UTF-8 (locale specification and character set encoding). On most systems, the command locale will show the locale environment settings and locale -a will show a list of all available locales.

--lc-collate=locale
Similar to --locale, but sets the locale used for collation (sorting data). The sort order cannot be changed after Greenplum Database is initialized, so it is important to choose a collation locale that is compatible with the character set encodings that you plan to use for your data. There is a special collation name of C or POSIX (byte-order sorting as opposed to dictionary-order sorting). The C collation can be used with any character encoding.

--lc-ctype=locale
Similar to --locale, but sets the locale used for character classification (what character sequences are valid and how they are interpreted). This cannot be changed after Greenplum Database is initialized, so it is important to choose a character classification locale that is compatible with the data you plan to store in Greenplum Database.

--lc-messages=locale
Similar to --locale, but sets the locale used for messages output by Greenplum Database. The current version of Greenplum Database does not support multiple locales for output messages (all messages are in English), so changing this setting will not have any effect.

--lc-monetary=locale
Similar to --locale, but sets the locale used for formatting currency amounts.

--lc-numeric=locale
Similar to --locale, but sets the locale used for formatting numbers.

--lc-time=locale
Similar to --locale, but sets the locale used for formatting dates and times.

-logfile_directory
The directory to write the log file. Defaults to ~/gpAdminLogs.

--max_connections=number | -m number
Sets the maximum number of client connections allowed to the master. The default is 250.

-0 output_configuration_file
When used with the -O option, gpinitsystem does not create a new Greenplum Database cluster but instead writes the supplied cluster configuration information to the specified output_configuration_file. This file defines Greenplum Database members and segments using the QD_PRIMARY_ARRAY,
PRIMAR Y_ ARRAY, and MIRR OR_ ARRAY parameters, and can be later used with -I
input_configuration_file to initialize a new cluster.

-p postgresql_conf_param_file
Optional. The name of a file that contains postgresql.conf parameter settings
that you want to set for Greenplum Database. These settings will be used when the
individual master and segment instances are initialized. You can also set parameters after
initialization using the gpconfig utility.

-q
Run in quiet mode. Command output is not displayed on the screen, but is still written to
the log file.

--shared_buffers=size | -b size
Sets the amount of memory a Greenplum server instance uses for shared memory buffers.
You can specify sizing in kilobytes (kB), megabytes (MB) or gigabytes (GB). The default is
125MB.

-s standby_master_host
Optional. If you wish to configure a backup master host, specify the host name using this
option. The Greenplum Database software must already be installed and configured on
this host.

-P standby_master_port
Optional. If you configure a standby master host, specify its port number using this option.
The Greenplum Database software must already be installed and configured on this host.

-F standby_master_filespaces
Optional. If you configure a standby master host, specify a list of filesystem names and the
associated locations using this option. Each filesystem name and its location is separated
by a colon. If there is more than one file space name, each pair (name and location) is
separated by a comma. For example:

  filesystem1_name:fs1_location,filesystem2_name:fs2_location

If this option is not specified, gpinitstandby prompts the user for the filesystem names
and locations.

If the list is not formatted correctly or number of filesystems do not match the number of
filesystems already created in the system, gpinitstandby returns an error.

--su_password=superuser_password | -e superuser_password
Use this option to specify the password to set for the Greenplum Database superuser
account (such as gpadmin). If this option is not specified, the default password gparray
is assigned to the superuser account. You can use the ALTER ROLE command to change
the password at a later time.

Recommended security best practices:
• Do not use the default password option for production environments.
• Change the password immediately after installation.

-S
If mirroring parameters are specified, spreads the mirror segments across the available
hosts. The default is to group the set of mirror segments together on an alternate host from
their primary segment set. Mirror spreading places each mirror on a different host within
the Greenplum Database array. Spreading is only allowed if the number of hosts is greater
than the number of segment instances.

-v
Displays the version of this utility.
Initialization Configuration File Format

gpinitsystem requires a cluster configuration file with the following parameters defined. An example initialization configuration file can be found in $GPHOME/docs/cli_help/gpconfigs/gpinitsystem_config.

To avoid port conflicts between Greenplum Database and other applications, the Greenplum Database port numbers should not be in the range specified by the operating system parameter net.ipv4.ip_local_port_range. For example, if net.ipv4.ip_local_port_range = 10000 65535, you could set Greenplum Database base port numbers to these values.

```
PORT_BASE = 6000
MIRROR_PORT_BASE = 7000
REPLICATION_PORT_BASE = 8000
MIRROR_REPLICATION_PORT_BASE = 9000
```

**ARRAY_NAME**

Required. A name for the array you are configuring. You can use any name you like. Enclose the name in quotes if the name contains spaces.

**MACHINE_LIST_FILE**

Optional. Can be used in place of the \(-h\) option. This specifies the file that contains the list of segment host address names that comprise the Greenplum Database system. The master host is assumed to be the host from which you are running the utility and should not be included in this file. If your segment hosts have multiple network interfaces, then this file would include all addresses for the host. Give the absolute path to the file.

**SEG_PREFIX**

Required. This specifies a prefix that will be used to name the data directories on the master and segment instances. The naming convention for data directories in a Greenplum Database system is \(SEG\_PREFIXnumber\) where \(number\) starts with 0 for segment instances (the master is always -1). So for example, if you choose the prefix gpseg, your master instance data directory would be named gpseg-1, and the segment instances would be named gpseg0, gpseg1, gpseg2, gpseg3, and so on.

**PORT_BASE**

Required. This specifies the base number by which primary segment port numbers are calculated. The first primary segment port on a host is set as PORT_BASE, and then incremented by one for each additional primary segment on that host. Valid values range from 1 through 65535.

**DATA_DIRECTORY**

Required. This specifies the data storage location(s) where the utility will create the primary segment data directories. The number of locations in the list dictate the number of primary segments that will get created per physical host (if multiple addresses for a host are listed in the host file, the number of segments will be spread evenly across the specified interface addresses). It is OK to list the same data storage area multiple times if you want your data directories created in the same location. The user who runs gpinitsystem (for example, the gpadmin user) must have permission to write to these directories. For example, this will create six primary segments per host:

```
declare -a DATA_DIRECTORY=(/data1/primary /data1/primary /data1/primary /data2/primary /data2/primary /data2/primary)
```

**MASTER_HOSTNAME**
**Required.** The host name of the master instance. This host name must exactly match the configured host name of the machine (run the `hostname` command to determine the correct hostname).

**MASTER_DIRECTORY**

**Required.** This specifies the location where the data directory will be created on the master host. You must make sure that the user who runs `gpinitpsystem` (for example, the `gpadmin` user) has permissions to write to this directory.

**MASTER_PORT**

**Required.** The port number for the master instance. This is the port number that users and client connections will use when accessing the Greenplum Database system.

**TRUSTED_SHELL**

**Required.** The shell the `gpinitpsystem` utility uses to execute commands on remote hosts. Allowed values are `ssh`. You must set up your trusted host environment before running the `gpinitpsystem` utility (you can use `gpssh-exkeys` to do this).

**CHECK_POINT_SEGMENTS**

**Required.** Maximum distance between automatic write ahead log (WAL) checkpoints, in log file segments (each segment is normally 16 megabytes). This will set the `checkpoint_segments` parameter in the `postgresql.conf` file for each segment instance in the Greenplum Database system.

**ENCODING**

**Required.** The character set encoding to use. This character set must be compatible with the `--locale` settings used, especially `--lc-collate` and `--lc-ctype`. Greenplum Database supports the same character sets as PostgreSQL.

**DATABASE_NAME**

**Optional.** The name of a Greenplum Database database to create after the system is initialized. You can always create a database later using the `CREATE DATABASE` command or the `createdb` utility.

**MIRROR_PORT_BASE**

**Optional.** This specifies the base number by which mirror segment port numbers are calculated. The first mirror segment port on a host is set as `MIRROR_PORT_BASE`, and then incremented by one for each additional mirror segment on that host. Valid values range from 1 through 65535 and cannot conflict with the ports calculated by `PORT_BASE`.

**REPLICATION_PORT_BASE**

**Optional.** This specifies the base number by which the port numbers for the primary file replication process are calculated. The first replication port on a host is set as `REPLICATION_PORT_BASE`, and then incremented by one for each additional primary segment on that host. Valid values range from 1 through 65535 and cannot conflict with the ports calculated by `PORT_BASE` or `MIRROR_PORT_BASE`.

**MIRROR_REPLICATION_PORT_BASE**

**Optional.** This specifies the base number by which the port numbers for the mirror file replication process are calculated. The first mirror replication port on a host is set as `MIRROR_REPLICATION_PORT_BASE`, and then incremented by one for each additional mirror segment on that host. Valid values range from 1 through 65535 and cannot conflict with the ports calculated by `PORT_BASE`, `MIRROR_PORT_BASE`, or `REPLICATION_PORT_BASE`.

**MIRROR_DATA_DIRECTORY**

**Optional.** This specifies the data storage location(s) where the utility will create the mirror segment data directories. There must be the same number of data directories declared for mirror segment instances as for primary segment instances (see the `DATA_DIRECTORY`
parameter). The user who runs `gpinitsystem` (for example, the `gpadmin` user) must have permission to write to these directories. For example:

```bash
declare -a MIRROR_DATA_DIRECTORY=(/data1/mirror /data1/mirror /data2/mirror /data2/mirror)
```

**QD_PRIMARY_ARRAY, PRIMARY_ARRAY, MIRROR_ARRAY**

These parameters can only be provided using an input configuration file, with the `gpinitsystem -I input_configuration_file` option. `QD_PRIMARY_ARRAY`, `PRIMARY_ARRAY`, and `MIRROR_ARRAY` define the Greenplum Database master host and the primary and mirror instances on the segment hosts, respectively, using the format:

```bash
host-port~data_directory/seg_prefix<segment_id>~dbid~content_id~replication_port
```

The Greenplum Database master always uses the value -1 for the segment ID and content ID. For example:

```bash
QD_PRIMARY_ARRAY=127.0.0.1~5432~/gpmaster/gpsne-1~1~-1~0
```

```bash
declare -a PRIMARY_ARRAY=(
  127.0.0.1~40000~/gpdata1/gpsne0~2~0~6000
  127.0.0.1~40001~/gpdata2/gpsne1~3~1~6001
)
declare -a MIRROR_ARRAY=(
  127.0.0.1~50000~/gpmirror1/gpsne0~4~0~51000
  127.0.0.1~50001~/gpmirror2/gpsne1~5~1~51001
)
```

You can use the `gpinitsystem -O output_configuration_file` to populate `QD_PRIMARY_ARRAY`, `PRIMARY_ARRAY`, `MIRROR_ARRAY` using the hosts, data directories, segment prefix, and base port values that you provide to the command. For recovery purposes, you can edit the segment and content IDs to match the values of an existing Greenplum Database backup.

**HEAP_CHECKSUM**

**Optional.** This parameter specifies if checksums are enabled for heap data. When enabled, checksums are calculated for heap storage in all databases, enabling Greenplum Database to detect corruption in the I/O system. This option is set when the system is initialized and cannot be changed later.

The `HEAP_CHECKSUM` option is on by default and turning it off is strongly discouraged. If you set this option to off, data corruption in storage can go undetected and make recovery much more difficult.

To determine if heap checksums are enabled in a Greenplum Database system, you can query the `data_checkums` server configuration parameter with the `gpconfig` management utility:

```bash
$ gpconfig -s data_checkums
```

**Examples**

Initialize a Greenplum Database array by supplying a cluster configuration file and a segment host address file, and set up a spread mirroring (`-S`) configuration:

```bash
$ gpinitsystem -c gpinitsystem_config -h hostfile_gpinitsystem -S
```
Initialize a Greenplum Database array and set the superuser remote password:

```
$ gpinitsystem -c gpinitsystem_config -h hostfile_gpinitsystem --su-password=mypassword
```

Initialize a Greenplum Database array with an optional standby master host:

```
$ gpinitsystem -c gpinitsystem_config -h hostfile_gpinitsystem -s host09
```

Instead of initializing a Greenplum Database array, write the provided configuration to an output file. The output file uses the `QD_PRIMARY_ARRAY` and `PRIMARY_ARRAY` parameters to define master and segment hosts:

```
$ gpinitsystem -c gpinitsystem_config -h hostfile_gpinitsystem -S -O cluster_init.config
```

Initialize a Greenplum Database using an input configuration file (a file that defines the Greenplum Database array using `QD_PRIMARY_ARRAY` and `PRIMARY_ARRAY` parameters:

```
$ gpinitsystem -I cluster_init.config
```

**See Also**

gpssh-exkeys, gpdeletesystem

gpload

Runs a load job as defined in a YAML formatted control file.

**Synopsis**

```
gpload -f control_file [-l log_file] [-h hostname] [-p port]
   [-U username] [-d database] [-W] [--gpfdist_timeout seconds]
   [--no_auto_trans] [[-v | -V] [-q]] [-D]
```

```
gpload -?
gpload --version
```

**Prerequisites**

The client machine where `gpload` is executed must have the following:

- Python 2.6.2 or later, pygresql (the Python interface to PostgreSQL), and pyyaml. Note that Python and the required Python libraries are included with the Greenplum Database server installation, so if you have Greenplum Database installed on the machine where `gpload` is running, you do not need a separate Python installation.
  
  **Note:** Greenplum Database Loaders for Windows supports only Python 2.5 (available from https://www.python.org).

- The `gpfdist` parallel file distribution program installed and in your `$PATH`. This program is located in `$GPHOME/bin` of your Greenplum Database server installation.

- Network access to and from all hosts in your Greenplum Database array (master and segments).

- Network access to and from the hosts where the data to be loaded resides (ETL servers).
Description

gpload is a data loading utility that acts as an interface to the Greenplum Database external table parallel loading feature. Using a load specification defined in a YAML formatted control file, gpload executes a load by invoking the Greenplum Database parallel file server (gpfdist), creating an external table definition based on the source data defined, and executing an INSERT, UPDATE or MERGE operation to load the source data into the target table in the database.

The operation, including any SQL commands specified in the SQL collection of the YAML control file (see Control File Format), are performed as a single transaction to prevent inconsistent data when performing multiple, simultaneous load operations on a target table.

Options

-f control_file
  Required. A YAML file that contains the load specification details. See Control File Format.

--gpfdist_timeout seconds
  Sets the timeout for the gpfdist parallel file distribution program to send a response. Enter a value from 0 to 30 seconds (entering "0" to disables timeouts). Note that you might need to increase this value when operating on high-traffic networks.

-l log_file
  Specifies where to write the log file. Defaults to ~/gpAdminLogs/gpload_YYYYMMDD. For more information about the log file, see Log File Format.

--no_auto_trans
  Specify --no_auto_trans to disable processing the load operation as a single transaction if you are performing a single load operation on the target table.

  By default, gpload processes each load operation as a single transaction to prevent inconsistent data when performing multiple, simultaneous operations on a target table.

-q (no screen output)
  Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

-D (debug mode)
  Check for error conditions, but do not execute the load.

-v (verbose mode)
  Show verbose output of the load steps as they are executed.

-V (very verbose mode)
  Shows very verbose output.

-? (show help)
  Show help, then exit.

--version
  Show the version of this utility, then exit.

Connection Options

-d database
  The database to load into. If not specified, reads from the load control file, the environment variable $PGDATABASE or defaults to the current system user name.

-h hostname
  Specifies the host name of the machine on which the Greenplum Database master database server is running. If not specified, reads from the load control file, the environment variable $PGHOST or defaults to localhost.
-p port
   Specifies the TCP port on which the Greenplum Database master database server is
   listening for connections. If not specified, reads from the load control file, the environment
   variable $PGPORT or defaults to 5432.

-U username
   The database role name to connect as. If not specified, reads from the load control file, the
   environment variable $PGUSER or defaults to the current system user name.

-W (force password prompt)
   Force a password prompt. If not specified, reads the password from the environment
   variable $PGPASSWORD or from a password file specified by $PGPASSFILE or in
   ~/.pgpass. If these are not set, then gpload will prompt for a password even if -W is not
   supplied.

Control File Format
The gpload control file uses the YAML 1.1 document format and then implements its own schema for
defining the various steps of a Greenplum Database load operation. The control file must be a valid YAML
document.

The gpload program processes the control file document in order and uses indentation (spaces) to
determine the document hierarchy and the relationships of the sections to one another. The use of white
space is significant. White space should not be used simply for formatting purposes, and tabs should not
be used at all.

The basic structure of a load control file is:

```yaml
---
VERSION: 1.0.0.1
DATABASE: db_name
USER: db_username
HOST: master_hostname
PORT: master_port
GPLOAD:
   INPUT:
      - SOURCE:
          LOCAL_HOSTNAME:
            hostname_or_ip
          PORT: http_port
          | PORT_RANGE: [start_port_range, end_port_range]
          FILE:
            /path/to/input_file
          SSL: true | false
          CERTIFICATES_PATH: /path/to/certificates
      - FULLY_QUALIFIED_DOMAIN_NAME: true | false
      - COLUMNS:
          - field_name: data_type
      - TRANSFORM: 'transformation'
      - TRANSFORM_CONFIG: 'configuration-file-path'
      - MAX_LINE_LENGTH: integer
      - FORMAT: text | csv
      - DELIMITER: 'delimiter_character'
      - ESCAPE: 'escape_character' | 'OFF'
      - NULL AS: 'null_string'
      - FORCE NOT NULL: true | false
      - QUOTE: 'csv_quote_character'
      - HEADER: true | false
      - ENCODING: database_encoding
      - ERROR_LIMIT: integer
      - LOG_ERRORS: true | false
      - EXTERNAL:
```
- **SCHEMA**: `schema | '%'`

**OUTPUT**:
- **TABLE**: `schema.table_name`
- **MODE**: `insert | update | merge`
- **MATCH_COLUMNS**:
  - `target_column_name`
- **UPDATE_COLUMNS**:
  - `target_column_name`
- **UPDATE_CONDITION**: `'boolean_condition'`
- **MAPPING**:
  - `target_column_name: source_column_name | 'expression'`

**PRELOAD**:
- **TRUNCATE**: `true | false`
- **STAGING_TABLE**: `external_table_name`
- **REUSE_TABLES**: `true | false`

**SQL**:
- **BEFORE**: `"sql_command"`
- **AFTER**: `"sql_command"`

**VERSION**
Optional. The version of the `gpload` control file schema. The current version is 1.0.0.1.

**DATABASE**
Optional. Specifies which database in the Greenplum Database system to connect to. If not specified, defaults to `$PGDATABASE` if set or the current system user name. You can also specify the database on the command line using the `-d` option.

**USER**
Optional. Specifies which database role to use to connect. If not specified, defaults to the current user or `$PGUSER` if set. You can also specify the database role on the command line using the `-U` option.

If the user running `gpload` is not a Greenplum Database superuser, then the appropriate rights must be granted to the user for the load to be processed. See the Greenplum Database Reference Guide for more information.

**HOST**
Optional. Specifies Greenplum Database master host name. If not specified, defaults to `localhost` or `$PGHOST` if set. You can also specify the master host name on the command line using the `-h` option.

**PORT**
Optional. Specifies Greenplum Database master port. If not specified, defaults to 5432 or `$PGPORT` if set. You can also specify the master port on the command line using the `-p` option.

**GPLOAD**
Required. Begins the load specification section. A `GPLOAD` specification must have an **INPUT** and an **OUTPUT** section defined.

**INPUT**
Required. Defines the location and the format of the input data to be loaded. `gpload` will start one or more instances of the `gpfdist` file distribution program on the current host and create the required external table definition(s) in Greenplum Database that point to the source data. Note that the host from which you run `gpload` must be accessible over the network by all Greenplum Database hosts (master and segments).

**SOURCE**
Required. The **SOURCE** block of an **INPUT** specification defines the location of a source file. An **INPUT** section can have more than one **SOURCE** block defined. Each **SOURCE** block defined corresponds to one instance of the `gpfdist` file distribution program that will be started on the local machine. Each **SOURCE** block defined must have a **FILE** specification.
For more information about using the gpfdist parallel file server and single and multiple gpfdist instances, see "Loading and Unloading Data" in the Greenplum Database Administrator Guide.

**LOCAL_HOSTNAME**
Optional. Specifies the host name or IP address of the local machine on which gpload is running. If this machine is configured with multiple network interface cards (NICs), you can specify the host name or IP of each individual NIC to allow network traffic to use all NICs simultaneously. The default is to use the local machine's primary host name or IP only.

**PORT**
Optional. Specifies the specific port number that the gpfdist file distribution program should use. You can also supply a PORT_RANGE to select an available port from the specified range. If both PORT and PORT_RANGE are defined, then PORT takes precedence. If neither PORT or PORT_RANGE are defined, the default is to select an available port between 8000 and 9000.

If multiple host names are declared in LOCAL_HOSTNAME, this port number is used for all hosts. This configuration is desired if you want to use all NICs to load the same file or set of files in a given directory location.

**PORT_RANGE**
Optional. Can be used instead of PORT to supply a range of port numbers from which gpload can choose an available port for this instance of the gpfdist file distribution program.

**FILE**
Required. Specifies the location of a file, named pipe, or directory location on the local file system that contains data to be loaded. You can declare more than one file so long as the data is of the same format in all files specified.

If the files are compressed using gzip or bzip2 (have a .gz or .bz2 file extension), the files will be uncompressed automatically (provided that gunzip or bunzip2 is in your path).

When specifying which source files to load, you can use the wildcard character (*) or other C-style pattern matching to denote multiple files. The files specified are assumed to be relative to the current directory from which gpload is executed (or you can declare an absolute path).

**SSL**
Optional. Specifies usage of SSL encryption. If SSL is set to true, gpload starts the gpfdist server with the --ssl option and uses the gpfdists:// protocol.

**CERTIFICATES_PATH**
Required when SSL is true; cannot be specified when SSL is false or unspecified. The location specified in CERTIFICATES_PATH must contain the following files:

- The server certificate file, server.crt
- The server private key file, server.key
- The trusted certificate authorities, root.crt

The root directory (/) cannot be specified as CERTIFICATES_PATH.

**FULLY_QUALIFIED_DOMAIN_NAME**
Optional. Specifies whether gpload resolve hostnames to the fully qualified domain name (FQDN) or the local hostname. If the value is set to true, names are resolved to the FQDN. If the value is set to false, resolution is to the local hostname. The default is false.
A fully qualified domain name might be required in some situations. For example, if the Greenplum Database system is in a different domain than an ETL application that is being accessed by `gpload`.

**COLUMNS**

Optional. Specifies the schema of the source data file(s) in the format of `field_name: data_type`. The DELIMITER character in the source file is what separates two data value fields (columns). A row is determined by a line feed character (0x0a).

If the input COLUMNS are not specified, then the schema of the output TABLE is implied, meaning that the source data must have the same column order, number of columns, and data format as the target table.

The default source-to-target mapping is based on a match of column names as defined in this section and the column names in the target TABLE. This default mapping can be overridden using the MAPPING section.

**TRANSFORM**

Optional. Specifies the name of the input transformation passed to `gpload`. For information about XML transformations, see "Loading and Unloading Data" in the Greenplum Database Administrator Guide.

**TRANSFORM_CONFIG**

Required when TRANSFORM is specified. Specifies the location of the transformation configuration file that is specified in the TRANSFORM parameter, above.

**MAX_LINE_LENGTH**

Optional. An integer that specifies the maximum length of a line in the XML transformation data passed to `gpload`.

**FORMAT**

Optional. Specifies the format of the source data file(s) - either plain text (TEXT) or comma separated values (CSV) format. Defaults to TEXT if not specified. For more information about the format of the source data, see "Loading and Unloading Data" in the Greenplum Database Administrator Guide.

**DELIMITER**

Optional. Specifies a single ASCII character that separates columns within each row (line) of data. The default is a tab character in TEXT mode, a comma in CSV mode. You can also specify a non-printable ASCII character or a non-printable unicode character, for example: "\x1B" or "\u001B". The escape string syntax, `E'character-code'`, is also supported for non-printable characters. The ASCII or unicode character must be enclosed in single quotes. For example: `E'\x1B'` or `E'\u001B'`.

**ESCAPE**

Specifies the single character that is used for C escape sequences (such as \
, \t, \100, and so on) and for escaping data characters that might otherwise be taken as row or column delimiters. Make sure to choose an escape character that is not used anywhere in your actual column data. The default escape character is a \ (backslash) for text-formatted files and a " (double quote) for csv-formatted files, however it is possible to specify another character to represent an escape. It is also possible to disable escaping in text-formatted files by specifying the value 'OFF' as the escape value. This is very useful for data such as text-formatted web log data that has many embedded backslashes that are not intended to be escapes.

**NULL_AS**

Optional. Specifies the string that represents a null value. The default is \N (backslash-N) in TEXT mode, and an empty value with no quotations in CSV mode. You might prefer an empty string even in TEXT mode for cases where you do not want to distinguish nulls.
from empty strings. Any source data item that matches this string will be considered a null value.

**FORCE NOT NULL**

Optional. In CSV mode, processes each specified column as though it were quoted and hence not a NULL value. For the default null string in CSV mode (nothing between two delimiters), this causes missing values to be evaluated as zero-length strings.

**QUOTE**

Required when `FORMAT` is `CSV`. Specifies the quotation character for `CSV` mode. The default is double-quote (").

**HEADER**

Optional. Specifies that the first line in the data file(s) is a header row (contains the names of the columns) and should not be included as data to be loaded. If using multiple data source files, all files must have a header row. The default is to assume that the input files do not have a header row.

**ENCODING**

Optional. Character set encoding of the source data. Specify a string constant (such as 'SQL_ASCII'), an integer encoding number, or 'DEFAULT' to use the default client encoding. If not specified, the default client encoding is used. For information about supported character sets, see the Greenplum Database Reference Guide.

**ERROR_LIMIT**

Optional. Enables single row error isolation mode for this load operation. When enabled, input rows that have format errors will be discarded provided that the error limit count is not reached on any Greenplum Database segment instance during input processing. If the error limit is not reached, all good rows will be loaded and any error rows will either be discarded or captured as part of error log information. The default is to abort the load operation on the first error encountered. Note that single row error isolation only applies to data rows with format errors; for example, extra or missing attributes, attributes of a wrong data type, or invalid client encoding sequences. Constraint errors, such as primary key violations, will still cause the load operation to abort if encountered. For information about handling load errors, see "Loading and Unloading Data" in the Greenplum Database Administrator Guide.

**LOG_ERRORS**

Optional when `ERROR_LIMIT` is declared. Value is either `true` or `false`. The default value is `false`. If the value is `true`, rows with formatting errors are logged internally when running in single row error isolation mode. You can examine formatting errors with the Greenplum Database built-in SQL function `gp_read_error_log('table_name')`. If formatting errors are detected when loading data, `gpload` generates a warning message with the name of the table that contains the error information similar to this message.

```
14:22:51/5:00/13 WARN: 1 bad row, please use GPDB built-in function gp_read_error_log('table-name') to access the detailed error row
```

If `LOG_ERRORS: true` is specified, `REUSE_TABLES: true` must be specified to retain the formatting errors in Greenplum Database error logs. If `REUSE_TABLES: true` is not specified, the error information is deleted after the `gpload` operation. Only summary information about formatting errors is returned. You can delete the formatting errors from the error logs with the Greenplum Database function `gp_truncate_error_log()`.

For more information about handling load errors, see "Loading and Unloading Data" in the Greenplum Database Administrator Guide. For information about the `gp_read_error_log()` function, see the `CREATE EXTERNAL TABLE` command in the Greenplum Database Reference Guide.
EXTERNAL
Optional. Defines the schema of the external table database objects created by gpload. The default is to use the Greenplum Database search_path.

SCHEMA
Required when EXTERNAL is declared. The name of the schema of the external table. If the schema does not exist, an error is returned.

If % (percent character) is specified, the schema of the table name specified by TABLE in the OUTPUT section is used. If the table name does not specify a schema, the default schema is used.

OUTPUT
Required. Defines the target table and final data column values that are to be loaded into the database.

TABLE
Required. The name of the target table to load into.

MODE
Optional. Defaults to INSERT if not specified. There are three available load modes:

- INSERT - Loads data into the target table using the following method:
  
  \[
  \text{INSERT INTO target_table SELECT } * \text{ FROM input_data;}
  \]

- UPDATE - Updates the UPDATE_COLUMNS of the target table where the rows have MATCH_COLUMNS attribute values equal to those of the input data, and the optional UPDATE_CONDITION is true.

- MERGE - Inserts new rows and updates the UPDATE_COLUMNS of existing rows where FOOBAR attribute values are equal to those of the input data, and the optional MATCH_COLUMNS is true. New rows are identified when the MATCH_COLUMNS value in the source data does not have a corresponding value in the existing data of the target table. In those cases, the entire row from the source file is inserted, not only the MATCH and UPDATE columns. If there are multiple new MATCH_COLUMNS values that are the same, only one new row for that value will be inserted. Use UPDATE_CONDITION to filter out the rows to discard.

MATCH_COLUMNS
Required if MODE is UPDATE or MERGE. Specifies the column(s) to use as the join condition for the update. The attribute value in the specified target column(s) must be equal to that of the corresponding source data column(s) in order for the row to be updated in the target table.

UPDATE_COLUMNS
Required if MODE is UPDATE or MERGE. Specifies the column(s) to update for the rows that meet the MATCH_COLUMNS criteria and the optional UPDATE_CONDITION.

UPDATE_CONDITION
Optional. Specifies a Boolean condition (similar to what you would declare in a WHERE clause) that must be met in order for a row in the target table to be updated (or inserted in the case of a MERGE).

MAPPING
Optional. If a mapping is specified, it overrides the default source-to-target column mapping. The default source-to-target mapping is based on a match of column names as defined in the source COLUMNS section and the column names of the target TABLE. A mapping is specified as either:

\[
\text{target_column_name: source_column_name}
\]
or

target_column_name: 'expression'

Where expression is any expression that you would specify in the SELECT list of a query, such as a constant value, a column reference, an operator invocation, a function call, and so on.

**PRELOAD**

Optional. Specifies operations to run prior to the load operation. Right now the only preload operation is TRUNCATE.

**TRUNCATE**

Optional. If set to true, gpload will remove all rows in the target table prior to loading it.

**STAGING_TABLE**

Optional. Specify the name of the temporary external table that is created during a gpload operation. The external table is used by gpfdist. REUSE_TABLES: true must also be specified. If REUSE_TABLES is false or not specified, STAGING_TABLE is ignored. By default, gpload creates a temporary external table with a randomly generated name.

If external_table_name contains a period (.), gpload returns an error. If the table exists, the utility uses the table. The utility returns an error if the existing table schema does not match the OUTPUT table schema.

The utility uses the value of SCHEMA in the EXTERNAL section as the schema for external_table_name. If the SCHEMA value is %, the schema for external_table_name is the same as the schema of the target table, the schema of TABLE in the OUTPUT section.

If SCHEMA is not set, the utility searches for the table (using the schemas in the database search_path). If the table is not found, external_table_name is created in the default PUBLIC schema.

**REUSE_TABLES**

Optional. If set to true, gpload will not drop the external table objects and staging table objects it creates. These objects will be reused for future load operations that use the same load specifications. This improves performance of trickle loads (ongoing small loads to the same target table).

If LOG_ERRORS: true is specified, REUSE_TABLES: true must be specified to retain the formatting errors in Greenplum Database error logs. If REUSE_TABLES: true is not specified, formatting error information is deleted after the gpload operation.

If the external_table_name exists, the utility uses the existing table. The utility returns an error if the table schema does not match the OUTPUT table schema.

**SQL**

Optional. Defines SQL commands to run before and/or after the load operation. You can specify multiple BEFORE and/or AFTER commands. List commands in the order of desired execution.

**BEFORE**

Optional. An SQL command to run before the load operation starts. Enclose commands in quotes.

**AFTER**

Optional. An SQL command to run after the load operation completes. Enclose commands in quotes.
Log File Format

Log files output by `gpload` have the following format:

```
timestamp|level|message
```

Where `timestamp` takes the form: `YYYY-MM-DD HH:MM:SS`, `level` is one of `DEBUG`, `LOG`, `INFO`, `ERROR`, and `message` is a normal text message.

Some INFO messages that may be of interest in the log files are (where `#` corresponds to the actual number of seconds, units of data, or failed rows):

```
INFO|running time: #.## seconds
INFO|transferred #.# kB of #.# kB.
INFO|gpload succeeded
INFO|gpload succeeded with warnings
INFO|gpload failed
INFO|1 bad row
INFO|# bad rows
```

Notes

If your database object names were created using a double-quoted identifier (delimited identifier), you must specify the delimited name within single quotes in the `gpload` control file. For example, if you create a table as follows:

```
CREATE TABLE "MyTable" ("MyColumn" text);
```

Your YAML-formatted `gpload` control file would refer to the above table and column names as follows:

```
- COLUMNS:
  - "MyColumn": text
OUTPUT:
  - TABLE: public."MyTable"
```

If the YAML control file contains the `ERROR_TABLE` element that was available in Greenplum Database 4.3.x, `gpload` logs a warning stating that `ERROR_TABLE` is not supported, and load errors are handled as if the `LOG_ERRORS` and `REUSE_TABLE` elements were set to `true`. Rows with formatting errors are logged internally when running in single row error isolation mode.

Examples

Run a load job as defined in `my_load.yml`:

```
gpload -f my_load.yml
```

Example load control file:

```
---
VERSION: 1.0.0.1
DATABASE: ops
USER: gpadmin
HOST: mdw-1
PORT: 5432
GPLOAD:
  INPUT:
    - SOURCE:
      LOCAL_HOSTNAME:
      - etl1-1
      - etl1-2
```
See Also

gpdist, create external table in the Greenplum Database Reference Guide

gplogfilter

Searches through Greenplum Database log files for specified entries.

Synopsis

```
gplogfilter [timestamp_options] [pattern_options] [output_options] [input_options] [input_file]
gplogfilter --help
gplogfilter --version
```

Description

The gplogfilter utility can be used to search through a Greenplum Database log file for entries matching the specified criteria. If an input file is not supplied, then gplogfilter will use the $MASTER_DATA_DIRECTORY environment variable to locate the Greenplum master log file in the standard logging location. To read from standard input, use a dash (-) as the input file name. Input files may be compressed using gzip. In an input file, a log entry is identified by its timestamp in YYYY-MM-DD [hh:mm[:ss]] format.

You can also use gplogfilter to search through all segment log files at once by running it through the gpssh utility. For example, to display the last three lines of each segment log file:

```
gpssh -f seg_host_file
 => source /usr/local/greenplum-db/greenplum_path.sh
 => gplogfilter -n 3 /gpdata/*/pg_log/gpdb*.csv
```

By default, the output of gplogfilter is sent to standard output. Use the -o option to send the output to a file or a directory. If you supply an output file name ending in .gz, the output file will be compressed

---

- etl-3
- etl-4
PORT: 8081
FILE:
  - /var/load/data/*
- COLUMNS:
  - name: text
  - amount: float4
  - category: text
  - desc: text
  - date: date
- FORMAT: text
- DELIMITER: '|'
- ERROR_LIMIT: 25
- LOG_ERRORS: true
OUTPUT:
  - TABLE: payables.expenses
  - MODE: INSERT
PRELOAD:
  - REUSE_TABLES: true
SQL:
  - BEFORE: "INSERT INTO audit VALUES('start', current_timestamp)"
  - AFTER: "INSERT INTO audit VALUES('end', current_timestamp)"
by default using maximum compression. If the output destination is a directory, the output file is given the same name as the input file.

**Options**

**Timestamp Options**

`-b datetime | --begin=datetime`

Specifies a starting date and time to begin searching for log entries in the format of `YYYY-MM-DD [hh:mm[:ss]]`. If a time is specified, the date and time must be enclosed in either single or double quotes. This example encloses the date and time in single quotes:

```
gplogfilter -b '2013-05-23 14:33'
```

`-e datetime | --end=datetime`

Specifies an ending date and time to stop searching for log entries in the format of `YYYY-MM-DD [hh:mm[:ss]]`. If a time is specified, the date and time must be enclosed in either single or double quotes. This example encloses the date and time in single quotes:

```
gplogfilter -e '2013-05-23 14:33'
```

`-d time | --duration=time`

Specifies a time duration to search for log entries in the format of `[hh][[:mm][[:ss]]]. If used without either the `-b` or `-e` option, will use the current time as a basis.

**Pattern Matching Options**

`-c i [gnore] | r [espect] | --case=i [gnore] | r [espect]`

Matching of alphabetic characters is case sensitive by default unless proceeded by the `--case=ignore` option.

`-C 'string' | --columns='string'`

Selects specific columns from the log file. Specify the desired columns as a comma-delimited string of column numbers beginning with 1, where the second column from left is 2, the third is 3, and so on. See "Viewing the Database Server Log Files" in the *Greenplum Database Administrator Guide* for details about the log file format and for a list of the available columns and their associated number.

`-f 'string' | --find='string'`

Finds the log entries containing the specified string.

`-F 'string' | --nofind='string'`

Rejects the log entries containing the specified string.

`-m regex | --match=regex`

Finds log entries that match the specified Python regular expression. See [https://docs.python.org/library/re.html](https://docs.python.org/library/re.html) for Python regular expression syntax.

`-M regex | --nomatch=regex`

Rejects log entries that match the specified Python regular expression. See [https://docs.python.org/library/re.html](https://docs.python.org/library/re.html) for Python regular expression syntax.

`-t | --trouble`

Finds only the log entries that have `ERROR:`, `FATAL:`, or `PANIC:` in the first line.

**Output Options**

`-n integer | --tail=integer`

Limits the output to the last `integer` of qualifying log entries found.
-s offset [limit] | --slice=offset [limit]
   From the list of qualifying log entries, returns the limit number of entries starting at the offset entry number, where an offset of zero (0) denotes the first entry in the result set and an offset of any number greater than zero counts back from the end of the result set.

-o output_file | --out=output_file
   Writes the output to the specified file or directory location instead of STDOUT.

-z 0-9 | --zip=0-9
   Compresses the output file to the specified compression level using gzip, where 0 is no compression and 9 is maximum compression. If you supply an output file name ending in .gz, the output file will be compressed by default using maximum compression.

-a | --append
   If the output file already exists, appends to the file instead of overwriting it.

Input Options

input_file
   The name of the input log file(s) to search through. If an input file is not supplied, gplogfilter will use the $MASTER_DATA_DIRECTORY environment variable to locate the Greenplum Database master log file. To read from standard input, use a dash (-) as the input file name.

-u | --unzip
   Uncompress the input file using gunzip. If the input file name ends in .gz, it will be uncompressed by default.

--help
   Displays the online help.

--version
   Displays the version of this utility.

Examples

Display the last three error messages in the master log file:

   gplogfilter -t -n 3

Display all log messages in the master log file timestamped in the last 10 minutes:

   gplogfilter -d :10

Display log messages in the master log file containing the string |con6 cmd11|:

   gplogfilter -f '|con6 cmd11|'

Using gpssh, run gplogfilter on the segment hosts and search for log messages in the segment log files containing the string con6 and save output to a file.

   gpssh -f seg_hosts_file -e 'source /usr/local/greenplum-db/greenplum_path.sh ; gplogfilter -f con6 /gpdata/*/pg_log/gpdb*.csv' > seglog.out

See Also

gpssh, gpscp
gpmapreduce

Runs Greenplum MapReduce jobs as defined in a YAML specification document.

Synopsis

```
gpmapreduce -f yaml_file [dbname [username]]
   [-k name=value | --key name=value]
   [-h hostname | --host hostname] [-p port | --port port]
   [-U username | --username username] [-W] [-v]

gpmapreduce -x | --explain

gpmapreduce -X | --explain-analyze

gpmapreduce -V | --version

gpmapreduce -h | --help
```

Prerequisites

The following are required prior to running this program:

- You must have your MapReduce job defined in a YAML file. For information about the Greenplum MapReduce specification, see the Greenplum Database Reference Guide.
- You must be a Greenplum Database superuser to run MapReduce jobs written in untrusted Perl or Python.
- You must be a Greenplum Database superuser to run MapReduce jobs with EXEC and FILE inputs.
- You must be a Greenplum Database superuser to run MapReduce jobs with GPFDIST input unless the user has the appropriate rights granted. See the Greenplum Database Reference Guide for more information.

Description

MapReduce is a programming model developed by Google for processing and generating large data sets on an array of commodity servers. Greenplum MapReduce allows programmers who are familiar with the MapReduce paradigm to write map and reduce functions and submit them to the Greenplum Database parallel engine for processing.

In order for Greenplum to be able to process MapReduce functions, the functions need to be defined in a YAML document, which is then passed to the Greenplum MapReduce program, gpmapreduce, for execution by the Greenplum Database parallel engine. The Greenplum system takes care of the details of distributing the input data, executing the program across a set of machines, handling machine failures, and managing the required inter-machine communication.

Options

- `-f yaml_file`
  Required. The YAML file that contains the Greenplum MapReduce job definitions. See the Greenplum Database Reference Guide.

- `--help`
  Show help, then exit.

- `--version`
  Show version information, then exit.

- `--verbose`
  Show verbose output.
Show verbose output.

-x | --explain
    Do not run MapReduce jobs, but produce explain plans.

-X | --explain-analyze
    Run MapReduce jobs and produce explain-analyze plans.

-k | --keyname=value
    Sets a YAML variable. A value is required. Defaults to "key" if no variable name is specified.

Connection Options

-h host | --host host
    Specifies the host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable PGHOST or defaults to localhost.

-p port | --port port
    Specifies the TCP port on which the Greenplum master database server is listening for connections. If not specified, reads from the environment variable PGPORT or defaults to 5432.

-U username | --username username
    The database role name to connect as. If not specified, reads from the environment variable PGUSER or defaults to the current system user name.

-W | --password
    Force a password prompt.

Examples

Run a MapReduce job as defined in my_yaml.txt and connect to the database mydatabase:

    gpmapreduce -f my_yaml.txt mydatabase

See Also

Greenplum MapReduce specification in the *Greenplum Database Reference Guide*
Prerequisites
The Data Domain systems that are used as local and remote backup systems for managed file replication must have Data Domain Boost and Replicator enabled.

The Greenplum Database master host segment hosts must be able to connect to both the local Data Domain system and the remote Data Domain system.

The login credentials for the local and remote Data Domain systems must be configured on the Greenplum master host with the gpcrondump utility. See "Backing Up and Restoring Databases" in the Greenplum Database Administrator Guide for information about setting up Data Domain systems for use with Greenplum Database.

See the Greenplum Database Release Notes for information about the supported version of Data Domain Boost.

Description
The gpmfr utility provides these capabilities:

- Lists the backup data sets that are on the local or the remote Data Domain system.
- Replicates a backup data set that is on the local Data Domain system to the remote system.
- Recovers a backup data set that is on the remote Data Domain system to the local system.
- Deletes a backup data set that is on the local or the remote Data Domain system.

The Greenplum Database backup sets are identified by timestamps (yyyymmddhhmmss).

gpmfr attempts to schedule the replication task for the files in backup data set. It ensures that the limit on the maximum number of I/O streams used for replication is never exceeded. The I/O streams limit is set with the --max-streams option that accompanies the --replicate or --recover option.

When cancelling a replication operation, gpmfr kills all active replication processes and cleans up all the files on replication Data Domain system.

Options
-a
Do not prompt the user for confirmation. Progress information is displayed on the output. Specify the option -q or --quiet to write progress information to the log file.

--ddboost-storage-unit=unit-ID
Optional. Specify a valid storage unit ID for the Data Domain system that is used for the gpmfr operation. A replicate or recover operation uses the same storage unit ID on both local and remote Data Domain systems. If the storage unit on the destination Data Domain system (where the backup is being copied) is created if it does not exist.
If this option is not specified, the utility uses the storage unit specified when configuring the DD Boost credentials or the default ID GPDB.

**--delete {LATEST | OLDEST | timestamp}**
Deletes a Greenplum Database backup set from the local Data Domain system. Specify the option --remote to delete the backup set from the remote Data Domain system.
LATEST specifies deleting the latest backup set (first in chronological order).
OLDEST specifies deleting the backup set that is oldest in chronological order.
timestamp specifies deleting the Greenplum Database backup set identified by the timestamp.

**--list**
Lists the Greenplum Database backup sets that are on the local Data Domain system. The backup sets are identified by timestamps (yyyymmddhhmss).
Specify the option --remote to list the Greenplum Database backup sets that are on the remote Data Domain system.

**--list-files {LATEST | OLDEST | timestamp}**
Lists the files in a Greenplum Database backup that is on the local Data Domain system. Specify the option --remote to list the files in the backup set that is on the remote Data Domain system.
LATEST specifies listing the files in the latest backup set (first in chronological order).
OLDEST specifies listing the files in the backup set that is oldest in chronological order.
timestamp specifies listing the file in the backup set identified by the timestamp.

**--master-port=master_port**
Specifies the Greenplum Database master port number. To validate backup sets, the utility retrieves information from the Greenplum Database instance that uses the port number. If the option is not specified, the default value is 5432.
If gpmfr does not find a Greenplum Database, validation is skipped and a warning is displayed.

**--max-streams max_IO_streams**
Specifies the maximum number of Data Domain I/O streams that can be used when copying the backup set between the local and remote Data Domain systems.

**-q | --quiet**
Runs in quiet mode. File transfer progress information is not displayed on the output, it is written to the log file. If this option is not specified, progress information is only displayed on screen, it is not written to the log file.

**--recover {LATEST | OLDEST | timestamp}**
Recovers a Greenplum Database backup set that is available on the remote Data Domain system to the local system.
LATEST specifies recovering the most recent backup set (first in chronological order).
OLDEST specifies recovering the backup set that is oldest in chronological order.
timestamp specifies recovering the backup set identified by the timestamp.
If a backup set with the same timestamp exists on local Data Domain system, the utility prompts you to confirm replacing the backup.
A progress bar indicating transfer status of the backup set is shown on shown at the output.

**--replicate {LATEST | OLDEST | timestamp}**
Replicates a Greenplum Database backup set that is on the local Data Domain system to the remote system.

LATEST specifies replicating the most recent backup set (first in chronological order).

OLDEST specifies replicating the backup set that is oldest in chronological order.

timestamp specifies replicating the backup set identified by the timestamp.

If a backup set with the same timestamp exists on remote Data Domain system, the utility prompts you to confirm replacing the backup.

A progress bar indicating transfer status of the backup set is shown at the output.

A backup set must be completely backed up to the local Domain system before it can be replicated to the remote Data Domain system.

**--remote**

Perform the operation on the remote Data Domain system that is used for disaster recovery.

For example, gpmfr --list lists the backup sets that are on the local Data Domain system that is used to back up Greenplum Database. gpmfr --list --remote lists the backup sets that are on the remote system.

**--show-streams**

Displays the replication I/O stream soft limit and the number of I/O streams that are in use.

**--skip-ping**

Specify this option to skip the ping of a Data Domain system. gpmfr uses ping to ensure that the Data Domain system is reachable. If the Data Domain host is configured to block ICMP ping probes, specify this option to skip the ping of the Data Domain system.

**-h | --help**

Displays the online help.

**-v | --verbose**

Specifies verbose logging mode. Additional log information is written to the log file during command execution.

**--version**

Displays the version of this utility.

**Example**

The following example replicates the latest backup set on the local Data Domain sever to the remote server. The maximum number of I/O streams that can be used for the replication is 30.

```
    gpmfr --replicate LATEST --max-streams 30
```

**See Also**

gpcrondump, gpdbrestore

gpmovemirrors

**gpmovemirrors**

Moves mirror segment instances to new locations.

**Synopsis**

```
gpmovemirrors -i move_config_file [-d master_data_directory] [-l logfile_directory]
```
Description
The `gpmovemirrors` utility moves mirror segment instances to new locations. You may want to move mirrors to new locations to optimize distribution or data storage.

Before moving segments, the utility verifies that they are mirrors, and that their corresponding primary segments are up and are in synchronizing or resynchronizing mode.

By default, the utility will prompt you for the file system location(s) where it will move the mirror segment data directories.

You must make sure that the user who runs `gpmovemirrors` (the `gpadmin` user) has permissions to write to the data directory locations specified. You may want to create these directories on the segment hosts and `chown` them to the appropriate user before running `gpmovemirrors`.

Options

- `-B parallel_processes`
  The number of mirror segments to move in parallel. If not specified, the utility will start up to 4 parallel processes depending on how many mirror segment instances it needs to move.

- `-d master_data_directory`
  The master data directory. If not specified, the value set for `$MASTER_DATA_DIRECTORY` will be used.

- `-i move_config_file`
  A configuration file containing information about which mirror segments to move, and where to move them.

  You must have one mirror segment listed for each primary segment in the system.

  Each line inside the configuration file has the following format (as per attributes in the `gp_segment_configuration`, `pg_filespace`, and `pg_filespace_entry` catalog tables):

  ```
  filespaceOrder=[filespace1_fsname[:filespace2_fsname:...]
  old_address:port:fselocation \n  [new_address:port:replication_port:fselocation[:fselocation:...]]
  ```

  Note that you only need to specify a name for `filespaceOrder` if your system has multiple filesystems configured. If your system does not have additional filesystems configured besides the default `pg_system` filesystem, this file will only have one location (for the default data directory filesystem, `pg_system`). `pg_system` does not need to be listed in the `filespaceOrder` line. It will always be the first `fselocation` listed after `replication_port`.

- `-l logfile_directory`
  The directory to write the log file. Defaults to `~/gpAdminLogs`.

- `-v (verbose)`
  Sets logging output to verbose.

- `--version (show utility version)`
  Displays the version of this utility.
-? (help)

Displays the online help.

**Examples**

Moves mirrors from an existing Greenplum Database system to a different set of hosts:

```
$ gpmovemirrors -i move_config_file
```

Where the `move_config_file` looks something like this (if you do not have additional filespaces configured besides the default `pg_system` filesystem):

```
filespaceOrder=filespacea
sdw1-1:61001:/data/mirrors/database/dbfast22/gp1
sdw2-1:61001:43001:/data/mirrors/database/dbfast22/gp1:
    /data/mirrors/database/dbfast22fs1
```

**gpperfmon_install**

Installs the `gpperfmon` database, which is used by Greenplum Command Center, and optionally enables the data collection agents.

**Synopsis**

```
gpperfmon_install --port gpdb_port  
    [--enable] [--password gpmon_password] [--pgpass path_to_file]  
    [--verbose]
gpperfmon_install --help | -h | -?
```

**Description**

The `gpperfmon_install` utility automates the steps required to enable the data collection agents. You must be the Greenplum Database system user (`gpadmin`) to run this utility. The `--port` option is required. When using the `--enable` option, the `--password` option is also required. Use the `--port` option to supply the port of the Greenplum Database master instance. If using the `--enable` option, Greenplum Database must be restarted after the utility completes.

When run without the `--enable` option, the utility just creates the `gpperfmon` database (the database used to store system metrics collected by the data collection agents). When run with the `--enable` option, the utility also runs the following additional tasks necessary to enable the performance monitor data collection agents:

1. Creates the `gpmon` superuser role in Greenplum Database. The data collection agents require this role to connect to the database and write their data. The `gpmon` superuser role uses MD5-encrypted password authentication by default. Use the `--password` option to set the `gpmon` superuser's password.
2. Updates the `$MASTER_DATA_DIRECTORY/pg_hba.conf` file. The utility adds these lines to the host-based authentication file (`pg_hba.conf`):

   ```
   local     gpperfmon  gpmon              md5
   host      all        gpmon  127.0.0.1/28   md5
   host      all        gpmon  ::1/128       md5
   ```

   The second and third lines, the `host` entries, give `gpmon` access to all Greenplum Database databases.
Note: It might be necessary to edit the lines in the pg_hba.conf file after running the gpperfmon_install utility to limit the gpmon role’s access to databases or to change the authentication method. After you edit the file, run gpstop -u to reload the file in Greenplum Database.

- To limit gpmon access to just the gpperfmon database, edit the host entries in the pg_hba.conf file. For the gpmon user change the second field from all to gpperfmon:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>local</td>
<td>gpperfmon</td>
<td>gpmon</td>
<td>md5</td>
</tr>
<tr>
<td>host</td>
<td>gpperfmon</td>
<td>gpmon</td>
<td>127.0.0.1/28 md5</td>
</tr>
<tr>
<td>host</td>
<td>gpperfmon</td>
<td>gpmon</td>
<td>::1/128 md5</td>
</tr>
</tbody>
</table>

- The gpperfmon_install utility assumes the default MD5 authentication method. Greenplum Database can optionally be configured to use the SHA-256 hash algorithm to compute the password hashes saved in the system catalog. This is incompatible with the MD5 authentication method, which expects an MD5 hash or clear text password in the system catalog. Because of this, if you have enabled the SHA-256 hash algorithm in the database, you must edit the pg_hba.conf file after running the gpperfmon_install utility. For the host entries, change the authentication method for the gpmon role from md5 to password:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>local</td>
<td>gpperfmon</td>
<td>gpmon</td>
<td>md5</td>
</tr>
<tr>
<td>host</td>
<td>all</td>
<td>gpmon</td>
<td>127.0.0.1/28 password</td>
</tr>
<tr>
<td>host</td>
<td>all</td>
<td>gpmon</td>
<td>::1/128 password</td>
</tr>
</tbody>
</table>

The password authentication method submits the user’s clear text password for authentication and should not be used on an untrusted network. See "Protecting Passwords in Greenplum Database" in the Greenplum Database Administrator Guide for more information about configuring password hashing.

3. Updates the password file (.pgpass). In order to allow the data collection agents to connect as the gpmon role without a password prompt, you must have a password file that has an entry for the gpmon user. The utility adds the following entry to your password file (if the file does not exist, the utility will create it):

*:5432:gpperfmon:gpmon:gpmon_password

If your password file is not located in the default location (~/.pgpass), use the --pgpass option to specify the file location.

4. Sets the server configuration parameters for Greenplum Command Center. The following parameters must be enabled for the data collection agents to begin collecting data. The utility sets the following parameters in the Greenplum Database postgresql.conf configuration files:

- \texttt{gp_enable_gpperfmon=on} (in all postgresql.conf files)
- \texttt{gpperfmon_port=8888} (in all postgresql.conf files)
- \texttt{gp_external_enable_exec=on} (in the master postgresql.conf file)

Data collection agents can be configured by setting parameters in the gpperfmon.conf configuration file. See Data Collection Agent Configuration for details.

For information about Greenplum Command Center, see the Greenplum Command Center Documentation.

Options

\texttt{--enable}

In addition to creating the gpperfmon database, performs the additional steps required to enable the data collection agents. When \texttt{--enable} is specified the utility will also create and configure the gpmon superuser account and set the Command Center server configuration parameters in the postgresql.conf files.
--password gpmon_password
Required if --enable is specified. Sets the password of the gpmon superuser. Disallowed if --enable is not specified.

--port gpdb_port
Required. Specifies the connection port of the Greenplum Database master.

--pgpass path_to_file
Optional if --enable is specified. If the password file is not in the default location of ~/.pgpass, specifies the location of the password file.

--verbose
Sets the logging level to verbose.

--help | -h | -?
Displays the online help.

Data Collection Agent Configuration
The $MASTER_DATA_DIRECTORY/gpperfmon/conf/gpperfmon.conf file stores configuration parameters for the data collection agents. For configuration changes to these options to take effect, you must save gpperfmon.conf and then restart Greenplum Database server (gpstop -r).

The gpperfmon.conf file contains the following configuration parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>log_location</td>
<td>Specifies a directory location for gpperfmon log files. Default is $MASTER_DATA_DIRECTORY/gpperfmon/logs.</td>
</tr>
<tr>
<td>min_query_time</td>
<td>Specifies the minimum query run time in seconds for statistics collection. All queries that run longer than this value are logged in the queries_history table. For queries with shorter run times, no historical data is collected. Defaults to 20 seconds. If you know that you want to collect data for all queries, you can set this parameter to a low value. Setting the minimum query run time to zero, however, collects data even for the numerous queries run by Greenplum Command Center, creating a large amount of data that may not be useful.</td>
</tr>
<tr>
<td>max_log_size</td>
<td>This parameter is not included in gpperfmon.conf, but it may be added to this file. To prevent the log files from growing to excessive size, you can add the max_log_size parameter to gpperfmon.conf. The value of this parameter is measured in bytes. For example:</td>
</tr>
<tr>
<td></td>
<td>max_log_size = 10485760</td>
</tr>
<tr>
<td></td>
<td>With this setting, the log files will grow to 10MB before the system rolls over to a new log file.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>partition_age</td>
<td>The number of months that gpperfmon statistics data will be retained. The default value is 0, which means that partitions are never dropped automatically.</td>
</tr>
<tr>
<td>quantum</td>
<td>Specifies the time in seconds between updates from data collection agents on all segments. Valid values are 10, 15, 20, 30, and 60. Defaults to 15 seconds. If you prefer a less granular view of performance, or want to collect and analyze minimal amounts of data for system metrics, choose a higher quantum. To collect data more frequently, choose a lower value.</td>
</tr>
<tr>
<td>harvest_interval</td>
<td>The time, in seconds, between data harvests. A data harvest moves recent data from the gpperfmon external(_tail) tables to their corresponding history files. The default is 120. The minimum value is 30.</td>
</tr>
<tr>
<td>ignore_qexec_packet</td>
<td>(Deprecated) When set to true, data collection agents do not collect performance data in the gpperfmon database queries_* tables: rows_out, cpu_elapsed, cpu_currpct, skew_cpu, and skew_rows. The default setting, true, reduces the amount of memory consumed by the gpmon process. Set this parameter to false if you require this additional performance data.</td>
</tr>
</tbody>
</table>
| smdw_aliases         | This parameter allows you to specify additional host names for the standby master. For example, if the standby master has two NICs, you can enter:

```bash
smdw_aliases=smdw-1,smdw-2
```

This optional fault tolerance parameter is useful if the Greenplum Command Center loses connectivity with the standby master. Instead of continuously retrying to connect to host smdw, it will try to connect to the NIC-based aliases of smdw-1 and/or smdw-2. This ensures that the Command Center Console can continuously poll and monitor the standby master.  

**Notes**  
The gpperfmon database and Greenplum Command Center require the gpmon role. After the gpperfmon database and gpmon role have been created, you can change the password for the gpmon role and update the information that Greenplum Command Center uses to connect to the gpperfmon database:
1. Log in to Greenplum Database as a superuser and change the `gpmon` password with the `ALTER ROLE` command.

   ```sql
   # ALTER ROLE gpmon WITH PASSWORD 'new_password';
   ```

2. Update the password in `.pgpass` file that is used by Greenplum Command Center. The default file location is the `gpadmin` home directory (`~/.pgpass`). The `.pgpass` file contains a line with the `gpmon` password.

   ```
   *:5432:gpperfmon:gpmon:new_password
   ```

3. Restart the Greenplum Command Center with the Command Center `gpcmdr` utility.

   ```
   $ gpcmdr --restart
   ```

   The `gpperfmon` monitoring system requires some initialization after startup. Monitoring information appears after a few minutes have passed, and not immediately after installation and startup of the `gpperfmon` system.

**Examples**

Create the `gpperfmon` database only:

```
$ su - gpadmin
$ gpperfmon_install --port 5432
```

Create the `gpperfmon` database, create the `gpmon` superuser, and enable the data collection agents:

```
$ su - gpadmin
$ gpperfmon_install --enable --password changeme --port 5432
$ gpstop -r
```

**See Also**

`gpstop`

**gppkg**

Installs Greenplum Database extensions in `.gppkg` format, such as PL/Java, PL/R, PostGIS, and MADlib, along with their dependencies, across an entire cluster.

**Synopsis**

```bash
gppkg [-i package | -u package | -r name-version | -c]
      [-d master_data_directory] [-a] [-v]

gppkg --migrate GPHOME_old GPHOME_new [-a] [-v]

gppkg [-q | --query] query_option

gppkg -? | --help | -h

gppkg --version
```
Description

The Greenplum Package Manager (gppkg) utility installs Greenplum Database extensions, along with any dependencies, on all hosts across a cluster. It will also automatically install extensions on new hosts in the case of system expansion and segment recovery.

Note: After a major upgrade to Greenplum Database, you must download and install all gppkg extensions again.

Examples of database extensions and packages software that are delivered using the Greenplum Package Manager are:
- PL/Java
- PL/R
- PostGIS
- MADlib

Options

-a (do not prompt)
Do not prompt the user for confirmation.

-c | --clean
Reconciles the package state of the cluster to match the state of the master host. Running this option after a failed or partial install/uninstall ensures that the package installation state is consistent across the cluster.

-d master_data_directory
The master data directory. If not specified, the value set for $MASTER_DATA_DIRECTORY will be used.

-i package | --install=package
Installs the given package. This includes any pre/post installation steps and installation of any dependencies.

--migrate GPHOME_old GPHOME_new
Migrates packages from a separate $GPHOME. Carries over packages from one version of Greenplum Database to another.

For example: gppkg --migrate /usr/local/greenplum-db-<old-version> /usr/local/greenplum-db-<new-version>

When migrating packages, these requirements must be met.
- At least the master instance of the destination Greenplum Database must be started (the instance installed in GPHOME_new). Before running the gppkg command start the Greenplum Database master with the command gpstart -m.
- Run the gppkg utility from the GPHOME_new installation. The migration destination installation directory.

-q | --query query_option
Provides information specified by query_option about the installed packages. Only one query_option can be specified at a time. The following table lists the possible values for query_option. <package_file> is the name of a package.

Table 77: Query Options for gppkg

<table>
<thead>
<tr>
<th>query_option</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;package_file&gt;</td>
<td>Whether the specified package is installed.</td>
</tr>
<tr>
<td>query_option</td>
<td>Returns</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>--info &lt;package_file&gt;</td>
<td>The name, version, and other information about the specified package.</td>
</tr>
<tr>
<td>--list &lt;package_file&gt;</td>
<td>The file contents of the specified package.</td>
</tr>
<tr>
<td>--all</td>
<td>List of all installed packages.</td>
</tr>
</tbody>
</table>

```bash
-r name-version | --remove=name-version
    Removes the specified package.
-u package | --update=package
    Updates the given package.
    **Warning:** The process of updating a package includes removing all previous versions of the system objects related to the package. For example, previous versions of shared libraries are removed. After the update process, a database function will fail when it is called if the function references a package file that has been removed.

--version (show utility version)
    Displays the version of this utility.
-v | --verbose
    Sets the logging level to verbose.
-? | -h | --help
    Displays the online help.
```

**gprecovearseg**

Recovers a primary or mirror segment instance that has been marked as down (if mirroring is enabled).

**Synopsis**

```bash
gprecovearseg -r
gprecovearseg -o output_recover_config_file | -S output_filespace_config_file [-p new_recover_host[,...]]
gprecovearseg -?
gprecovearseg --version
```

**Description**

In a system with mirrors enabled, the `gprecovearseg` utility reactivates a failed segment instance and identifies the changed database files that require resynchronization. Once `gprecovearseg` completes this process, the system goes into *resynchronizing* mode until the recovered segment is brought up to date. The system is online and fully operational during resynchronization.

During an incremental recovery (the `-F` option is not specified), if `gprecovearseg` detects a segment instance with mirroring disabled in a system with mirrors enabled, the utility reports that mirroring is
disabled for the segment, does not attempt to recover that segment instance, and continues the recovery process.

A segment instance can fail for several reasons, such as a host failure, network failure, or disk failure. When a segment instance fails, its status is marked as **down** in the Greenplum Database system catalog, and its mirror is activated in **change tracking** mode. In order to bring the failed segment instance back into operation again, you must first correct the problem that made it fail in the first place, and then recover the segment instance in Greenplum Database using `gprecoverseg`.

Segment recovery using `gprecoverseg` requires that you have an active mirror to recover from. For systems that do not have mirroring enabled, or in the event of a double fault (a primary and mirror pair both down at the same time) — you must take manual steps to recover the failed segment instances and then perform a system restart to bring the segments back online. For example, this command restarts a system.

```
  gpstop -r
```

By default, a failed segment is recovered in place, meaning that the system brings the segment back online on the same host and data directory location on which it was originally configured. In this case, use the following format for the recovery configuration file (using `-i`).

```plaintext
  filespaceOrder=[filespace1_fsname, filespace2_fsname[, ...]]
  <failed_host_address>:<port>:<data_directory>
```

In some cases, this may not be possible (for example, if a host was physically damaged and cannot be recovered). In this situation, `gprecoverseg` allows you to recover failed segments to a completely new host (using `-p`), on an alternative data directory location on your remaining live segment hosts (using `-s`), or by supplying a recovery configuration file (using `-i`) in the following format. The word SPACE indicates the location of a required space. Do not add additional spaces.

```plaintext
  filespaceOrder=[filespace1_fsname, filespace2_fsname[, ...]]
  <failed_host_address>:<port>:<data_directory>
  SPACE
  <recovery_host_address>:<port>:<replication_port>:<data_directory>
  [:<fselocation>:...]
```

See the `-i` option below for details and examples of a recovery configuration file.

The `gp_segment_configuration`, `pg_filespace`, and `pg_filespace_entry` system catalog tables can help you determine your current segment configuration so that you can plan your mirror recovery configuration. For example, run the following query:

```
  =# SELECT dbid, content, address, port,
       replication_port, fselocation as datadir
  FROM gp_segment_configuration, pg_filespace_entry
  WHERE dbid=fsedbid
  ORDER BY dbid;
```

The new recovery segment host must be pre-installed with the Greenplum Database software and configured exactly the same as the existing segment hosts. A spare data directory location must exist on all currently configured segment hosts and have enough disk space to accommodate the failed segments.

The recovery process marks the segment as up again in the Greenplum Database system catalog, and then initiates the resynchronization process to bring the transactional state of the segment up-to-date with the latest changes. The system is online and available during resynchronization. To check the status of the resynchronization process run:

```
  gpstate -m
```

### Options

- `-a` (do not prompt)
Do not prompt the user for confirmation.

-B parallel_processes
The number of segments to recover in parallel. If not specified, the utility will start up to four parallel processes depending on how many segment instances it needs to recover.

-d master_data_directory
Optional. The master host data directory. If not specified, the value set for $MASTER_DATA_DIRECTORY will be used.

-F (full recovery)
Optional. Perform a full copy of the active segment instance in order to recover the failed segment. The default is to only copy over the incremental changes that occurred while the segment was down.

-i recover_config_file
Specifies the name of a file with the details about failed segments to recover. Each line in the file is in the following format. The word SPACE indicates the location of a required space. Do not add additional spaces.

```
filespaceOrder=[filespace1_fsname[, filespace2_fsname[, ...]]]
<failed_host_address>:<port>:<data_directory>SPACE
<recovery_host_address>:<port>:<replication_port>:<data_directory>
[:<fselocation>:...]
```

Comments
Lines beginning with # are treated as comments and ignored.

Filespace Order
The first comment line that is not a comment specifies filespace ordering. This line starts with filespaceOrder= and is followed by list of filespace names delimited by a colon. For example:

```
filespaceOrder=raid1:raid2
```

The default pg_system filespace should not appear in this list. The list should be left empty on a system with no filespaces other than the default pg_system filespace. For example:

```
filespaceOrder=
```

Segments to Recover
Each line after the first specifies a segment to recover. This line can have one of two formats. In the event of in-place recovery, enter one group of colon delimited fields in the line. For example:

```
failedAddress:failedPort:failedDataDirectory
```

For recovery to a new location, enter two groups of fields separated by a space in the line. The required space is indicated by SPACE. Do not add additional spaces.

```
failedAddress:failedPort:failedDataDirectorySPACEnewAddress:
newPort:newReplicationPort:newDataDirectory
```

On a system with additional filespaces, the second group of fields is expected to be followed with a list of the corresponding filespace locations separated by additional colons. For example, on a system with two additional filespaces, enter two additional directories...
in the second group, as follows. The required space is indicated by \textbf{SPACE}. Do not add additional spaces.

```
failedAddress:failedPort:failedDataDirectory\textbf{SPACE}newAddress:
newPort:newReplicationPort:newDataDirectory:location1:location2
```

**Examples**

**In-place recovery of a single mirror**

```
filespaceOrder=
sdw1-1:50001:/data1/mirror/gpseg16
```

**Recovery of a single mirror to a new host**

```
filespaceOrder=
sdw1-1:50001:/data1/mirror/gpseg16\textbf{SPACE}sdw4-1:
50001:51001:/data1/recover1/gpseg16
```

**Recovery of a single mirror to a new host on a system with an extra filespace**

```
filespaceOrder=
fs1sdw1-1:50001:/data1/mirror/gpseg16\textbf{SPACE}sdw4-1:
50001:51001:/data1/recover1/gpseg16:/data1/fs1/gpseg16
```

**Obtaining a Sample File**

You can use the \texttt{-o} option to output a sample recovery configuration file to use as a starting point.

- \texttt{-l logfile_directory}
  The directory to write the log file. Defaults to \texttt{~/gpAdminLogs}.

- \texttt{-o output_recover_config_file}
  Specifies a file name and location to output a sample recovery configuration file. The output file lists the currently invalid segments and their default recovery location in the format that is required by the \texttt{-i} option. Use together with the \texttt{-p} option to output a sample file for recovering on a different host. This file can be edited to supply alternate recovery locations if needed.

- \texttt{-p new_recover_host[,\ldots]}
  Specifies a spare host outside of the currently configured Greenplum Database array on which to recover invalid segments. In the case of multiple failed segment hosts, you can specify a comma-separated list. The spare host must have the Greenplum Database software installed and configured, and have the same hardware and OS configuration as the current segment hosts (same OS version, locales, \texttt{gpadmin} user account, data directory locations created, ssh keys exchanged, number of network interfaces, network interface naming convention, and so on.).

- \texttt{-q (no screen output)}
  Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

- \texttt{-r (rebalance segments)}
  After a segment recovery, segment instances may not be returned to the preferred role that they were given at system initialization time. This can leave the system in a potentially unbalanced state, as some segment hosts may have more active segments than is optimal for top system performance. This option rebalances primary and mirror segments by returning them to their preferred roles. All segments must be valid and synchronized before
running `gprecoverseg -r`. If there are any in progress queries, they will be cancelled and rolled back.

### `-s` `filespace_config_file`

Specifies the name of a configuration file that contains file system locations on the currently configured segment hosts where you can recover failed segment instances. The filespace configuration file is in the format of:

```plaintext
pg_system=default_fselocation
filespace1_name=filespace1_fselocation
filespace2_name=filespace2_fselocation
...
```

If your system does not have additional filespaces configured, this file will only have one location (for the default filespace, `pg_system`). These file system locations must exist on all segment hosts in the array and have sufficient disk space to accommodate recovered segments.

Note: The `-s` and `-S` options are only used when you recover to existing hosts in the cluster. You cannot use these options when you recover to a new host. To recover to a new host, use the `-i` and `-o` options.

### `-S` `output_filespace_config_file`

Specifies a file name and location to output a sample filespace configuration file in the format that is required by the `-s` option. This file should be edited to supply the correct alternate filespace locations.

### `-v` (verbose)

Sets logging output to verbose.

### `--version` (version)

Displays the version of this utility.

### `-?` (help)

Displays the online help.

## Examples

### Recover any failed segment instances in place:

```bash
$ gprecoverseg
```

Rebalance your Greenplum Database system after a recovery by resetting all segments to their preferred role. First check that all segments are up and synchronized.

```bash
$ gpstate -m
$ gprecoverseg -r
```

### Recover any failed segment instances to a newly configured spare segment host:

```bash
$ gprecoverseg -i recover_config_file
```

Output the default recovery configuration file:

```bash
$ gprecoverseg -o /home/gpadmin/recover_config_file
```

## See Also

`gpstart`, `gpstop`
**gpreload**

Reloads Greenplum Database table data sorting the data based on specified columns.

**Synopsis**

```
gpreload -d database [-p port] { -t | --table-file } path_to_file [-a]
gpreload -h
   gpreload --version
```

**Description**

The `gpreload` utility reloads table data with column data sorted. For tables that were created with the table storage option `APPENDONLY=TRUE` and compression enabled, reloading the data with sorted data can improve table compression. You specify a list of tables to be reloaded and the table columns to be sorted in a text file.

Compression is improved by sorting data when the data in the column has a relatively low number of distinct values when compared to the total number of rows.

For a table being reloaded, the order of the columns to be sorted might affect compression. The columns with the fewest distinct values should be listed first. For example, listing state then city would generally result in better compression than listing city then state.

```
public.cust_table: state, city
public.cust_table: city, state
```

For information about the format of the file used with `gpreload`, see the `--table-file` option.

**Notes**

To improve reload performance, indexes on tables being reloaded should be removed before reloading the data.

Running the `ANALYZE` command after reloading table data might query performance because of a change in the data distribution of the reloaded data.

For each table, the utility copies table data to a temporary table, truncates the existing table data, and inserts data from the temporary table to the table in the specified sort order. Each table reload is performed in a single transaction.

For a partitioned table, you can reload the data of a leaf child partition. However, data is inserted from the root partition table, which acquires a `ROW EXCLUSIVE` lock on the entire table.

**Options**

- `-a` *(do not prompt)*

  Optional. If specified, the `gpreload` utility does not prompt the user for confirmation.

- `-d database`

  The database that contains the tables to be reloaded. The `gpreload` utility connects to the database as the user running the utility.

- `-p port`

  The Greenplum Database master port. If not specified, the value of the `PGPORT` environment variable is used. If the value is not available, an error is returned.

- `{ -t | --table-file } path_to_file`
The location and name of file containing list of schema qualified table names to reload and the column names to reorder from the Greenplum Database. Only user defined tables are supported. Views or system catalog tables are not supported.

If indexes are defined on table listed in the file, gpreload prompts to continue.

Each line specifies a table name and the list of columns to sort. This is the format of each line in the file:

```
schema.table_name: column [desc] [, column2 [desc] ... ]
```

The table name is followed by a colon (:) and then at least one column name. If you specify more than one column, separate the column names with a comma. The columns are sorted in ascending order. Specify the keyword desc after the column name to sort the column in descending order.

Wildcard characters are not supported.

If there are errors in the file, gpreload reports the first error and exits. No data is reloaded.

The following example reloads three tables:

```
public.clients: region, state, rep_id desc
public.merchants: region, state
test.lineitem: group, assy, whse
```

In the first table public.clients, the data in the rep_id column is sorted in descending order. The data in the other columns are sorted in ascending order.

```
--version (show utility version)
```

Displays the version of this utility.

```
-? (help)
```

Displays the online help.

**Example**

This example command reloads the tables in the database mytest that are listed in the file data-tables.txt.

```
gpreload -d mytest --table-file data-tables.txt
```

**See Also**

CREATE TABLE in the Greenplum Database Reference Guide

**gprestore**

Restore a Greenplum Database backup that was created using the gpbackup utility. By default gprestore uses backed up metadata files and DDL files located in the Greenplum Database master host data directory, with table data stored locally on segment hosts in CSV data files.

**Synopsis**

```
gprestore --timestamp YYYYMMDDHHMMSS
   [--backup-dir directory]
   [--create-db]
   [--debug]
   [--exclude-schema schema_name]
```
Description
To use `gprestore` to restore from a backup set, you must include the `--timestamp` option to specify the exact timestamp value (`YYYYMMDDHHMMSS`) of the backup set to restore. If you specified a custom `--backup-dir` to consolidate the backup files, include the same `--backup-dir` option with `gprestore` to locate the backup files.

When restoring from a backup set, `gprestore` restores to a database with same name as the name specified when creating the backup set. If the target database exists and a table being restored exists in the database, the restore operation fails. Include the `--create-db` option if the target database does not exist in the cluster. You can optionally restore a backup set to a different database by using the `--redirect-db` option.

When restoring a backup set that contains data from some leaf partitions of a partitioned tables, the partitioned table is restored along with the data for the leaf partitions. For example, you create a backup with the `gpbackup` option `--include-table-file` and the text file lists some leaf partitions of a partitioned table. Restoring the backup creates the partitioned table and restores the data only for the leaf partitions listed in the file.

Greenplum Database system objects are automatically included in a `gpbackup` backup set, but these objects are only restored if you include the `--with-globals` option to `gprestore`. Similarly, if you backed up query plan statistics using the `--with-stats` option, you can restore those statistics by providing `--with-stats` to `gprestore`. By default, only database objects in the backup set are restored.

Performance of restore operations can be improved by creating multiple parallel connections to restore table data and metadata. By default `gprestore` uses 1 connection, but you can increase this number with the `--jobs` option for large restore operations.

When a restore operation completes, `gprestore` returns a status code. See `Return Codes`.

`gprestore` can send status email notifications after a back up operation completes. You specify when the utility sends the mail and the email recipients in a configuration file. See `Configuring Email Notifications`.

Options
`--timestamp YYYYMMDDHHMMSS`
Required. Specifies the timestamp of the `gpbackup` backup set to restore. By default `gprestore` tries to locate metadata files for the timestamp on the Greenplum Database master host in the `$MASTER_DATA_DIRECTORY/backups/YYYYMDD/YYYYMMDDhhmmss/` directory, and CSV data files in the `<seg_dir>/backups/YYYYMDDYYYYMDDhhmmss/` directory of each segment host.

`--backup-dir directory`
Optional. Sources all backup files (metadata files and data files) from the specified directory. You must specify `directory` as an absolute path (not relative). If you do not supply
this option, gprestore tries to locate metadata files for the timestamp on the Greenplum Database master host in the $MASTER_DATA_DIRECTORY/backups/YYYYMMDD/YYYYMMDDhhmmss/ directory. CSV data files must be available on each segment in the <seg_dir>/backups/YYYYMMDD/YYYYMMDDhhmmss/ directory. Include this option when you specify a custom backup directory with gpbackup.

--create-db
Optional. Creates the database before restoring the database object metadata. The database is created by cloning the empty standard system database template0.

--debug
Optional. Displays verbose debug messages during operation.

--exclude-schema schema_name
Optional. Specifies a database schema to exclude from the restore operation. You can specify this option multiple times to exclude multiple schemas. You cannot combine this option with the option --include-schema, or a table filtering option such as --exclude-table.

--exclude-table schema.table
Optional. Specifies a table to exclude from the restore operation. The table must be in the format <schema-name>.<table-name>. If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. You can specify this option multiple times. If the table is not in the backup set, the restore operation fails. You cannot specify a leaf partition of a partitioned table.

You cannot combine this option with the option --exclude-schema, or another a table filtering option such as --include-table.

--exclude-table-file file_name
Optional. Specifies a text file containing a list of tables to exclude from the restore operation. Each line in the text file must define a single table using the format <schema-name>.<table-name>. The file must not include trailing lines. If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. If a table is not in the backup set, the restore operation fails. You cannot specify a leaf partition of a partitioned table.

You cannot combine this option with the option --exclude-schema, or another a table filtering option such as --include-table.

--include-schema schema_name
Optional. Specifies a database schema to restore. You can specify this option multiple times to include multiple schemas. If you specify this option, any schemas that you specify must be available in the backup set. Any schemas that are not included in subsequent --include-schema options are omitted from the restore operation.

If a schema that you specify for inclusion exists in the database, the utility issues an error and continues the operation. The utility fails if a table being restored exists in the database.

You cannot use this option if objects in the backup set have dependencies on multiple schemas. See Filtering the Contents of a Backup or Restore for more information.

--include-table schema.table
Optional. Specifies a table to restore. The table must be in the format <schema-name>.<table-name>. If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. You can specify this option multiple times. You cannot specify a leaf partition of a partitioned table.
You cannot combine this option with a schema filtering option such as `--include-schema`, or another table filtering option such as `--exclude-table-file`.

`--include-table-file file_name`
Optional. Specifies a text file containing a list of tables to restore. Each line in the text file must define a single table using the format `<schema-name>.<table-name>`. The file must not include trailing lines. If a table or schema name uses any character other than a lowercase letter, number, or an underscore character, then you must include that name in double quotes. Any tables not listed in this file are omitted from the restore operation. You cannot specify a leaf partition of a partitioned table.

If you use the `--include-table-file` option, `gprestore` does not create roles or set the owner of the tables. The utility restores table indexes and rules. Triggers are also restored but are not supported in Greenplum Database.

See Filtering the Contents of a Backup or Restore for more information.

`--jobs int`
Optional. Specifies the number of parallel connections to use when restoring table data and metadata. By default, `gprestore` uses 1 connection. Increasing this number can improve the speed of restoring data.

**Note:** If you used the `gpbackup --single-data-file` option to combine table backups into a single file per segment, you cannot set `--jobs` to a value higher than 1 to perform a parallel restore operation.

`--plugin-config config-file_location`
Specify the location of the `gpbackup` plugin configuration file, a YAML-formatted text file. The file contains configuration information for the plugin application that `gprestore` uses during the restore operation.

If you specify the `--plugin-config` option when you back up a database, you must specify this option with configuration information for a corresponding plugin application when you restore the database from the backup.

For information about using the S3 storage plugin application, see Using the S3 Storage Plugin with gpbackup and gprestore.

`--quiet`
Optional. Suppress all non-warning, non-error log messages.

`--redirect-db database_name`
Optional. Restore to the specified `database_name` instead of to the database that was backed up.

`--verbose`
Optional. Print verbose log messages.

`--version`
Optional. Print the version number and exit.

`--with-globals`
Optional. Restores Greenplum Database system objects in the backup set, in addition to database objects. See Objects Included in a Backup or Restore.

`--with-stats`
Optional. Restore query plan statistics from the backup set.

`--help`
Displays the online help.
Return Codes
One of these codes is returned after `gprestore` completes.

- **0** – Restore completed with no problems.
- **1** – Restore completed with non-fatal errors. See log file for more information.
- **2** – Restore failed with a fatal error. See log file for more information.

Examples
Create the demo database and restore all schemas and tables in the backup set for the indicated timestamp:

```
$ dropdb demo
$ gprestore --timestamp 20171103152558 --create-db
```

Restore the backup set to the "demo2" database instead of the "demo" database that was backed up:

```
$ createdb demo2
$ gprestore --timestamp 20171103152558 --redirect-db demo2
```

Restore global Greenplum Database metadata and query plan statistics in addition to the database objects:

```
$ gprestore --timestamp 20171103152558 --create-db --with-globals --with-stats
```

Restore, using backup files that were created in the `/home/gpadmin/backup` directory, creating 8 parallel connections:

```
$ gprestore --backup-dir /home/gpadmin/backups/ --timestamp 20171103153156 --create-db --jobs 8
```

Restore only the "wikipedia" schema included in the backup set:

```
$ dropdb demo
$ gprestore --include-schema wikipedia --backup-dir /home/gpadmin/backups/ --timestamp 20171103153156 --create-db
```

See Also
`gpbackup`, *Parallel Backup with gpbackup and gprestore* and *Using the S3 Storage Plugin with gpbackup and gprestore*

gpscp
Copies files between multiple hosts at once.

Synopsis

```
gpscp { -f hostfile_gpssh | -h hostname [-h hostname ...] } 
       [-J character] [-v] [[user@]hostname:]file_to_copy [...] 
       [[user@]hostname:]copy_to_path
```

```
gpscp -?
gpscp --version
```
Description

The `gpscp` utility allows you to copy one or more files from the specified hosts to other specified hosts in one command using SCP (secure copy). For example, you can copy a file from the Greenplum Database master host to all of the segment hosts at the same time.

To specify the hosts involved in the SCP session, use the `-f` option to specify a file containing a list of host names, or use the `-h` option to name single host names on the command-line. At least one host name (`-h`) or a host file (`-f`) is required. The `-J` option allows you to specify a single character to substitute for the `hostname` in the copy from and copy to destination strings. If `-J` is not specified, the default substitution character is an equal sign (`=`). For example, the following command will copy `.bashrc` from the local host to `/home/gpadmin` on all hosts named in `hostfile_gpssh`:

```bash
gscp -f hostfile_gpssh .bashrc =:/home/gpadmin
```

If a user name is not specified in the host list or with `user@` in the file path, `gpscp` will copy files as the currently logged in user. To determine the currently logged in user, do a `whoami` command. By default, `gpscp` goes to `$HOME` of the session user on the remote hosts after login. To ensure the file is copied to the correct location on the remote hosts, it is recommended that you use absolute paths.

Before using `gpscp`, you must have a trusted host setup between the hosts involved in the SCP session. You can use the utility `gpssh-exkeys` to update the known host files and exchange public keys between hosts if you have not done so already.

Options

- `-f hostfile_gpssh`
  Specifies the name of a file that contains a list of hosts that will participate in this SCP session. The syntax of the host file is one host per line as follows:

  ```
  <hostname>
  ```

- `-h hostname`
  Specifies a single host name that will participate in this SCP session. You can use the `-h` option multiple times to specify multiple host names.

- `-J character`
  The `-J` option allows you to specify a single character to substitute for the `hostname` in the copy from and copy to destination strings. If `-J` is not specified, the default substitution character is an equal sign (`=`).

- `-v` (verbose mode)
  Optional. Reports additional messages in addition to the SCP command output.

- `file_to_copy`
  Required. The file name (or absolute path) of a file that you want to copy to other hosts (or file locations). This can be either a file on the local host or on another named host.

- `copy_to_path`
  Required. The path where you want the file(s) to be copied on the named hosts. If an absolute path is not used, the file will be copied relative to `$HOME` of the session user. You can also use the equal sign `=` (or another character that you specify with the `-J` option) in place of a `hostname`. This will then substitute in each host name as specified in the supplied host file (`-f`) or with the `-h` option.

- `-?` (help)
  Displays the online help.

- `--version`
  Displays the version of this utility.
Examples

Copy the file named `installer.tar` to `/` on all the hosts in the file `hostfile_gpssh`.

```
gpscp -f hostfile_gpssh installer.tar =:/
```

Copy the file named `myfuncs.so` to the specified location on the hosts named `sdw1` and `sdw2`:

```
gpscp -h sdw1 -h sdw2 myfuncs.so =:/usr/local/greenplum-db/lib
```

See Also

`gpssh`, `gpssh-exkeys`

**gpseginstall**

Installs Greenplum Database on segment hosts.

Synopsis

```
gpseginstall -f hostfile [-u gpdb_admin_user] [-p password] [-c u|p|c|s|E|e|l|v]
gpseginstall --help
```

Description

The `gpseginstall` utility provides a simple way to quickly install Greenplum Database on segment hosts that you specify in a host list file. The utility does not install or update Greenplum Database on the master host. You can run `gpseginstall` as root or as a non-root user. `gpseginstall` does not perform database initialization. See `gpinitsystem` for more information about initializing Greenplum Database.

When run as root, `gpseginstall` default actions are to add a system user (default is `gpadmin`), create a password (default is `changeme`), and deploy and install Greenplum Database on segment hosts. To do this, `gpseginstall` locates the current Greenplum Database binaries on the master from the installation path in the current user’s environment variables (`$GPHOME`). It compresses Greenplum Database software into a `tar.gz` file and performs an MD5 checksum to verify file integrity.

Then, it copies Greenplum Database to the segment hosts, installs (decompresses) Greenplum Database, and changes the ownership of the Greenplum Database installation to the system user you specify with the `-u` option. Lastly, it exchanges keys between all Greenplum Database hosts as both root and as the system user you specify with the `-u` option. `gpseginstall` also perform a user limit check and verifies the version number of Greenplum Database on all the segments.

If you run `gpseginstall` as a non-root user, `gpseginstall` only compresses, copies, and installs Greenplum Database on segment hosts. It can also exchanges keys between Greenplum Database hosts for the current system user, and verifies the version number of Greenplum Database on all the segments.

Options

```
-c | --commands option_list
```

Optional. This allows you to customize `gpseginstall` actions. Note that these command options are executed by default if you do not specify the `-c` option in the `gpseginstall` syntax.

- `u`: Adds a system user. (root only)
- `p`: Changes the password for a system user. (root only)
- `s`: Compresses, copies, decompresses (installs) Greenplum Database on all segments.
• c: Changes the ownership of the Greenplum Database installation directory on the segment hosts. (root only)
• E: Exchange keys between Greenplum Database master and segment hosts for the root user. (root only)
• e: Exchange keys between Greenplum Database master and segment hosts for the non-root system user.
• l: (Linux only) Checks and modifies the user limits configuration file (/etc/security/limits.conf file) when adding a new user to segment hosts. (root only)
• v: Verifies the version of Greenplum Database running on all segments.
  gpseginstall checks the version number of the Greenplum Database installation referenced by the $GPHOME environment variable and symbolic link to the installation directory. An error occurs if there is a version number mismatch or the Greenplum Database installation directory cannot be found.

-f | --file hostfile

Required. This specifies the file that lists the segment hosts onto which you want to install Greenplum Database.

The host list file must have one host name per line and includes a host name for each segment host in your Greenplum system. Make sure there are no blank lines or extra spaces. If a host has multiple configured host names, use only one host name per host.

For example:

sdw1-1
sdw2-1
sdw3-1
sdw4-1

If available, you can use the same gpssh-exkeys host list file you used to exchange keys between Greenplum Database hosts.

-p | --password password

Optional. Sets the password for the user you specify with the -u option. The default password is changeme. This option is only available when you run gpsetinstall as root.

Recommended security best practices:

• Always use passwords.
• Do not use default passwords.
• Change default passwords immediately after installation.

-u | --user user

Optional. This specifies the system user. This user is also the Greenplum Database administrative user. This user owns Greenplum Database installation and administers the database. This is also the user under which Greenplum Database is started/initialized. This option is only available when you run gpseginstall as root. The default is gpadmin.

--help (help)

Displays the online help.

Examples

As root, install a Greenplum Database on all segments, leave the system user as the default (gpadmin) and set the gpadmin password to secret123:

# gpseginstall -f my_host_list_file -p secret123
As a non-root user, compress and copy Greenplum Database binaries to all segments (as `gpadmin`):

```
$ gpseginstall -f host_file
```

As root, add a user (`gpadmin2`), set the password for the user (`secret1234`), exchange keys between hosts as the new user, check user limits, and verify version numbers, but do not change ownership of Greenplum binaries, compress/copy/install Greenplum Database on segments, or exchange keys as root.

```
$ gpseginstall -f host_file -u gpadmin2 -p secret1234 -c upelv
```

**See Also**

`gpinitsystem`, `gpssh-exkeys`

### gpssh

Provides SSH access to multiple hosts at once.

**Synopsis**

```
gpssh [ -f hostfile_gpssh | - h hostname [ -h hostname ... ] ] [ -s ] [ -e ]
[ -d seconds ] [ -t multiplier ] [ -v ]
[ bash_command ]
```

```
gpssh -?
gpssh --version
```

**Description**

The `gpssh` utility allows you to run bash shell commands on multiple hosts at once using SSH (secure shell). You can execute a single command by specifying it on the command-line, or omit the command to enter into an interactive command-line session.

To specify the hosts involved in the SSH session, use the `-f` option to specify a file containing a list of host names, or use the `-h` option to name single host names on the command-line. At least one host name (`-h`) or a host file (`-f`) is required. Note that the current host is *not* included in the session by default — to include the local host, you must explicitly declare it in the list of hosts involved in the session.

Before using `gpssh`, you must have a trusted host setup between the hosts involved in the SSH session. You can use the utility `gpssh-exkeys` to update the known host files and exchange public keys between hosts if you have not done so already.

If you do not specify a command on the command-line, `gpssh` will go into interactive mode. At the `gpssh` command prompt (`=>`), you can enter a command as you would in a regular bash terminal command-line, and the command will be executed on all hosts involved in the session. To end an interactive session, press `CTRL+D` on the keyboard or type `exit` or `quit`.

If a user name is not specified in the host file, `gpssh` will execute commands as the currently logged in user. To determine the currently logged in user, do a `whoami` command. By default, `gpssh` goes to `$HOME` of the session user on the remote hosts after login. To ensure commands are executed correctly on all remote hosts, you should always enter absolute paths.

If you encounter network timeout problems when using `gpssh`, you can use `-d` and `-t` options or set parameters in the `gpssh.conf` file to control the timing that `gpssh` uses when validating the initial `ssh` connection. For information about the configuration file, see `gpssh Configuration File`. 
Options

bash_command
A bash shell command to execute on all hosts involved in this session (optionally enclosed in quotes). If not specified, gpssh starts an interactive session.

-d (delay) seconds
Optional. Specifies the time, in seconds, to wait at the start of a gpssh interaction with ssh. Default is 0.05. This option overrides the delaybeforesend value that is specified in the gpssh.conf configuration file.
Increasing this value can cause a long wait time during gpssh startup.

-e (echo)
Optional. Echoes the commands passed to each host and their resulting output while running in non-interactive mode.

-f hostfile_gpssh
Specifies the name of a file that contains a list of hosts that will participate in this SSH session. The host name is required, and you can optionally specify an alternate user name and/or SSH port number per host. The syntax of the host file is one host per line as follows:
[username@]hostname[:ssh_port]

-h hostname
Specifies a single host name that will participate in this SSH session. You can use the -h option multiple times to specify multiple host names.

-s
Optional. If specified, before executing any commands on the target host, gpssh sources the file greenplum_path.sh in the directory specified by the $GPHOME environment variable.
This option is valid for both interactive mode and single command mode.

-t multiplier
Optional. A decimal number greater than 0 (zero) that is the multiplier for the timeout that gpssh uses when validating the ssh prompt. Default is 1. This option overrides the prompt_validation_timeout value that is specified in the gpssh.conf configuration file.
Increasing this value has a small impact during gpssh startup.

-v (verbose mode)
Optional. Reports additional messages in addition to the command output when running in non-interactive mode.

--version
Displays the version of this utility.

-? (help)
Displays the online help.

gpssh Configuration File
The gpssh.conf file contains parameters that let you adjust the timing that gpssh uses when validating the initial ssh connection. These parameters affect the network connection before the gpssh session executes commands with ssh. The location of the file is specified by the environment variable MASTER_DATA_DIRECTORY. If the environment variable is not defined or the gpssh.conf file does not
exist, gpssh uses the default values or the values set with the -d and -t options. For information about the environment variable, see the Greenplum Database Reference Guide.

The gpssh.conf file is a text file that consists of a [gpssh] section and parameters. On a line, the # (pound sign) indicates the start of a comment. This is an example gpssh.conf file.

```
[gpssh]
delaybeforesend = 0.05
prompt_validation_timeout = 1.0
sync_retries = 5
```

These are the gpssh.conf parameters.

- **delaybeforesend = seconds**
  Specifies the time, in seconds, to wait at the start of a gpssh interaction with ssh. Default is 0.05. Increasing this value can cause a long wait time during gpssh startup. The -d option overrides this parameter.

- **prompt_validation_timeout = multiplier**
  A decimal number greater than 0 (zero) that is the multiplier for the timeout that gpssh uses when validating the ssh prompt. Increasing this value has a small impact during gpssh startup. Default is 1. The -t option overrides this parameter.

- **sync_retries = attempts**
  A non-negative integer that specifies the maximum number of times that gpssh attempts to connect to a remote Greenplum Database host. The default is 3. If the value is 0, gpssh returns an error if the initial connection attempt fails. Increasing the number of attempts also increases the time between retry attempts. This parameter cannot be configured with a command-line option.

  The -t option also affects the time between retry attempts.

  Increasing this value can compensate for slow network performance or segment host performance issues such as heavy CPU or I/O load. However, when a connection cannot be established, an increased value also increases the delay when an error is retransmitted.

**Examples**

Start an interactive group SSH session with all hosts listed in the file hostfile_gpssh:

```
$ gpssh -f hostfile_gpssh
```

At the gpssh interactive command prompt, run a shell command on all the hosts involved in this session.

```
=> ls -a /data/primary/*
```

Exit an interactive session:

```
=> exit
=> quit
```

Start a non-interactive group SSH session with the hosts named sdw1 and sdw2 and pass a file containing several commands named command_file to gpssh:

```
$ gpssh -h sdw1 -h sdw2 -v -e < command_file
```

Execute single commands in non-interactive mode on hosts sdw2 and localhost:

```
$ gpssh -h sdw2 -h localhost -v -e 'ls -a /data/primary/*'
$ gpssh -h sdw2 -h localhost -v -e 'echo $GPHOME'
```
See Also

gpssh-exkeys, gpscp

gpssh-exkeys

Exchanges SSH public keys between hosts.

Synopsis

```
gpssh-exkeys -f hostfile_exkeys | -h hostname [-h hostname ...]
gpssh-exkeys -e hostfile_exkeys -x hostfile_gpexpand
gpssh-exkeys -?
gpssh-exkeys --version
```

Description

The `gpssh-exkeys` utility exchanges SSH keys between the specified host names (or host addresses). This allows SSH connections between Greenplum hosts and network interfaces without a password prompt. The utility is used to initially prepare a Greenplum Database system for password-free SSH access, and also to add additional ssh keys when expanding a Greenplum Database system.

To specify the hosts involved in an initial SSH key exchange, use the `-f` option to specify a file containing a list of host names (recommended), or use the `-h` option to name single host names on the command-line. At least one host name (`-h`) or a host file is required. Note that the local host is included in the key exchange by default.

To specify new expansion hosts to be added to an existing Greenplum Database system, use the `-e` and `-x` options. The `-e` option specifies a file containing a list of existing hosts in the system that already have SSH keys. The `-x` option specifies a file containing a list of new hosts that need to participate in the SSH key exchange.

Keys are exchanged as the currently logged in user. You should perform the key exchange process twice: once as `root` and once as the `gpadmin` user (the user designated to own your Greenplum Database installation). The Greenplum Database management utilities require that the same non-root user be created on all hosts in the Greenplum Database system, and the utilities must be able to connect as that user to all hosts without a password prompt.

The `gpssh-exkeys` utility performs key exchange using the following steps:

- Creates an RSA identification key pair for the current user if one does not already exist. The public key of this pair is added to the `authorized_keys` file of the current user.
- Updates the `known_hosts` file of the current user with the host key of each host specified using the `-h`, `-f`, `-e`, and `-x` options.
- Connects to each host using `ssh` and obtains the `authorized_keys`, `known_hosts`, and `id_rsa.pub` files to set up password-free access.
- Adds keys from the `id_rsa.pub` files obtained from each host to the `authorized_keys` file of the current user.
- Updates the `authorized_keys`, `known_hosts`, and `id_rsa.pub` files on all hosts with new host information (if any).

Options

- `-e hostfile_exkeys`
When doing a system expansion, this is the name and location of a file containing all configured host names and host addresses (interface names) for each host in your current Greenplum system (master, standby master and segments), one name per line without blank lines or extra spaces. Hosts specified in this file cannot be specified in the host file used with -x.

-f hostfile_exkeys
Specifies the name and location of a file containing all configured host names and host addresses (interface names) for each host in your Greenplum system (master, standby master and segments), one name per line without blank lines or extra spaces.

-h hostname
Specifies a single host name (or host address) that will participate in the SSH key exchange. You can use the -h option multiple times to specify multiple host names and host addresses.

--version
Displays the version of this utility.

-x hostfile_gpexpand
When doing a system expansion, this is the name and location of a file containing all configured host names and host addresses (interface names) for each new segment host you are adding to your Greenplum system, one name per line without blank lines or extra spaces. Hosts specified in this file cannot be specified in the host file used with -e.

-? (help)
Displays the online help.

Examples
Exchange SSH keys between all host names and addresses listed in the file hostfile_exkeys:

$ gpssh-exkeys -f hostfile_exkeys

Exchange SSH keys between the hosts sdw1, sdw2, and sdw3:

$ gpssh-exkeys -h sdw1 -h sdw2 -h sdw3

Exchange SSH keys between existing hosts sdw1, sdw2, and sdw3, and new hosts sdw4 and sdw5 as part of a system expansion operation:

$ cat hostfile_exkeys
mdw
mdw-1
mdw-2
smdw
smdw-1
smdw-2
sdw1
sdw1-1
sdw1-2
sdw2
sdw2-1
sdw2-2
sdw3
sdw3-1
sdw3-2
$ cat hostfile_gpexpand
sdw4
sdw4-1
sdw4-2

When doing a system expansion, this is the name and location of a file containing all configured host names and host addresses (interface names) for each host in your current Greenplum system (master, standby master and segments), one name per line without blank lines or extra spaces. Hosts specified in this file cannot be specified in the host file used with -x.

-f hostfile_exkeys
Specifies the name and location of a file containing all configured host names and host addresses (interface names) for each host in your Greenplum system (master, standby master and segments), one name per line without blank lines or extra spaces.

-h hostname
Specifies a single host name (or host address) that will participate in the SSH key exchange. You can use the -h option multiple times to specify multiple host names and host addresses.

--version
Displays the version of this utility.

-x hostfile_gpexpand
When doing a system expansion, this is the name and location of a file containing all configured host names and host addresses (interface names) for each new segment host you are adding to your Greenplum system, one name per line without blank lines or extra spaces. Hosts specified in this file cannot be specified in the host file used with -e.

-? (help)
Displays the online help.

Examples
Exchange SSH keys between all host names and addresses listed in the file hostfile_exkeys:

$ gpssh-exkeys -f hostfile_exkeys

Exchange SSH keys between the hosts sdw1, sdw2, and sdw3:

$ gpssh-exkeys -h sdw1 -h sdw2 -h sdw3

Exchange SSH keys between existing hosts sdw1, sdw2, and sdw3, and new hosts sdw4 and sdw5 as part of a system expansion operation:

$ cat hostfile_exkeys
mdw
mdw-1
mdw-2
smdw
smdw-1
smdw-2
sdw1
sdw1-1
sdw1-2
sdw2
sdw2-1
sdw2-2
sdw3
sdw3-1
sdw3-2
$ cat hostfile_gpexpand
sdw4
sdw4-1
sdw4-2
gpssh-exkeys -e hostfile_exkeys -x hostfile_gpexpand

See Also
gpssh, gpscp

gpstart

Starts a Greenplum Database system.

Synopsis

gpstart [-d master_data_directory] [-B parallel_processes] [-R]
[-m] [-y] [-a] [-t timeout_seconds] [-l logfile_directory]
[--skip-heap-checksum-validation]
[-v | -q]
gpstart -? | -h | --help
gpstart --version

Description

The gpstart utility is used to start the Greenplum Database server processes. When you start a
Greenplum Database system, you are actually starting several postgres database server listener
processes at once (the master and all of the segment instances). The gpstart utility handles the startup
of the individual instances. Each instance is started in parallel.

The first time an administrator runs gpstart, the utility creates a hosts cache file named .gphostcache
in the user's home directory. Subsequently, the utility uses this list of hosts to start the system more
efficiently. If new hosts are added to the system, you must manually remove this file from the gpadmin
user's home directory. The utility will create a new hosts cache file at the next startup.

As part of the startup process, the utility checks the consistency of heap checksum setting among the
Greenplum Database master and segment instances, either enabled or disabled on all instances. If the
heap checksum setting is different among the instances, an error is returned and Greenplum Database
does not start. The validation can be disabled by specifying the option --skip-heap-checksum-
validation. For more information about heap checksums, see Enabling High Availability and Data
Consistency Features in the Greenplum Database Administrator Guide.

Note: Before you can start a Greenplum Database system, you must have initialized the system
using gpinitsystem. Enabling or disabling heap checksums is set when you initialize the system
and cannot be changed after initialization.

Options

-a
Do not prompt the user for confirmation.

-B parallel_processes
The number of segments to start in parallel. If not specified, the utility will start up to 64
parallel processes depending on how many segment instances it needs to start.

-d master_data_directory
Optional. The master host data directory. If not specified, the value set for
$MASTER_DATA_DIRECTORY will be used.
-l `logfile_directory`
   The directory to write the log file. Defaults to `~/gpAdminLogs`.

-`m`
   Optional. Starts the master instance only, which may be useful for maintenance tasks. This mode only allows connections to the master in utility mode. For example:

   ```
   PGOPTIONS='-c gp_session_role=utility' psql
   ```

   The consistency of the heap checksum setting on master and segment instances is not checked.

-`q`
   Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

-`R`
   Starts Greenplum Database in restricted mode (only database superusers are allowed to connect).

--skip-heap-checksum-validation
   During startup, the utility does not validate the consistency of the heap checksum setting among the Greenplum Database master and segment instances. The default is to ensure that the heap checksum setting is the same on all instances, either enabled or disabled.

   **Warning**: Starting Greenplum Database without this validation could lead to data loss. Use this option to start Greenplum Database only when it is necessary to ignore the heap checksum verification errors to recover data or to troubleshoot the errors.

-`t timeout_seconds`
   Specifies a timeout in seconds to wait for a segment instance to start up. If a segment instance was shutdown abnormally (due to power failure or killing its `postgres` database listener process, for example), it may take longer to start up due to the database recovery and validation process. If not specified, the default timeout is 60 seconds.

-`v`
   Displays detailed status, progress and error messages output by the utility.

-`y`
   Optional. Do not start the standby master host. The default is to start the standby master host and synchronization process.

-`?` | `-h` | `--help`
   Displays the online help.

--version
   Displays the version of this utility.

**Examples**

Start a Greenplum Database system:

`gpstart`

Start a Greenplum Database system in restricted mode (only allow superuser connections):

`gpstart -R`
Start the Greenplum master instance only and connect in utility mode:

```bash
gpstart -m PGOPTIONS=-c gp_session_role=utility' psql
```

See Also

gpstop, gpinisystem

**gpstate**

Shows the status of a running Greenplum Database system.

**Synopsis**

```
gpstate [-d master_data_directory] [-B parallel_processes] 
   [-l log_directory] 
gpstate -? | -h | --help
```

**Description**

The `gpstate` utility displays information about a running Greenplum Database instance. There is additional information you may want to know about a Greenplum Database system, since it is comprised of multiple PostgreSQL database instances (segments) spanning multiple machines. The `gpstate` utility provides additional status information for a Greenplum Database system, such as:

- Which segments are down.
- Master and segment configuration information (hosts, data directories, etc.).
- The ports used by the system.
- A mapping of primary segments to their corresponding mirror segments.

**Options**

- `-b` *(brief status)*
  
  Optional. Display a brief summary of the state of the Greenplum Database system. This is the default option.

- `-B parallel_processes`
  
  The number of segments to check in parallel. If not specified, the utility will start up to 60 parallel processes depending on how many segment instances it needs to check.

- `-c` *(show primary to mirror mappings)*
  
  Optional. Display mapping of primary segments to their corresponding mirror segments.

- `-d master_data_directory`
  
  Optional. The master data directory. If not specified, the value set for `MASTER_DATA_DIRECTORY` will be used.

- `-e` *(show segments with mirror status issues)*
  
  Show details on primary/mirror segment pairs that have potential issues such as 1) the active segment is running in change tracking mode, meaning a segment is down 2) the active segment is in resynchronization mode, meaning it is catching up changes to the mirror 3) a segment is not in its preferred role, for example a segment that was a primary at system initialization time is now acting as a mirror, meaning you may have one or more segment hosts with unbalanced processing load.

- `-f` *(show standby master details)*


Display details of the standby master host if configured.

-\-i  (**show Greenplum Database version**)
Display the Greenplum Database software version information for each instance.

-\-l  (**logfile directory**)
The directory to write the log file. Defaults to \~\/gpAdminLogs.

-\-m  (**list mirrors**)
Optional. List the mirror segment instances in the system, their current role, and synchronization status.

-\-p  (**show ports**)
List the port numbers used throughout the Greenplum Database system.

-\-q  (**no screen output**)
Optional. Run in quiet mode. Except for warning messages, command output is not displayed on the screen. However, this information is still written to the log file.

-\-Q  (**quick status**)
Optional. Checks segment status in the system catalog on the master host. Does not poll the segments for status.

-\-s  (**detailed status**)
Optional. Displays detailed status information for the Greenplum Database system.

-\-v  (**verbose output**)
Optional. Displays error messages and outputs detailed status and progress information.

-\--help (**help**)
Displays the online help.

**Output Field Definitions**
The following output fields are reported by `gpstate -s` for the master:

<table>
<thead>
<tr>
<th>Output Data</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master host</td>
<td>host name of the master</td>
</tr>
<tr>
<td>Master postgres process ID</td>
<td>PID of the master database listener process</td>
</tr>
<tr>
<td>Master data directory</td>
<td>file system location of the master data directory</td>
</tr>
<tr>
<td>Master port</td>
<td>port of the master postgres database listener process</td>
</tr>
</tbody>
</table>
| Master current role                | dispatch = regular operating mode  
                                | utility = maintenance mode                  |
| Greenplum array configuration type | Standard = one NIC per host            
<pre><code>                            | Multi-Home = multiple NICs per host           |
</code></pre>
<p>| Greenplum init system version      | version of Greenplum Database when system was first initialized |
| Greenplum current version          | current version of Greenplum Database            |</p>
<table>
<thead>
<tr>
<th>Output Data</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postgres version</td>
<td>version of PostgreSQL that Greenplum Database is based on</td>
</tr>
<tr>
<td>Greenplum mirroring status</td>
<td>physical mirroring or none</td>
</tr>
<tr>
<td>Master standby</td>
<td>host name of the standby master</td>
</tr>
<tr>
<td>Standby master state</td>
<td>status of the standby master: active or passive</td>
</tr>
</tbody>
</table>

The following output fields are reported by `gpstate -s` for each segment:

**Table 79: gpstate output data for segments**

<table>
<thead>
<tr>
<th>Output Data</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hostname</td>
<td>system-configured host name</td>
</tr>
<tr>
<td>Address</td>
<td>network address host name (NIC name)</td>
</tr>
<tr>
<td>Datadir</td>
<td>file system location of segment data directory</td>
</tr>
<tr>
<td>Port</td>
<td>port number of segment <code>postgres</code> database listener process</td>
</tr>
<tr>
<td>Current Role</td>
<td>current role of a segment: <code>Mirror</code> or <code>Primary</code></td>
</tr>
<tr>
<td>Preferred Role</td>
<td>role at system initialization time: <code>Mirror</code> or <code>Primary</code></td>
</tr>
<tr>
<td>Mirror Status</td>
<td>status of a primary/mirror segment pair:</td>
</tr>
<tr>
<td></td>
<td><em>Synchronized</em> = data is up to date on both</td>
</tr>
<tr>
<td></td>
<td><em>Resynchronization</em> = data is currently being copied from one to the other</td>
</tr>
<tr>
<td></td>
<td><em>Change Tracking</em> = segment down and active segment is logging changes</td>
</tr>
<tr>
<td>Change tracking data size</td>
<td>when in <em>Change Tracking</em> mode, the size of the change log file (may grow and shrink as compression is applied)</td>
</tr>
<tr>
<td>Estimated total data to synchronize</td>
<td>when in <em>Resynchronization</em> mode, the estimated size of data left to synchronize</td>
</tr>
<tr>
<td>Data synchronized</td>
<td>when in <em>Resynchronization</em> mode, the estimated size of data that has already been synchronized</td>
</tr>
<tr>
<td>Estimated resync progress with mirror</td>
<td>When in <em>Resynchronization</em> mode, the estimated percentage of completion</td>
</tr>
<tr>
<td>Estimated resync end time</td>
<td>when in <em>Resynchronization</em> mode, the estimated time to complete</td>
</tr>
<tr>
<td>File <code>postmaster.pid</code></td>
<td>status of <code>postmaster.pid</code> lock file: <code>Found</code> or <code>Missing</code></td>
</tr>
<tr>
<td>PID from <code>postmaster.pid</code> file</td>
<td>PID found in the <code>postmaster.pid</code> file</td>
</tr>
<tr>
<td>Lock files in <code>/tmp</code></td>
<td>a segment port lock file for its <code>postgres</code> process is created in <code>/tmp</code> (file is removed when a segment shuts down)</td>
</tr>
</tbody>
</table>
Output Data | Description
--- | ---
Active PID | active process ID of a segment
Master reports status as | segment status as reported in the system catalog: *Up* or *Down*
Database status | status of Greenplum Database to incoming requests: *Up*, *Down*, or *Suspended*. A *Suspended* state means database activity is temporarily paused while a segment transitions from one state to another.

The following output fields are reported by `gpstate -f` for standby master replication status:

Table 80: `gpstate` output data for master replication

<table>
<thead>
<tr>
<th>Output Data</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standby address</td>
<td>hostname of the standby master</td>
</tr>
<tr>
<td>Standby data dir</td>
<td>file system location of the standby master data directory</td>
</tr>
<tr>
<td>Standby port</td>
<td>port of the standby master <code>postgres</code> database listener process</td>
</tr>
<tr>
<td>Standby PID</td>
<td>process ID of the standby master</td>
</tr>
<tr>
<td>Standby status</td>
<td>status of the standby master: <em>Standby host passive</em></td>
</tr>
<tr>
<td>WAL Sender State</td>
<td>write-ahead log (WAL) streaming state: <em>streaming</em>, <em>startup</em>, <em>backup</em>, <em>catchup</em></td>
</tr>
<tr>
<td>Sync state</td>
<td>WAL sender synchronization state: <em>sync</em></td>
</tr>
<tr>
<td>Sent Location</td>
<td>WAL sender transaction log (xlog) record sent location</td>
</tr>
<tr>
<td>Flush Location</td>
<td>WAL receiver xlog record flush location</td>
</tr>
<tr>
<td>Replay Location</td>
<td>standby xlog record replay location</td>
</tr>
</tbody>
</table>

**Examples**

Show detailed status information of a Greenplum Database system:

```
gpstate -s
```

Do a quick check for down segments in the master host system catalog:

```
gpstate -Q
```

Show information about mirror segment instances:

```
gpstate -m
```

Show information about the standby master configuration:

```
gpstate -f
```
Display the Greenplum software version information:

gpstate -i

See Also

gpstart, gplogfilter

gpstop

Stops or restarts a Greenplum Database system.

Synopsis

```
gpstop [-d master_data_directory] [-B parallel_processes]
       [-M smart | fast | immediate] [-t timeout_seconds] [-r] [-y] [-a]
       [-l logfile_directory] [-v] [-q]
gpstop -m [-d master_data_directory] [-y] [-l logfile_directory] [-v] [-q]
gpstop -u [-d master_data_directory] [-l logfile_directory] [-v] [-q]
gpstop --host host_name [-d master_data_directory] [-l logfile_directory]
       [-t timeout_seconds] [-a] [-v] [-q]
gpstop --version

gpstop -? | -h | --help
```

Description

The `gpstop` utility is used to stop the database servers that comprise a Greenplum Database system. When you stop a Greenplum Database system, you are actually stopping several `postgres` database server processes at once (the master and all of the segment instances). The `gpstop` utility handles the shutdown of the individual instances. Each instance is shutdown in parallel.

By default, you are not allowed to shut down Greenplum Database if there are any client connections to the database. Use the `-M fast` option to roll back all in progress transactions and terminate any connections before shutting down. If there are any transactions in progress, the default behavior is to wait for them to commit before shutting down.

With the `-u` option, the utility uploads changes made to the master `pg_hba.conf` file or to `runtime` configuration parameters in the master `postgresql.conf` file without interruption of service. Note that any active sessions will not pickup the changes until they reconnect to the database.

Options

- `-a`
  Do not prompt the user for confirmation.

- `-B parallel_processes`
  The number of segments to stop in parallel. If not specified, the utility will start up to 64 parallel processes depending on how many segment instances it needs to stop.

- `-d master_data_directory`
  Optional. The master host data directory. If not specified, the value set for $MASTER_DATA_DIRECTORY will be used.

- `--host host_name`
  

The utility shuts down the Greenplum Database segment instances on the specified host to allow maintenance on the host. Each primary segment instance on the host is shut down and the associated mirror segment instance is promoted to a primary segment if the mirror segment is on another host. Mirror segment instances on the host are shut down.

The segment instances are not shut down and the utility returns an error in these cases:

• Segment mirroring is not enabled for the system.
• The master or standby master is on the host.
• Both a primary segment instance and its mirror are on the host.

This option cannot be specified with the -m, -r, -u, or -y options.

Note: The gprecoverseg utility restores segment instances. Run gprecoverseg commands to start the segments as mirrors and then to return the segments to their preferred role (primary segments).

-l logfile_directory
The directory to write the log file. Defaults to ~/gpAdminLogs.

-m
Optional. Shuts down a Greenplum master instance that was started in maintenance mode.

-M fast
Fast shut down. Any transactions in progress are interrupted and rolled back.

-M immediate
Immediate shut down. Any transactions in progress are aborted.
This mode kills all postgres processes without allowing the database server to complete transaction processing or clean up any temporary or in-process work files.

-M smart
Smart shut down. If there are active connections, this command fails with a warning. This is the default shutdown mode.

-q
Run in quiet mode. Command output is not displayed on the screen, but is still written to the log file.

-r
Restart after shutdown is complete.

-t timeout_seconds
Specifies a timeout threshold (in seconds) to wait for a segment instance to shutdown. If a segment instance does not shutdown in the specified number of seconds, gpstop displays a message indicating that one or more segments are still in the process of shutting down and that you cannot restart Greenplum Database until the segment instance(s) are stopped. This option is useful in situations where gpstop is executed and there are very large transactions that need to rollback. These large transactions can take over a minute to rollback and surpass the default timeout period of 600 seconds.

-u
This option reloads the pg_hba.conf files of the master and segments and the runtime parameters of the postgresql.conf files but does not shutdown the Greenplum Database array. Use this option to make new configuration settings active after editing postgresql.conf or pg_hba.conf. Note that this only applies to configuration parameters that are designated as runtime parameters.

-v
Displays detailed status, progress and error messages output by the utility.
-y
Do not stop the standby master process. The default is to stop the standby master.

-? | -h | --help
Displays the online help.

--version
Displays the version of this utility.

Examples
Stop a Greenplum Database system in smart mode:

```bash
gpstop
```

Stop a Greenplum Database system in fast mode:

```bash
gpstop -M fast
```

Stop all segment instances and then restart the system:

```bash
gpstop -r
```

Stop a master instance that was started in maintenance mode:

```bash
gpstop -m
```

Reload the `postgresql.conf` and `pg_hba.conf` files after making configuration changes but do not shutdown the Greenplum Database array:

```bash
gpstop -u
```

See Also
`gpstart`

`gpsys1`
Displays information about your operating system.

Synopsis

```bash
gpsys1 [ -a | -m | -p ]
gpsys1 -?
gpsys1 --version
```

Description
`gpsys1` displays the platform and installed memory (in bytes) of the current host. For example:

```bash
linux 1073741824
```

Options
- `a` (show all)
Shows both platform and memory information for the current host. This is the default.

- **m (show memory only)**
  Shows system memory installed in bytes.

- **p (show platform only)**
  Shows the OS platform. Platform can be linux, darwin or sunos5.

- **? (help)**
  Displays the online help.

- **--version**
  Displays the version of this utility.

**Examples**
Show information about the current host operating system:

```bash
gpsys1
```

**See Also**
gpcheckperf

**gptransfer**

The gptransfer utility copies objects from databases in a source Greenplum Database system to databases in a destination Greenplum Database system.

**Synopsis**
gptransfer

```
{ --full | 
  { [ -d database1 [ -d database2 ... ] ] | 
    [ -t db.schema.table [ -t db.schemal.table1 ... ] ] | 
    [ -f table-file [ --partition-transfer |
      --partition-transfer-non-partition-target ] ] 
    [ -T db.schema.table [ -T db.schemal.table1 ... ] ] 
    [ -F table-file ] } } 
  [ --skip-existing | --truncat | --drop] 
  [ --analyze] [ --validate=type] [ -x] [ --dry-run] 
  [ --schema-only ]
  [ --source-host=source_host [ --source-port=source_port ]
   [ --source-user=source_user ]]
  [ --base-port=base_gpfdist_port]
  [ --dest-host=dest_host --source-map-file=host_map_file]
  [ --dest-port=port] [ --dest-user=dest_user ] 
  [ --dest-database=dest_database_name] 
  [ --batch-size=batch_size] [ --sub-batch-size=sub_batch_size]
  [ --timeout=seconds]
  [ --max-line-length=length]
  [ --work-base-dir=work_dir] [ -l log_dir]
  [ --format=[CSV|TEXT] ]
  [ --quote=character ]
  [ --no-final-count ]

  [ -v | --verbose]
  [-q | --quiet]
  [ --gpfdist-verbose ]
  [ --gpfdist-very-verbose ]
```
gptransfer --version

gptransfer -h | -? | --help

Description
The `gptransfer` utility copies database objects from a source Greenplum Database system to a destination system. You can perform one of the following types of operations:

- **Copy a Greenplum Database system with the --full option.**
  
  This option copies all user created databases in a source system to a different destination system. If you specify the `--full` option, you must specify both a source and destination system. The destination system cannot contain any user-defined databases, only the default databases `postgres`, `template0`, and `template1`.

- **Copy a set of user defined database tables to a destination system.** The `-f`, and `-t` options copy a specified set of user defined tables, table data, and re-creates the table indexes. The `-d` option copies all user defined tables, table data, and re-creates the table indexes from a specified database.

  If the destination system is the same as the source system, you must also specify a destination database with the `--dest-database` option. When you specify a destination database, the source database tables are copied into the specified destination database.

  For partitioned tables, you can specify the `--partition-transfer` or the `--partition-transfer-non-partition-target` option with `-f` option to copy specific leaf child partitions of partitioned tables from a source database. The leaf child partitions are the lowest level partitions of a partitioned database. For the `--partition-transfer` option, the destination tables are leaf child partitions. For the `--partition-transfer-non-partition-target` option, the destination tables are non-partitioned tables.

If an invalid set of `gptransfer` options are specified, or if a specified source table or database does not exist, `gptransfer` returns an error and quits. No data is copied.

To copy database objects between Greenplum Database systems `gptransfer` utility uses:

- **The Greenplum Database utility `gpfdist` on the source database system.** The `gpfdists` protocol is not supported.

- **Writable external tables on the source database system and readable external tables on the destination database system.** Note that `gptransfer` creates external tables with the `execute` protocol, so the `source_user` account must have superuser privileges (the default is `gpadmin`).

- **Named pipes that transfer the data between a writable external table and a readable external table.**

When copying data into the destination system, it is redistributed on the Greenplum Database segments of the destination system. This is the flow of data when `gptransfer` copies database data:

`writable external table > gpfdist > named pipe > gpfdist > readable external table`

For information about transferring data with `gptransfer`, see "Migrating Data with Gptransfer" in the Greenplum Database Administrator Guide.

About Database, Schema, and Table Names
When you transfer an entire database, schema and table names in the database can contain only alphanumeric characters and the underscore character (_). Also, Unicode characters are not supported. The same naming restrictions apply when you specify a database, schema, or table as an option or in a file.
Notes

The gptransfer utility efficiently transfers tables with large amounts of data. Because of the overhead required to set up parallel transfers, the utility is not recommended for transferring tables with small amounts of data. It might be more efficient to copy the schema and smaller tables to the destination database using other methods, such as the SQL COPY command, and then use gptransfer to transfer large tables in batches.

When transferring data between databases, you can run only one instance of gptransfer at a time. Running multiple, concurrent instances of gptransfer is not supported.

When copying database data between different Greenplum Database systems, gptransfer requires a text file that lists all the source segment host names and IP addresses. Specify the name and location of the file with the --source-map-file option. If the file is missing or not all segment hosts are listed, gptransfer returns an error and quits. See the description of the option for file format information.

The source and destination Greenplum Database segment hosts need to be able to communicate with each other. To ensure that the segment hosts can communicate, you can use a tool such as the Linux netperf utility.

If a filespace has been created for a source Greenplum Database system, a corresponding filespace must exist on the target system.

SSH keys must be exchanged between the two systems before using gptransfer. The gptransfer utility connects to the source system with SSH to create the named pipes and start the gpfdist instances. You can use the Greenplum Database gpush-exkeys utility with a list of all the source and destination primary hosts to exchange keys between Greenplum Database hosts.

Source and destination systems must be able to access the gptransfer work directory. The default directory is the user's home directory. You can specify a different directory with the --work-base-dir option.

The gptransfer utility logs messages in the ~/gpAdminLogs directory on the master host. gptransfer creates a log file with the name gptransfer_date.log and appends messages to it each time it runs on that day. You can specify a different directory for the log file using the -l log_directory option.

Work directories named ~/gptransfer_process_id are created on segment hosts in the source cluster. Log files for the gpfdist instances that gptransfer creates are in these directories. Adding the --gpfdist-verbose or --gpfdist-very-verbose options to the gptransfer command line increases the gpfdist logging level.

The gptransfer utility does not move configuration files such as postgres.conf and pg_hba.conf. You must set up the destination system configuration separately.

The gptransfer utility does not move external objects such as Greenplum Database extensions, third party jar files, and shared object files. You must install the external objects separately.

The gptransfer utility does not move dependent database objects unless you specify the --full option. For example, if a table has a default value on a column that is a user-defined function, that function must exist in the destination system database when using the -t, -d, or -f options.

If you move a set of database tables with the -d, -t, or -f option, and the destination table or database does not exist, gptransfer creates it. The utility re-creates any indexes on tables before copying data.

If a table exists on the destination system and one of the options --skip-existing, --truncate, or --drop is not specified, gptransfer returns an error and quits.

If an error occurs when during the process of copying a table, or table validation fails, gptransfer continues copying the other specified tables. After gptransfer finishes, it displays a list of tables where an error occurred, writes the names of tables that failed into a text file, and then prints the name of the file. You can use this file with the gptransfer -f option to retry copying tables.
The name of the file that contains the list of tables where errors occurred is `failed_migrated_tables_yyymmmdd_hhmmss.txt`. The `yyymmmdd_hhmmss` is a time stamp when the `gptransfer` process was started. The file is created in the directory were `gptransfer` is executed.

After `gptransfer` completes copying database objects, the utility compares the row count of each table copied to the destination databases with the table in the source database. The utility returns the validation results for each table. You can disable the table row count validation by specifying the `--no-final-count` option.

**Note:** If the number of rows do not match, the table is not added to the file that lists the tables where transfer errors occurred.

The `gp_external_max_segs` server configuration parameter controls the number of segment instances that can access a single `gpfdist` instance simultaneously. Setting a low value might affect `gptransfer` performance. For information about the parameter, see the Greenplum Database Reference Guide.

### Limitation for the Source and Destination Systems

If you are copying data from a system with a larger number of segments to a system with a fewer number of segment hosts, then the total number of primary segments on the destination system must be greater than or equal to the total number of segment hosts on the source system.

For example, assume a destination system has a total of 24 primary segments. This means that the source system cannot have more than 24 segment hosts.

When you copy data from a source Greenplum Database system with a larger number of primary segment instances than on the destination system, the data transfer might be slower when compared to a transfer where the source system has fewer segment instances than the destination system. The `gptransfer` utility uses a different configuration of named pipes and `gpfdist` instances in the two situations.

### Options

- `-a`
  Quiet mode, do not prompt the user for confirmation.

- `--analyze`
  Run the `ANALYZE` command on non-system tables. The default is to not run the `ANALYZE` command.

- `--base-port=base_gpfdist_port`
  Base port for `gpfdist` on source segment systems. If not specified, the default is 8000.

- `--batch-size=batch_size`
  Sets the maximum number of tables that `gptransfer` concurrently copies to the destination database. If not specified, the default is 2. The maximum is 10.

  **Note:** If the order of the transfer is important, specify a value of 1. The tables are transferred sequentially based on the order specified in the `-t` and `-f` options.

- `-d database`
  A source database to copy. This option can be specified multiple times to copy multiple databases to the destination system. All the user defined tables and table data are copied to the destination system.

  A set of databases can be specified using the Python regular expression syntax. The regular expression pattern must be enclosed in slashes (`/RE pattern/`). If you use a regular expression, the name must be enclosed in double quotes (`"`). This example `-d "demo/.*"` specifies all databases in the Greenplum Database installation that begin with `demo`.
Note: Note the following two examples for the \texttt{-d} option are equivalent. They both specify a set of databases that begins with \texttt{demo} and ends with zero or more digits.

\begin{verbatim}
-d "demo/[0-9]*/"
-d "/demo[0-9]*/"
\end{verbatim}

If the source database does not exist, \texttt{gptransfer} returns an error and quits. If a destination database does not exist a database is created.

Not valid with the \texttt{--full}, \texttt{-f}, \texttt{-t}, \texttt{--partition-transfer}, or \texttt{--partition-transfer-non-partition-target} options.

Alternatively, specify the \texttt{-t} or \texttt{-f} option to copy a specified set of tables.

\texttt{--delimiter=delim}

Delimiter to use for writable external tables created by \texttt{gptransfer}. Specify a single ASCII character that separates columns within each row of data. The default value is a comma (,). If \texttt{delim} is a comma (,) or if this option is not specified, \texttt{gptransfer} uses the CSV format for writable external tables. Otherwise, \texttt{gptransfer} uses the TEXT format.

If \texttt{--delimiter}, \texttt{--format}, and \texttt{--quote} options are not specified, these are settings for writable external tables:

\begin{verbatim}
FORMAT 'CSV' ( DELIMITER ',' QUOTE E'\001' )
\end{verbatim}

You can specify a delimiter character such as a non-printing character with the format \texttt{"\digits"} (octal). A backslash followed by the octal value for the character. The octal format must be enclosed in double quotes. This example specifies the octal character \texttt{\001}, the SOH character:

\begin{verbatim}
--delimiter="\001"
\end{verbatim}

\texttt{--dest-database=dest_database_name}

The database in the destination Greenplum Database system. If not specified, the source tables are copied into a destination system database with the same name as the source system database.

This option is required if the source and destination Greenplum Database systems are the same.

If destination database does not exist, it is created.

Not valid with the \texttt{--full}, \texttt{--partition-transfer}, or \texttt{--partition-transfer-non-partition-target} options.

\texttt{--dest-host=dest_host}

Destination Greenplum Database hostname or IP address. If not specified, the default is the host the system running \texttt{gptransfer} (127.0.0.1)

\texttt{--dest-port=dest_port}

Destination Greenplum Database port number, If not specified, the default is 5432.

\texttt{--dest-user=dest_user}

User ID that is used to connect to the destination Greenplum Database system. If not specified, the default is the user gpadmin.

\texttt{--drop}

Specify this option to drop the table that is in the destination database if it already exists. Before copying table data, \texttt{gptransfer} drops the table and creates it again.
At most, only one of the options can be specified --skip-existing, --truncate, or --drop. If one of them is not specified and the table exists in the destination system, gptransfer returns an error and quits.

Not valid with the --full, --partition-transfer, or --partition-transfer-non-partition-target options.

--dry-run

When you specify this option, gptransfer generates a list of the migration operations that would have been performed with the specified options. The data is not migrated. The information is displayed at the command line and written to the log file.

-f table-file

The location and name of file containing list of fully qualified table names to copy from the Greenplum Database source system. In the text file, you specify a single fully qualified table per line (database.schema.table).

A set of tables can be specified using the Python regular expression syntax. See the -d option for information about using regular expressions.

If the source table does not exist, gptransfer returns an error and quits. If the destination database or table does not exist, it is created.

Only the table and table data are copied and indexes are re-created. Dependent objects are not copied.

You cannot specify views, or system catalog tables. The --full option copies user defined views.

If you specify the -d option to copy all the tables from a database, you cannot specify individual tables from the database.

Not valid with the --full, -d, or -t options.

--partition-transfer (partitioned destination table)

Specify this option with the -f option to copy data from leaf child partition tables of partitioned tables from a source database to the leaf child partition tables in a destination database. The text file specified by the -f option contains a list of fully qualified leaf child partition table names with this syntax.

```
src_db.src_schema.src_prt_tbl[, dst_db.dst_schema.dst_prt_tbl]
```

Wildcard characters are not supported in the fully qualified table names. The destination partitioned table must exist. If the destination leaf child partition table is not specified in the file, gptransfer copies the data to the same fully qualified table name (db_name.schema.table) in the destination Greenplum Database system. If the source and destination Greenplum Database systems are the same, you must specify a destination table where at least one of the following must be different between the source and destination table: db_name, schema, or table.

If either the source or destination table is not a leaf child partition, the utility returns an error and no data are transferred.

These characteristics must be the same for the partitioned table in the source and destination database.

- Number of table columns and the order of the column data types (the source and destination table names and table column names can be different)
- Partition level of the specified source and destination tables
- Partitioning criteria of the specified source and destination leaf child partitions and child partitions above them in the hierarchy (partition type and partition column)
This option is not valid with these options: -d, --dest-database, --drop, -F, --full, --schema-only, -T, -t.

Note: If a destination table is not empty or the data in the source or destination table changes during a transfer operation (rows are inserted or deleted), the table row count validation fails due to row count mismatch.

If the destination table is not empty, you can specify the -trunc option to truncate the table before the transfer operation.

You can specify the -x option to acquire exclusive locks on the tables during a transfer operation.

`--partition-transfer-non-partition-target` (non-partitioned destination table)

Specify this option with the -f option to copy data from leaf child partition tables of partitioned tables in a source database to non-partitioned tables in a destination database. The text file specified by the -f option contains a list of fully qualified leaf child partition table names in the source database and non-partitioned tables names in the destination database with this syntax.

```
src_db.src_schema.src_part_tbl, dest_db.dest_schema.dest_tbl
```

Wildcard characters are not supported in the fully qualified table names. The destination tables must exist, and both source and destination table names are required in the file.

If a source table is not a leaf child partition table or a destination table is not a normal (non-partitioned) table, the utility returns an error and no data are transferred.

If the source and destination Greenplum Database systems are the same, you must specify a destination table where at least one of the following must be different between the source and destination table: db_name, schema, or table.

For the partitioned table in the source database and the table in the destination database, the number of table columns and the order of the column data types must be the same (the source and destination table column names can be different).

The same destination table can be specified in the file for multiple source leaf child partition tables that belong to a single partitioned table. Transferring data from source leaf child partition tables that belong to different partitioned tables to a single non-partitioned table is not supported.

This option is not valid with these options: -d, --dest-database, --drop, -F, --full, --schema-only, -T, -t, -trunc, --validate.

Note: If the data in the source or destination table changes during a transfer operation (rows are inserted or deleted), the table row count validation fails due to row count mismatch.

You can specify the -x option to acquire exclusive locks on the tables during a transfer operation.

`-F table-file`

The location and name of file containing list of fully qualified table names to exclude from transferring to the destination system. In the text file, you specify a single fully qualified table per line.

A set of tables can be specified using the Python regular expression syntax. See the -d option for information about using regular expressions.

The utility removes the excluded tables from the list of tables that are being transferred to the destination database before starting the transfer. If excluding tables results in no tables being transferred, the database or schema is not created in the destination system.
If a source table does not exist, `gptransfer` displays a warning. Only the specified tables are excluded. To exclude dependent objects, you must explicitly specify them.

You cannot specify views, or system catalog tables.

Not valid with the `--full`, `--partition-transfer`, or `--partition-transfer-non-partition-target` options.

You can specify the `--dry-run` option to test the command. The `-v` option, displays and logs the excluded tables.

`--format=[CSV | TEXT]`
Specify the format of the writable external tables that are created by `gptransfer` to transfer data. Values are `CSV` for comma separated values, or `TEXT` for plain text. The default value is `CSV`.

If the options `--delimiter`, `--format`, and `--quote` are not specified, these are default settings for writable external tables:

```
FORMAT 'CSV' ( DELIMITER ',' QUOTE E'\001' )
```

If you specify `TEXT`, you must also specify a non-comma delimiter with the `--delimiter=delim` option. These are settings for writable external tables:

```
FORMAT 'TEXT' ( DELIMITER delim ESCAPE 'off' )
```

`--full`
Full migration of a Greenplum Database source system to a destination system. You must specify the options for the destination system, the `--source-map-file` option, the `--dest-host` option, and if necessary, the other destination system options.

The `--full` option cannot be specified with the `-t`, `-d`, `-f`, `--partition-transfer`, or `--partition-transfer-non-partition-target` options.

A full migration copies all database objects including, tables, indexes, views, users, roles, functions, and resource queues for all user defined databases. The default databases, postgres, template0 and template1 are not moved.

If a database exists in the destination system, besides the default postgres, template0 and template1 databases, `gptransfer` returns an error and quits.

**Note:** The `--full` option is recommended only when the databases contain a large number of tables with large amounts of data. Because of the overhead required to set up parallel transfers, the utility is not recommended when the databases contain tables with small amounts of data. For more information, see [Notes](#).

`--gpfdist-verbose`
Set the logging level for `gpfdist` processes to verbose (`-v`). Cannot be specified with `--gpfdist-very-verbose`.

The output is recorded in `gpfdist` log files in the `~/gptransfer_process_id` directory on segment hosts in the source Greenplum Database cluster.

`--gpfdist-very-verbose`
Set the logging level for `gpfdist` processes to very verbose (`-v`). Cannot be specified with `--gpfdist-verbose`.

The output is recorded in `gpfdist` log files in the `~/gptransfer_process_id` directory on segment hosts in the source Greenplum Database cluster.

`-l log_dir`
Specify the `gptransfer` log file directory. If not specified, the default is `~/gpAdminLogs`. This directory is created on the master host in the source Greenplum cluster.
--max-line-length=\texttt{length}

Sets the maximum allowed data row length in bytes for the \texttt{gpfdist} utility. If not specified, the default is 10485760. Valid range is 32768 (32K) to 268435456 (256MB).

Should be used when user data includes very wide rows (or when \texttt{line too long} error message occurs). Should not be used otherwise as it increases resource allocation.

--no-final-count

Disable table row count validation that is performed after \texttt{gptransfer} completes copying database objects to the target database. The default is to compare the row count of tables copied to the destination databases with the tables in the source database.

-\texttt{q} | --quiet

If specified, suppress status messages. Messages are only sent to the log file.

--quote=\texttt{character}

The quotation character when \texttt{gptransfer} creates writable external tables with the CSV format. Specify a single ASCII character that is used to enclose column data. The default value is the octal character \texttt{\textbackslash 001}, the SOH character.

You can specify a delimiter character such as a non-printing character with the format \texttt{"\textbackslash digits"} (octal). A backslash followed by the octal value for the character. The octal value must be enclosed in double quotes.

--schema-only

Create only the schemas specified by the command. Data is not transferred.

If specified with the --full option, \texttt{gptransfer} replicates the complete database schema, including all tables, indexes, views, user defined types (UDT), and user defined functions (UDF) for the source databases. No data is transferred.

If you specify databases with the -d option or tables with the -t or -f options, \texttt{gptransfer} creates only the tables and indexes. No data is transferred.

\textbf{Note:} Because of the overhead required to set up parallel transfers, the --schema-only option is not recommended when transferring information for a large number of tables. For more information, see \textit{Notes}.

--skip-existing

Specify this option to skip copying a table from the source database if the table already exists in the destination database.

At most, only one of the options can be specified --skip-existing, --truncate, or --drop. If one of them is not specified and the table exists in the destination system, \texttt{gptransfer} returns an error and quits.

Not valid with the --full option.

--source-host=\texttt{source\_host}

Source Greenplum Database host name or IP address. If not specified, the default host is the system running \texttt{gptransfer} (127.0.0.1).

--source-map-file=\texttt{host\_map\_file}

File that lists source segment host name and IP addresses. If the file is missing or not all segment hosts are listed, \texttt{gptransfer} returns an error and quits.
Each line of the file contains a source host name and the host IP address separated by a comma: `hostname,IPaddress`. This example lists four Greenplum Database hosts and their IP addresses.

```
sdw1,192.0.2.1
sdw2,192.0.2.2
sdw3,192.0.2.3
sdw4,192.0.2.4
```

This option is required if the `--full` option is specified or if the source Greenplum Database system is different than the destination system. This option is not required if source and destination systems are the same.

`--source-port=source_port`
Source Greenplum Database port number. If not specified, the default is 5432.

`--source-user=source_user`
User ID that is used to connect to the source Greenplum Database system. If not specified, the default is the user gpadmin.

**Note:** `gptransfer` creates external tables with the `execute` protocol, so the `--source_user` that you specify must have superuser privileges.

`--sub-batch-size=sub_batch_size`
Specifies the maximum degree of parallelism of the operations performed when migrating a table such as starting gpfdist instances, creating named pipes for the move operations. If not specified, the default is 25. The maximum is 50.

Specify the `--batch-size` option to control the maximum number of tables that `gptransfer` concurrently processes.

`-t db.schema.table`
A table from the source database system to copy. The fully qualified table name must be specified.

A set of tables can be specified using the Python regular expression syntax. See the `-d` option for information about using regular expressions.

If the destination table or database does not exist, it is created. This option can be specified multiple times to include multiple tables. Only the table and table data are copied and indexes are re-created. Dependent objects are not copied.

If the source table does not exist, `gptransfer` returns an error and quits.

If you specify the `-d` option to copy all the tables from a database, you do not need to specify individual tables from the database.

Not valid with the `--full`, `-d`, `-f`, `--partition-transfer`, or `--partition-transfer-non-partition-target` options.

`-T db.schema.table`
A table from the source database system to exclude from transfer. The fully qualified table name must be specified.

A set of tables can be specified using the Python regular expression syntax. See the `-d` option for information about using regular expressions.

This option can be specified multiple times to include multiple tables. Only the specified tables are excluded. To exclude dependent objects, you must explicitly specify them.

The utility removes the excluded tables from the list of tables that are being transferred to the destination database before starting the transfer. If excluding tables results in no tables being transferred, the database or schema is not created in the destination system.
If a source table does not exist, `gptransfer` displays a warning.

Not valid with the `--full`, `--partition-transfer`, or `--partition-transfer-non-partition-target` options.

You can specify the `--dry-run` option to test the command. The `-v` option displays and logs the excluded tables.

`--timeout seconds`
Specify the time out value in seconds that `gptransfer` passes the `gpfdist` processes that `gptransfer` uses. The value is the time allowed for Greenplum Database to establish a connection to a `gpfdist` process. You might need to increase this value when operating on high-traffic networks.

The default value is 300 seconds (5 minutes). The minimum value is 2 seconds, the maximum value is 600 seconds.

`--truncate`
Specify this option to truncate the table that is in the destination database if it already exists.

At most, only one of the options can be specified `--skip-existing`, `--truncate`, or `--drop`. If one of them is not specified and the table exists in the destination system, `gptransfer` returns an error and quits.

Not valid with the `--full` option.

`--validate=type`
Perform data validation on table data. These are the supported types of validation.

`count` - Specify this value to compare row counts between source and destination table data.

`MD5` - Specify this value to compare MD5 values between source and destination table data.

If validation for a table fails, `gptransfer` displays the name of the table and writes the file name to the text file `failed_migrated_tables_yyyymmdd_hhmmss.txt`. The `yyyymmdd_hhmmss` is a time stamp when the `gptransfer` process was started. The file is created in the directory where `gptransfer` is executed.

*Note:* The file contains the table names where validation failed or other errors occurred during table migration.

`-v` | `--verbose`
If specified, sets the logging level to verbose. Additional log information is written to the log file and the command line during command execution.

`--work-base-dir=work_dir`
Specify the directory that `gptransfer` uses to store temporary working files such as PID files and named pipes. The default directory is the user's home directory.

Source and destination systems must be able to access the `gptransfer` work directory.

`-x`
Acquire an exclusive lock on tables during the migration to prevent insert or updates.

On the source database, an exclusive lock is acquired when `gptransfer` inserts into the external table and is released after validation.

On the destination database, an exclusive lock is acquired when `gptransfer` selects from external table and released after validation.
If \(-x\) option is not specified and \(--validate\) is specified, validation failures occur if data is inserted into either the source or destination table during the migration process. The \texttt{gptransfer} utility displays messages if validation errors occur.

\texttt{-h | -? | \(--help\)}  
Displays the online help.

\texttt{--version}  
Displays the version of this utility.

**Examples**

This command copies the table \texttt{public.t1} from the database \texttt{db1} and all tables in the database \texttt{db2} to the system \texttt{mytest2}.

```
gptransfer -t db1.public.t1 -d db2 --dest-host=mytest2 \\ --source-map-file=gp-source-hosts --truncate
```

If the databases \texttt{db1} and \texttt{db2} do not exist on the system \texttt{mytest2}, they are created. If any of the source tables exist on the destination system, \texttt{gptransfer} truncates the table and copies the data from the source to the destination table.

This command copies leaf child partition tables from a source system to a destination system.

```
gptransfer -f input_file --partition-transfer --source-host=source_host \\ --source-user=source_user --source-port=source_port --dest-host=dest_host \\ --dest-user=dest_user --dest-port=dest_port --source-map-file=host_map_file
```

This line in \texttt{input_file} copies a leaf child partition from the source system to the destination system.

```
srcdb.people.person_1_prt_experienced, destdb.public.employee_1_prt_seniors
```

The line assumes partitioned tables in the source and destination systems similar to the following tables.

- In the \texttt{people} schema of the \texttt{srcdb} database of the source system, a partitioned table with a leaf child partition table \texttt{person_1_prt_experienced}. This \texttt{CREATE TABLE} command creates a partitioned table with the leaf child partition table.

```sql
CREATE TABLE person(id int, title char(1))
    DISTRIBUTED BY (id)
    PARTITION BY list (title)
    (PARTITION experienced VALUES ('S'),
       PARTITION entry_level VALUES ('J'),
       DEFAULT PARTITION other);
```

- In the \texttt{public} schema of the \texttt{destdb} database of the source system, a partitioned table with a leaf child partition table \texttt{public.employee_1_prt_seniors}. This \texttt{CREATE TABLE} command creates a partitioned table with the leaf child partition table.

```sql
CREATE TABLE employee(id int, level char(1))
    DISTRIBUTED BY (id)
    PARTITION BY list (level)
    (PARTITION seniors VALUES ('S'),
       PARTITION juniors VALUES ('J'),
       DEFAULT PARTITION other);
```

This example uses Python regular expressions in a filter file to specify the set of tables to transfer. This command specifies the \(-f\) option with the filter file \texttt{/tmp/filter_file} to limit the tables that are transferred.

```
gptransfer -f /tmp/filter_file --source-port 5432 --source-host test4 \
```
This is the contents of /tmp/filter_file.

"test1.arc/.*/./.*/"
"test1.c/(..)/y./.*/"

In the first line, the regular expressions for the schemas, arc/.*/, and for the tables, ./.*, limit the transfer to all tables with the schema names that start with arc.

In the second line, the regular expressions for the schemas, c/(..)/y, and for the tables, ./.*, limit the transfer to all tables with the schema names that are four characters long and that start with c and end with y, for example, crty.

When the command is run, tables in the database test1 that satisfy either condition are transferred to the destination database.

See Also

gpfdist

For information about loading and unloading data, see the Greenplum Database Administrator Guide.

**pgbouncer**

Manages database connection pools.

**Synopsis**

```
pgbouncer [OPTION ...] config.ini
```

```
OPTION
  [ -d | --daemon ]
  [ -R | --restart ]
  [ -q | --quiet ]
  [ -v | --verbose ]
  [ (-u | --user)=username ]
pgbouncer [ -V | --version ] | [ -h | --help ]
```

**Description**

PgBouncer is a light-weight connection pool manager for Greenplum and PostgreSQL databases. Databases may be on different Greenplum Database clusters or PostgreSQL backends. PgBouncer creates a pool for each database user and database combination. A pooled connection can only be reused for another connection request for the same user and database. The client application connects to the connection pool's host and port instead of the Greenplum Database master host and port. PgBouncer either creates a new database connection for the client or reuses an existing connection. When the client disconnects, the connection is returned to the pool for re-use.

PgBouncer supports the standard connection interface that PostgreSQL and Greenplum Database share. A client requesting a database connection provides the host name and port where PgBouncer is running, as well as the database name, username, and password. PgBouncer looks up the requested database (which may be an alias for the actual database) in its configuration file to find the host name, port, and database name for the database connection. The configuration file entry also determines how to authenticate the user and what database role will be used for the connection—a "forced user" can override the username provided with the client's connection request.
PgBouncer requires an authentication file, a text file that contains a list of users and passwords. Passwords may be either clear text, MD5-encoded, or an LDAP/AD lookup string. You can also set up PgBouncer to query the `pg_shadow` table in the destination database for users that are not in the authentication file.

PgBouncer shares connections in one of three pool modes:

- **Session pooling** – When a client connects, a connection is assigned to it as long as it remains connected. When the client disconnects, the connection is placed back into the pool.

- **Transaction pooling** – A connection is assigned to a client for the duration of a transaction. When PgBouncer notices the transaction is done, the connection is placed back into the pool. This mode can be used only with applications that do not use features that depend upon a session.

- **Statement pooling** – Statement pooling is like transaction pooling, but multi-statement transactions are not allowed. This mode is intended to enforce autocommit mode on the client and is targeted for PL/Proxy on PostgreSQL.

A default pool mode can be set for the PgBouncer instance and the mode can be overridden for individual databases and users.

By connecting to a virtual `pgbouncer` database, you can monitor and manage PgBouncer using SQL-like commands. Configuration parameters can be changed without having to restart PgBouncer, and the configuration file can be reloaded to pick up changes.

PgBouncer does not yet support SSL connections. If you want to encrypt traffic between clients and PgBouncer, you can use `stunnel`, a free software utility that creates TLS-encrypted tunnels using the OpenSSL cryptography library. See "Securing PgBouncer Connections with stunnel" in the Greenplum Database Administrator Guide for directions.

See the PgBouncer FAQ for additional usage information.

This reference topic includes the following additional reference information:

- PgBouncer Configuration File
- PgBouncer Authentication File Format
- PgBouncer Administration Console Commands

**Options**

- **-d | --daemon**
  
  Run PgBouncer as a daemon (a background process). The default is to run as a foreground process.

  PgBouncer displays start up messages when starting as a daemon. To disable the display of messages add the `-q` option.

  To shut down a PgBouncer daemon, log in to the administration console and issue the `SHUTDOWN` command.

  **Note:** This option does not work on Windows servers.

- **-R | --restart**

  Restart PgBouncer using the specified command line arguments. Non-TLS connections to databases are maintained during restart; TLS connections are dropped.

  If you specify only the `-R` option, PgBouncer displays log information on the command line after restart. To restart PgBouncer as a daemon specify the options `-Rd`.

  **Note:** Works only if the operating system supports Unix sockets and the PgBouncer configuration has no `unix_socket_dir`. This option does not work on Windows servers.

- **-q | --quiet**

  Run quietly. Do not display messages on the command line (stdout).
**Greenplum Database Utility Guide**

### PgBouncer Configuration File

The PgBouncer configuration file (usually `pgbouncer.ini`) is in the "ini" format. Section names are enclosed in square braces ([ and ]). Lines beginning with ";" or "#" are comments and are ignored. The characters ";" and "#" are not recognized when they appear later in the line.

#### Synopsys

```ini
[databases]
db = ...

[pgbouncer]...

[users]...
```

#### Description

A PgBouncer configuration file has up to three sections:
- **[databases] Section**
- **[pgbouncer] Section**
- **[users] Section**

**[databases] Section**

The databases section contains key=value pairs, where the key is a database name and the value is a libpq connect-string list of key=value pairs.

A database name can contain characters [0-9A-Za-z_.-] without quoting. Names that contain other chars must be quoted with standard SQL identifier quoting

- Enclose names in double quotes ("")
- Represent a double-quote within an identifier with two consecutive double quote characters

The database name ".*" is the fallback database. The value for this key is a connect string for the requested database. Automatically created database entries like these are cleaned up if they remain idle longer then the time specified in `autodb_idle_timeout` parameter.

The PgBouncer configuration file can contain `%include` directives, which specify another file to read and process. This allows splitting the configuration file into separate parts. For example:

```ini
%include filename
```

#### Location Parameters

The following parameters may be included in the value to specify the location of the database.
dbname
The destination database name.
Default: same as the client-side database name.

host
The name or IP address of the Greenplum master host. Host names are resolved at connect time. If DNS returns several results, they are used in a round-robin manner. The DNS result is cached and the `dns_max_ttl` parameter determines when the cache entry expires.
Default: not set, means the connection is made through a Unix socket.

port
The Greenplum Database master port. Default: 5432

user, password
If `user=` is set, all connections to the destination database are made with the specified user. This means there will be just one pool for the database.
If the `user=` parameter is not set, PgBouncer attempts to log in to the destination database with the user name passed by the client. This means there will be one pool for each user who connects to the database.

auth_user
If `auth_user` is set, any user who is not specified in `auth_file` is authenticated by querying the `pg_shadow` table in the database as the `auth_user`. The `auth_user` password must be set in the `auth_file`.

Pool Configuration

pool_size
Set maximum size of pools for this database. If not set, the `default_pool_size` is used.

connect_query
Query to be executed after a connection is established, but before allowing the connection to be used by any clients. If the query raises errors, they are logged but ignored otherwise.

pool_mode
Set the pool mode for this database. If not set, the default `pool_mode` is used.

max_db_connections
Set a database-wide maximum number of connections for this database. The total number of connections for all pools for this database will not exceed this value.

Extra Parameters
The following parameters allow setting default parameters on server connections.
Note that since version 1.1 PgBouncer tracks client changes for their values, so their use in `pgbouncer.ini` is deprecated now.

client_encoding
Ask specific `client_encoding` from server.

datestyle
Ask specific `datestyle` from server.

timezone
Ask specific `timezone` from server.
[pgbouncer] Section

logfile
Specifies the location of the log file. The log file is kept open. After log rotation execute
kill -HUP or run the RELOAD command in the PgBouncer Administrative Console.
Default: not set.

Note: On Windows machines, the service must be stopped and started.

pidfile
The name of the pid file. Without a pidfile, PgBouncer cannot be run as a background
process (daemon).
Default: not set.

listen_addr
A list of interface addresses where PgBouncer listens for TCP connections. You may also
use *, which means to listen on all interfaces. If not set, only Unix socket connections are
allowed.
Addresses can be specified numerically (IPv4/IPv6) or by name.
Default: not set

listen_port
Which port to listen on. Applies to both TCP and Unix sockets.
Default: 6432

unix_socket_dir
Specifies location for Unix sockets. Applies to both listening socket and server
connections. If set to an empty string, Unix sockets are disabled. Required for online
reboot (-R option) to work.
Note: Not supported on Windows machines.
Default: /tmp

unix_socket_mode
Filesystem mode for Unix socket.
Default: 0777

unix_socket_group
Group name to use for Unix socket.
Default: not set

user
If set, specifies the Unix user to change to after startup. This only works if PgBouncer is
started as root or if user is the same as the current user. Note: Not supported on Windows
machines.
Default: not set

auth_file
The name of the file containing the user names and passwords to load. The file format is
the same as the Greenplum Database pg_auth/pg_pwd file, so this parameter can be
set to one of those backend files. See Authentication File Format for details.
Default: not set.
**auth_type**

How to authenticate users.

**cert**

Clients must connect with TLS using a valid client certificate. The client's username is taken from CommonName field in the certificate.

**md5**

Use MD5-based password check. auth_file may contain both MD5-encrypted or plain-text passwords. This is the default authentication method.

**plain**

Clear-text password is sent over wire. *Deprecated.*

**trust**

No authentication is done. The username must still exist in the auth_file.

**any**

Like the trust method, but the username supplied is ignored. Requires that all databases are configured to log in with a specific user. Additionally, the console database allows any user to log in as admin.

**auth_query**

Query to load a user's password from database. If a user does not exist in the auth_file and the database entry includes an auth_user, this query is run in the database as auth_user to lookup up the user.

Default: `SELECT usename, passwd FROM pg_shadow WHERE usename=$1`

**pool_mode**

Specifies when a server connection can be reused by other clients.

**session**

Connection is returned to the pool when the client disconnects. Default.

**transaction**

Connection is returned to the pool when the transaction finishes.

**statement**

Connection is returned to the pool when the current query finishes. Long transactions with multiple statements are disallowed in this mode.

**max_client_conn**

Maximum number of client connections allowed. When increased then the file descriptor limits should also be increased. The actual number of file descriptors used is more than max_client_conn. The theoretical maximum used, when each user connects with its own username to the server is:

\[
\text{max_client_conn} + (\text{max_pool_size} \times \text{total_databases} \times \text{total_users})
\]

If a database user is specified in the connect string, all users connect using the same username. Then the theoretical maximum connections is:

\[
\text{max_client_conn} + (\text{max_pool_size} \times \text{total_databases})
\]

The theoretical maximum should be never reached, unless someone deliberately crafts a load for it. Still, it means you should set the number of file descriptors to a safely high number. Search for ulimit in your operating system documentation.

**Note:** ulimit does not apply in a Windows environment.

Default: 100
**default_pool_size**
The number of server connections to allow per user/database pair. This can be overridden in the per-database configuration.
Default: 20

**min_pool_size**
Add more server connections to the pool when it is lower than this number. This improves behavior when the usual load drops and then returns suddenly after a period of total inactivity.
Default: 0 (disabled)

**reserve_pool_size**
The number of additional connections to allow for a pool. 0 disables.
Default: 0 (disabled)

**reserve_pool_timeout**
If a client has not been serviced in this many seconds, PgBouncer enables use of additional connections from reserve pool. 0 disables.
Default: 5.0

**max_db_connections**
The maximum number of connections per database. If you hit the limit, closing a client connection to one pool does not immediately allow a server connection to be established for another pool, because the server connection for the first pool is still open. Once the server connection closes (due to idle timeout), a new server connection will be opened for the waiting pool.
Default: unlimited

**max_user_connections**
The maximum number of connections per-user. When you hit the limit, closing a client connection to one pool does not immediately allow a connection to be established for another pool, because the connection for the first pool is still open. After the connection for the first pool has closed (due to idle timeout), a new server connection is opened for the waiting pool.

**server_round_robin**
By default, PgBouncer reuses server connections in LIFO (last-in, first-out) order, so that a few connections get the most load. This provides the best performance when a single server serves a database. But if there is TCP round-robin behind a database IP, then it is better if PgBouncer also uses connections in that manner to achieve uniform load.
Default: 0

**ignore_startup_parameters**
By default, PgBouncer allows only parameters it can keep track of in startup packets: client_encoding, datestyle, timezone, and standard_conforming_strings. All others parameters raise an error. To allow other parameters, specify them here so that PgBouncer can ignore them.
Default: empty

**disable_pqexec**
Disable Simple Query protocol (PQexec). Unlike Extended Query protocol, Simple Query protocol allows multiple queries in one packet, which allows some classes of SQL-injection attacks. Disabling it can improve security. This means that only clients that exclusively use Extended Query protocol will work.
application_name_add_host
Add the client host address and port to the application name setting set on connection start. This helps in identifying the source of bad queries. The setting is overwritten without detection if the application executes `SET APPLICATION_NAME` after connecting.
Default: 1

Log Settings

syslog
Toggles syslog on and off. On Windows, eventlog is used instead.
Default: 0

syslog_ident
Under what name to send logs to syslog.
Default: pgbouncer

syslog_facility
Under what facility to send logs to syslog. Some possibilities are: `auth, authpriv, daemon, user, local0-7`
Default: daemon

log_connections
Log successful logins.
Default: 1

log_disconnections
Log disconnections, with reasons.
Default: 1

log_pooler_errors
Log error messages that the pooler sends to clients.
Default: 1

stats_period
How often to write aggregated statistics to the log.
Default: 60

Console Access Control

admin_users
Comma-separated list of database users that are allowed to connect and run all commands on console. Ignored when `auth_mode=any`, in which case any username is allowed in as admin.
Default: empty

stats_users
Comma-separated list of database users that are allowed to connect and run read-only queries on console. That means all SHOW commands except SHOW FDS.
Default: empty

Connection Sanity Checks, Timeouts

server_reset_query
Query sent to server on connection release, before making it available to other clients. At
that moment no transaction is in progress so it should not include \texttt{ABORT} or \texttt{ROLLBACK}.

A good choice for Postgres 8.2 and below, and Greenplum Database, is:

\begin{verbatim}
server_reset_query = RESET ALL; SET SESSION AUTHORIZATION DEFAULT;
\end{verbatim}

For Postgres 8.3 and above, the following is sufficient:

\begin{verbatim}
server_reset_query = DISCARD ALL;
\end{verbatim}

When transaction pooling is used, the server\_reset\_query should be empty, as clients
should not use any session features. If clients do use session features, they will be broken
because transaction pooling does not guarantee that the next query will run on the same
connection.

\textbf{Default:} \texttt{RESET ALL; SET SESSION AUTHORIZATION DEFAULT;}

\textbf{server\_reset\_query\_always}

Whether server\_reset\_query should be run in all pooling modes. When this setting
is off (default), the server\_reset\_query will be run only in pools that are in sessions
pooling mode. Connections in transaction pooling mode should not have any need for
reset query.

\textbf{Default:} 0

\textbf{server\_check\_delay}

How long to keep released connections available for re-use without running sanity-check
queries on it. If 0 then the query is run always.

\textbf{Default:} 30.0

\textbf{server\_check\_query}

A simple do-nothing query to test the server connection.

If an empty string, then sanity checking is disabled.

\textbf{Default:} \texttt{SELECT 1;}

\textbf{server\_lifetime}

The pooler tries to close server connections that have been connected longer than this
number of seconds. Setting it to 0 means the connection is to be used only once, then
closed.

\textbf{Default:} 3600.0

\textbf{server\_idle\_timeout}

If a server connection has been idle more than this many seconds it is dropped. If this
parameter is set to 0, timeout is disabled. [seconds]

\textbf{Default:} 600.0

\textbf{server\_connect\_timeout}

If connection and login will not finish in this number of seconds, the connection will be
closed.

\textbf{Default:} 15.0

\textbf{server\_login\_retry}

If a login fails due to failure from \texttt{connect()} or authentication, the pooler waits this many
seconds before retrying to connect.


**client_login_timeout**

If a client connects but does not manage to login in this number of seconds, it is disconnected. This is needed to avoid dead connections stalling SUSPEND and thus online restart.

Default: 60.0

**autodb_idle_timeout**

If database pools created automatically (via "") have been unused this many seconds, they are freed. Their statistics are also forgotten.

Default: 3600.0

**dns_max_ttl**

How long to cache DNS lookups, in seconds. If a DNS lookup returns several answers, PgBouncer round-robs between them in the meantime. The actual DNS TTL is ignored.

Default: 15.0

**dns_nxdomain_ttl**

How long error and NXDOMAIN DNS lookups can be cached, in seconds.

Default: 15.0

**dns_zone_check_period**

Period to check if zone serial numbers have changed.

PgBouncer can collect DNS zones from hostnames (everything after first dot) and then periodically check if the zone serial numbers change. If changes are detected, all hostnames in that zone are looked up again. If any host IP changes, its connections are invalidated.

Works only with UDNS backend (--with-udns to configure).

Default: 0.0 (disabled)

**Dangerous Timeouts**

Setting the following timeouts can cause unexpected errors.

**query_timeout**

Queries running longer than this (seconds) are canceled. This parameter should be used only with a slightly smaller server-side statement_timeout, to trap queries with network problems. [seconds]

Default: 0.0 (disabled)

**query_wait_timeout**

The maximum time, in seconds, queries are allowed to wait for execution. If the query is not assigned a connection during that time, the client is disconnected. This is used to prevent unresponsive servers from grabbing up connections.

Default: 0.0 (disabled)

**client_idle_timeout**

Client connections idling longer than this many seconds are closed. This should be larger than the client-side connection lifetime settings, and only used for network problems.

Default: 0.0 (disabled)

**idle_transaction_timeout**

If client has been in "idle in transaction" state longer than this (seconds), it is disconnected.
Default: 0.0 (disabled)

**Low-level Network Settings**

**pkt_buf**
Internal buffer size for packets. Affects the size of TCP packets sent and general memory usage. Actual libpq packets can be larger than this so there is no need to set it large.
Default: 2048

**max_packet_size**
Maximum size for packets that PgBouncer accepts. One packet is either one query or one result set row. A full result set can be larger.
Default: 2147483647

**listen_backlog**
Backlog argument for the `listen(2)` system call. It how many new unanswered connection attempts are kept in queue. When the queue is full, further new connection attempts are dropped.
Default: 128

**sbuf_loopcnt**
How many times to process data on one connection, before proceeding. Without this limit, one connection with a big result set can stall PgBouncer for a long time. One loop processes one `pkt_buf` amount of data. 0 means no limit.
Default: 5

**suspend_timeout**
How many seconds to wait for buffer flush during `SUSPEND` or reboot (-R). Connection is dropped if flush does not succeed.
Default: 10

**tcp_defer_accept**
For details on this and other TCP options, please see the `tcp(7)` man page.
Default: 45 on Linux, otherwise 0

**tcp_socket_buffer**
Default: not set

**tcp_keepalive**
Turns on basic keepalive with OS defaults.
On Linux, the system defaults are `tcp_keepidle=7200, tcp_keepintvl=75, tcp_keepcnt=9`.
Default: 1

**tcp_keepcnt**
Default: not set

**tcp_keepidle**
Default: not set

**tcp_keepintvl**
Default: not set
**[users] Section**

This section contains *key=value* pairs, where the key is a user name and the value is a libpq connect-string list of *key=value* pairs.

**Pool configuration**

`pool_mode`

Set the pool mode to be used for all connections from this user. If not set, the database or default `pool_mode` is used.

**Example Configuration Files**

**Minimal Configuration**

```plaintext
[databases]
postgres = host=127.0.0.1 dbname=postgres auth_user=gpadmin

[pgbouncer]
pool_mode = session
listen_port = 6543
listen_addr = 127.0.0.1
auth_type = md5
auth_file = users.txt
logfile = pgbouncer.log
pidfile = pgbouncer.pid
admin_users = someuser
stats_users = stat_collector
```

Use connection parameters passed by the client:

```plaintext
[databases]
* =

[pgbouncer]
listen_port = 65432
listen_addr = 0.0.0.0
auth_type = trust
auth_file = bouncer/users.txt
logfile = pgbouncer.log
pidfile = pgbouncer.pid
ignore_startup_parameters=options
```

**Database Defaults**

```plaintext
[databases]
; foodb over unix socket
foodb =

; redirect bardb to bazdb on localhost
bardb = host=127.0.0.1 dbname=bazdb

; access to destination database will go with single user
forcedb = host=127.0.0.1 port=300 user=baz password=foo
    client_encoding=UNICODE datestyle=ISO
```
PgBouncer Authentication File Format

PgBouncer requires its own user database, a text file in following format:

```
"username1" "password" ...
"username2" "md5abcdef012342345" ...
```

There is one line per user. Each line must have at least two fields. Fields are enclosed in double quotes (""). The first field is the user name and the second is either a plain-text or an MD5-encoded password. The remainder of the line is ignored.

This file format is similar to text files used by Greenplum Database for authentication information, and PgBouncer can work directly with the Greenplum Database authentication files.

To avoid plain-text passwords, encode user passwords with MD5. The format for an MD5 encoded password is:

```
"md5" + md5(password + username)
```

For example, the following command generates the MD5 string for the user admin with password 1234:

```
$ echo -n "1234admin" | md5sum
$ 45f2603610af569b6155c45067268c6b
```

The MD5-hidden password is:

```
md545f2603610af569b6155c45067268c6b
```

PgBouncer Administration Console Commands

The PgBouncer Administration Console is accessed by connecting to the database pgbouncer.

```
$ psql -p 6543 pgbouncer
```

Only users listed in configuration parameters admin_users or stats_users can log in to the console. However, when auth_mode=any, then any user may log in as a stats_user.

The user name pgbouncer may also log in without a password through a Unix socket if the client has the same Unix user UID as the running process.

Administration Console Command Syntax

```
pgbouncer=# show help;
NOTICE:  Console usage
DETAIL:
   SHOW HELP|CONFIG|DATABASES|POOLS|CLIENTS|SERVERS|VERSION
   SHOW STATS|FDS|SOCKETS|ACTIVE_SOCKETS|LISTS|MEM
   SHOW DNS_HOSTS|DNS_ZONES
   SET key = arg
   RELOAD
   PAUSE ["<db>"]
   RESUME ["<db>"]
   DISABLE <db>
   ENABLE <db>
   KILL <db>
   SUSPEND
   SHUTDOWN
```
**Administration Commands**

From the PgBouncer Administrator console you can control connections between PgBouncer and Greenplum Database. You can also set PgBouncer configuration parameters.

The following PgBouncer administration commands control the PgBouncer process.

**PAUSE [database]**

If no database is specified, PgBouncer tries to disconnect from all servers, first waiting for all queries to complete. The command will not return before all queries are finished. This command is to be used to prepare to restart the database.

If a database name is specified, only that database is paused.

If you run a `PAUSE database` command, and then a `PAUSE` command to pause all databases, you must execute two `RESUME` commands, one for all databases, and one for the named database.

**SUSPEND**

All socket buffers are flushed and PgBouncer stops listening for data on them. The command will not return before all buffers are empty. To be used when rebooting PgBouncer online.

**RESUME [database]**

Resume work from a previous `PAUSE` or `SUSPEND` command.

If a database was specified for the `PAUSE` command, the database must also be specified with the `RESUME` command.

After pausing all databases with the `PAUSE` command, resuming a single database with `RESUME database` is not supported.

**DISABLE database**

Reject all new client connections on the database.

**ENABLE database**

Allow new client connections on the database.

**KILL database**

Immediately drop all client and server connections to the named database.

**SHUTDOWN**

Stop PgBouncer process. To exit from the `psql` command line session, enter `\q`.

**RELOAD**

The PgBouncer process reloads the current configuration file and updates the changeable settings.

**SET key = value**

Override specified configuration setting. See the `SHOW CONFIG` command.

**SHOW Command**

The `SHOW category` command displays different types of PgBouncer information. You can specify one of the following categories:

- `ACTIVE_SOCKETS`
- `CLIENTS`
- `CONFIG`
- `DATABASES`
- `DNS_ZONES`
**ACTIVE_SOCKETS**

Table 81: Active Socket Information

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>S, for server, C for client.</td>
</tr>
<tr>
<td>user</td>
<td>Username \texttt{pgbouncer} uses to connect to server.</td>
</tr>
<tr>
<td>database</td>
<td>Database name.</td>
</tr>
<tr>
<td>state</td>
<td>State of the server connection, one of \texttt{active}, \texttt{used} or \texttt{idle}.</td>
</tr>
<tr>
<td>addr</td>
<td>IP address of PostgreSQL server.</td>
</tr>
<tr>
<td>port</td>
<td>Port of PostgreSQL server.</td>
</tr>
<tr>
<td>local_addr</td>
<td>Connection start address on local machine.</td>
</tr>
<tr>
<td>local_port</td>
<td>Connection start port on local machine.</td>
</tr>
<tr>
<td>connect_time</td>
<td>When the connection was made.</td>
</tr>
<tr>
<td>request_time</td>
<td>When last request was issued.</td>
</tr>
<tr>
<td>ptr</td>
<td>Address of internal object for this connection. Used as unique ID.</td>
</tr>
<tr>
<td>link</td>
<td>Address of client connection the server is paired with.</td>
</tr>
<tr>
<td>recv_pos</td>
<td>Receive position in the I/O buffer.</td>
</tr>
<tr>
<td>pkt_pos</td>
<td>Parse position in the I/O buffer.</td>
</tr>
<tr>
<td>pkt_remain</td>
<td>Number of packets remaining on the socket.</td>
</tr>
<tr>
<td>send_pos</td>
<td>Send position in the packet.</td>
</tr>
<tr>
<td>send_remain</td>
<td>Total packet length remaining to send.</td>
</tr>
<tr>
<td>pkt_avail</td>
<td>Amount of I/O buffer left to parse.</td>
</tr>
<tr>
<td>send_avail</td>
<td>Amount of I/O buffer left to send.</td>
</tr>
</tbody>
</table>

**CLIENTS**

Table 82: Clients

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>C, for client.</td>
</tr>
<tr>
<td>user</td>
<td>Client connected user.</td>
</tr>
<tr>
<td>database</td>
<td>Database name.</td>
</tr>
<tr>
<td>Column</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>state</td>
<td>State of the client connection, one of active, used, waiting or idle.</td>
</tr>
<tr>
<td>addr</td>
<td>IP address of client, or unix for a socket connection.</td>
</tr>
<tr>
<td>port</td>
<td>Port client is connected to.</td>
</tr>
<tr>
<td>local_addr</td>
<td>Connection end address on local machine.</td>
</tr>
<tr>
<td>local_port</td>
<td>Connection end port on local machine.</td>
</tr>
<tr>
<td>connect_time</td>
<td>Timestamp of connect time.</td>
</tr>
<tr>
<td>request_time</td>
<td>Timestamp of latest client request.</td>
</tr>
<tr>
<td>ptr</td>
<td>Address of internal object for this connection. Used as unique ID.</td>
</tr>
<tr>
<td>link</td>
<td>Address of server connection the client is paired with.</td>
</tr>
<tr>
<td>remote_pid</td>
<td>Process ID, if client connects with Unix socket and the OS supports getting it.</td>
</tr>
</tbody>
</table>

**CONFIG**

List of current PgBouncer parameter settings

**Table 83: Config**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>key</td>
<td>Configuration variable name</td>
</tr>
<tr>
<td>value</td>
<td>Configuration value</td>
</tr>
<tr>
<td>changeable</td>
<td>Either yes or no. Shows whether the variable can be changed while running. If no, the variable can be changed only at boot time.</td>
</tr>
</tbody>
</table>

**DATABASES**

**Table 84: Databases**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>Name of configured database entry.</td>
</tr>
<tr>
<td>host</td>
<td>Host pgbouncer connects to.</td>
</tr>
<tr>
<td>port</td>
<td>Port pgbouncer connects to.</td>
</tr>
<tr>
<td>database</td>
<td>Actual database name pgbouncer connects to.</td>
</tr>
<tr>
<td>force_user</td>
<td>When user is part of the connection string, the connection between pgbouncer and the database server is forced to the given user, whatever the client user.</td>
</tr>
<tr>
<td>pool_size</td>
<td>Maximum number of server connections.</td>
</tr>
<tr>
<td>reserve_pool</td>
<td>The number of additional connections that can be created if the pool reaches pool_size.</td>
</tr>
<tr>
<td>pool_mode</td>
<td>The database's override pool_mode or NULL if the default will be used instead.</td>
</tr>
</tbody>
</table>
### Column Description

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>max_connections</td>
<td>Maximum number of connections for all pools for this database.</td>
</tr>
<tr>
<td>current_connections</td>
<td>The total count of connections for all pools for this database.</td>
</tr>
</tbody>
</table>

**DNS_ZONES**

**Table 85: DNS Zones in Cache**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>zonename</td>
<td>Zone name</td>
</tr>
<tr>
<td>serial</td>
<td>Current DNS serial number</td>
</tr>
<tr>
<td>count</td>
<td>Hostnames belonging to this zone</td>
</tr>
</tbody>
</table>

**FDS**

SHOW FDS is an internal command used for an online restart, for example when upgrading to a new PgBouncer version. It shows a list of file descriptors in use with the internal state attached to them. This command blocks the internal event loop, so it should not be used while PgBouncer is in use.

When the connected user has username "pgbouncer", connects through a Unix socket, and has the same UID as the running process, the actual file descriptors are passed over the connection. Note: This does not work on Windows machines.

**Table 86: FDS**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>fd</td>
<td>File descriptor numeric value.</td>
<td></td>
</tr>
<tr>
<td>task</td>
<td>One of pooler, client, or server.</td>
<td></td>
</tr>
<tr>
<td>user</td>
<td>User of the connection using the file descriptor.</td>
<td></td>
</tr>
<tr>
<td>database</td>
<td>Database of the connection using the file descriptor.</td>
<td></td>
</tr>
<tr>
<td>addr</td>
<td>IP address of the connection using the file descriptor, &quot;unix&quot; if a Unix socket is used.</td>
<td></td>
</tr>
<tr>
<td>port</td>
<td>Port used by the connection using the file descriptor.</td>
<td></td>
</tr>
<tr>
<td>cancel</td>
<td>Cancel key for this connection.</td>
<td></td>
</tr>
<tr>
<td>link</td>
<td>File descriptor for corresponding server/client. NULL if idle.</td>
<td></td>
</tr>
<tr>
<td>client_encoding</td>
<td>Character set used for the database.</td>
<td></td>
</tr>
<tr>
<td>std_strings</td>
<td>This controls whether ordinary string literals ('...') treat backslashes literally, as specified in the SQL standard.</td>
<td></td>
</tr>
<tr>
<td>datestyle</td>
<td>Display format for date and time values.</td>
<td></td>
</tr>
<tr>
<td>timezone</td>
<td>The timezone for interpreting and displaying time stamps.</td>
<td></td>
</tr>
</tbody>
</table>

**LISTS**

Shows the following PgBouncer statistics in two columns: the item label and value.
Table 87: Count of PgBouncer Items

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>databases</td>
<td>Count of databases.</td>
</tr>
<tr>
<td>users</td>
<td>Count of users.</td>
</tr>
<tr>
<td>pools</td>
<td>Count of pools.</td>
</tr>
<tr>
<td>free_clients</td>
<td>Count of free clients.</td>
</tr>
<tr>
<td>used_clients</td>
<td>Count of used clients.</td>
</tr>
<tr>
<td>login_clients</td>
<td>Count of clients in login state.</td>
</tr>
<tr>
<td>free_servers</td>
<td>Count of free servers.</td>
</tr>
<tr>
<td>used_servers</td>
<td>Count of used servers.</td>
</tr>
<tr>
<td>dns_names</td>
<td>Count of DNS names.</td>
</tr>
<tr>
<td>dns_zones</td>
<td>Count of DNS zones.</td>
</tr>
<tr>
<td>dns_queries</td>
<td>Count of DNS queries.</td>
</tr>
<tr>
<td>dns_pending</td>
<td>Count of in-flight DNS queries.</td>
</tr>
</tbody>
</table>

**MEM**

Shows cache memory information for these PgBouncer caches:

- user_cache
- db_cache
- pool_cache
- server_cache
- client_cache
- iobuf_cache

Table 88: In Memory Cache

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>Name of cache.</td>
</tr>
<tr>
<td>size</td>
<td>The size of a single slot in the cache.</td>
</tr>
<tr>
<td>used</td>
<td>Number of used slots in the cache.</td>
</tr>
<tr>
<td>free</td>
<td>The number of available slots in the cache.</td>
</tr>
<tr>
<td>memtotal</td>
<td>Total bytes used by the cache.</td>
</tr>
</tbody>
</table>

**POOLS**

A new pool entry is made for each pair of (database, user).

Table 89: Pools

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>database</td>
<td>Database name.</td>
</tr>
<tr>
<td>user</td>
<td>User name.</td>
</tr>
<tr>
<td>Column</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>cl_active</td>
<td>Client connections that are linked to server connection and can process queries.</td>
</tr>
<tr>
<td>cl_waiting</td>
<td>Client connections have sent queries but have not yet got a server connection.</td>
</tr>
<tr>
<td>sv_active</td>
<td>Server connections that linked to client.</td>
</tr>
<tr>
<td>sv_idle</td>
<td>Server connections that are unused and immediately usable for client queries.</td>
</tr>
<tr>
<td>sv_used</td>
<td>Server connections that have been idle more than server_check_delay. The server_check_query query must be run on them before they can be used.</td>
</tr>
<tr>
<td>sv_tested</td>
<td>Server connections that are currently running either server_reset_query or server_check_query.</td>
</tr>
<tr>
<td>sv_login</td>
<td>Server connections currently in process of logging in.</td>
</tr>
<tr>
<td>maxwait</td>
<td>How long the first (oldest) client in the queue has waited, in seconds. If this begins to increase, the current pool of servers does not handle requests fast enough. The cause may be either an overloaded server or the pool_size setting is too small.</td>
</tr>
<tr>
<td>pool_mode</td>
<td>The pooling mode in use.</td>
</tr>
</tbody>
</table>

**SERVERS**

Table 90: Servers

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>S, for server.</td>
</tr>
<tr>
<td>user</td>
<td>User ID that pgbouncer uses to connect to server.</td>
</tr>
<tr>
<td>database</td>
<td>Database name.</td>
</tr>
<tr>
<td>state</td>
<td>State of the pgbouncer server connection, one of active, used, or idle.</td>
</tr>
<tr>
<td>addr</td>
<td>IP address of the Greenplum or PostgreSQL server.</td>
</tr>
<tr>
<td>port</td>
<td>Port of the Greenplum or PostgreSQL server.</td>
</tr>
<tr>
<td>local_addr</td>
<td>Connection start address on local machine.</td>
</tr>
<tr>
<td>local_port</td>
<td>Connection start port on local machine.</td>
</tr>
<tr>
<td>connect_time</td>
<td>When the connection was made.</td>
</tr>
<tr>
<td>request_time</td>
<td>When the last request was issued.</td>
</tr>
<tr>
<td>ptr</td>
<td>Address of the internal object for this connection. Used as unique ID.</td>
</tr>
<tr>
<td>link</td>
<td>Address of the client connection the server is paired with.</td>
</tr>
<tr>
<td>remote_pid</td>
<td>Pid of backend server process. If the connection is made over Unix socket and the OS supports getting process ID info, it is the OS pid. Otherwise it is extracted from the cancel packet the server sent, which should be PID in case server is PostgreSQL, but it is a random number in case server is another PgBouncer.</td>
</tr>
</tbody>
</table>
**STATS**
Shows statistics.

**Table 91: Stats**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>database</td>
<td>Statistics are presented per database.</td>
</tr>
<tr>
<td>total_requests</td>
<td>Total number of SQL requests pooled by pgbouncer.</td>
</tr>
<tr>
<td>total_received</td>
<td>Total volume in bytes of network traffic received by pgbouncer.</td>
</tr>
<tr>
<td>total_sent</td>
<td>Total volume in bytes of network traffic sent by pgbouncer.</td>
</tr>
<tr>
<td>total_query_time</td>
<td>Total number of microseconds spent by pgbouncer when actively connected to the database server.</td>
</tr>
<tr>
<td>avg_req</td>
<td>Average requests per second in last stat period.</td>
</tr>
<tr>
<td>avg_recv</td>
<td>Average received (from clients) bytes per second.</td>
</tr>
<tr>
<td>avg_sent</td>
<td>Average sent (to clients) bytes per second.</td>
</tr>
<tr>
<td>avg_query</td>
<td>Average query duration in microseconds.</td>
</tr>
</tbody>
</table>

**USERS**

**Table 92: Users**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>The user name</td>
</tr>
<tr>
<td>pool_mode</td>
<td>The user’s override pool_mode, or NULL if the default will be used instead.</td>
</tr>
</tbody>
</table>

**VERSION**

Display PgBouncer version information.

**Note:** This reference documentation is based on the PgBouncer 1.6.1 documentation.
Client Utility Reference

Describes the command-line client utilities provided with Greenplum Database.

Greenplum Database uses the standard PostgreSQL client programs and provides additional client utilities for administering a distributed Greenplum Database DBMS. Greenplum Database client utilities reside in $GPHOME/bin.

The following are the Greenplum Database client utilities.

- `clusterdb`
- `createdb`
- `createtemplate`
- `createuser`
- `dropdb`
- `droptemplate`
- `dropuser`
- `pg_config`
- `pg_dump`
- `pg_dumpall`
- `pg_restore`
- `psql`
- `reindexdb`
- `vacuumdb`

**Client Utility Summary**

**clusterdb**

Reclusters tables that were previously clustered with CLUSTER.

```
clusterdb [connection-option ...] [-v] [-t table] [-d] dbname
```

```
clusterdb [connection-option ...] [-a] [-v]
```

```
clusterdb --help
```

```
clusterdb --version
```

See `clusterdb` for more information.

**createdb**

Creates a new database.

```
createdb [connection_option ...] [-D tablespace] [-E encoding]
  [-O owner] [-T template] [-e] [dbname ['description']]`
```

```
createdb --help
```

```
createdb --version
```

See `createdb` for more information.
**createlang**
Defines a new procedural language for a database.

```
createlang [connection_option ...] [-e] langname [[-d] dbname]
createlang [connection-option ...] -l dbname
createlang --help
createlang --version
```

See *createlang* for more information.

**createuser**
Creates a new database role.

```
createuser [connection_option ...] [role_attribute ...] [-e] role_name
createuser --help
createuser --version
```

See *createuser* for more information.

**dropdb**
Removes a database.

```
dropdb [connection_option ...] [-e] [-i] dbname
dropdb --help
dropdb --version
```

See *dropdb* for more information.

**droplang**
Removes a procedural language.

```
droplang [connection-option ...] [-e] langname [[-d] dbname]
droplang [connection-option ...] [-e] -l dbname
droplang --help
droplang --version
```

See *droplang* for more information.

**dropuser**
Removes a database role.

```
dropuser [connection_option ...] [-e] [-i] role_name
dropuser --help
```
**dropuser --version**

See `dropuser` for more information.

**pg_config**
Retrieves information about the installed version of Greenplum Database.

`pg_config [option ...]`

See `pg_config` for more information.

**pg_dump**
Extracts a database into a single script file or other archive file.

`pg_dump [connection_option ...] [dump_option ...] dbname`

See `pg_dump` for more information.

**pg_dumpall**
Extracts all databases in a Greenplum Database system to a single script file or other archive file.

`pg_dumpall [connection_option ...] [dump_option ...]`

See `pg_dumpall` for more information.

**pg_restore**
Restores a database from an archive file created by `pg_dump`.

`pg_restore [connection_option ...] [restore_option ...] filename`

See `pg_restore` for more information.

**psql**
Interactive command-line interface for Greenplum Database

`psql [option ...] [dbname [username]]`

See `psql` for more information.

**reindexdb**
Rebuilds indexes in a database.

`reindexdb [connection-option ...] [--table | -t table ] [--index | -i index ] [dbname]`

`reindexdb [connection-option ...] [--all | -a]`

`reindexdb [connection-option ...] [--system | -s] [dbname]`

`reindexdb --help`

`reindexdb --version`
See `reindexdb` for more information.

**vacuumdb**
Garbage-collects and analyzes a database.

```
vacuumdb [connection-option...] [--full | -f] [-F] [--verbose | -v]
    [--analyze | -z] [--table | -t] [table (column [...])]
    [dbname]
```

```
vacuumdb [connection-option...] [--all | -a] [--full | -f] [-F]
    [--verbose | -v] [--analyze | -z]
```

`vacuumdb --help`
`vacuumdb --version`

See `vacuumdb` for more information.

**clusterdb**
Reclusters tables that were previously clustered with `CLUSTER`.

**Synopsis**

```
clusterdb [connection-option ...] [-v] [-t] [table [table [...]]] [dbname]
```

```
clusterdb [connection-option ...] [-a] [-v]
```

`clusterdb --help`
`clusterdb --version`

**Description**
To cluster a table means to physically reorder a table on disk according to an index so that index scan operations can access data on disk in a somewhat sequential order, thereby improving index seek performance for queries that use that index.

The `clusterdb` utility will find any tables in a database that have previously been clustered with the `CLUSTER` SQL command, and clusters them again on the same index that was last used. Tables that have never been clustered are not affected.

`clusterdb` is a wrapper around the SQL command `CLUSTER`. Although clustering a table in this way is supported in Greenplum Database, it is not recommended because the `CLUSTER` operation itself is extremely slow.

If you do need to order a table in this way to improve your query performance, Greenplum recommends using a `CREATE TABLE AS` statement to reorder the table on disk rather than using `CLUSTER`. If you do 'cluster' a table in this way, then `clusterdb` would not be relevant.

**Options**

- `-a | --all`
  Cluster all databases.

- `[-d] dbname | [--dbname] dbname`
  Specifies the name of the database to be clustered. If this is not specified, the database name is read from the environment variable `PGDATABASE`. If that is not set, the user name specified for the connection is used.
-e | --echo
Echo the commands that `clusterdb` generates and sends to the server.

-q | --quiet
Do not display a response.

-t table | --table table
Cluster the named table only.

-v | --verbose
Print detailed information during processing.

Connection Options
-h host | --host host
The host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable PGHOST or defaults to localhost.

-p port | --port port
The TCP port on which the Greenplum master database server is listening for connections. If not specified, reads from the environment variable PGPORT or defaults to 5432.

-U username | --username username
The database role name to connect as. If not specified, reads from the environment variable PGUSER or defaults to the current system role name.

-w | --no-password
Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W | --password
Force a password prompt.

Examples
To cluster the database test:

```
clusterdb test
```

To cluster a single table foo in a database named xyzzy:

```
clusterdb --table foo xyzzy
```

See Also
`CLUSTER` in the `Greenplum Database Reference Guide`

createdb
Creates a new database.

Synopsis
```
createdb [connection_option ...] [-D tablespace] [-E encoding] [-O owner] [-T template] [-e] [dbname ['description']]
createdb --help
```
createdb --version

Description

createdb creates a new database in a Greenplum Database system.

Normally, the database user who executes this command becomes the owner of the new database. However a different owner can be specified via the --owner option, if the executing user has appropriate privileges.

createdb is a wrapper around the SQL command CREATE DATABASE.

Options
dbname

The name of the database to be created. The name must be unique among all other databases in the Greenplum system. If not specified, reads from the environment variable PGDATABASE, then PGUSER or defaults to the current system user.

description

A comment to be associated with the newly created database. Descriptions containing white space must be enclosed in quotes.

-D tablespace | --tablespace tablespace

The default tablespace for the database.

e echo

Echo the commands that createdb generates and sends to the server.

-E encoding | --encoding encoding

Character set encoding to use in the new database. Specify a string constant (such as 'UTF8'), an integer encoding number, or DEFAULT to use the default encoding. See the Greenplum Database Reference Guide for information about supported character sets.

-O owner | --owner owner

The name of the database user who will own the new database. Defaults to the user executing this command.

-T template | --template template

The name of the template from which to create the new database. Defaults to template1.

Connection Options

-h host | --host host

The host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable PGHOST or defaults to localhost.

-p port | --port port

The TCP port on which the Greenplum master database server is listening for connections. If not specified, reads from the environment variable PGPORT or defaults to 5432.

-U username | --username username

The database role name to connect as. If not specified, reads from the environment variable PGUSER or defaults to the current system role name.

-w | --no-password

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.


-\texttt{W} | \texttt{--password} \\
\hspace{1cm} Force a password prompt.

\textbf{Examples} \\

To create the database \texttt{test} using the default options:

\begin{verbatim}
createdb test
\end{verbatim}

To create the database \texttt{demo} using the Greenplum master on host \texttt{gpmaster}, port 54321, using the \texttt{LATIN1} encoding scheme:

\begin{verbatim}
createdb -p 54321 -h gpmaster -E LATIN1 demo
\end{verbatim}

\textbf{See Also} \\

\texttt{CREATE DATABASE} in the \textit{Greenplum Database Reference Guide}

\textbf{createuser} \\

Creates a new database role.

\textbf{Synopsis} \\

\begin{verbatim}
createuser [connection_option ...] [role_attribute ...] [-e] role_name
createuser --help
createuser --version
\end{verbatim}

\textbf{Description} \\

\texttt{createuser} creates a new Greenplum Database role. You must be a superuser or have the \texttt{CREATEROLE} privilege to create new roles. You must connect to the database as a superuser to create new superusers.

Superusers can bypass all access permission checks within the database, so superuser privileges should not be granted lightly.

\texttt{createuser} is a wrapper around the SQL command \texttt{CREATE ROLE}.

\textbf{Options} \\

\texttt{role_name} \\
\hspace{1cm} The name of the role to be created. This name must be different from all existing roles in this Greenplum Database installation.

\texttt{-c number | --connection-limit number} \\
\hspace{1cm} Set a maximum number of connections for the new role. The default is to set no limit.

\texttt{-D | --no-createdb} \\
\hspace{1cm} The new role will not be allowed to create databases. This is the default.

\texttt{-d | --createdb} \\
\hspace{1cm} The new role will be allowed to create databases.

\texttt{-e | --echo} \\
\hspace{1cm} Echo the commands that \texttt{createuser} generates and sends to the server.

\texttt{-E | --encrypted}
Encrypts the role’s password stored in the database. If not specified, the default password behavior is used.

-i | --inherit
The new role will automatically inherit privileges of roles it is a member of. This is the default.

-I | --no-inherit
The new role will not automatically inherit privileges of roles it is a member of.

-l | --login
The new role will be allowed to log in to Greenplum Database. This is the default.

-L | --no-login
The new role will not be allowed to log in (a group-level role).

-N | --unencrypted
Does not encrypt the role’s password stored in the database. If not specified, the default password behavior is used.

-P | --pwprompt
If given, createuser will issue a prompt for the password of the new role. This is not necessary if you do not plan on using password authentication.

-r | --createrole
The new role will be allowed to create new roles (CREATEROLE privilege).

-R | --no-createrole
The new role will not be allowed to create new roles. This is the default.

-s | --superuser
The new role will be a superuser.

-S | --no-superuser
The new role will not be a superuser. This is the default.

Connection Options
-h host | --host host
The host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable PGHOST or defaults to localhost.

-p port | --port port
The TCP port on which the Greenplum master database server is listening for connections. If not specified, reads from the environment variable PGPORT or defaults to 5432.

-U username | --username username
The database role name to connect as. If not specified, reads from the environment variable PGUSER or defaults to the current system role name.

-w | --no-password
Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W | --password
Force a password prompt.
Examples
Create a role named joe using the default options:

```
createuser joe
Shall the new role be a superuser? (y/n) n
Shall the new role be allowed to create databases? (y/n) n
Shall the new role be allowed to create more new roles? (y/n) n
CREATE ROLE
```

To create the same role `joe` using connection options and avoiding the prompts and taking a look at the underlying command:

```
createuser -h masterhost -p 54321 -S -D -R -e joe
CREATE ROLE joe NOSUPERUSER NOCREATEDB NOCREATEROLE INHERIT
LOGIN;
CREATE ROLE
```

To create the role `joe` as a superuser, and assign password `admin123` immediately:

```
createuser -P -s -e joe
Enter password for new role: admin123
Enter it again: admin123
CREATE ROLE joe PASSWORD 'admin123' SUPERUSER CREATEDB
CREATEROLE INHERIT LOGIN;
CREATE ROLE
```

In the above example, the new password is not actually echoed when typed, but we show what was typed for clarity. However the password will appear in the echoed command, as illustrated if the `--e` option is used.

See Also
CREATE ROLE in the *Greenplum Database Reference Guide*

dropdb
Removes a database.

Synopsis

```
dropdb [connection_option ...] [-e] [-i] dbname

dropdb --help

dropdb --version
```

Description
dropdb destroys an existing database. The user who executes this command must be a superuser or the owner of the database being dropped.

dropdb is a wrapper around the SQL command DROP DATABASE. See the *Greenplum Database Reference Guide* for information about DROP DATABASE.

Options
`dbname`
The name of the database to be removed.
-e | --echo
   Echo the commands that dropdb generates and sends to the server.

-i | --interactive
   Issues a verification prompt before doing anything destructive.

Connection Options
-h host | --host host
   The host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable PGHOST or defaults to localhost.

-p port | --port port
   The TCP port on which the Greenplum master database server is listening for connections. If not specified, reads from the environment variable PGPORT or defaults to 5432.

-U username | --username username
   The database role name to connect as. If not specified, reads from the environment variable PGUSER or defaults to the current system role name.

-w | --no-password
   Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W | --password
   Force a password prompt.

Examples
To destroy the database named demo using default connection parameters:

```
dropdb demo
```

To destroy the database named demo using connection options, with verification, and a peek at the underlying command:

```
dropdb -p 54321 -h masterhost -i -e demo
```

```
Database "demo" will be permanently deleted.
Are you sure? (y/n) y
DROP DATABASE "demo"
DROP DATABASE
```

See Also
DROP DATABASE in the Greenplum Database Reference Guide

droplang
Removes a procedural language.

Synopsis

droplang [connection-option ...] [-e] langname [[-d] dbname]
droplang [connection-option ...] [-e] -l dbname
droplang --help
droplang --version

Description

droplang removes an existing programming language from a database. droplang can drop any procedural language, even those not supplied by the Greenplum Database distribution.

Although programming languages can be removed directly using several SQL commands, it is recommended to use droplang because it performs a number of checks and is much easier to use.

droplang is a wrapper for the SQL command DROP LANGUAGE.

Options

langname

  Specifies the name of the programming language to be removed.

[-d] dbname | [--dbname] dbname

  Specifies from which database the language should be removed. The default is to use the PGDATABASE environment variable setting, or the same name as the current system user.

-e | --echo

  Echo the commands that droplang generates and sends to the server.

-l | --list

  Show a list of already installed languages in the target database.

Connection Options

-h host | --host host

  The host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable PGHOST or defaults to localhost.

-p port | --port port

  The TCP port on which the Greenplum master database server is listening for connections. If not specified, reads from the environment variable PGPORT or defaults to 5432.

-U username | --username username

  The database role name to connect as. If not specified, reads from the environment variable PGUSER or defaults to the current system role name.

-w | --no-password

  Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W | --password

  Force a password prompt.

Examples

To remove the language pltcl from the mydatabase database:

droplang pltcl mydatabase

See Also

DROP LANGUAGE in the Greenplum Database Reference Guide
dropuser
Removes a database role.

Synopsis

```
dropuser [connection_option ...] [-e] [-i] role_name
```

```
dropuser --help
```

```
dropuser --version
```

Description
dropuser removes an existing role from Greenplum Database. Only superusers and users with the CREATEROLE privilege can remove roles. To remove a superuser role, you must yourself be a superuser.
dropuser is a wrapper around the SQL command DROP ROLE.

Options

**role_name**
The name of the role to be removed. You will be prompted for a name if not specified on the command line.

```
-e | --echo
```
Echo the commands that dropuser generates and sends to the server.

```
-i | --interactive
```
Prompt for confirmation before actually removing the role.

Connection Options

```
-h host | --host host
```
The host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable PGHOST or defaults to localhost.

```
-p port | --port port
```
The TCP port on which the Greenplum master database server is listening for connections. If not specified, reads from the environment variable PGPORT or defaults to 5432.

```
-U username | --username username
```
The database role name to connect as. If not specified, reads from the environment variable PGUSER or defaults to the current system role name.

```
-w | --no-password
```
Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

```
-W | --password
```
Force a password prompt.

Examples

To remove the role joe using default connection options:

```
dropuser joe
```
### DROP ROLE

To remove the role `joe` using connection options, with verification, and a peek at the underlying command:

```bash
dropuser -p 54321 -h masterhost -i -e joe
```

Role "joe" will be permanently removed.
Are you sure? (y/n) y
DROP ROLE "joe"
DROP ROLE

### See Also

DROP ROLE in the *Greenplum Database Reference Guide*

### createlang

Defines a new procedural language for a database.

#### Synopsis

```
createlang [connection_option ...] [-e] langname [[-d] dbname]
createlang [connection-option ...] -l dbname
createlang --help
createlang --version
```

#### Description

The `createlang` utility adds a new programming language to a database. `createlang` is a wrapper around the SQL command `CREATE LANGUAGE`.

The procedural language packages included in the standard Greenplum Database distribution are:

- PL/pgSQL
- PL/Perl
- PL/Python

The PL/pgSQL language is registered in all databases by default.

Greenplum Database also has language handlers for PL/Java and PL/R, but those languages are not pre-installed with Greenplum Database. See the *Procedural Languages* section in the PostgreSQL documentation for more information.

#### Options

- **langname**
  
  Specifies the name of the procedural programming language to be defined.

- **[-d] dbname | [--dbname] dbname**
  
  Specifies to which database the language should be added. The default is to use the `PGDATABASE` environment variable setting, or the same name as the current system user.

- **-e | --echo**
  
  Echo the commands that `createlang` generates and sends to the server.

- **-l dbname | --list dbname**
  
  Show a list of already installed languages in the target database.

#### Connection Options
-h host | --host host
  The host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable PGHOST or defaults to localhost.

-p port | --port port
  The TCP port on which the Greenplum master database server is listening for connections. If not specified, reads from the environment variable PGPORT or defaults to 5432.

-U username | --username username
  The database role name to connect as. If not specified, reads from the environment variable PGUSER or defaults to the current system role name.

-w | --no-password
  Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

-W | --password
  Force a password prompt.

Examples
To install the language plperl into the database mytestdb:

```
createdb plperl mytestdb
```

See Also
CREATE LANGUAGE and DROP LANGUAGE in the Greenplum Database Reference Guide

pg_config
Retrieves information about the installed version of Greenplum Database.

Synopsis

```
pg_config [option ...]
```

Description
The pg_config utility prints configuration parameters of the currently installed version of Greenplum Database. It is intended, for example, to be used by software packages that want to interface to Greenplum Database to facilitate finding the required header files and libraries. Note that information printed out by pg_config is for the Greenplum Database master only.

If more than one option is given, the information is printed in that order, one item per line. If no options are given, all available information is printed, with labels.

Options

- --bindir
  Print the location of user executables. Use this, for example, to find the psql program. This is normally also the location where the pg_config program resides.

- --docdir
  Print the location of documentation files.
--includedir
Print the location of C header files of the client interfaces.

--pkgincludedir
Print the location of other C header files.

--includedir-server
Print the location of C header files for server programming.

--libdir
Print the location of object code libraries.

--pkglibdir
Print the location of dynamically loadable modules, or where the server would search for them. (Other architecture-dependent data files may also be installed in this directory.)

--localedir
Print the location of locale support files.

--mandir
Print the location of manual pages.

--sharedir
Print the location of architecture-independent support files.

--sysconfdir
Print the location of system-wide configuration files.

--pgxs
Print the location of extension makefiles.

--configure
Print the options that were given to the configure script when Greenplum Database was configured for building.

--cc
Print the value of the CC variable that was used for building Greenplum Database. This shows the C compiler used.

--cppflags
Print the value of the CPPFLAGS variable that was used for building Greenplum Database. This shows C compiler switches needed at preprocessing time.

--cflags
Print the value of the CFLAGS variable that was used for building Greenplum Database. This shows C compiler switches.

--cflags_sl
Print the value of the CFLAGS_SL variable that was used for building Greenplum Database. This shows extra C compiler switches used for building shared libraries.

--ldflags
Print the value of the LDFLAGS variable that was used for building Greenplum Database. This shows linker switches.

--ldflags_sl
Print the value of the LDFLAGS_SL variable that was used for building Greenplum Database. This shows linker switches used for building shared libraries.

--libs
Print the value of the \texttt{LIBS} variable that was used for building Greenplum Database. This normally contains \texttt{-l} switches for external libraries linked into Greenplum Database.

\texttt{--version}

Print the version of Greenplum Database.

**Examples**

To reproduce the build configuration of the current Greenplum Database installation, run the following command:

```
 eval ./configure \ 'pg\_config \ --\-configure'
```

The output of \texttt{pg\_config \ --\-configure} contains shell quotation marks so arguments with spaces are represented correctly. Therefore, using \texttt{eval} is required for proper results.

**pg\_dump**

Extracts a database into a single script file or other archive file.

**Synopsis**

\begin{verbatim}
 pg\_dump [connection\_option ...] [dump\_option ...] dbname
\end{verbatim}

**Description**

\texttt{pg\_dump} is a standard PostgreSQL utility for backing up a database, and is also supported in Greenplum Database. It creates a single (non-parallel) dump file. For routine backups of Greenplum Database, it is better to use the Greenplum Database backup utility, \texttt{gpcrondump}, for the best performance.

Use \texttt{pg\_dump} if you are migrating your data to another database vendor's system, or to another Greenplum Database system with a different segment configuration (for example, if the system you are migrating to has greater or fewer segment instances). To restore, you must use the corresponding \texttt{pg\_restore} utility (if the dump file is in archive format), or you can use a client program such as \texttt{psql} (if the dump file is in plain text format).

Since \texttt{pg\_dump} is compatible with regular PostgreSQL, it can be used to migrate data into Greenplum Database. The \texttt{pg\_dump} utility in Greenplum Database is very similar to the PostgreSQL \texttt{pg\_dump} utility, with the following exceptions and limitations:

- If using \texttt{pg\_dump} to backup a Greenplum Database database, keep in mind that the dump operation can take a long time (several hours) for very large databases. Also, you must make sure you have sufficient disk space to create the dump file.
- If you are migrating data from one Greenplum Database system to another, use the \texttt{--gp\_syntax} command-line option to include the \texttt{DISTRIBUTED BY} clause in \texttt{CREATE TABLE} statements. This ensures that Greenplum Database table data is distributed with the correct distribution key columns upon restore.

\texttt{pg\_dump} makes consistent backups even if the database is being used concurrently. \texttt{pg\_dump} does not block other users accessing the database (readers or writers).

When used with one of the archive file formats and combined with \texttt{pg\_restore}, \texttt{pg\_dump} provides a flexible archival and transfer mechanism. \texttt{pg\_dump} can be used to backup an entire database, then \texttt{pg\_restore} can be used to examine the archive and/or select which parts of the database are to be restored. The most flexible output file format is the \texttt{custom} format (\texttt{-Fc}). It allows for selection and reordering of all archived items, and is compressed by default. The tar format (\texttt{-Ft}) is not compressed and it is not possible to reorder data when loading, but it is otherwise quite flexible. It can be manipulated with standard UNIX tools such as \texttt{tar}.
Note: The `--ignore-version` option is deprecated and will be removed in a future release.

**Options**

**dbname**

Specifies the name of the database to be dumped. If this is not specified, the environment variable `PGDATABASE` is used. If that is not set, the user name specified for the connection is used.

**Dump Options**

- `a | --data-only`
  
  Dump only the data, not the schema (data definitions). This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call `pg_restore`.

- `b | --blobs`
  
  Include large objects in the dump. This is the default behavior except when `--schema`, `--table`, or `--schema-only` is specified, so the `-b` switch is only useful to add large objects to selective dumps.

- `c | --clean`
  
  Adds commands to the text output file to clean (drop) database objects prior to (the commands for) creating them. Note that objects are not dropped before the dump operation begins, but `DROP` commands are added to the DDL dump output files so that when you use those files to do a restore, the `DROP` commands are run prior to the `CREATE` commands. This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call `pg_restore`.

- `C | --create`
  
  Begin the output with a command to create the database itself and reconnect to the created database. (With a script of this form, it doesn't matter which database you connect to before running the script.) This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call `pg_restore`.

- `d | --inserts`
  
  Dump data as `INSERT` commands (rather than `COPY`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL-based databases. Also, since this option generates a separate command for each row, an error in reloading a row causes only that row to be lost rather than the entire table contents. Note that the restore may fail altogether if you have rearranged column order. The `-D` option is safe against column order changes, though even slower.

- `D | --column-inserts | --attribute-inserts`
  
  Dump data as `INSERT` commands with explicit column names (`INSERT INTO table (column, ...) VALUES ...`). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL-based databases. Also, since this option generates a separate command for each row, an error in reloading a row causes only that row to be lost rather than the entire table contents.

- `E encoding | --encoding=encoding`
  
  Create the dump in the specified character set encoding. By default, the dump is created in the database encoding. (Another way to get the same result is to set the `PGCLIENTENCODING` environment variable to the desired dump encoding.)

- `f file | --file=file`
  
  Send output to the specified file. If this is omitted, the standard output is used.

- `F p|c|t | --format=plain|custom|tar`
  
  Selects the format of the output. format can be one of the following:
p | plain — Output a plain-text SQL script file (the default).

c | custom — Output a custom archive suitable for input into `pg_restore`. This is the most flexible format in that it allows reordering of loading data as well as object definitions. This format is also compressed by default.

t | tar — Output a tar archive suitable for input into `pg_restore`. Using this archive format allows reordering and/or exclusion of database objects at the time the database is restored. It is also possible to limit which data is reloaded at restore time.

-i | --ignore-version

  **Note:** This option is deprecated and will be removed in a future release.

Ignore version mismatch between `pg_dump` and the database server. `pg_dump` can dump from servers running previous releases of Greenplum Database (or PostgreSQL), but very old versions may not be supported anymore. Use this option if you need to override the version check.

-n schema | --schema=schema

Dump only schemas matching the schema pattern; this selects both the schema itself, and all its contained objects. When this option is not specified, all non-system schemas in the target database will be dumped. Multiple schemas can be selected by writing multiple `-n` switches. Also, the schema parameter is interpreted as a pattern according to the same rules used by `psql`'s `\d` commands, so multiple schemas can also be selected by writing wildcard characters in the pattern. When using wildcards, be careful to quote the pattern if needed to prevent the shell from expanding the wildcards.

**Note:** When `-n` is specified, `pg_dump` makes no attempt to dump any other database objects that the selected schema(s) may depend upon. Therefore, there is no guarantee that the results of a specific-schema dump can be successfully restored by themselves into a clean database.

  **Note:** Non-schema objects such as blobs are not dumped when `-n` is specified. You can add blobs back to the dump with the `--blobs` switch.

-N schema | --exclude-schema=schema

Do not dump any schemas matching the schema pattern. The pattern is interpreted according to the same rules as for `-n`. `-N` can be given more than once to exclude schemas matching any of several patterns. When both `-n` and `-N` are given, the behavior is to dump just the schemas that match at least one `-n` switch but no `-N` switches. If `-N` appears without `-n`, then schemas matching `-N` are excluded from what is otherwise a normal dump.

-o | --oids

Dump object identifiers (OIDs) as part of the data for every table. Use of this option is not recommended for files that are intended to be restored into Greenplum Database.

-O | --no-owner

Do not output commands to set ownership of objects to match the original database. By default, `pg_dump` issues `ALTER OWNER` or `SET SESSION AUTHORIZATION` statements to set ownership of created database objects. These statements will fail when the script is run unless it is started by a superuser (or the same user that owns all of the objects in the script). To make a script that can be restored by any user, but will give that user ownership of all the objects, specify `-O`. This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call `pg_restore`.

-s | --schema-only

Dump only the object definitions (schema), not data.

-S username | --superuser=username
Specify the superuser user name to use when disabling triggers. This is only relevant if --disable-triggers is used. It is better to leave this out, and instead start the resulting script as a superuser.

**Note:** Greenplum Database does not support user-defined triggers.

**-t table | --table=table**

Dump only tables (or views or sequences) matching the table pattern. Specify the table in the format schema.table.

Multiple tables can be selected by writing multiple -t switches. Also, the table parameter is interpreted as a pattern according to the same rules used by psql's \d commands, so multiple tables can also be selected by writing wildcard characters in the pattern.

When using wildcards, be careful to quote the pattern if needed to prevent the shell from expanding the wildcards. The -n and -h switches have no effect when -t is used, because tables selected by -t will be dumped regardless of those switches, and non-table objects will not be dumped.

**Note:** When -t is specified, pg_dump makes no attempt to dump any other database objects that the selected table(s) may depend upon. Therefore, there is no guarantee that the results of a specific-table dump can be successfully restored by themselves into a clean database.

Also, -t cannot be used to specify a child table partition. To dump a partitioned table, you must specify the parent table name.

**-T table | --exclude-table=table**

Do not dump any tables matching the table pattern. The pattern is interpreted according to the same rules as for -t. -T can be given more than once to exclude tables matching any of several patterns. When both -t and -T are given, the behavior is to dump just the tables that match at least one -t switch but no -T switches. If -T appears without -t, then tables matching -T are excluded from what is otherwise a normal dump.

**-v | --verbose**

Specifies verbose mode. This will cause pg_dump to output detailed object comments and start/stop times to the dump file, and progress messages to standard error.

**-x | --no-privileges | --no-acl**

Prevent dumping of access privileges (GRANT/REVOKE commands).

**--disable-dollar-quoting**

This option disables the use of dollar quoting for function bodies, and forces them to be quoted using SQL standard string syntax.

**--disable-triggers**

This option is only relevant when creating a data-only dump. It instructs pg_dump to include commands to temporarily disable triggers on the target tables while the data is reloaded. Use this if you have triggers on the tables that you do not want to invoke during data reload. The commands emitted for --disable-triggers must be done as superuser. So, you should also specify a superuser name with -S, or preferably be careful to start the resulting script as a superuser. This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call pg_restore.

**Note:** Greenplum Database does not support user-defined triggers.

**--use-set-session-authorization**

Output SQL-standard SET SESSION AUTHORIZATION commands instead of ALTER OWNER commands to determine object ownership. This makes the dump more standards compatible, but depending on the history of the objects in the dump, may not restore properly. A dump using SET SESSION AUTHORIZATION will require superuser privileges to restore correctly, whereas ALTER OWNER requires lesser privileges.
--gp-syntax | --no-gp-syntax
Use --gp-syntax to dump Greenplum Database syntax in the CREATE TABLE statements. This allows the distribution policy (DISTRIBUTED BY or DISTRIBUTED RANDOMLY clauses) of a Greenplum Database table to be dumped, which is useful for restoring into other Greenplum Database systems. The default is to include Greenplum Database syntax when connected to a Greenplum Database system, and to exclude it when connected to a regular PostgreSQL system.

-Z 0..9 | --compress=0..9
Specify the compression level to use in archive formats that support compression. Currently only the custom archive format supports compression.

Connection Options
-h host | --host host
The host name of the machine on which the Greenplum Database master database server is running. If not specified, reads from the environment variable PGHOST or defaults to localhost.

-p port | --port port
The TCP port on which the Greenplum Database master database server is listening for connections. If not specified, reads from the environment variable PGPORT or defaults to 5432.

-U username | --username username
The database role name to connect as. If not specified, reads from the environment variable PGUSER or defaults to the current system role name.

-W | --password
Force a password prompt.

Notes
When a data-only dump is chosen and the option --disable-triggers is used, pg_dump emits commands to disable triggers on user tables before inserting the data and commands to re-enable them after the data has been inserted. If the restore is stopped in the middle, the system catalogs may be left in the wrong state.

Members of tar archives are limited to a size less than 8 GB. (This is an inherent limitation of the tar file format.) Therefore this format cannot be used if the textual representation of any one table exceeds that size. The total size of a tar archive and any of the other output formats is not limited, except possibly by the operating system.

The dump file produced by pg_dump does not contain the statistics used by the optimizer to make query planning decisions. Therefore, it is wise to run ANALYZE after restoring from a dump file to ensure good performance.

Examples
Dump a database called mydb into a SQL-script file:

    pg_dump mydb > db.sql

To reload such a script into a (freshly created) database named newdb:

    psql -d newdb -f db.sql

Dump a Greenplum Database in tar file format and include distribution policy information:

    pg_dump -Ft --gp-syntax mydb > db.tar
To dump a database into a custom-format archive file:

```
pg_dump -Fc mydb > db.dump
```

To reload an archive file into a (freshly created) database named `newdb`:

```
pg_restore -d newdb db.dump
```

To dump a single table named `mytab`:

```
pg_dump -t mytab mydb > db.sql
```

To specify an upper-case or mixed-case name in `-t` and related switches, you need to double-quote the name; else it will be folded to lower case. But double quotes are special to the shell, so in turn they must be quoted. Thus, to dump a single table with a mixed-case name, you need something like:

```
pg_dump -t "'MixedCaseName'" mydb > mytab.sql
```

### See Also

`pg_dumpall, pg_restore, psql`

#### pg_dumpall

Extracts all databases in a Greenplum Database system to a single script file or other archive file.

### Synopsis

```
pg_dumpall [connection_option ...] [dump_option ...]
```

### Description

`pg_dumpall` is a standard PostgreSQL utility for backing up all databases in a Greenplum Database (or PostgreSQL) instance, and is also supported in Greenplum Database. It creates a single (non-parallel) dump file. For routine backups of Greenplum Database it is better to use the Greenplum Database backup utility, `gpcrondump`, for the best performance.

`pg_dumpall` creates a single script file that contains SQL commands that can be used as input to `psql` to restore the databases. It does this by calling `pg_dump` for each database. `pg_dumpall` also dumps global objects that are common to all databases. (`pg_dump` does not save these objects.) This currently includes information about database users and groups, and access permissions that apply to databases as a whole.

Since `pg_dumpall` reads tables from all databases you will most likely have to connect as a database superuser in order to produce a complete dump. Also you will need superuser privileges to execute the saved script in order to be allowed to add users and groups, and to create databases.

The SQL script will be written to the standard output. Shell operators should be used to redirect it into a file.

`pg_dumpall` needs to connect several times to the Greenplum Database master server (once per database). If you use password authentication it is likely to ask for a password each time. It is convenient to have a `~/.pgpass` file in such cases.

Note: The `--ignore-version` option is deprecated and will be removed in a future release.

### Options

#### Dump Options

```
-a | --data-only
```
Dump only the data, not the schema (data definitions). This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call pg_restore.

-c | --clean
Output commands to clean (drop) database objects prior to (the commands for) creating them. This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call pg_restore.

-d | --inserts
Dump data as INSERT commands (rather than COPY). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL-based databases. Also, since this option generates a separate command for each row, an error in reloading a row causes only that row to be lost rather than the entire table contents. Note that the restore may fail altogether if you have rearranged column order. The -D option is safe against column order changes, though even slower.

-D | --column-inserts | --attribute-inserts
Dump data as INSERT commands with explicit column names (INSERT INTO table (column, ...) VALUES ...). This will make restoration very slow; it is mainly useful for making dumps that can be loaded into non-PostgreSQL-based databases. Also, since this option generates a separate command for each row, an error in reloading a row causes only that row to be lost rather than the entire table contents.

-F | --filespaces
Dump filespace definitions.

-f filename | --file=filename
Send output to the specified file.

-g | --globals-only
Dump only global objects (roles and tablespaces), no databases.

-i | --ignore-version
  **Note:** This option is deprecated and will be removed in a future release.
Ignore version mismatch between pg_dump and the database server. pg_dump can dump from servers running previous releases of Greenplum Database (or PostgreSQL), but very old versions may not be supported anymore. Use this option if you need to override the version check.

-o | --oids
Dump object identifiers (OIDs) as part of the data for every table. Use of this option is not recommended for files that are intended to be restored into Greenplum Database.

-O | --no-owner
Do not output commands to set ownership of objects to match the original database. By default, pg_dump issues ALTER OWNER or SET SESSION AUTHORIZATION statements to set ownership of created database objects. These statements will fail when the script is run unless it is started by a superuser (or the same user that owns all of the objects in the script). To make a script that can be restored by any user, but will give that user ownership of all the objects, specify -O. This option is only meaningful for the plain-text format. For the archive formats, you may specify the option when you call pg_restore.

-s | --schema-only
Dump only the object definitions (schema), not data.

-S username | --superuser=username
Specify the superuser user name to use when disabling triggers. This is only relevant if --disable-triggers is used. It is better to leave this out, and instead start the resulting script as a superuser.

Note: Greenplum Database does not support user-defined triggers.

-t | --tablespaces-only
Dump only tablespaces, not databases or roles.

-v | --verbose
Specifies verbose mode. This will cause `pg_dump` to output detailed object comments and start/stop times to the dump file, and progress messages to standard error.

-x | --no-privileges | --no-acl
Prevent dumping of access privileges (GRANT/REVOKE commands).

--disable-dollar-quoting
This option disables the use of dollar quoting for function bodies, and forces them to be quoted using SQL standard string syntax.

--disable-triggers
This option is only relevant when creating a data-only dump. It instructs `pg_dumpall` to include commands to temporarily disable triggers on the target tables while the data is reloaded. Use this if you have triggers on the tables that you do not want to invoke during data reload. The commands emitted for --disable-triggers must be done as superuser. So, you should also specify a superuser name with -S, or preferably be careful to start the resulting script as a superuser.

Note: Greenplum Database does not support user-defined triggers.

--resource-queues
Dump resource queue definitions.

--resource-groups
Dump resource group definitions.

--roles-only
Dump only roles, not databases, tablespaces, or filespaces.

--use-set-session-authorization
Output SQL-standard SET SESSION AUTHORIZATION commands instead of ALTER OWNER commands to determine object ownership. This makes the dump more standards compatible, but depending on the history of the objects in the dump, may not restore properly. A dump using SET SESSION AUTHORIZATION will require superuser privileges to restore correctly, whereas ALTER OWNER requires lesser privileges.

--gp-syntax
Output Greenplum Database syntax in the CREATE TABLE statements. This allows the distribution policy (DISTRIBUTED BY or DISTRIBUTED RANDOMLY clauses) of a Greenplum Database table to be dumped, which is useful for restoring into other Greenplum Database systems.

--no-gp-syntax
Do not output the table distribution clauses in the CREATE TABLE statements.

Connection Options
-h host | --host=host
The host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable PGHOST or defaults to localhost.
-l  `dbname` | `--database=dbname`
    Specifies the name of the database in which to connect to dump global objects. If not specified, the `postgres` database is used. If the `postgres` database does not exist, the `template1` database is used.

-`p`  `port` | `--port=port`
    The TCP port on which the Greenplum master database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to 5432.

-`U`  `username` | `--username=username`
    The database role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system role name.

-w
    Never prompt for a password.

-W | `--password`
    Force a password prompt.

Notes
Since `pg_dumpall` calls `pg_dump` internally, some diagnostic messages will refer to `pg_dump`.

Once restored, it is wise to run `ANALYZE` on each database so the query planner has useful statistics. You can also run `vacuumdb -a -z` to analyze all databases.

`pg_dumpall` requires all needed tablespace (filesystem) directories to exist before the restore or database creation will fail for databases in non-default locations.

Examples
To dump all databases:

```
pg_dumpall > db.out
```

To reload this file:

```
psql template1 -f db.out
```

To dump only global objects (including filesystems and resource queues):

```
pg_dumpall -g -F --resource-queues
```

See Also
`pg_dump`

`pg_restore`
Restores a database from an archive file created by `pg_dump`.

Synopsis

```
pg_restore  [connection_option ...] [restore_option ...] filename
```
Description

*pg_restore* is a utility for restoring a database from an archive created by *pg_dump* in one of the non-plain-text formats. It will issue the commands necessary to reconstruct the database to the state it was in at the time it was saved. The archive files also allow *pg_restore* to be selective about what is restored, or even to reorder the items prior to being restored.

*pg_restore* can operate in two modes. If a database name is specified, the archive is restored directly into the database. Otherwise, a script containing the SQL commands necessary to rebuild the database is created and written to a file or standard output. The script output is equivalent to the plain text output format of *pg_dump*. Some of the options controlling the output are therefore analogous to *pg_dump* options.

*pg_restore* cannot restore information that is not present in the archive file. For instance, if the archive was made using the "dump data as INSERT commands" option, *pg_restore* will not be able to load the data using COPY statements.

*Note:* The **--ignore-version** option is deprecated and will be removed in a future release.

Options

**filename**

Specifies the location of the archive file to be restored. If not specified, the standard input is used.

**Restore Options**

- **-a | --data-only**
  
  Restore only the data, not the schema (data definitions).

- **-c | --clean**
  
  Clean (drop) database objects before recreating them.

- **-C | --create**
  
  Create the database before restoring into it. (When this option is used, the database named with `-d` is used only to issue the initial `CREATE DATABASE` command. All data is restored into the database name that appears in the archive.)

- **-d dbname | --dbname=dbname**
  
  Connect to this database and restore directly into this database. The default is to use the `PGDATABASE` environment variable setting, or the same name as the current system user.

- **-e | --exit-on-error**
  
  Exit if an error is encountered while sending SQL commands to the database. The default is to continue and to display a count of errors at the end of the restoration.

- **-f outfilename | --file=outfilename**
  
  Specify output file for generated script, or for the listing when used with `-l`. Default is the standard output.

- **-F t |c | --format=tar | custom**
  
  The format of the archive produced by *pg_dump*. It is not necessary to specify the format, since *pg_restore* will determine the format automatically. Format can be either `tar` or `custom`.

- **-i | --ignore-version**
  
  *Note:* This option is deprecated and will be removed in a future release.

  Ignore database version checks.

- **-I index | --index=index**
  
  Restore definition of named index only.
-l | --list
List the contents of the archive. The output of this operation can be used with the -L option to restrict and reorder the items that are restored.

-L list-file | --use-list=list-file
Restore elements in the list-file only, and in the order they appear in the file. Lines can be moved and may also be commented out by placing a ; at the start of the line.

-n schema | --schema=schema
Restore only objects that are in the named schema. This can be combined with the -t option to restore just a specific table.

-O | --no-owner
Do not output commands to set ownership of objects to match the original database.
By default, pg_restore issues ALTER OWNER or SET SESSION AUTHORIZATION statements to set ownership of created schema elements. These statements will fail unless the initial connection to the database is made by a superuser (or the same user that owns all of the objects in the script). With -O, any user name can be used for the initial connection, and this user will own all the created objects.

-P 'function-name(argtype [, ...])' | --function='function-name(argtype [, ...])'
Restore the named function only. The function name must be enclosed in quotes. Be careful to spell the function name and arguments exactly as they appear in the dump file's table of contents (as shown by the --list option).

-s | --schema-only
Restore only the schema (data definitions), not the data (table contents). Sequence current values will not be restored, either. (Do not confuse this with the --schema option, which uses the word schema in a different meaning.)

-S username | --superuser=username
Specify the superuser user name to use when disabling triggers. This is only relevant if --disable-triggers is used.

Note: Greenplum Database does not support user-defined triggers.

-t table | --table=table
Restore definition and/or data of named table only.

-T trigger | --trigger=trigger
Restore named trigger only.

Note: Greenplum Database does not support user-defined triggers.

-v | --verbose
Specifies verbose mode.

-x | --no-privileges | --no-acl
Prevent restoration of access privileges (GRANT/REVOKE commands).

--disable-triggers
This option is only relevant when performing a data-only restore. It instructs pg_restore to execute commands to temporarily disable triggers on the target tables while the data is reloaded. Use this if you have triggers on the tables that you do not want to invoke during data reload. The commands emitted for --disable-triggers must be done as superuser. So, you should also specify a superuser name with -S, or preferably run pg_restore as a superuser.

Note: Greenplum Database does not support user-defined triggers.
--no-data-for-failed-tables

By default, table data is restored even if the creation command for the table failed (e.g., because it already exists). With this option, data for such a table is skipped. This behavior is useful when the target database may already contain the desired table contents. Specifying this option prevents duplicate or obsolete data from being loaded. This option is effective only when restoring directly into a database, not when producing SQL script output.

Connection Options
-h host | --host host

The host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable PGHOST or defaults to localhost.

-p port | --port port

The TCP port on which the Greenplum Database master database server is listening for connections. If not specified, reads from the environment variable PGPORT or defaults to 5432.

-U username | --username username

The database role name to connect as. If not specified, reads from the environment variable PGUSER or defaults to the current system role name.

-W | --password

Force a password prompt.

-1 | --single-transaction

Execute the restore as a single transaction. This ensures that either all the commands complete successfully, or no changes are applied.

Notes

If your installation has any local additions to the template1 database, be careful to load the output of pg_restore into a truly empty database; otherwise you are likely to get errors due to duplicate definitions of the added objects. To make an empty database without any local additions, copy from template0 not template1, for example:

```
CREATE DATABASE foo WITH TEMPLATE template0;
```

When restoring data to a pre-existing table and the option --disable-triggers is used, pg_restore emits commands to disable triggers on user tables before inserting the data then emits commands to re-enable them after the data has been inserted. If the restore is stopped in the middle, the system catalogs may be left in the wrong state.

pg_restore will not restore large objects for a single table. If an archive contains large objects, then all large objects will be restored.

See also the pg_dump documentation for details on limitations of pg_dump.

Once restored, it is wise to run ANALYZE on each restored table so the query planner has useful statistics.

Examples

Assume we have dumped a database called mydb into a custom-format dump file:

```
pg_dump -Fc mydb > db.dump
```

To drop the database and recreate it from the dump:

```
dropdb mydb
```
pg_restore -C -d template1 db.dump

To reload the dump into a new database called newdb. Notice there is no -C, we instead connect directly to the database to be restored into. Also note that we clone the new database from template0 not template1, to ensure it is initially empty:

createdb -T template0 newdb
pg_restore -d newdb db.dump

To reorder database items, it is first necessary to dump the table of contents of the archive:

gp_restore -l db.dump > db.list

The listing file consists of a header and one line for each item, for example,

; Archive created at Fri Jul 28 22:28:36 2006
;    dbname: mydb
;    TOC Entries: 74
;    Compression: 0
;    Dump Version: 1.4-0
;    Format: CUSTOM
;    Selected TOC Entries:
;    2; 145344 TABLE species postgres
    3; 145344 ACL species
    4; 145359 TABLE nt_header postgres
    5; 145359 ACL nt_header
    6; 145402 TABLE species_records postgres
    7; 145402 ACL species_records
    8; 145416 TABLE ss_old postgres
    9; 145416 ACL ss_old
    10; 145433 TABLE map_resolutions postgres
    11; 145433 ACL map_resolutions
    12; 145443 TABLE hs_old postgres
    13; 145443 ACL hs_old

Semicolons start a comment, and the numbers at the start of lines refer to the internal archive ID assigned to each item. Lines in the file can be commented out, deleted, and reordered. For example,

10; 145433 TABLE map_resolutions postgres
;2; 145344 TABLE species postgres
;4; 145359 TABLE nt_header postgres
6; 145402 TABLE species_records postgres
;8; 145416 TABLE ss_old postgres

Could be used as input to pg_restore and would only restore items 10 and 6, in that order:

gp_restore -L db.list db.dump

See Also

pg_dump

psql

Interactive command-line interface for Greenplum Database
Synopsis

```
psql [option ...] [dbname [username]]
```

Description

`psql` is a terminal-based front-end to Greenplum Database. It enables you to type in queries interactively, issue them to Greenplum Database, and see the query results. Alternatively, input can be from a file. In addition, it provides a number of meta-commands and various shell-like features to facilitate writing scripts and automating a wide variety of tasks.

Options

- `-a | --echo-all`
  Print all input lines to standard output as they are read. This is more useful for script processing rather than interactive mode.

- `-A | --no-align`
  Switches to unaligned output mode. (The default output mode is aligned.)

- `-c 'command' | --command 'command'`
  Specifies that `psql` is to execute the specified command string, and then exit. This is useful in shell scripts. `command` must be either a command string that is completely parseable by the server, or a single backslash command. Thus you cannot mix SQL and `psql` meta-commands with this option. To achieve that, you could pipe the string into `psql`, like this:
  
  ```
  echo '\x \ \ SELECT * FROM foo;' | psql
  ```

  (\x is the separator meta-command.)

  If the command string contains multiple SQL commands, they are processed in a single transaction, unless there are explicit `BEGIN/COMMIT` commands included in the string to divide it into multiple transactions. This is different from the behavior when the same string is fed to `psql`'s standard input.

- `-d dbname | --dbname dbname`
  Specifies the name of the database to connect to. This is equivalent to specifying `dbname` as the first non-option argument on the command line.

  If this parameter contains an equals sign, it is treated as a `conninfo` string; for example you can pass `'dbname=postgres user=username password=mypass'` as `dbname`.

- `-e | --echo-queries`
  Copy all SQL commands sent to the server to standard output as well.

- `-E | --echo-hidden`
  Echo the actual queries generated by `\d` and other backslash commands. You can use this to study `psql`'s internal operations.

- `-f filename | --file filename`
  Use a file as the source of commands instead of reading commands interactively. After the file is processed, `psql` terminates. If `filename` is `-` (hyphen), then standard input is read. Using this option is subtly different from writing `psql < filename`. In general, both will do what you expect, but using `-f` enables some nice features such as error messages with line numbers.

- `-F separator | --field-separator separator`
  Use the specified separator as the field separator for unaligned output.

- `-H | --html`
Turn on HTML tabular output.

-\ l | --list
List all available databases, then exit. Other non-connection options are ignored.

-\ L filename | --log-file filename
Write all query output into the specified log file, in addition to the normal output destination.

-\ o filename | --output filename
Put all query output into the specified file.

-\ P assignment | --pset assignment
Allows you to specify printing options in the style of \pset on the command line. Note that here you have to separate name and value with an equal sign instead of a space. Thus to set the output format to LaTeX, you could write -P format=latex.

-\ q | --quiet
Specifies that psql should do its work quietly. By default, it prints welcome messages and various informational output. If this option is used, none of this happens. This is useful with the -c option.

-\ R separator | --record-separator separator
Use separator as the record separator for unaligned output.

-\ s | --single-step
Run in single-step mode. That means the user is prompted before each command is sent to the server, with the option to cancel execution as well. Use this to debug scripts.

-\ S | --single-line
Runs in single-line mode where a new line terminates an SQL command, as a semicolon does.

-\ t | --tuples-only
Turn off printing of column names and result row count footers, etc. This command is equivalent to \pset tuples_only and is provided for convenience.

-\ T table_options | --table-attr table_options
Allows you to specify options to be placed within the HTML table tag. See \pset for details.

-\ v assignment | --set assignment | --variable assignment
Perform a variable assignment, like the \set internal command. Note that you must separate name and value, if any, by an equal sign on the command line. To unset a variable, leave off the equal sign. To just set a variable without a value, use the equal sign but leave off the value. These assignments are done during a very early stage of start-up, so variables reserved for internal purposes might get overwritten later.

-\ V | --version
Print the psql version and exit.

-\ x | --expanded
Turn on the expanded table formatting mode.

-\ X | --no-psqlrc
Do not read the start-up file (neither the system-wide psqlrc file nor the user's ~/.psqlrc file).

-\ l | --single-transaction
When psql executes a script with the -f option, adding this option wraps BEGIN/COMMIT around the script to execute it as a single transaction. This ensures that either all the commands complete successfully, or no changes are applied.
If the script itself uses \texttt{BEGIN, COMMIT, or ROLLBACK}, this option will not have the desired effects. Also, if the script contains any command that cannot be executed inside a transaction block, specifying this option will cause that command (and hence the whole transaction) to fail.

\texttt{-? | --help}

Show help about \texttt{psql} command line arguments, and exit.

\textbf{Connection Options}

\texttt{-h host | --host host}

The host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable \texttt{PGHOST} or defaults to localhost.

When starting \texttt{psql} on the master host, if the \texttt{host} value begins with a slash, it is used as the directory for the UNIX-domain socket.

\texttt{-p port | --port port}

The TCP port on which the Greenplum master database server is listening for connections. If not specified, reads from the environment variable \texttt{PGPORT} or defaults to 5432.

\texttt{-U username | --username username}

The database role name to connect as. If not specified, reads from the environment variable \texttt{PGUSER} or defaults to the current system role name.

\texttt{-W | --password}

Force a password prompt. \texttt{psql} should automatically prompt for a password whenever the server requests password authentication. However, currently password request detection is not totally reliable, hence this option to force a prompt. If no password prompt is issued and the server requires password authentication, the connection attempt will fail.

\texttt{-w --no-password}

Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a .pgpass file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

\textbf{Exit Status}

\texttt{psql} returns 0 to the shell if it finished normally, 1 if a fatal error of its own (out of memory, file not found) occurs, 2 if the connection to the server went bad and the session was not interactive, and 3 if an error occurred in a script and the variable \texttt{ON_ERROR_STOP} was set.

\textbf{Usage}

\textbf{Connecting to a Database}

\texttt{psql} is a client application for Greenplum Database. In order to connect to a database you need to know the name of your target database, the host name and port number of the Greenplum master server and what database user name you want to connect as. \texttt{psql} can be told about those parameters via command line options, namely \texttt{-d}, \texttt{-h}, \texttt{-p}, and \texttt{-U} respectively. If an argument is found that does not belong to any option it will be interpreted as the database name (or the user name, if the database name is already given). Not all these options are required; there are useful defaults. If you omit the host name, \texttt{psql} will connect via a UNIX-domain socket to a master server on the local host, or via TCP/IP to localhost on machines that do not have UNIX-domain sockets. The default master port number is 5432. If you use a different port for the master, you must specify the port. The default database user name is your UNIX user name, as is the default database name. Note that you cannot just connect to any database under any user name. Your database administrator should have informed you about your access rights.
When the defaults are not right, you can save yourself some typing by setting any or all of the environment variables `PGAPPNAME`, `PGDATABASE`, `PGHOST`, `PGPORT`, and `PGUSER` to appropriate values.

It is also convenient to have a `~/.pgpass` file to avoid regularly having to type in passwords. This file should reside in your home directory and contain lines of the following format:

```
hostname:port:database:username:password
```

The permissions on `.pgpass` must disallow any access to world or group (for example: `chmod 0600 ~/.pgpass`). If the permissions are less strict than this, the file will be ignored. (The file permissions are not currently checked on Microsoft Windows clients, however.)

If the connection could not be made for any reason (insufficient privileges, server is not running, etc.), `psql` will return an error and terminate.

**Entering SQL Commands**

In normal operation, `psql` provides a prompt with the name of the database to which `psql` is currently connected, followed by the string `=>` for a regular user or `=#` for a superuser. For example:

```
testdb=>
testdb=#
```

At the prompt, the user may type in SQL commands. Ordinarily, input lines are sent to the server when a command-terminating semicolon is reached. An end of line does not terminate a command. Thus commands can be spread over several lines for clarity. If the command was sent and executed without error, the results of the command are displayed on the screen.

**Meta-Commands**

Anything you enter in `psql` that begins with an unquoted backslash is a `psql` meta-command that is processed by `psql` itself. These commands help make `psql` more useful for administration or scripting. Meta-commands are more commonly called slash or backslash commands.

The format of a `psql` command is the backslash, followed immediately by a command verb, then any arguments. The arguments are separated from the command verb and each other by any number of whitespace characters.

To include whitespace into an argument you may quote it with a single quote. To include a single quote into such an argument, use two single quotes. Anything contained in single quotes is furthermore subject to C-like substitutions for `\n` (new line), `\t` (tab), `\digits` (octal), and `\xdigits` (hexadecimal).

If an unquoted argument begins with a colon (`:`), it is taken as a `psql` variable and the value of the variable is used as the argument instead.

Arguments that are enclosed in backquotes (`'`) are taken as a command line that is passed to the shell. The output of the command (with any trailing newline removed) is taken as the argument value. The above escape sequences also apply in backquotes.

Some commands take an SQL identifier (such as a table name) as argument. These arguments follow the syntax rules of SQL: Unquoted letters are forced to lowercase, while double quotes (`"`) protect letters from case conversion and allow incorporation of whitespace into the identifier. Within double quotes, paired double quotes reduce to a single double quote in the resulting name. For example, `FOO"BAR"BAZ` is interpreted as `fooBARbaz`, and "A weird" name becomes `A weird` name.

Parsing for arguments stops when another unquoted backslash occurs. This is taken as the beginning of a new meta-command. The special sequence `\` (two backslashes) marks the end of arguments and continues parsing SQL commands, if any. That way SQL and `psql` commands can be freely mixed on a line. But in any case, the arguments of a meta-command cannot continue beyond the end of the line.

The following meta-commands are defined:

```
\a
```
If the current table output format is unaligned, it is switched to aligned. If it is not unaligned, it is set to unaligned. This command is kept for backwards compatibility. See \pset for a more general solution.

\cd [directory]
Changes the current working directory. Without argument, changes to the current user's home directory. To print your current working directory, use \!pwd.

\C [title]
Sets the title of any tables being printed as the result of a query or unset any such title. This command is equivalent to \pset title.

\c | \connect [dbname [username] [host] [port]]
Establishes a new connection. If the new connection is successfully made, the previous connection is closed. If any of dbname, username, host or port are omitted, the value of that parameter from the previous connection is used. If the connection attempt failed, the previous connection will only be kept if psql is in interactive mode. When executing a non-interactive script, processing will immediately stop with an error. This distinction was chosen as a user convenience against typos, and a safety mechanism that scripts are not accidentally acting on the wrong database.

\conninfo
Displays information about the current connection including the database name, the user name, the type of connection (UNIX domain socket, TCP/IP, etc.), the host, and the port.

\copy {table} [(column_list)] | (query) {from | to} {filename} | stdin | stdout | pstdin | pstdout} [with] [binary] [oids] [delimiter [as] 'character'] [null [as] 'string'] [csv [header] [quote [as] 'character'] [escape [as] 'character'] [force quote column_list] [force not null column_list]]
Performs a frontend (client) copy. This is an operation that runs an SQL COPY command, but instead of the server reading or writing the specified file, psql reads or writes the file and routes the data between the server and the local file system. This means that file accessibility and privileges are those of the local user, not the server, and no SQL superuser privileges are required.

The syntax of the command is similar to that of the SQL COPY command. Note that, because of this, special parsing rules apply to the \copy command. In particular, the variable substitution rules and backslash escapes do not apply.

\copy ... from stdin | to stdout reads/writes based on the command input and output respectively. All rows are read from the same source that issued the command, continuing until \ is read or the stream reaches EOF. Output is sent to the same place as command output. To read/write from psql's standard input or output, use pstdin or pstdout. This option is useful for populating tables in-line within a SQL script file.

This operation is not as efficient as the SQL COPY command because all data must pass through the client/server connection.

\copyright
Shows the copyright and distribution terms of PostgreSQL on which Greenplum Database is based.

\d [relation_pattern] | \d+ [relation_pattern] | \dS [relation_pattern]
For each relation (table, external table, view, index, or sequence) matching the relation pattern, show all columns, their types, the tablespace (if not the default) and any special attributes such as NOT NULL or defaults, if any. Associated indexes, constraints, rules, and triggers are also shown, as is the view definition if the relation is a view.
• The command form `\d+` is identical, except that more information is displayed: any comments associated with the columns of the table are shown, as is the presence of OIDs in the table.

For partitioned tables, the command `\d` or `\d+` specified with the root partition table or child partition table displays information about the table including partition keys on the current level of the partition table. The command `\d+` also displays the immediate child partitions of the table and whether the child partition is an external table or regular table.

For append-optimized tables and column-oriented tables, `\d+` displays the storage options for a table. For append-optimized tables, the options are displayed for the table. For column-oriented tables, storage options are displayed for each column.

• The command form `\dS` is identical, except that system information is displayed as well as user information. For example, `\dt` displays user tables, but not system tables; `\dtS` displays both user and system tables. Both these commands can take the `+` parameter to display additional information, as in `\dt+` and `\dtS+`.

If `\d` is used without a pattern argument, it is equivalent to `\dtvs` which will show a list of all tables, views, and sequences.

```
\da [aggregate_pattern]
  Lists all available aggregate functions, together with the data types they operate on. If a pattern is specified, only aggregates whose names match the pattern are shown.

\db [tablespace_pattern] | \db+ [tablespace_pattern]
  Lists all available tablespaces and their corresponding filespace locations. If pattern is specified, only tablespaces whose names match the pattern are shown. If `+` is appended to the command name, each object is listed with its associated permissions.

\dc [conversion_pattern]
  Lists all available conversions between character-set encodings. If pattern is specified, only conversions whose names match the pattern are listed.

\dC
  Lists all available type casts.

\dd [object_pattern]
  Lists all available objects. If pattern is specified, only matching objects are shown.

\DD [domain_pattern]
  Lists all available domains. If pattern is specified, only matching domains are shown.

\DE [relation_pattern]
  Lists all external tables, or only those that match the pattern.

\df [function_pattern] | \df+ [function_pattern]
  Lists available functions, together with their argument and return types. If pattern is specified, only functions whose names match the pattern are shown. If the form `\df+` is used, additional information about each function, including language and description, is shown. To reduce clutter, `\df` does not show data type I/O functions. This is implemented by ignoring functions that accept or return type `cstring`.

\dg [role_pattern]
  Lists all database roles. If pattern is specified, only those roles whose names match the pattern are listed.

\distPvES [index | sequence | table | parent_table | view | external_table | system_object]
  This is not the actual command name: the letters `i`, `s`, `t`, `P`, `v`, `E`, `S` stand for index, sequence, table, parent table, view, external table, and system table, respectively. You
can specify any or all of these letters, in any order, to obtain a listing of all the matching objects. The letter $S$ restricts the listing to system objects; without $S$, only non-system objects are shown. If $+$ is appended to the command name, each object is listed with its associated description, if any. If a pattern is specified, only objects whose names match the pattern are listed.

\dl
This is an alias for \lo_list, which shows a list of large objects.

\dn [schema_pattern] | \dn+ [schema_pattern]
Lists all available schemas (namespaces). If pattern is specified, only schemas whose names match the pattern are listed. Non-local temporary schemas are suppressed. If $+$ is appended to the command name, each object is listed with its associated permissions and description, if any.

\do [operator_pattern]
Lists available operators with their operand and return types. If pattern is specified, only operators whose names match the pattern are listed.

\dp [relation_pattern_to_show_privileges]
Produces a list of all available tables, views and sequences with their associated access privileges. If pattern is specified, only tables, views and sequences whose names match the pattern are listed. The GRANT and REVOKE commands are used to set access privileges.

\dT [datatype_pattern] | \dT+ [datatype_pattern]
Lists all data types or only those that match pattern. The command form \dT+ shows extra information.

\du [role_pattern]
Lists all database roles, or only those that match pattern.

\dx [extension_pattern] | \dx+ [extension_pattern]
Lists all installed extensions, or only those that match the pattern. \dx and \dx+ are functionally equivalent.

\e | \edit [filename]
If a file name is specified, the file is edited; after the editor exits, its content is copied back to the query buffer. If no argument is given, the current query buffer is copied to a temporary file which is then edited in the same fashion. The new query buffer is then re-parsed according to the normal rules of psql, where the whole buffer is treated as a single line. (Thus you cannot make scripts this way. Use \i for that.) This means also that if the query ends with (or rather contains) a semicolon, it is immediately executed. In other cases it will merely wait in the query buffer.

psql searches the environment variables PSQL_EDITOR, EDITOR, and VISUAL (in that order) for an editor to use. If all of them are unset, vi is used on UNIX systems, notepad.exe on Windows systems.

\echo text [ ... ]
Prints the arguments to the standard output, separated by one space and followed by a newline. This can be useful to intersperse information in the output of scripts.

If you use the \o command to redirect your query output you may wish to use \qecho instead of this command.

\encoding [encoding]
Sets the client character set encoding. Without an argument, this command shows the current encoding.

\f [field_separator_string]
Sets the field separator for unaligned query output. The default is the vertical bar (\). See also \pset for a generic way of setting output options.

\g [[filename | | command ]]

Sends the current query input buffer to the server and optionally stores the query's output in a file or pipes the output into a separate UNIX shell executing command. A bare \g is virtually equivalent to a semicolon. A \g with argument is a one-shot alternative to the \o command.

\h | \help [sql_command]

Gives syntax help on the specified SQL command. If a command is not specified, then psql will list all the commands for which syntax help is available. Use an asterisk (*) to show syntax help on all SQL commands. To simplify typing, commands that consist of several words do not have to be quoted.

\H

Turns on HTML query output format. If the HTML format is already on, it is switched back to the default aligned text format. This command is for compatibility and convenience, but see \pset about setting other output options.

\i input_filename

Reads input from a file and executes it as though it had been typed on the keyboard. If you want to see the lines on the screen as they are read you must set the variable ECHO to all.

\l | \list | \l+ | \list+

List the names, owners, and character set encodings of all the databases in the server. If + is appended to the command name, database descriptions are also displayed.

\lo_export loid filename

Reads the large object with OID loid from the database and writes it to filename. Note that this is subtly different from the server function lo_export, which acts with the permissions of the user that the database server runs as and on the server's file system. Use \lo_list to find out the large object's OID.

\lo_import large_object_filename [comment]

Stores the file into a large object. Optionally, it associates the given comment with the object. Example:

```
mydb=> \lo_import '/home/gpadmin/pictures/photo.xcf' 'a picture of me'
lo_import 152801
```

The response indicates that the large object received object ID 152801 which one ought to remember if one wants to access the object ever again. For that reason it is recommended to always associate a human-readable comment with every object. Those can then be seen with the \lo_list command. Note that this command is subtly different from the server-side lo_import because it acts as the local user on the local file system, rather than the server's user and file system.

\lo_list

Shows a list of all large objects currently stored in the database, along with any comments provided for them.

\lo_unlink largeobject_oid

Deletes the large object of the specified OID from the database. Use \lo_list to find out the large object's OID.

\o [ {query_result_filename | |command} ]

Saves future query results to a file or pipes them into a UNIX shell command. If no arguments are specified, the query output will be reset to the standard output. Query
results include all tables, command responses, and notices obtained from the database server, as well as output of various backslash commands that query the database (such as \d), but not error messages. To intersperse text output in between query results, use 'echo.

\p
Print the current query buffer to the standard output.

\password [username]
Changes the password of the specified user (by default, the current user). This command prompts for the new password, encrypts it, and sends it to the server as an ALTER ROLE command. This makes sure that the new password does not appear in cleartext in the command history, the server log, or elsewhere.

\prompt [ text ] name
Prompts the user to set a variable name. Optionally, you can specify a prompt. Enclose prompts longer than one word in single quotes.

By default, \prompt uses the terminal for input and output. However, use the -f command line switch to specify standard input and standard output.

\pset print_option [value]
This command sets options affecting the output of query result tables. print_option describes which option is to be set. Adjustable printing options are:

- **format** – Sets the output format to one of unaligned, aligned, html, latex, troff-ms, or wrapped. First letter abbreviations are allowed. Unaligned writes all columns of a row on a line, separated by the currently active field separator. This is intended to create output that might be intended to be read in by other programs. Aligned mode is the standard, human-readable, nicely formatted text output that is default. The HTML and LaTeX modes put out tables that are intended to be included in documents using the respective mark-up language. They are not complete documents! (This might not be so dramatic in HTML, but in LaTeX you must have a complete document wrapper.)

  The wrapped option sets the output format like the aligned parameter, but wraps wide data values across lines to make the output fit in the target column width. The target width is set with the columns option. To specify the column width and select the wrapped format, use two \pset commands; for example, to set the with to 72 columns and specify wrapped format, use the commands \pset columns 72 and then \pset format wrapped.

  **Note:** Since psql does not attempt to wrap column header titles, the wrapped format behaves the same as aligned if the total width needed for column headers exceeds the target.

- **border** – The second argument must be a number. In general, the higher the number the more borders and lines the tables will have, but this depends on the particular format. In HTML mode, this will translate directly into the border=... attribute, in the others only values 0 (no border), 1 (internal dividing lines), and 2 (table frame) make sense.

- **columns** – Sets the target width for the wrapped format, and also the width limit for determining whether output is wide enough to require the pager. The default is zero. Zero causes the target width to be controlled by the environment variable COLUMNS, or the detected screen width if COLUMNS is not set. In addition, if columns is zero then the wrapped format affects screen output only. If columns is nonzero then file and pipe output is wrapped to that width as well.

After setting the target width, use the command \pset format wrapped to enable the wrapped format.
- **expanded | x** – Toggles between regular and expanded format. When expanded format is enabled, query results are displayed in two columns, with the column name on the left and the data on the right. This mode is useful if the data would not fit on the screen in the normal horizontal mode. Expanded mode is supported by all four output formats.

- **linestyle [unicode | ascii | old-ascii]** – Sets the border line drawing style to one of unicode, ascii, or old-ascii. Unique abbreviations, including one letter, are allowed for the three styles. The default setting is ascii. This option only affects the aligned and wrapped output formats.

  - **ascii** – uses plain ASCII characters. Newlines in data are shown using a + symbol in the right-hand margin. When the wrapped format wraps data from one line to the next without a newline character, a dot (.) is shown in the right-hand margin of the first line, and again in the left-hand margin of the following line.

  - **old-ascii** – style uses plain ASCII characters, using the formatting style used in PostgreSQL 8.4 and earlier. Newlines in data are shown using a : symbol in place of the left-hand column separator. When the data is wrapped from one line to the next without a newline character, a ; symbol is used in place of the left-hand column separator.

  - **unicode** – style uses Unicode box-drawing characters. Newlines in data are shown using a carriage return symbol in the right-hand margin. When the data is wrapped from one line to the next without a newline character, an ellipsis symbol is shown in the right-hand margin of the first line, and again in the left-hand margin of the following line.

  When the **border** setting is greater than zero, this option also determines the characters with which the border lines are drawn. Plain ASCII characters work everywhere, but Unicode characters look nicer on displays that recognize them.

- **null 'string'** – The second argument is a string to print whenever a column is null. The default is not to print anything, which can easily be mistaken for an empty string. For example, the command `\psetnull '(empty)'` displays *(empty)* in null columns.

- **fieldsep** – Specifies the field separator to be used in unaligned output mode. That way one can create, for example, tab- or comma-separated output, which other programs might prefer. To set a tab as field separator, type `\pset fieldsep '\t'`. The default field separator is '| '(a vertical bar).

- **footer** – Toggles the display of the default footer (x rows).

- **numericlocale** – Toggles the display of a locale-aware character to separate groups of digits to the left of the decimal marker. It also enables a locale-aware decimal marker.

- **recordsep** – Specifies the record (line) separator to use in unaligned output mode. The default is a newline character.

- **title [text]** – Sets the table title for any subsequently printed tables. This can be used to give your output descriptive tags. If no argument is given, the title is unset.

- **tableattr | T [text]** – Allows you to specify any attributes to be placed inside the HTML table tag. This could for example be cellpadding or bgcolor. Note that you probably don’t want to specify border here, as that is already taken care of by \pset border.

- **tuples_only | t [novalue | on | off]** – The `\pset tuples_only` command by itself toggles between tuples only and full display. The values on and off set the tuples display, regardless of the current setting. Full display may show extra information such as column headers, titles, and various footers. In tuples only mode, only actual table data is shown. The `\t` command is equivalent to `\psettuples_only` and is provided for convenience.

- **pager** – Controls the use of a pager for query and psql help output. When on, if the environment variable PAGER is set, the output is piped to the specified program.
Otherwise a platform-dependent default (such as `more`) is used. When `off`, the pager is not used. When `on`, the pager is used only when appropriate. Pager can also be set to `always`, which causes the pager to be always used.

\q
Quits the `psql` program.

\qecho text [ ... ]
This command is identical to `\echo` except that the output will be written to the query output channel, as set by `\o`.

\r
Resets (clears) the query buffer.

\s [history_filename]
Print or save the command line history to `filename`. If `filename` is omitted, the history is written to the standard output.

\set [name [value [ ... ]]]
Sets the internal variable `name` to `value` or, if more than one value is given, to the concatenation of all of them. If no second argument is given, the variable is just set with no value. To unset a variable, use the `\unset` command.

Valid variable names can contain characters, digits, and underscores. See "Variables" in Advanced Features. Variable names are case-sensitive.

Although you are welcome to set any variable to anything you want, `psql` treats several variables as special. They are documented in the topic about variables.

This command is totally separate from the SQL command `SET`.

\t [novalue | on | off]
The `\t` command by itself toggles a display of output column name headings and row count footer. The values `on` and `off` set the tuples display, regardless of the current setting. This command is equivalent to `\pset tuples_only` and is provided for convenience.

\T table_options
Allows you to specify attributes to be placed within the table tag in HTML tabular output mode.

\timing [novalue | on | off]
The `\timing` command by itself toggles a display of how long each SQL statement takes, in milliseconds. The values `on` and `off` set the time display, regardless of the current setting.

\w {filename | |command}
Outputs the current query buffer to a file or pipes it to a UNIX command.

\x
Toggles expanded table formatting mode.

\z [relation_to_show_privileges]
Produces a list of all available tables, views and sequences with their associated access privileges. If a pattern is specified, only tables, views and sequences whose names match the pattern are listed. This is an alias for `\dp`.

\! [command]
Escapes to a separate UNIX shell or executes the UNIX command. The arguments are not further interpreted, the shell will see them as is.

\?
Shows help information about the \psql\ backslash commands.

**Patterns**

The various \d commands accept a pattern parameter to specify the object name(s) to be displayed. In the simplest case, a pattern is just the exact name of the object. The characters within a pattern are normally folded to lower case, just as in SQL names; for example, \dt FOO will display the table named foo. As in SQL names, placing double quotes around a pattern stops folding to lower case. Should you need to include an actual double quote character in a pattern, write it as a pair of double quotes within a double-quote sequence; again this is in accord with the rules for SQL quoted identifiers. For example, \dt "FOO""BAR" will display the table named FOO"BAR (not foo"bar). Unlike the normal rules for SQL names, you can put double quotes around just part of a pattern, for instance \dt FOO"FOO"BAR will display the table named fooFOObar.

Within a pattern, * matches any sequence of characters (including no characters) and ? matches any single character. (This notation is comparable to UNIX shell file name patterns.) For example, \dt int* displays all tables whose names begin with int. But within double quotes, * and ? lose these special meanings and are just matched literally.

A pattern that contains a dot (\.) is interpreted as a schema name pattern followed by an object name pattern. For example, \dt foo*.bar* displays all tables whose table name starts with bar that are in schemas whose schema name starts with foo. When no dot appears, then the pattern matches only objects that are visible in the current schema search path. Again, a dot within double quotes loses its special meaning and is matched literally.

Advanced users can use regular-expression notations. All regular expression special characters work as specified in the PostgreSQL documentation on regular expressions, except for \ which is taken as a separator as mentioned above, * which is translated to the regular-expression notation .*, and ? which is translated to .\. You can emulate these pattern characters at need by writing ? for \, (R+|) for R*, or (R\) for R?\. Remember that the pattern must match the whole name, unlike the usual interpretation of regular expressions; write * at the beginning and/or end if you don't wish the pattern to be anchored. Note that within double quotes, all regular expression special characters lose their special meanings and are matched literally. Also, the regular expression special characters are matched literally in operator name patterns (such as the argument of \do{}).

Whenever the pattern parameter is omitted completely, the \d commands display all objects that are visible in the current schema search path – this is equivalent to using the pattern *. To see all objects in the database, use the pattern *.*.

**Advanced Features**

**Variables**

\psql provides variable substitution features similar to common UNIX command shells. Variables are simply name/value pairs, where the value can be any string of any length. To set variables, use the \psql meta-command \set:

```
testdb=> \set foo bar
```

sets the variable foo to the value bar. To retrieve the content of the variable, precede the name with a colon and use it as the argument of any slash command:

```
testdb=> \echo :foo
```

**Note:** The arguments of \set are subject to the same substitution rules as with other commands. Thus you can construct interesting references such as \set :foo 'something' and get 'soft links' or 'variable variables' of Perl or PHP fame, respectively. Unfortunately, there is no way to do anything useful with these constructs. On the other hand, \set bar :foo is a perfectly valid way to copy a variable.
If you call `\set` without a second argument, the variable is set, with an empty string as `value`. To unset (or delete) a variable, use the command `\unset`.

`psql`'s internal variable names can consist of letters, numbers, and underscores in any order and any number of them. A number of these variables are treated specially by `psql`. They indicate certain option settings that can be changed at run time by altering the value of the variable or represent some state of the application. Although you can use these variables for any other purpose, this is not recommended, as the program behavior might behave unexpectedly. By convention, all specially treated variables consist of all upper-case letters (and possibly numbers and underscores). To ensure maximum compatibility in the future, avoid using such variable names for your own purposes. A list of all specially treated variables are as follows:

**AUTOCOMMIT**

When on (the default), each SQL command is automatically committed upon successful completion. To postpone commit in this mode, you must enter a `BEGIN` or `START TRANSACTION` SQL command. When off or unset, SQL commands are not committed until you explicitly issue `COMMIT` or `END`. The autocommit-on mode works by issuing an implicit `BEGIN` for you, just before any command that is not already in a transaction block and is not itself a `BEGIN` or other transaction-control command, nor a command that cannot be executed inside a transaction block (such as `VACUUM`).

In autocommit-off mode, you must explicitly abandon any failed transaction by entering `ABORT` or `ROLLBACK`. Also keep in mind that if you exit the session without committing, your work will be lost.

The autocommit-on mode is PostgreSQL's traditional behavior, but autocommit-off is closer to the SQL spec. If you prefer autocommit-off, you may wish to set it in your `~/.psqlrc` file.

**DBNAME**

The name of the database you are currently connected to. This is set every time you connect to a database (including program start-up), but can be unset.

**ECHO**

If set to all, all lines entered from the keyboard or from a script are written to the standard output before they are parsed or executed. To select this behavior on program start-up, use the switch `-a`. If set to queries, `psql` merely prints all queries as they are sent to the server. The switch for this is `-e`.

**ECHO_HIDDEN**

When this variable is set and a backslash command queries the database, the query is first shown. This way you can study the Greenplum Database internals and provide similar functionality in your own programs. (To select this behavior on program start-up, use the switch `-E`.) If you set the variable to the value `noexec`, the queries are just shown but are not actually sent to the server and executed.

**ENCODING**

The current client character set encoding.

**FETCH_COUNT**

If this variable is set to an integer value > 0, the results of `SELECT` queries are fetched and displayed in groups of that many rows, rather than the default behavior of collecting the entire result set before display. Therefore only a limited amount of memory is used, regardless of the size of the result set. Settings of 100 to 1000 are commonly used when enabling this feature. Keep in mind that when using this feature, a query may fail after having already displayed some rows.

Although you can use any output format with this feature, the default aligned format tends to look bad because each group of `FETCH_COUNT` rows will be formatted separately,
leading to varying column widths across the row groups. The other output formats work better.

**HISTCONTROL**

If this variable is set to `ignorespace`, lines which begin with a space are not entered into the history list. If set to a value of `ignoredups`, lines matching the previous history line are not entered. A value of `ignoreboth` combines the two options. If unset, or if set to any other value than those above, all lines read in interactive mode are saved on the history list.

**HISTFILE**

The file name that will be used to store the history list. The default value is `~/.psql_history`. For example, putting

```
\set HISTFILE ~/.psql_history- :DBNAME
```

in `~/.psqlrc` will cause `psql` to maintain a separate history for each database.

**HISTSIZE**

The number of commands to store in the command history. The default value is 500.

**HOST**

The database server host you are currently connected to. This is set every time you connect to a database (including program start-up), but can be unset.

**IGNOREEOF**

If unset, sending an `EOF` character (usually `CTRL+D`) to an interactive session of `psql` will terminate the application. If set to a numeric value, that many `EOF` characters are ignored before the application terminates. If the variable is set but has no numeric value, the default is 10.

**LASTOID**

The value of the last affected OID, as returned from an `INSERT` or `lo_insert` command. This variable is only guaranteed to be valid until after the result of the next SQL command has been displayed.

**ON_ERROR_Rollback**

When on, if a statement in a transaction block generates an error, the error is ignored and the transaction continues. When interactive, such errors are only ignored in interactive sessions, and not when reading script files. When off (the default), a statement in a transaction block that generates an error aborts the entire transaction. The `on_error_rollback-on` mode works by issuing an implicit `SAVEPOINT` for you, just before each command that is in a transaction block, and rolls back to the savepoint on error.

**ON_ERROR_STOP**

By default, if non-interactive scripts encounter an error, such as a malformed SQL command or internal meta-command, processing continues. This has been the traditional behavior of `psql` but it is sometimes not desirable. If this variable is set, script processing will immediately terminate. If the script was called from another script it will terminate in the same fashion. If the outermost script was not called from an interactive `psql` session but rather using the `-f` option, `psql` will return error code 3, to distinguish this case from fatal error conditions (error code 1).

**PORT**

The database server port to which you are currently connected. This is set every time you connect to a database (including program start-up), but can be unset.

**PROMPT1**

**PROMPT2**

**PROMPT3**
These specify what the prompts `psql` issues should look like. See “Prompting”.

**QUIET**

This variable is equivalent to the command line option `-q`. It is not very useful in interactive mode.

**SINGLELINE**

This variable is equivalent to the command line option `-S`.

**SINGLESTEP**

This variable is equivalent to the command line option `-s`.

**USER**

The database user you are currently connected as. This is set every time you connect to a database (including program start-up), but can be unset.

**VERBOSITY**

This variable can be set to the values `default`, `verbose`, or `terse` to control the verbosity of error reports.

**SQL Interpolation**

An additional useful feature of `psql` variables is that you can substitute (interpolate) them into regular SQL statements. The syntax for this is again to prepend the variable name with a colon (`:`).

```
  testdb=> \set foo 'my_table'
  testdb=> SELECT * FROM :foo;
```

would then query the table `my_table`. The value of the variable is copied literally, so it can even contain unbalanced quotes or backslash commands. You must make sure that it makes sense where you put it. Variable interpolation will not be performed into quoted SQL entities.

A popular application of this facility is to refer to the last inserted OID in subsequent statements to build a foreign key scenario. Another possible use of this mechanism is to copy the contents of a file into a table column. First load the file into a variable and then proceed as above.

```
  testdb=> \set content ''' `cat my_file.txt` '''
  testdb=> INSERT INTO my_table VALUES (:content);
```

One problem with this approach is that `my_file.txt` might contain single quotes. These need to be escaped so that they don't cause a syntax error when the second line is processed. This could be done with the program `sed`:

```
  testdb=> \set content ''' `sed -e "s/'/''/g" < my_file.txt` '''
```

If you are using non-standard-conforming strings then you'll also need to double backslashes. This is a bit tricky:

```
  testdb=> \set content ''' `sed -e "s/'/''/g" -e "s/\\/\\\\/g" < my_file.txt` '''
```

Note the use of different shell quoting conventions so that neither the single quote marks nor the backslashes are special to the shell. Backslashes are still special to `sed`, however, so we need to double them.

Since colons may legally appear in SQL commands, the following rule applies: the character sequence `":name"` is not changed unless "name" is the name of a variable that is currently set. In any case you can escape a colon with a backslash to protect it from substitution. (The colon syntax for variables is standard SQL for embedded query languages, such as ECPG. The colon syntax for array slices and type casts are Greenplum Database extensions, hence the conflict.)
Prompting

The prompts `psql` issues can be customized to your preference. The three variables `PROMPT1`, `PROMPT2`, and `PROMPT3` contain strings and special escape sequences that describe the appearance of the prompt. Prompt 1 is the normal prompt that is issued when `psql` requests a new command. Prompt 2 is issued when more input is expected during command input because the command was not terminated with a semicolon or a quote was not closed. Prompt 3 is issued when you run an SQL `COPY` command and you are expected to type in the row values on the terminal.

The value of the selected prompt variable is printed literally, except where a percent sign (%) is encountered. Depending on the next character, certain other text is substituted instead. Defined substitutions are:

- `%M`  
The full host name (with domain name) of the database server, or `[local]` if the connection is over a UNIX domain socket, or `[local:/dir/name]`, if the UNIX domain socket is not at the compiled in default location.
- `%m`  
The host name of the database server, truncated at the first dot, or `[local]` if the connection is over a UNIX domain socket.
- `%>`  
The port number at which the database server is listening.
- `%n`  
The database session user name. (The expansion of this value might change during a database session as the result of the command `SET SESSION AUTHORIZATION`.)
- `%/`  
The name of the current database.
- `%~`  
Like `%/`, but the output is `~` (tilde) if the database is your default database.
- `%#`  
If the session user is a database superuser, then a `#`, otherwise a `>`. (The expansion of this value might change during a database session as the result of the command `SET SESSION AUTHORIZATION`.)
- `%R`  
In prompt 1 normally `=`, but `^` if in single-line mode, and `!` if the session is disconnected from the database (which can happen if `\connect` fails). In prompt 2 the sequence is replaced by `^-`, a single quote, a double quote, or a dollar sign, depending on whether `psql` expects more input because the command wasn't terminated yet, because you are inside a `/* ... */` comment, or because you are inside a quoted or dollar-escaped string. In prompt 3 the sequence doesn't produce anything.
- `%x`  
Transaction status: an empty string when not in a transaction block, or `*` when in a transaction block, or `!` when in a failed transaction block, or `?` when the transaction state is indeterminate (for example, because there is no connection).
- `%digits`  
The character with the indicated octal code is substituted.
- `%:name:`  
The value of the `psql` variable name. See "Variables" in Advanced Features for details.
- `% `command` `  
The output of command, similar to ordinary back-tick substitution.
Prompts may contain terminal control characters which, for example, change the color, background, or style of the prompt text, or change the title of the terminal window. In order for line editing to work properly, these non-printing control characters must be designated as invisible by surrounding them with [% and %]. Multiple pairs of these may occur within the prompt. For example,

testdb=> \set PROMPT1 '%[^{033[1;33;40m}]%n@%/%R%^{033[0m}]%#'

results in a boldfaced (1;) yellow-on-black (33;40) prompt on VT100-compatible, color-capable terminals. To insert a percent sign into your prompt, write %%.
Notes

`psql` only works smoothly with servers of the same version. That does not mean other combinations will fail outright, but subtle and not-so-subtle problems might come up. Backslash commands are particularly likely to fail if the server is of a different version.

Notes for Windows users

`psql` is built as a console application. Since the Windows console windows use a different encoding than the rest of the system, you must take special care when using 8-bit characters within `psql`. If `psql` detects a problematic console code page, it will warn you at startup. To change the console code page, two things are necessary:

Set the code page by entering:

```
cmd.exe /c chcp 1252
```

1252 is a character encoding of the Latin alphabet, used by Microsoft Windows for English and some other Western languages. If you are using Cygwin, you can put this command in `/etc/profile`.

Set the console font to Lucida Console, because the raster font does not work with the ANSI code page.

Examples

Start `psql` in interactive mode:

```
psql -p 54321 -U sally mydatabase
```

In `psql` interactive mode, spread a command over several lines of input. Notice the changing prompt:

```
testdb=> CREATE TABLE my_table ( 
    first integer not null default 0, 
    second text 
) ;
CREATE TABLE
```

Look at the table definition:

```
testdb=> \d my_table
    Table "my_table"
    Attribute |  Type   |      Modifier
    -----------+---------+-------------------
    first     | integer | not null default 0
    second    | text    |
```

Run `psql` in non-interactive mode by passing in a file containing SQL commands:

```
psql -f /home/gpadmin/test/myscript.sql
```

reindexdb

Rebuilds indexes in a database.

Synopsis

```
reindexdb [connection-option ...] [--table | -t table ]
    [--index | -i index ] [dbname]
reindexdb [connection-option ...] [--all | -a]
```
### reindexdb

**Description**

reindexdb is a utility for rebuilding indexes in Greenplum Database, and is a wrapper around the SQL command REINDEX.

**Options**

- **-a | --all**
  - Reindex all databases.

- **[-d] dbname | [--dbname] dbname**
  - Specifies the name of the database to be reindexed. If this is not specified and `-all` is not used, the database name is read from the environment variable `PGDATABASE`. If that is not set, the user name specified for the connection is used.

- **-e | --echo**
  - Echo the commands that `reindexdb` generates and sends to the server.

- **-i index | --index index**
  - Recreate index only.

- **-q | --quiet**
  - Do not display a response.

- **-s | --system**
  - Reindex system catalogs.

- **-t table | --table table**
  - Reindex table only.

**Connection Options**

- **-h host | --host host**
  - Specifies the host name of the machine on which the Greenplum master database server is running. If not specified, reads from the environment variable `PGHOST` or defaults to localhost.

- **-p port | --port port**
  - Specifies the TCP port on which the Greenplum master database server is listening for connections. If not specified, reads from the environment variable `PGPORT` or defaults to 5432.

- **-U username | --username username**
  - The database role name to connect as. If not specified, reads from the environment variable `PGUSER` or defaults to the current system user name.

- **-w | --no-password**
  - Never issue a password prompt. If the server requires password authentication and a password is not available by other means such as a `.pgpass` file, the connection attempt will fail. This option can be useful in batch jobs and scripts where no user is present to enter a password.

- **-W | --password**
  - Force a password prompt.
Notes
reindexdb might need to connect several times to the master server, asking for a password each time. It is convenient to have a ~/.pgpass file in such cases.

Examples
To reindex the database mydb:

reindexdb mydb

To reindex the table foo and the index bar in a database named abcd:

reindexdb --table foo --index bar abcd

See Also
REINDEX in the Greenplum Database Reference Guide

vacuumdb
Garbage-collects and analyzes a database.

Synopsis


vacuumdb --help
vacuumdb --version

Description
vacuumdb is a utility for cleaning a PostgreSQL database. vacuumdb will also generate internal statistics used by the PostgreSQL query optimizer.

vacuumdb is a wrapper around the SQL command VACUUM. There is no effective difference between vacuuming databases via this utility and via other methods for accessing the server.

Options
-a | --all
Vaccumms all databases.

[-d] dbname | [--dbname] dbname
The name of the database to vacuum. If this is not specified and -all is not used, the database name is read from the environment variable PGDATABASE. If that is not set, the user name specified for the connection is used.

-e | --echo
Echo the commands that reindexdb generates and sends to the server.

-f | --full
Selects a full vacuum, which may reclaim more space, but takes much longer and exclusively locks the table.
Warning: A VACUUM FULL is not recommended in Greenplum Database.

-F | --freeze
  Freeze row transaction information.
-q | --quiet
  Do not display a response.
-t table [(column)] | --table table [(column)]
  Clean or analyze this table only. Column names may be specified only in conjunction
  with the --analyze option. If you specify columns, you probably have to escape the
  parentheses from the shell.
-v | --verbose
  Print detailed information during processing.
-z | --analyze
  Collect statistics for use by the query planner.

Connection Options
-h host | --host host
  Specifies the host name of the machine on which the Greenplum master database server
  is running. If not specified, reads from the environment variable PGHOST or defaults to
  localhost.
-p port | --port port
  Specifies the TCP port on which the Greenplum master database server is listening for
  connections. If not specified, reads from the environment variable PGPORT or defaults to
  5432.
-U username | --username username
  The database role name to connect as. If not specified, reads from the environment
  variable PGUSER or defaults to the current system user name.
-w | --no-password
  Never issue a password prompt. If the server requires password authentication and a
  password is not available by other means such as a .pgpass file, the connection attempt
  will fail. This option can be useful in batch jobs and scripts where no user is present to
  enter a password.
-W | --password
  Force a password prompt.

Notes
vacuumdb might need to connect several times to the master server, asking for a password each time. It is
convenient to have a ~/.pgpass file in such cases.

Examples
To clean the database test:

```bash
vacuumdb test
```

To clean and analyze a database named bigdb:

```bash
vacuumdb --analyze bigdb
```
To clean a single table `foo` in a database named `mydb`, and analyze a single column `bar` of the table. Note the quotes around the table and column names to escape the parentheses from the shell:

```
vacuumdb --analyze --verbose --table 'foo(bar)' mydb
```

**See Also**

VACUUM and ANALYZE in the *Greenplum Database Reference Guide*
Additional Supplied Modules

This section describes additional modules available in the Greenplum Database contrib subdirectory.

citext Data Type

The citext module provides a case-insensitive character string type, citext. Essentially, it internally calls the lower function when comparing values. Otherwise, it behaves almost exactly like the text data type.

The standard method to perform case-insensitive matches on text values is to use the lower function when comparing values, for example

```
SELECT * FROM tab WHERE lower(col) = LOWER(?);
```

This method works well, but has drawbacks:

- It makes your SQL statements verbose, and you must remember to use lower on both the column and the query value.
- It does not work with an index, unless you create a functional index using lower.

The citext data type allows you to eliminate calls to lower in SQL queries and you can create case-insensitive indexes on columns of type citext. citext is locale-aware, like the text type, which means comparing uppercase and lowercase characters depends on the rules of the LC_CTYPE locale setting. This behavior is the same as using lower in queries, but it is done transparently by the data type, so you do not have to do anything special in your queries.

Installing citext

Before you can use the citext data type, run the installation script $GPHOME/share/postgresql/contrib/citext.sql in each database where you want to use the type:

```
$ psql -d testdb -f $GPHOME/share/postgresql/contrib/citext.sql
```

Using the citext Type

Here is a simple example defining a citext table column:

```
CREATE TABLE users (
    id bigint PRIMARY KEY,
    nick CITEXT NOT NULL,
    pass TEXT NOT NULL
) DISTRIBUTED BY (id);

INSERT INTO users VALUES (1, 'larry', md5(random()::text) );
INSERT INTO users VALUES (2, 'Tom', md5(random()::text) );
INSERT INTO users VALUES (3, 'Damian', md5(random()::text) );
INSERT INTO users VALUES (4, 'NEAL', md5(random()::text) );
INSERT INTO users VALUES (5, 'Bjørn', md5(random()::text) );

SELECT * FROM users WHERE nick = 'Larry';
```

The SELECT statement returns one tuple, even though the nick column is set to larry and the query specified Larry.
String Comparison Behavior

citext performs comparisons by converting each string to lower case (as though the lower function were called) and then comparing the results normally. Two strings are considered equal if lower would produce identical results for them.

In order to emulate a case-insensitive collation as closely as possible, there are citext-specific versions of a number of string-processing operators and functions. So, for example, the regular expression operators ~ and ~* exhibit the same behavior when applied to citext: they both match case-insensitively. The same is true for !~ and !~*, as well as for the LIKE operators ~~ and ~~*, and !~~ and !~~*.

If you want to match case-sensitively, you can cast the operator’s arguments to text.

The following functions perform matching case-insensitively if their arguments are citext:

- regexp_match()
- regexp_matches()
- regexp_replace()
- regexp_split_to_array()
- regexp_split_to_table()
- replace()
- split_part()
- strpos()
- translate()

For the regexp functions, if you want to match case-sensitively, you can specify the “c” flag to force a case-sensitive match. If you want case-sensitive behavior, you must cast to text before using one of these functions.

Limitations

- A column of type citext cannot be part of a primary key or distribution key in a CREATE TABLE statement.
- The citext type’s case-folding behavior depends on the LC_CTYPE setting of your database. How it compares values is therefore determined when the database is created. It is not truly case-insensitive in the terms defined by the Unicode standard. Effectively, what this means is that, as long as you’re happy with your collation, you should be happy with citext’s comparisons. But if you have data in different languages stored in your database, users of one language may find their query results are not as expected if the collation is for another language.
- citext is not as efficient as text because the operator functions and the B-tree comparison functions must make copies of the data and convert them to lower case for comparisons. It is, however, slightly more efficient than using lower to perform case-insensitive matching.
- citext may not be the best option if you need data to compare case-sensitively in some contexts and case-insensitively in other contexts. The standard recommendation is to use the text type and manually apply the lower function when you need to compare case-insensitively. This works if case-insensitive comparison is needed only infrequently. If you need case-insensitive behavior most of the time and case-sensitive infrequently, consider storing the data as citext and explicitly casting the column to text when you want case-sensitive comparison. In either situation, you will need two indexes if you want both types of searches to be fast.
- The schema containing the citext operators must be in the current search_path (typically public); if it is not, the normal case-sensitive text operators will be invoked instead.
**dblink Functions**

The dblink module supports connections to other Greenplum Database databases from within a database session. These databases may reside on the same database host, or on a remote host.

Greenplum Database supports dblink connections between databases in Greenplum Database installations with the same major version number. dblink may also connect to other Greenplum Database installations that use compatible libpq libraries.

dblink is intended for database users to perform short ad hoc queries in other databases. dblink is not intended for use as a replacement for external tables or for administrative tools such as gptransfer.

**Limitations**

In this release of Greenplum Database, statements that modify table data cannot use named or implicit dblink connections. Instead, you must provide the connection string directly in the dblink() function. For example:

```sql
gpadmin=# CREATE TABLE testdblocal (a int, b text) DISTRIBUTED BY (a);
CREATE TABLE

gpadmin=# INSERT INTO testdblocal select * FROM dblink('dbname=postgres', 'SELECT * FROM testdblink') AS dbltab(id int, product text);
INSERT 0 2
```

The Greenplum Database version of dblink disables the following asynchronous functions:

- dblink_send_query()
- dblink_is_busy()
- dblink_get_result()

See dblink in the PostgreSQL documentation for more information about individual functions.

**Using dblink**

The following procedure identifies the basic steps for configuring and using dblink in Greenplum Database. Refer to dblink in the PostgreSQL documentation for more information about individual dblink functions.

**Note:** You must specify both a hostname and a password to connect with dblink as a non-superuser.

1. Begin by creating a sample table to query using the dblink functions. These commands create a small table in the postgres database, which you will later query from the gpadmin database using dblink:

```bash
$ psql -d postgres
psql (8.3.23)
Type "help" for help.

postgres=# CREATE TABLE testdblink (a int, b text) DISTRIBUTED BY (a);
CREATE TABLE

postgres=# INSERT INTO testdblink VALUES (1, 'Cheese');
INSERT 0 1

postgres=# INSERT INTO testdblink VALUES (2, 'Fish');
INSERT 0 1

postgres=# \q
```

2. Log into a different database (gpadmin in this example) and install the dblink functions if they are not already available. You install the dblink functions using the $GPHOME/share/postgresql/contrib/dblink.sql script:

```
$ psql -d gpadmin
psql (8.3.23)
Type "help" for help.
gpadmin=# \i /usr/local/greenplum-db/share/postgresql/contrib/dblink.sql
SET
CREATE FUNCTION
CREATE FUNCTION
CREATE FUNCTION
CREATE FUNCTION
REVOKE
REVOKE
CREATE FUNCTION
CREATE FUNCTION
... 
```

3. Use the `dblink_connect()` function to create both implicit and named connections to other databases. The connection string that you provide should be a libpq-style keyword/value string. For example, to create a named connection to the postgres database on the local Greenplum Database system:

```
gpadmin=# SELECT dblink_connect('mylocalconn', 'dbname=postgres');
         dblink_connect
-----------
          OK
(1 row)
```

To make a connection to a remote database system, simply include host and port information in the connection string. For example, to create an implicit dblink connection to a remote system:

```
gpadmin=# SELECT dblink_connect('host=remotehost port=5432 dbname=postgres');
```

**Note:** You must specify both a hostname and a password in the connection string to connect as a non-superuser.

4. Use the basic `dblink()` function to query a database using a configured connection. Keep in mind that this function returns a record type, so you must assign the columns returned in the dblink() query.

For example, the following command uses the named connection to query the table you created in Step 1:

```
gpadmin=# SELECT * FROM dblink('mylocalconn', 'SELECT * FROM testdblink') AS dbltab(id int, product text);
 id | product
----+---------
  1 | Cheese
  2 | Fish
(2 rows)
```

**hstore Functions**

The hstore module implements a data type for storing sets of (key,value) pairs within a single Greenplum Database data field. This can be useful in various scenarios, such as rows with many attributes that are rarely examined, or semi-structured data.
In the current implementation, neither the key nor the value string can exceed 65535 bytes in length; an error will be thrown if this limit is exceeded. These maximum lengths may change in future releases.

Installing hstore

Before you can use hstore data type and functions, run the installation script `$GPHOME/share/postgresql/contrib/hstore.sql` in each database where you want the ability to query other databases:

```
$ psql -d testdb -f $GPHOME/share/postgresql/contrib/hstore.sql
```

hstore External Representation

The text representation of an hstore value includes zero or more key => value items, separated by commas. For example:

```
k => v
foo => bar, baz => whatever
"1-a" => "anything at all"
```

The order of the items is not considered significant (and may not be reproduced on output). Whitespace between items or around the => sign is ignored. Use double quotes if a key or value includes whitespace, comma, = or >. To include a double quote or a backslash in a key or value, precede it with another backslash. (Keep in mind that depending on the setting of `standard_conforming_strings`, you may need to double backslashes in SQL literal strings.)

A value (but not a key) can be a SQL NULL. This is represented as

```
key => NULL
```

The NULL keyword is not case-sensitive. Again, use double quotes if you want the string null to be treated as an ordinary data value.

Currently, double quotes are always used to surround key and value strings on output, even when this is not strictly necessary.

hstore Operators and Functions

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
<th>Example</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>hstore -&gt; text</td>
<td>get value for key (null if not present)</td>
<td>'a=&gt;x, b= &gt;y':hstore -&gt; 'a'</td>
<td>x</td>
</tr>
<tr>
<td>text =&gt; text</td>
<td>make single-item hstore</td>
<td>'a' =&gt; 'b'</td>
<td>&quot;a&quot;=&quot;b&quot;</td>
</tr>
<tr>
<td>hstore</td>
<td></td>
<td></td>
<td>hstore</td>
</tr>
<tr>
<td>hstore ? text</td>
<td>does hstore contain key?</td>
<td>'a=&gt;l':hstore ? 'a'</td>
<td>t</td>
</tr>
<tr>
<td>hstore @&gt; hstore</td>
<td>does left operand contain right?</td>
<td>'a=&gt;b, b=&gt;l, c= &gt;NULL':hstore @&gt; 'b=&gt;l'</td>
<td>t</td>
</tr>
</tbody>
</table>
### Operator

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
<th>Example</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>hstore &lt;@ hstore</td>
<td>is left operand contained in right?</td>
<td>'a=&gt;c': hstore &lt;@ 'a=&gt;b, b=&gt;1, c=&gt;NULL'</td>
<td>f</td>
</tr>
</tbody>
</table>

**Note:** The `=>` operator is deprecated and may be removed in a future release. Use the `hstore(text, text)` function instead.

### Table 94: hstore Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Return Type</th>
<th>Description</th>
<th>Example</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>hstore(text, text)</td>
<td>hstore</td>
<td>make single-item hstore</td>
<td>hstore('a', 'b')</td>
<td>&quot;a&quot;=&quot;b&quot;</td>
</tr>
<tr>
<td>akeys(hstore)</td>
<td>text[]</td>
<td>get hstore's keys as array</td>
<td>akeys('a=&gt;1,b=&gt;2')</td>
<td>(a, b)</td>
</tr>
</tbody>
</table>
| skeys(hstore) | setof text  | get hstore's keys as set     | skeys('a=>1,b=>2') | a
|               |             |                              |                  | b      |
| avals(hstore) | text[]      | get hstore's values as array | avals('a=>1,b=>2') | (1,2)  |
| svals(hstore) | setof text  | get hstore's values as set   | svals('a=>1,b=>2') | 1
|               |             |                              |                  | 2      |
| each(hstore)  | setof (key text, value text) | get hstore's keys and values as set | select * from each('a=>1,b=>2') | key | value |
|               |             |                              |                  | -----+-------|
|               |             |                              |                  | a    | 1      |
|               |             |                              |                  | b    | 2      |
| exist(hstore, text) | boolean  | does hstore contain key?     | exist('a=>1','a') | t      |
| defined(hstore, text) | boolean | does hstore contain non-null value for key? | defined('a=>NULL','a') | f      |
| delete(hstore, text) | hstore    | delete any item matching key | delete('a=>1,b=>2','b') | "a"=>"l" |

### Indexes

`hstore` has index support for `@>` and `?` operators. You can use the GiST index type. For example:

```
CREATE INDEX hidx ON testhstore USING GIST(h);
```

### Examples

Add a key, or update an existing key with a new value:

```
UPDATE tab SET h = h || ('c' => '3');
```
Delete a key:

```sql
UPDATE tab SET h = delete(h, 'k1');
```

Statistics

The `hstore` type, because of its intrinsic liberality, could contain a lot of different keys. Checking for valid keys is the task of the application. Examples below demonstrate several techniques for checking keys and obtaining statistics.

Simple example:

```sql
SELECT * FROM each('aaa=>bq, b=>NULL, ""=>1');
```

Using a table:

```sql
SELECT (each(h)).key, (each(h)).value INTO stat FROM testhstore;
```

Online statistics:

```sql
SELECT key, count(*) FROM
  (SELECT (each(h)).key FROM testhstore) AS stat
GROUP BY key
ORDER BY count DESC, key;
```

<table>
<thead>
<tr>
<th>key</th>
<th>count</th>
</tr>
</thead>
<tbody>
<tr>
<td>line</td>
<td>883</td>
</tr>
<tr>
<td>query</td>
<td>207</td>
</tr>
<tr>
<td>pos</td>
<td>203</td>
</tr>
<tr>
<td>node</td>
<td>202</td>
</tr>
<tr>
<td>space</td>
<td>197</td>
</tr>
<tr>
<td>status</td>
<td>195</td>
</tr>
<tr>
<td>public</td>
<td>194</td>
</tr>
<tr>
<td>title</td>
<td>190</td>
</tr>
<tr>
<td>org</td>
<td>189</td>
</tr>
<tr>
<td>.......</td>
<td>.......</td>
</tr>
</tbody>
</table>

**Oracle Compatibility Functions**

Describes the Oracle Compatibility SQL functions in Greenplum Database. These functions target PostgreSQL.

**Installing Oracle Compatibility Functions**

Before using any Oracle Compatibility Functions, run the installation script `$GPHOME/share/postgresql/contrib/orafunc.sql` once for each database. For example, to install the functions in database `testdb`, use the following command:

```bash
$ psql -d testdb -f $GPHOME/share/postgresql/contrib/orafunc.sql
```

To uninstall Oracle Compatibility Functions, run the `uninstall_orafunc.sql` script:

```bash
$GPHOME/share/postgresql/contrib/uninstall_orafunc.sql
```

The following functions are available by default and do not require running the Oracle Compatibility installer:

- `sinh`
- `tanh`
- `cosh`
- `decode`

**Note:** The Oracle Compatibility Functions reside in the `oracompat` schema. To access them, prefix the schema name (`oracompat`) or alter the database search path to include the schema name. For example:

```
ALTER DATABASE db_name SET search_path = $user, public, oracompat;
```

If you alter the database search path, you must restart the database.

**Oracle and Greenplum Implementation Differences**

There are some differences in the implementation of these compatibility functions in the Greenplum Database from the Oracle implementation. If you use validation scripts, the output may not be exactly the same as in Oracle. Some of the differences are as follows:

- Oracle performs a decimal round off, Greenplum Database does not:
  - 2.00 becomes 2 in Oracle.
  - 2.0.0 remains 2.00 in Greenplum Database.
- The provided Oracle Compatibility functions handle implicit type conversions differently. For example, using the `decode` function:

  ```
  decode(expression, value, return [,value, return]... [, default])
  ```

  Oracle automatically converts `expression` and each `value` to the datatype of the first `value` before comparing. Oracle automatically converts `return` to the same datatype as the first result.

  The Greenplum implementation restricts `return` and `default` to be of the same data type. The `expression` and `value` can be different types if the data type of `value` can be converted into the data type of the `expression`. This is done implicitly. Otherwise, `decode` fails with an `invalid input syntax` error. For example:

  ```
  SELECT decode('M',true,false);
  CASE
  ------
  f
  (1 row)
  SELECT decode(1,'M',true,false);
  ERROR: Invalid input syntax for integer:"M"
  LINE 1: SELECT decode(1,'M',true,false);
  ```

- Numbers in `bigint` format are displayed in scientific notation in Oracle, but not in Greenplum Database:
  - 9223372036854775 displays as 9.2234E+15 in Oracle.
  - 9223372036854775 remains 9223372036854775 in Greenplum Database.
- The default date and timestamp format in Oracle is different than the default format in Greenplum Database. If the following code is executed:

  ```
  CREATE TABLE TEST(date1 date, time1 timestamp, time2 timestamp with timezone);
  INSERT INTO TEST VALUES ('2001-11-11','2001-12-13 01:51:15','2001-12-13 01:51:15 -08:00');
  SELECT DECODE(date1, '2001-11-11', '2001-01-01') FROM TEST;
  ```

  Greenplum Database returns the row, but Oracle does not return any rows.
Note: The correct syntax in Oracle to return the row is:

```sql
SELECT DECODE(to_char(date1, 'YYYY-MM-DD'), '2001-11-11', '2001-01-01') FROM TEST
```

### Oracle Compatibility Functions Reference

The following are the Oracle Compatibility Functions.

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<th>nanvl</th>
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</thead>
<tbody>
<tr>
<td>bitand</td>
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<td>concat</td>
<td>next_day (2)</td>
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<td>cosh</td>
<td>nlssort</td>
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<tr>
<td>decode</td>
<td>nvl</td>
</tr>
<tr>
<td>dump</td>
<td>nvl2</td>
</tr>
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<td>oracle.substr</td>
</tr>
<tr>
<td>last_day</td>
<td>reverse</td>
</tr>
<tr>
<td>listagg</td>
<td>round</td>
</tr>
<tr>
<td>listagg (2)</td>
<td>sinh</td>
</tr>
<tr>
<td>lnnvl</td>
<td>tanh</td>
</tr>
<tr>
<td>months_between</td>
<td>trunc</td>
</tr>
</tbody>
</table>

### add_months

Oracle-compliant function to add a given number of months to a given date.

**Synopsis**

```sql
add_months(date_expression, months_to_add)
```

**Description**

This Oracle-compatible function adds `months_to_add` to a `date_expression` and returns a `DATE`.

If the `date_expression` specifies the last day of the month, or if the resulting month has fewer days than the `date_expression`, then the returned value is the last day of the resulting month. Otherwise, the returned value has the same day of the month as the `date_expression`.

**Parameters**

- `date_expression`
  
  The starting date. This can be any expression that can be implicitly converted to `DATE`.

- `months_to_add`
  
  The number of months to add to the `date_expression`. This is an integer or any value that can be implicitly converted to an integer. This parameter can be positive or negative.

### Example

```sql
SELECT name, phone, nextcalldate FROM clientdb
```
WHERE nextcalldate >= add_months(CURRENT_DATE,6);

Returns name, phone, and nextcalldate for all records where nextcalldate is at least six months in the future.

Compatibility
This command is compatible with Oracle syntax and is provided for convenience.

`bitand`
Oracle-compliant function that computes a logical AND operation on the bits of two non-negative values.

**Synopsis**

`bitand(expr1, expr2)`

**Description**
This Oracle-compatible function returns an integer representing an AND operation on the bits of two non-negative values (`expr1` and `expr2`). 1 is returned when the values are the same. 0 is returned when the values are different. Only significant bits are compared. For example, an AND operation on the integers 5 (binary 101) and 1 (binary 001 or 1) compares only the rightmost bit, and results in a value of 1 (binary 1).

The types of `expr1` and `expr2` are NUMBER, and the result is of type NUMBER. If either argument is NULL, the result is NULL.

The arguments must be in the range $-(2^{(n-1)}) .. ((2^{(n-1)})-1)$. If an argument is out of this range, the result is undefined.

**Note:**
- The current implementation of BITAND defines n = 128.
- PL/SQL supports an overload of BITAND for which the types of the inputs and of the result are all BINARY_INTEGER and for which n = 32.

**Parameters**

`expr1`
A non-negative integer expression.

`expr2`
A non-negative integer expression.

**Example**

```
SELECT bitand(expr1, expr2)
FROM ClientDB;
```

Compatibility
This command is compatible with Oracle syntax and is provided for convenience.

`concat`
Oracle-compliant function to concatenate two strings together.
Synopsis
concat (string1, string2)

Description
This Oracle-compatible function concatenates two strings (string1 and string2) together.
The string returned is in the same character set as string1. Its datatype depends on the datatypes of the arguments.
In concatenations of two different datatypes, the datatype returned is the one that results in a lossless conversion. Therefore, if one of the arguments is a LOB, then the returned value is a LOB. If one of the arguments is a national datatype, then the returned value is a national datatype. For example:

<table>
<thead>
<tr>
<th>Function</th>
<th>Datatype</th>
</tr>
</thead>
<tbody>
<tr>
<td>concat(CLOB, NCLOB)</td>
<td>returns NCLOB</td>
</tr>
<tr>
<td>concat(NCLOB, NCHAR)</td>
<td>returns NCLOB</td>
</tr>
<tr>
<td>concat(NCLOB, CHAR)</td>
<td>returns NCLOB</td>
</tr>
<tr>
<td>concat(NCHAR, CLOB)</td>
<td>returns NCLOB</td>
</tr>
</tbody>
</table>

This function is equivalent to the concatenation operator (||).

Parameters
string1/string2
    The two strings to concatenate together.
    Both string1 and string2 can be any of the datatypes CHAR, VARCHAR2, NCHAR, NVARCHAR2, CLOB, or NCLOB.

Example

```
SELECT concat(concat(last_name, '''s job category is '),
              job_id)
FROM employees
```

Returns 'Smith's job category is 4B'

Compatibility
This command is compatible with Oracle syntax and is provided for convenience.

cosh
Oracle-compliant function to return the hyperbolic cosine of a given number.

Synopsis
cosh(float8)

Description
This Oracle-compatible function returns the hyperbolic cosine of the floating 8 input number (float8).

Note: This function is available by default and can be accessed without running the Oracle Compatibility installer.

Parameters
float8
The input number.

**Example**

```
SELECT cosh(0.2)
FROM ClientDB;
```

Returns '1.02006675561908' (hyperbolic cosine of 0.2)

**Compatibility**

This command is compatible with Oracle syntax and is provided for convenience.

**decode**

Oracle-compliant function to transform a data value to a specified return value. This function is a way to implement a set of `CASE` statements.

- **Note:** `decode` is converted into a reserved word in Greenplum Database. If you want to use the Postgres two-argument `decode` function that decodes binary strings previously encoded to ASCII-only representation, you must invoke it by using the full schema-qualified syntax, `pg_catalog.decode()`, or by enclosing the function name in quotes "decode" ()

- **Note:** Greenplum's implementation of this function transforms `decode` into `case`.

This results in the following type of output:

```
gptest=# select decode(a, 1, 'A', 2, 'B', 'C') from decodetest;
            case
           -------
           |   C   |
           |   A   |
           |   B   |
           |   C   |
           ------
(5 rows)
```

This also means that if you deparse your view with `decode`, you will see `case` expression instead.

You should use the `case` function instead of `decode`.

**Synopsis**

```
decode(expression, value, return [, value, return]... [, default])
```

**Description**

The Oracle-compatible function `decode` searches for a value in an expression. If the value is found, the function returns the specified value.

- **Note:** This function is available by default and can be accessed without running the Oracle Compatibility installer.

**Parameters**

- **expression**
  - The expression to search.

- **value**
The value to find in the expression.

**return**
What to return if expression matches value.

**default**
What to return if expression does not match any of the values.

Only one expression is passed to the function. Multiple value/return pairs can be passed.

The default parameter is optional. If default is not specified and if expression does not match any of the passed value parameters, decode returns null. The Greenplum implementation restricts return and default to be of the same data type. The expression and value can be different types if the data type of value can be converted into the data type of the expression. This is done implicitly. Otherwise, decode fails with an invalid input syntax error.

**Examples**

In the following code, decode searches for a value for company_id and returns a specified value for that company. If company_id is not one of the listed values, the default value Other is returned.

```sql
SELECT decode(company_id, 1, 'EMC',
               2, 'Greenplum',
               'Other')
FROM suppliers;
```

The following code using CASE statements to produce the same result as the example using decode.

```sql
SELECT CASE company_id
        WHEN IS NOT DISTINCT FROM 1 THEN 'EMC'
        WHEN IS NOT DISTINCT FROM 2 THEN 'Greenplum'
        ELSE 'Other'
END
FROM suppliers;
```

**Notes**

To assign a range of values to a single return value, either pass an expression for each value in the range, or pass an expression that evaluates identically for all values in the range. For example, if a fiscal year begins on August 1, the quarters are shown in the following table.

**Table 95: Months and Quarters for Fiscal Year Beginning on August 1**

<table>
<thead>
<tr>
<th>Range (Alpha)</th>
<th>Range (Numeric)</th>
<th>Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>August — October</td>
<td>8 — 10</td>
<td>Q1</td>
</tr>
<tr>
<td>November — January</td>
<td>11 — 1</td>
<td>Q2</td>
</tr>
<tr>
<td>February — April</td>
<td>2 — 4</td>
<td>Q3</td>
</tr>
<tr>
<td>May — July</td>
<td>5 — 7</td>
<td>Q4</td>
</tr>
</tbody>
</table>

The table contains a numeric field curr_month that holds the numeric value of a month, 1 – 12. There are two ways to use decode to get the quarter:

- **Method 1** - Include 12 values in the decode function:

```sql
SELECT decode(curr_month, 1, 'Q2',
              2, 'Q3',
              3, 'Q3',
              /* other values */
              11, 'Q2',
              12, 'Q2')
```
Method 2 - Use an expression that defines a unique value to decode:

```sql
SELECT decode((1+MOD(curr_month+4,12)/3)::int, 1, 'Q1',
            2, 'Q2',
            3, 'Q3',
            4, 'Q4',
    FROM suppliers;
```

**Compatibility**

This command is compatible with Oracle syntax and is provided for convenience.

**See Also**

PostgreSQL `decode` (not compatible with Oracle)

dump

Oracle-compliant function that returns a text value that includes the datatype code, the length in bytes, and the internal representation of the expression.

**Synopsis**

```
dump(expression [,integer])
```

**Description**

This Oracle-compatible function returns a text value that includes the datatype code, the length in bytes, and the internal representation of the expression.

**Parameters**

`expression`

Any expression

`integer`

The number of characters to return

**Example**

```
dump('Tech') returns 'Typ=96 Len=4: 84,101,99,104'
dump('tech') returns 'Typ=96 Len=4: 84,101,99,104'
dump('Tech', 10) returns 'Typ=96 Len=4: 84,101,99,104'
dump('Tech', 16) returns 'Typ=96 Len=4: 54,65,63,68'
```
dump('Tech', 1016) returns 'Typ=96 Len=4 CharacterSet=US7ASCII: 54,65,63,68'
dump('Tech', 1017) returns 'Typ=96 Len=4 CharacterSet=US7ASCII: T,e,c,h'

Compatibility
This command is compatible with Oracle syntax and is provided for convenience.

instr
Oracle-compliant function to return the location of a substring in a string.

Synopsis

instr(string, substring, [position[,occurrence]])

Description
This Oracle-compatible function searches for a substring in a string. If found, it returns an integer indicating the position of the substring in the string, if not found, the function returns 0.

Optionally you can specify that the search starts at a given position in the string, and only return the nth occurrence of the substring in the string.

instr calculates strings using characters as defined by the input character set.

The value returned is of NUMBER datatype.

Parameters

string
The string to search.

substring
The substring to search for in string.

Both string and substring can be any of the datatypes CHAR, VARCHAR2, NCHAR, NVARCHAR2, CLOB, or NCLOB.

position
The position is a nonzero integer in string where the search will start. If not specified, this defaults to 1. If this value is negative, the function counts backwards from the end of string then searches towards to beginning from the resulting position.

occurrence
Occurrence is an integer indicating which occurrence of the substring should be searched for. The value of occurrence must be positive.

Both position and occurrence must be of datatype NUMBER, or any datatype that can be implicitly converted to NUMBER, and must resolve to an integer. The default values of both position and occurrence are 1, meaning that the search begins at the first character of string for the first occurrence of substring. The return value is relative to the beginning of string, regardless of the value of position, and is expressed in characters.

Examples

SELECT instr('Greenplum', 'e')
FROM ClientDB;
Returns 3; the first occurrence of 'e'

```
SELECT instr('Greenplum', 'e',1,2)
FROM ClientDB;
```

Returns 4; the second occurrence of 'e'

**Compatibility**
This command is compatible with Oracle syntax and is provided for convenience.

**last_day**
Oracle-compliant function to return the last day in a given month.

**Synopsis**

```
last_day(date_expression)
```

**Description**
This Oracle-compatible function returns the last day of the month specified by a `date_expression`.
The return type is always `DATE`, regardless of the datatype of `date_expression`.

**Parameters**

- `date_expression`
The date value used to calculate the last day of the month. This can be any expression that can be implicitly converted to `DATE`.

**Example**

```
SELECT name, hiredate, last_day(hiredate) "Option Date"
FROM employees;
```

Returns the `name`, `hiredate`, and `last_day` of the month of `hiredate` labeled "Option Date."

**Compatibility**
This command is compatible with Oracle syntax and is provided for convenience.

**listagg**
Oracle-compliant function that aggregates text values into a string.

**Note:** This function is an overloaded function. There are two Oracle-compliant `listagg` functions, one that takes one argument, the text to be aggregated (see below), and one that takes two arguments, the text to be aggregated and a delimiter (see next page).

**Synopsis**

```
listagg(text)
```

**Description**
This Oracle-compatible function aggregates text values into a string.
Parameters

text

The text value to be aggregated into a string.

Example

```
SELECT listagg(t) FROM (VALUES('abc'), ('def')) as l(t)
```

Returns: abcdef

Compatibility

This command is compatible with Oracle syntax and is provided for convenience.

listagg (2)

Oracle-compliant function that aggregates text values into a string, separating each by the separator specified in a second argument.

Note: This function is an overloaded function. There are two Oracle-compliant listagg functions, one that takes one argument, the text to be aggregated (see previous page), and one that takes two arguments, the text to be aggregated and a delimiter (see below).

Synopsis

```
listagg(text, separator)
```

Description

This Oracle-compatible function aggregates text values into a string, separating each by the separator specified in a second argument (separator).

Parameters

text

The text value to be aggregated into a string.

separator

The separator by which to delimit the text values.

Example

```
SELECT oracompat.listagg(t, '.') FROM (VALUES('abc'), ('def')) as l(t)
```

Returns: abc.def

Compatibility

This command is compatible with Oracle syntax and is provided for convenience.

lnnv1

Oracle-compliant function that returns true if the argument is false or NULL, or false.
**Synopsis**

\[
\text{lnnv1}(\text{condition})
\]

**Description**

This Oracle-compatible function takes as an argument a condition and returns `true` if the condition is false or `NULL` and `false` if the condition is true.

**Parameters**

\[
\text{condition}
\]

Any condition that evaluates to `true`, `false`, or `NULL`.

**Example**

```sql
SELECT lnnvl(true)
```

Returns: `false`

```sql
SELECT lnnvl(NULL)
```

Returns: `true`

```sql
SELECT lnnvl(false)
```

Returns: `true`

```sql
SELECT (3=5)
```

Returns: `true`

**Compatibility**

This command is compatible with Oracle syntax and is provided for convenience.

**months_between**

Oracle-compliant function to evaluate the number of months between two given dates.

**Synopsis**

\[
\text{months_between}(\text{date_expression1}, \text{date_expression2})
\]

**Description**

This Oracle-compatible function returns the number of months between `date_expression1` and `date_expression2`.

If `date_expression1` is later than `date_expression2`, then the result is positive.

If `date_expression1` is earlier than `date_expression2`, then the result is negative.

If `date_expression1` and `date_expression2` are either the same days of the month or both last days of months, then the result is always an integer. Otherwise the function calculates the fractional portion of the month based on a 31-day month.
Parameters

date_expression1, date_expression2

The date values used to calculate the number of months. This can be any expression that can be implicitly converted to DATE.

Examples

SELECT months_between
    (to_date ('2003/07/01', 'yyyy/mm/dd'),
    to_date ('2003/03/14', 'yyyy/mm/dd'));

Returns the number of months between July 1, 2003 and March 14, 2014.

SELECT * FROM employees
    where months_between(hire_date, leave_date) <12;

Returns the number of months between hire_date and leave_date.

Compatibility

This command is compatible with Oracle syntax and is provided for convenience.

nanvl

Oracle-compliant function to substitute a value for a floating point number when a non-number value is encountered.

Synopsis

nanvl(float1, float2)

Description

This Oracle-compatible function evaluates a floating point number (float1) such as BINARY_FLOAT or BINARY_DOUBLE. If it is a non-number ('not a number', NaN), the function returns float2. This function is most commonly used to convert non-number values into either NULL or 0.

Parameters

float1

The BINARY_FLOAT or BINARY_NUMBER to evaluate.

float2

The value to return if float1 is not a number.

float1 and float2 can be any numeric datatype or any nonnumeric datatype that can be implicitly converted to a numeric datatype. The function determines the argument with the highest numeric precedence, implicitly converts the remaining arguments to that datatype, and returns that datatype.

Example

SELECT nanvl(binary1, 0)
FROM MyDB;

Returns 0 if the binary1 field contained a non-number value. Otherwise, it would return the binary1 value.
Compatibility
This command is compatible with Oracle syntax and is provided for convenience.

next_day
Oracle-compliant function to return the date of the next specified weekday after a date.
This section describes using this function with a string argument; see the following page for details about
using this function with an integer argument.

Note: This function is an overloaded function. There are two Oracle-compliant next_day
functions, one that takes a date and a day of the week as its arguments (see below), and one that
takes a date and an integer as its arguments (see next page).

Synopsis

next_day(date_expression, day_of_the_week)

Description
This Oracle-compatible function returns the first day_of_the_week (Tuesday, Wednesday, etc.) to occur
after a date_expression.
The weekday must be specified in English.
The case of the weekday is irrelevant.
The return type is always DATE, regardless of the datatype of date_expression.

Parameters
date_expression
The starting date. This can be any expression that can be implicitly converted to DATE.
day_of_the_week
A string containing the name of a day, in English; for example 'Tuesday'. day_of_the_week
is case-insensitive.

Example

SELECT name, next_day(hiredate,"MONDAY") "Second Week Start"
FROM employees;

Returns the name and the date of the next Monday after hiredate labeled "Second Week Start".

Compatibility
This command is compatible with Oracle syntax and is provided for convenience.

next_day (2)
Oracle-compliant function to add a given number of days to a date and returns the date of the following
day.

Note: This function is an overloaded function. There are two Oracle next_day functions, one that
takes a date and a day of the week as its arguments (see previous page), and one that takes a date
and an integer as its arguments (see below).
Synopsis

next_day(date_expression, days_to_add)

Description

This Oracle-compatible function adds the number of days_to_add to a date_expression and returns the date of the day after the result.

The return type is always DATE, regardless of the datatype of date_expression.

Parameters

date_expression
   The starting date. This can be any expression that can be implicitly converted to DATE.

days_to_add
   The number of days to be add to the date_expression. This is an integer or any value that can be implicitly converted to an integer. This parameter can be positive or negative.

Example

SELECT name, next_day(hiredate,90) "Benefits Eligibility Date"
FROM EMPLOYEES;

Returns the name and the date that is 90 days after hiredate labeled "Benefits Eligibility Date".

Compatibility

This command is compatible with Oracle syntax and is provided for convenience.

nlssort

Oracle-compliant function that sorts data according to a specific collation.

Synopsis

nlssort (variable, collation)

Description

This Oracle-compatible function sorts data according to a specific collation.

Parameters

variable
   The data to sort.

collation
   The collation type by which to sort.

Example

CREATE TABLE test (name text);
INSERT INTO test VALUES('Anne'), ('anne'), ('Bob'), ('bob');
SELECT * FROM test ORDER BY nlssort(name, 'en_US.UTF-8');
In the first example, the UTF-8 collation rules are specified. This groups characters together regardless of case.

In the second example, ASCII (C) collation is specified. This sorts according to ASCII order. The result is that upper case characters are sorted ahead of lower case ones.

**Compatibility**
This command is compatible with Oracle syntax and is provided for convenience.

**nvl**
Oracle-compliant function to substitute a specified value when an expression evaluates to null.

*Note:* This function is analogous to the PostgreSQL `coalesce` function.

**Synopsis**
```
nvl(expression_to_evaluate, null_replacement_value)
```

**Description**
This Oracle-compatible function evaluates `expression_to_evaluate`. If it is null, the function returns `null_replacement_value`; otherwise, it returns `expression_to_evaluate`.

**Parameters**
- `expression_to_evaluate`  
  The expression to evaluate for a null value.
- `null_replacement_value`  
  The value to return if `expression_to_evaluate` is null.

Both `expression_to_evaluate` and `null_replacement_value` must be the same data type.

**Examples**
```
SELECT nvl(contact_name,'None')
FROM clients;
SELECT nvl(amount_past_due,0)
FROM txns;
SELECT nvl(nickname, firstname)
FROM contacts;
```
nvl2
Oracle-compliant function that returns alternate values for both null and non-null values.

Synopsis
```
nvl2(expression_to_evaluate, non_null_replacement_value, null_replacement_value)
```

Description
This Oracle-compatible function evaluates `expression_to_evaluate`. If it is not `null`, the function returns `non_null_replacement_value`; otherwise, it returns `null_replacement_value`.

Parameters
- **expression_to_evaluate**: The expression to evaluate for a null value.
- **non_null_replacement_value**: The value to return if `expression_to_evaluate` is not `null`.
- **null_replacement_value**: The value to return if `expression_to_evaluate` is `null`.

Example
```
select nvl2(unit_number,'Multi Unit','Single Unit')
from clients;
```

Compatibility
This command is compatible with Oracle syntax and is provided for convenience.

See Also
- `decode`
- `oracle.substr`

This Oracle-compliant function extracts a portion of a string.

Synopsis
```
oracle.substr(string, [start [,char_count]])
```

Description
This Oracle-compatible function extract a portion of a string.

If `start` is 0, it is evaluated as 1.

If `start` is negative, the starting position is negative, the starting position is `start` characters moving backwards from the end of string.

If `char_count` is not passed to the function, all characters from start to the end of string are returned.

If `char_count` is less than 1, null is returned.
If `start` or `char_count` is a number, but not an integer, the values are resolved to integers.

**Parameters**

`string`

The string from which to extract.

`start`

An integer specifying the starting position in the string.

`char_count`

An integer specifying the number of characters to extract.

**Example**

```
oracle.substr(name,1,15)
```

Returns the first 15 characters of `name`.

```
oracle.substr("Greenplum",-4,4)
```

Returns "plum".

```
oracle.substr(name,2)
```

Returns all characters of `name`, beginning with the second character.

**Compatibility**

PostgreSQL `substr` (not compatible with Oracle)

**reverse**

Oracle-compliant function to return the input string in reverse order.

**Synopsis**

```
reverse (string)
```

**Description**

This Oracle-compatible function returns the input string (`string`) in reverse order.

**Parameters**

`string`

The input string.

**Example**

```
SELECT reverse('gnirts')
FROM ClientDB;
```

Returns 'string'

**Compatibility**

This command is compatible with Oracle syntax and is provided for convenience.
**round**

Oracle-compliant function to round a date to a specific unit of measure (day, week, etc.).

**Note:** This function is an overloaded function. It shares the same name with the Postgres `round` mathematical function that rounds numeric input to the nearest integer or optionally to the nearest x number of decimal places.

**Synopsis**

```
round (date_time_expression, [unit_of_measure])
```

**Description**

This Oracle-compatible function rounds a `date_time_expression` to the nearest `unit_of_measure` (day, week, etc.). If a `unit_of_measure` is not specified, the `date_time_expression` is rounded to the nearest day. It operates according to the rules of the Gregorian calendar.

If the `date_time_expression` datatype is `TIMESTAMP`, the value returned is always of datatype `TIMESTAMP`.

If the `date_time_expression` datatype is `DATE`, the value returned is always of datatype `DATE`.

**Parameters**

- **date_time_expression**
  The date to round. This can be any expression that can be implicitly converted to `DATE` or `TIMESTAMP`.

- **unit_of_measure**
  The unit of measure to apply for rounding. If not specified, then the `date_time_expression` is rounded to the nearest day. Valid parameters are:

<table>
<thead>
<tr>
<th>Unit</th>
<th>Valid parameters</th>
<th>Rounding Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>SYYYY, YYYY, YEAR, SYEAR, YYY, YY, Y</td>
<td>Rounds up on July 1st</td>
</tr>
<tr>
<td>ISO Year</td>
<td>IYYYY, IY, I</td>
<td></td>
</tr>
<tr>
<td>Quarter</td>
<td>Q</td>
<td>Rounds up on the 16th day of the second month of the quarter</td>
</tr>
<tr>
<td>Month</td>
<td>MONTH, MON, MM, RM</td>
<td>Rounds up on the 16th day of the month</td>
</tr>
<tr>
<td>Week</td>
<td>WW</td>
<td>Same day of the week as the first day of the year</td>
</tr>
<tr>
<td>IW</td>
<td>IW</td>
<td>Same day of the week as the first day of the ISO year</td>
</tr>
<tr>
<td>W</td>
<td>W</td>
<td>Same day of the week as the first day of the month</td>
</tr>
<tr>
<td>Day</td>
<td>DDD, DD, J</td>
<td>Rounds to the nearest day</td>
</tr>
<tr>
<td>Start day of the week</td>
<td>DAY, DY, D</td>
<td>Rounds to the nearest start (sunday) day of the week</td>
</tr>
</tbody>
</table>
### Example

<table>
<thead>
<tr>
<th>Unit</th>
<th>Valid parameters</th>
<th>Rounding Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hour</td>
<td>HH, HH12, HH24</td>
<td>Rounds to the next hour</td>
</tr>
<tr>
<td>Minute</td>
<td>MI</td>
<td>Rounds to the next minute</td>
</tr>
</tbody>
</table>

#### Example

```sql
SELECT round(TO_DATE('27-OCT-00','DD-MON-YY'), 'YEAR')
FROM ClientDB;
```

Returns '01-JAN-01' (27 Oct 00 rounded to the first day of the following year (YEAR))

```sql
SELECT round('startdate','Q')
FROM ClientDB;
```

Returns '01-JUL-92' (the startdate rounded to the first day of the quarter (Q))

### Compatibility

This command is compatible with Oracle syntax and is provided for convenience.

### See Also

PostgreSQL **round** (not compatible with Oracle)

#### sinh

Oracle-compliant function to return the hyperbolic sine of a given number.

### Synopsis

```
sinh(float8)
```

### Description

This Oracle-compatible function returns the hyperbolic sine of the floating 8 input number (float8).

**Note:** This function is available by default and can be accessed without running the Oracle Compatibility installer.

### Parameters

- **float8**
  
The input number.

### Example

```sql
SELECT sinh(3)
FROM ClientDB;
```

Returns '10.0178749274099' (hyperbolic sine of 3)

### Compatibility

This command is compatible with Oracle syntax and is provided for convenience.
**tanh**

Oracle-compliant function to return the hyperbolic tangent of a given number.

**Synopsis**

```
tanh(float8)
```

**Description**

This Oracle-compatible function returns the hyperbolic tangent of the floating 8 input number (`float8`).

**Note:**

This function is available by default and can be accessed without running the Oracle Compatibility installer.

**Parameters**

`float8`

The input number.

**Example**

```
SELECT tanh(3)
FROM ClientDB;
```

Returns `0.99505475368673' (hyperbolic tangent of 3)

**Compatibility**

This command is compatible with Oracle syntax and is provided for convenience.

**trunc**

Oracle-compliant function to truncate a date to a specific unit of measure (day, week, hour, etc).

**Note:**

This function is an overloaded function. It shares the same name with the Postgres `trunc` and the Oracle `trunc` mathematical functions. Both of these truncate numeric input to the nearest integer or optionally to the nearest x number of decimal places.

**Synopsis**

```
trunc(date_time_expression, [unit_of_measure])
```

**Description**

This Oracle-compatible function truncates a `date_time_expression` to the nearest `unit_of_measure` (day, week, etc.). If a `unit_of_measure` is not specified, the `date_time_expression` is truncated to the nearest day. It operates according to the rules of the Gregorian calendar.

If the `date_time_expression` datatype is `TIMESTAMP`, the value returned is always of datatype `TIMESTAMP`, truncated to the hour/min level.

If the `date_time_expression` datatype is `DATE`, the value returned is always of datatype `DATE`. 
Parameters

`date_time_expression`  
The date to truncate. This can be any expression that can be implicitly converted to `DATE` or `TIMESTAMP`.

`unit_of_measure`  
The unit of measure to apply for truncating. If not specified, then `date_time_expression` is truncated to the nearest day. Valid formats are:

<table>
<thead>
<tr>
<th>Unit</th>
<th>Valid parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>SYYYY, YYYY, YEAR, SYEAR, YYY, YY, Y</td>
</tr>
<tr>
<td>ISO Year</td>
<td>IYYYY, IY, I</td>
</tr>
<tr>
<td>Quarter</td>
<td>Q</td>
</tr>
<tr>
<td>Month</td>
<td>MONTH, MON, MM, RM</td>
</tr>
<tr>
<td>Week</td>
<td>WW</td>
</tr>
<tr>
<td>IW</td>
<td>IW</td>
</tr>
<tr>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>Day</td>
<td>DDD, DD, J</td>
</tr>
<tr>
<td>Start day of the week</td>
<td>DAY, DY, D</td>
</tr>
<tr>
<td>Hour</td>
<td>HH, HH12, HH24</td>
</tr>
<tr>
<td>Minute</td>
<td>MI</td>
</tr>
</tbody>
</table>

Examples

```
SELECT TRUNC(TO_DATE('27-OCT-92','DD-MON-YY'), 'YEAR')
FROM ClientDB;
```

Returns '01-JAN-92' (27 Oct 92 truncated to the first day of the year (`YEAR`))

```
SELECT TRUNC(startdate,'Q')
FROM ClientDB;
```

Returns '1992-07-01' (the `startdate` truncated to the first day of the quarter (`Q`), depending on the `date_style` setting)

Compatibility

This command is compatible with Oracle syntax and is provided for convenience.

See Also

PostgreSQL `trunc` (not compatible with Oracle)

`passwordcheck`

The `passwordcheck` module checks users' passwords whenever they are set with `CREATE ROLE` or `ALTER ROLE`. If a password is considered too weak, it will be rejected and the command will terminate with an error.
To enable this module, add `$libdir/passwordcheck' to shared_preload_libraries in postgresql.conf, then restart the server.

By default, this module enforces a few simple rules for password strength, which you can modify or extend as you see fit. It is also possible to adapt this module to your needs by modifying the Makefile and rebuilding the module.

**Caution:** To prevent unencrypted passwords from being sent across the network, written to the server log, or otherwise stolen by a database administrator, Greenplum Database enables you to supply pre-encrypted passwords. Many client programs make use of this functionality and encrypt the password before sending it to the server. This limits the usefulness of the passwordcheck module, because in that case it can only try to guess the password. For this reason, passwordcheck is not recommended if your security requirements are high. It is more secure to use an external authentication method such as Kerberos than to rely on passwords within the database. Alternatively, you could modify passwordcheck to reject pre-encrypted passwords, but forcing users to set their passwords in clear text carries its own security risks.
Chapter 15

Greenplum Database Reference Guide

Reference information for Greenplum Database systems including SQL commands, system catalogs, environment variables, server configuration parameters, character set support, datatypes, and Greenplum Database extensions.
SQL Command Reference

The following SQL commands are available in Greenplum Database:

- ABORT
- ALTER AGGREGATE
- ALTER CONVERSION
- ALTER DATABASE
- ALTER DOMAIN
- ALTER EXTERNAL TABLE
- ALTER FILESPACE
- ALTER FOREIGN DATA WRAPPER*
- ALTER FOREIGN TABLE*
- ALTER FUNCTION
- ALTER GROUP
- ALTER INDEX
- ALTER LANGUAGE
- ALTER OPERATOR
- ALTER OPERATOR CLASS
- ALTER OPERATOR FAMILY
- ALTER PROTOCOL
- ALTER RESOURCE GROUP
- ALTER RESOURCE QUEUE
- ALTER ROLE
- ALTER SCHEMA
- ALTER SEQUENCE
- ALTER SERVER*
- ALTER TABLE
- ALTER TABLESPACE
- ALTER TYPE
- ALTER USER
- ALTER USER MAPPING*
- ALTER VIEW
- ANALYZE
- BEGIN
- CHECKPOINT
- CLOSE
- CLUSTER
- COMMENT
- COMMIT
- COPY
- CREATE AGGREGATE
- CREATE CAST
- CREATE CONVERSION
- CREATE DATABASE
- CREATE DOMAIN
- CREATE EXTERNAL TABLE
- CREATE FOREIGN DATA WRAPPER*
- CREATE FOREIGN TABLE*
- CREATE FUNCTION
- CREATE GROUP
- CREATE INDEX
- CREATE LANGUAGE
- CREATE OPERATOR
- CREATE OPERATOR CLASS
- CREATE OPERATOR FAMILY
- CREATE PROTOCOL
- CREATE RESOURCE GROUP
- CREATE RESOURCE QUEUE
- CREATE ROLE
- CREATE RULE
- CREATE SCHEMA
- CREATE SEQUENCE
- CREATE SERVER*
- CREATE TABLE
- CREATE TABLE AS
- CREATE TABLESPACE
- CREATE TYPE
- CREATE USER
- CREATE USER MAPPING*
- CREATE VIEW
- DEALLOCATE
- DECLARE
- DELETE
- DISCARD
- DO
- DROP AGGREGATE
- DROP CAST
- DROP CONVERSION
- DROP DATABASE
- DROP DOMAIN
- DROP EXTERNAL TABLE
- DROP FILESPACE
- DROP FOREIGN DATA WRAPPER*
- DROP FOREIGN TABLE*
- DROP FUNCTION
- DROP GROUP
- DROP INDEX
- DROP LANGUAGE
- DROP OPERATOR
- DROP OPERATOR CLASS
- DROP OPERATOR FAMILY
- DROP OWNED
- DROP PROTOCOL
- DROP RESOURCE GROUP
- DROP RESOURCE QUEUE
- DROP ROLE
- DROP RULE
- DROP SCHEMA
• DROP SEQUENCE
• DROP SERVER*
• DROP TABLE
• DROP TABLESPACE
• DROP TYPE
• DROP USER
• DROP USER MAPPING*
• DROP VIEW
• END
• EXECUTE
• EXPLAIN
• FETCH
• GRANT
• INSERT
• LOAD
• LOCK
• MOVE
• PREPARE
• REASSIGN OWNED
• REINDEX
• RELEASE SAVEPOINT
• RESET
• REVOKE
• ROLLBACK
• ROLLBACK TO SAVEPOINT
• SAVEPOINT
• SELECT
• SELECT INTO
• SET
• SET ROLE
• SET SESSION AUTHORIZATION
• SET TRANSACTION
• SHOW
• START TRANSACTION
• TRUNCATE
• UPDATE
• VACUUM
• VALUES

* Not implemented in 5.0

**SQL Syntax Summary**

**ABORT**

Aborts the current transaction.

```
ABORT [WORK | TRANSACTION]
```

See **ABORT** for more information.
ALTER AGGREGATE
Changes the definition of an aggregate function

```
ALTER AGGREGATE name ( type [ , ... ] ) RENAME TO new_name
ALTER AGGREGATE name ( type [ , ... ] ) OWNER TO new_owner
ALTER AGGREGATE name ( type [ , ... ] ) SET SCHEMA new_schema
```

See ALTER AGGREGATE for more information.

ALTER CONVERSION
Changes the definition of a conversion.

```
ALTER CONVERSION name RENAME TO newname
ALTER CONVERSION name OWNER TO newowner
```

See ALTER CONVERSION for more information.

ALTER DATABASE
Changes the attributes of a database.

```
ALTER DATABASE name [ WITH CONNECTION LIMIT connlimit ]
ALTER DATABASE name SET parameter { TO | = } { value | DEFAULT }
ALTER DATABASE name RESET parameter
ALTER DATABASE name RENAME TO newname
ALTER DATABASE name OWNER TO new_owner
```

See ALTER DATABASE for more information.

ALTER DOMAIN
Changes the definition of a domain.

```
ALTER DOMAIN name { SET DEFAULT expression | DROP DEFAULT }
ALTER DOMAIN name { SET | DROP } NOT NULL
ALTER DOMAIN name ADD domain_constraint
ALTER DOMAIN name DROP CONSTRAINT constraint_name [RESTRICT | CASCADE]
ALTER DOMAIN name OWNER TO new_owner
ALTER DOMAIN name SET SCHEMA new_schema
```

See ALTER DOMAIN for more information.

ALTER EXTENSION
Change the definition of an extension that is registered in a Greenplum database.

```
ALTER EXTENSION name UPDATE [ TO new_version ]
```
ALTER EXTENSION  name  SET SCHEMA  new_schema
ALTER EXTENSION  name  ADD  member_object
ALTER EXTENSION  name  DROP  member_object

where  member_object  is:

ACCESS METHOD  object_name  |
AGGREGATE  aggregate_name  ( aggregate_signature )  |
CAST  (source_type  AS  target_type)  |
COLLATION  object_name  |
CONVERSION  object_name  |
DOMAIN  object_name  |
EVENT TRIGGER  object_name  |
FOREIGN DATA WRAPPER  object_name  |
FOREIGN TABLE  object_name  |
FUNCTION  function_name  ( [ [ argmode ] [ argname ] argtype [ , ... ] ] )  |
MATERIALIZED VIEW  object_name  |
OPERATOR  operator_name  (left_type, right_type)  |
OPERATOR CLASS  object_name  USING  index_method  |
OPERATOR FAMILY  object_name  USING  index_method  |
[ PROCEDURAL ] LANGUAGE  object_name  |
SCHEMA  object_name  |
SEQUENCE  object_name  |
SERVER  object_name  |
TABLE  object_name  |
TEXT SEARCH CONFIGURATION  object_name  |
TEXT SEARCH DICTIONARY  object_name  |
TEXT SEARCH PARSER  object_name  |
TEXT SEARCH TEMPLATE  object_name  |
TYPE  object_name  |
VIEW  object_name

and  aggregate_signature  is:

*  |  [ [ argmode ] [ argname ] argtype [ , ... ] ]  |
[ [ argmode ] [ argname ] argtype [ , ... ] ]  |
ORDER BY  [ argmode ] [ argname ] argtype [ , ... ]

See  ALTER EXTENSION  for more information.

**ALTER EXTERNAL TABLE**

Changes the definition of an external table.

ALTER EXTERNAL TABLE  name  action  [, ... ]

where  action  is one of:

ADD  [COLUMN]  new_column  type
DROP  [COLUMN]  column  [RESTRICT|CASCADE]
ALTER  [COLUMN]  column  TYPE  type  [USING  expression]
OWNER  TO  new_owner

See  ALTER EXTERNAL TABLE  for more information.

**ALTER FILESPACE**

Changes the definition of a filespace.

ALTER FILESPACE  name  RENAME TO  newname
ALTER FILESPACE name OWNER TO newowner

See ALTER FILESPACE for more information.

**ALTER FUNCTION**

Changes the definition of a function.

\[
\text{ALTER FUNCTION} \quad \text{name} \quad (\quad [\quad \text{argmode} \quad [\text{argname} \quad \text{argtype} \quad [, \quad \ldots \quad ]]} \quad ) \\
\quad \quad \quad \text{action} \quad [, \quad \ldots \quad ] \quad [\text{RESTRICT}] \\
\text{ALTER FUNCTION} \quad \text{name} \quad (\quad [\quad \text{argmode} \quad [\text{argname} \quad \text{argtype} \quad [, \quad \ldots \quad ]]} \quad ) \\
\quad \quad \quad \text{RENAME TO} \quad \text{new_name} \\
\text{ALTER FUNCTION} \quad \text{name} \quad (\quad [\quad \text{argmode} \quad [\text{argname} \quad \text{argtype} \quad [, \quad \ldots \quad ]]} \quad ) \\
\quad \quad \quad \text{OWNER TO} \quad \text{new_owner} \\
\text{ALTER FUNCTION} \quad \text{name} \quad (\quad [\quad \text{argmode} \quad [\text{argname} \quad \text{argtype} \quad [, \quad \ldots \quad ]]} \quad ) \\
\quad \quad \quad \text{SET SCHEMA} \quad \text{new_schema}
\]

See ALTER FUNCTION for more information.

**ALTER GROUP**

Changes a role name or membership.

\[
\text{ALTER GROUP} \quad \text{groupname} \quad \text{ADD USER} \quad \text{username} \quad [, \quad \ldots \quad ] \\
\text{ALTER GROUP} \quad \text{groupname} \quad \text{DROP USER} \quad \text{username} \quad [, \quad \ldots \quad ] \\
\text{ALTER GROUP} \quad \text{groupname} \quad \text{RENAME TO} \quad \text{newname}
\]

See ALTER GROUP for more information.

**ALTER INDEX**

Changes the definition of an index.

\[
\text{ALTER INDEX} \quad \text{name} \quad \text{RENAME TO} \quad \text{new_name} \\
\text{ALTER INDEX} \quad \text{name} \quad \text{SET TABLESPACE} \quad \text{tablespace_name} \\
\text{ALTER INDEX} \quad \text{name} \quad \text{SET} \quad (\quad \text{FILLFACTOR} \quad = \quad \text{value} \quad ) \\
\text{ALTER INDEX} \quad \text{name} \quad \text{RESET} \quad (\quad \text{FILLFACTOR} \quad )
\]

See ALTER INDEX for more information.

**ALTER LANGUAGE**

Changes the name of a procedural language.

\[
\text{ALTER LANGUAGE} \quad \text{name} \quad \text{RENAME TO} \quad \text{newname} \\
\text{ALTER LANGUAGE} \quad \text{name} \quad \text{OWNER TO} \quad \text{new_owner}
\]

See ALTER LANGUAGE for more information.
**ALTER OPERATOR**
Changes the definition of an operator.

```
ALTER OPERATOR name ( {lefttype | NONE} , {righttype | NONE} )
OWNER TO newowner
```

See **ALTER OPERATOR** for more information.

**ALTER OPERATOR CLASS**
Changes the definition of an operator class.

```
ALTER OPERATOR CLASS name USING index_method RENAME TO newname
ALTER OPERATOR CLASS name USING index_method OWNER TO newowner
```

See **ALTER OPERATOR CLASS** for more information.

**ALTER OPERATOR FAMILY**
Changes the definition of an operator family.

```
ALTER OPERATOR FAMILY name USING index_method ADD
{  OPERATOR strategy_number operator_name ( op_type, op_type ) [ RECHECK ]
  | FUNCTION support_number [ ( op_type [ , op_type ] ) ] funcname
  ( argument_type [, ... ] )
} [, ... ]
ALTER OPERATOR FAMILY name USING index_method DROP
{  OPERATOR strategy_number ( op_type, op_type )
  | FUNCTION support_number [ ( op_type [ , op_type ] )
} [, ... ]
ALTER OPERATOR FAMILY name USING index_method RENAME TO newname
ALTER OPERATOR FAMILY name USING index_method OWNER TO newowner
```

See **ALTER OPERATOR FAMILY** for more information.

**ALTER PROTOCOL**
Changes the definition of a protocol.

```
ALTER PROTOCOL name RENAME TO newname
ALTER PROTOCOL name OWNER TO newowner
```

See **ALTER PROTOCOL** for more information.

**ALTER RESOURCE GROUP**
Changes the limits of a resource group.

```
ALTER RESOURCE GROUP name SET group_attribute value
```

See **ALTER RESOURCE GROUP** for more information.
**ALTER RESOURCE QUEUE**
Changes the limits of a resource queue.

```sql
ALTER RESOURCE QUEUE name WITH ( queue_attribute=value [, ... ] )
```

See `ALTER RESOURCE QUEUE` for more information.

**ALTER ROLE**
Changes a database role (user or group).

```sql
ALTER ROLE name RENAME TO newname
ALTER ROLE name SET config_parameter {TO | =} {value | DEFAULT}
ALTER ROLE name RESET config_parameter
ALTER ROLE name RESOURCE QUEUE {queue_name | NONE}
ALTER ROLE name RESOURCE GROUP {group_name | NONE}
ALTER ROLE name [ [WITH] option [ ... ] ]
```

See `ALTER ROLE` for more information.

**ALTER SCHEMA**
Changes the definition of a schema.

```sql
ALTER SCHEMA name RENAME TO newname
ALTER SCHEMA name OWNER TO newowner
```

See `ALTER SCHEMA` for more information.

**ALTER SEQUENCE**
Changes the definition of a sequence generator.

```sql
ALTER SEQUENCE name [INCREMENT [ BY ] increment]
 [MINVALUE minvalue | NO MINVALUE]
 [MAXVALUE maxvalue | NO MAXVALUE]
 [RESTART [ WITH ] start]
 [CACHE cache] [ [ NO ] CYCLE]
 [OWNED BY {table.column | NONE}]
ALTER SEQUENCE name RENAME TO new_name
ALTER SEQUENCE name SET SCHEMA new_schema
```

See `ALTER SEQUENCE` for more information.

**ALTER TABLE**
Changes the definition of a table.

```sql
ALTER TABLE [ONLY] name RENAME [COLUMN] column TO new_column
ALTER TABLE name RENAME TO new_name
```
### ALTER TABLE

Changes the schema of a table.

```sql
ALTER TABLE name SET SCHEMA new_schema
```

### ALTER TABLE [ONLY] name SET DISTRIBUTED BY (column, [ ... ] )

### ALTER TABLE [ONLY] name SET DISTRIBUTED RANDOMLY

### ALTER TABLE [ONLY] name DISTRIBUTED BY (column, [ ... ] ) WITH (REORGANIZE=true|false)

### ALTER TABLE [ONLY] name action [, ... ]

### ALTER TABLE name

- ALTER PARTITION { partition_name | FOR (RANK(number)) |
  | FOR (value) } partition_action [... ] }
- partition_action

See **ALTER TABLE** for more information.

### ALTER TABLESPACE

Changes the definition of a tablespace.

```sql
ALTER TABLESPACE name RENAME TO newname
ALTER TABLESPACE name OWNER TO newowner
```

See **ALTER TABLESPACE** for more information.

### ALTER TYPE

Changes the definition of a data type.

```sql
ALTER TYPE name
  OWNER TO new_owner | SET SCHEMA new_schema
```

See **ALTER TYPE** for more information.

### ALTER USER

Changes the definition of a database role (user).

```sql
ALTER USER name RENAME TO newname
ALTER USER name SET config_parameter {TO | =} {value | DEFAULT}
ALTER USER name RESET config_parameter
ALTER USER name RESOURCE QUEUE {queue_name | NONE}
ALTER USER name RESOURCE GROUP {group_name | NONE}
ALTER USER name [ [WITH] option [ ... ] ]
```

See **ALTER USER** for more information.

### ALTER VIEW

Changes the definition of a view.

```sql
ALTER VIEW name RENAME TO newname
```

See **ALTER VIEW** for more information.
**ANALYZE**
Collects statistics about a database.

```
ANALYZE [VERBOSE] [ROOTPARTITION [ALL] ]
  [table [ (column [, ...] ) ]]
```

See `ANALYZE` for more information.

**BEGIN**
Starts a transaction block.

```
BEGIN [WORK | TRANSACTION] [transaction_mode]
  [READ ONLY | READ WRITE]
```

See `BEGIN` for more information.

**CHECKPOINT**
Forces a transaction log checkpoint.

```
CHECKPOINT
```

See `CHECKPOINT` for more information.

**CLOSE**
Closes a cursor.

```
CLOSE cursor_name
```

See `CLOSE` for more information.

**CLUSTER**
Physically reorders a heap storage table on disk according to an index. Not a recommended operation in Greenplum Database.

```
CLUSTER indexname ON tablename

CLUSTER tablename

CLUSTER
```

See `CLUSTER` for more information.

**COMMENT**
Defines or change the comment of an object.

```
COMMENT ON
{ TABLE object_name |
  COLUMN table_name.column_name |
  AGGREGATE agg_name (agg_type [, ...]) |
  CAST (sourcetype AS targettype) |
  CONSTRAINT constraint_name ON table_name |
  CONVERSION object_name |
  DATABASE object_name |
  DOMAIN object_name |
```

See `COMMENT` for more information.

**COMMIT**

Commits the current transaction.

```
COMMIT [WORK | TRANSACTION]
```

See `COMMIT` for more information.

**COPY**

Copies data between a file and a table.

```
```
See COPY for more information.

**CREATE AGGREGATE**
Defines a new aggregate function.

```sql
CREATE [ORDERED] AGGREGATE name (input_data_type [ , ... ]) 
( SFUNC = sfunc, 
  STYPE = state_data_type 
  [, PREFUNC = prefunc] 
  [, FINALFUNC = ffunc] 
  [, INITCOND = initial_condition] 
  [, SORTOP = sort_operator] )
```

See CREATE AGGREGATE for more information.

**CREATE CAST**
Defines a new cast.

```sql
CREATE CAST (sourcetype AS targettype) 
WITH FUNCTION funcname (argtypes) 
[AS ASSIGNMENT | AS IMPLICIT]
```

CREATE CAST (sourcetype AS targettype) WITHOUT FUNCTION 
[AS ASSIGNMENT | AS IMPLICIT]

See CREATE CAST for more information.

**CREATE CONVERSION**
Defines a new encoding conversion.

```sql
CREATE [DEFAULT] CONVERSION name FOR source_encoding TO dest_encoding FROM funcname
```

See CREATE CONVERSION for more information.

**CREATE DATABASE**
Creates a new database.

```sql
CREATE DATABASE name [ [WITH] [OWNER [=] dbowner] 
[TEMPLATE [=] template] 
[ENCODING [=] encoding] 
[TABLESPACE [=] tablespace] 
[CONNECTION LIMIT [=] connlimit ] ]
```

See CREATE DATABASE for more information.

**CREATE DOMAIN**
Defines a new domain.

```sql
CREATE DOMAIN name [AS] data_type [DEFAULT expression] 
[CONSTRAINT constraint_name 
| NOT NULL | NULL 
| CHECK (expression) [...]]
```

See CREATE DOMAIN for more information.
CREATE EXTENSION
Registers an extension in a Greenplum database.

CREATE EXTENSION [ IF NOT EXISTS ] extension_name
[ WITH ] [ SCHEMA schema_name ]
[ VERSION version ]
[ FROM old_version ]
[ CASCADE ]

See CREATE EXTENSION for more information.

CREATE EXTERNAL TABLE
Defines a new external table.

CREATE [READABLE] EXTERNAL TABLE table_name
( column_name data_type [, ...] | LIKE other_table )
LOCATION ('file://seghost[:port]/path/file' [, ...])
| ('gpfdist://filehost[:port]/file_pattern[#transform=trans_name]' [, ...])
| ('gpfdists://filehost[:port]/file_pattern[#transform=trans_name]' [, ...])
| ('gphdfs://hdfs_host[:port]/path/file')
| ('pxf://path-to-data:PROFILE[&custom-option=value[...]])
| ('s3://S3_endpoint[:port]/bucket_name/[S3_prefix]
 [region=S3-region]
 [config=config_file]')
[ON MASTER]
FORMAT 'TEXT'
[ ([ [HEADER]
 [DELIMITER [AS] 'delimiter' | 'OFF']
 [NULL [AS] 'null string']
 [ESCAPE [AS] 'escape' | 'OFF']
 [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
 [FILL MISSING FIELDS] )
 | 'CSV'
 | [, [ [HEADER]
 [QUOTE [AS] 'quote']
 [DELIMITER [AS] 'delimiter']
 [NULL [AS] 'null string']
 [FORCE NOT NULL column [, ...]]
 [ESCAPE [AS] 'escape']
 [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
 [FILL MISSING FIELDS] )
 | 'AVRO'
 | 'PARQUET'
 | 'CUSTOM' (Formatter=<formatter_specifications>)
 | [ ENCODING 'encoding' ]
 | [ [ LOG ERRORS ] SEGMENT REJECT LIMIT count
 [ROWS | PERCENT] ]

CREATE [READABLE] EXTERNAL WEB TABLE table_name
( column_name data_type [, ...] | LIKE other_table )
LOCATION ('http://webhost[:port]/path/file' [, ...])
| EXECUTE 'command' [ON ALL
 | MASTER
 | number_of_segments
 | HOST ['segment_hostname']
 | SEGMENT segment_id ]

FORMAT 'TEXT'
[ ([ [HEADER]
 [DELIMITER [AS] 'delimiter' | 'OFF']
 | [FORCE NOT NULL column [, ...]]
 | [ESCAPE [AS] 'escape']
 | [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
 | [FILL MISSING FIELDS] )
 | 'CSV'
 | [, [ [HEADER]
 [QUOTE [AS] 'quote']
 [DELIMITER [AS] 'delimiter']
 [NULL [AS] 'null string']
 [FORCE NOT NULL column [, ...]]
 [ESCAPE [AS] 'escape']
 [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
 [FILL MISSING FIELDS] )
 | 'AVRO'
 | 'PARQUET'
 | 'CUSTOM' (Formatter=<formatter_specifications>)
 | [ ENCODING 'encoding' ]
 | [ [ LOG ERRORS ] SEGMENT REJECT LIMIT count
 [ROWS | PERCENT] ]

CREATE WRITABLE EXTERNAL TABLE table_name
  ( column_name data_type [, ...] | LIKE other_table )
  LOCATION('gpfdist://outputhost[:port]/filename[#transform=trans_name]' [, ...])
  | ('gpfdists://outputhost[:port]/file_pattern[#transform=trans_name]' [, ...])
  | ('gphdfs://hdfs_host[:port]/path')
  FORMAT 'TEXT'
  | '('DELIMITER [AS] 'delimiter']
  | [NULL [AS] 'null string']
  | [ESCAPE [AS] 'escape' | 'OFF'] )
| 'CSV'
  | '('QUOTE [AS] 'quote']
  | [DELIMITER [AS] 'delimiter']
  | [NULL [AS] 'null string']
  | [FORCE NOT NULL column [, ...]]
  | [ESCAPE [AS] 'escape']
  | [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
  | [FILL MISSING FIELDS] )
| 'CUSTOM' (Formatter=<formatter specifications>)
| [ENCODING 'encoding']
| [LOG ERRORS] SEGMENT REJECT LIMIT count
| [ROWS | PERCENT ]

CREATE WRITABLE EXTERNAL TABLE table_name
  ( column_name data_type [, ...] | LIKE other_table )
  LOCATION('s3://S3_endpoint[:port]/bucket_name/S3_prefix'[region=S3-region]
  | [config=config_file'])
| [ON MASTER]
FORMAT 'TEXT'
  | '('DELIMITER [AS] 'delimiter']
  | [NULL [AS] 'null string']
  | [ESCAPE [AS] 'escape' | 'OFF'] )
| 'CSV'
  | '('QUOTE [AS] 'quote']
  | [DELIMITER [AS] 'delimiter']
  | [NULL [AS] 'null string']
  | [FORCE QUOTE column [, ...]]
  | [ESCAPE [AS] 'escape'] )
| 'AVRO'
| 'PARQUET'

CREATE WRITABLE EXTERNAL WEB TABLE table_name
  ( column_name data_type [, ...] | LIKE other_table )
EXECUTE 'command' [ON ALL]
FORMAT 'TEXT'
  | '('DELIMITER [AS] 'delimiter']
CREATE FUNCTION

Defines a new function.

CREATE [OR REPLACE] FUNCTION name
  ( [ [argmode] [argname] argtype [ { DEFAULT | = } defexpr ] [, ...] ] )
  [ RETURNS { [ SETOF ] rettype ]
  | TABLE { [{ argname argtype | LIKE other table } [, ...] ]

  [ ]

  { LANGUAGE lanname
  | IMMUTABLE | STABLE | VOLATILE
  | CALLED ON NULL INPUT | RETURNS NULL ON NULL INPUT | STRICT
  | [EXTERNAL] SECURITY INVOKER | [EXTERNAL] SECURITY DEFINE
  | COST execution_cost
  | SET configuration_parameter { TO value | = value | FROM CURRENT }
  | AS 'definition'
  | AS 'obj_file', 'link_symbol' } ... 
  | WITH { { DESCRIBE = describe_function
  | [, ...] ] } ]

See CREATE FUNCTION for more information.

CREATE GROUP

Defines a new database role.

CREATE GROUP name [[WITH] option [ ... ]]

See CREATE GROUP for more information.

CREATE INDEX

Defines a new index.

CREATE [UNIQUE] INDEX name ON table
  [USING btree|bitmap|gist]
  ( { column | (expression) [opclass] [, ...] } )
  [ WITH ( FILLFACTOR = value ) ]
  [ TABLESPACE tablespace]
  [WHERE predicate]

See CREATE INDEX for more information.
CREATE LANGUAGE
Defines a new procedural language.

CREATE [PROCEDURAL] LANGUAGE name
CREATE [TRUSTED] [PROCEDURAL] LANGUAGE name
    HANDLER call_handler [ INLINE inline_handler ]
[VALIDATOR valfunction]

See CREATE LANGUAGE for more information.

CREATE OPERATOR
Defines a new operator.

CREATE OPERATOR name ( 
    PROCEDURE = funcname 
    [, LEFTARG = lefttype] [, RIGHTARG = righttype] 
    [, COMMUTATOR = com_op] [, NEGATOR = neg_op] 
    [, RESTRICT = res_proc] [, JOIN = join_proc] 
    [, HASHES] [, MERGES] )

See CREATE OPERATOR for more information.

CREATE OPERATOR CLASS
Defines a new operator class.

CREATE OPERATOR CLASS name [DEFAULT] FOR TYPE data_type
    USING index_method AS 
    { 
        OPERATOR strategy_number op_name [(op_type, op_type)] [RECHECK] 
        | FUNCTION support_number funcname (argument_type [, ...] ) 
        | STORAGE storage_type 
    } [, ... ]

See CREATE OPERATOR CLASS for more information.

CREATE OPERATOR FAMILY
Defines a new operator family.

CREATE OPERATOR FAMILY name USING index_method

See CREATE OPERATOR FAMILY for more information.

CREATE PROTOCOL
Registers a custom data access protocol that can be specified when defining a Greenplum Database external table.

CREATE [TRUSTED] PROTOCOL name ( 
    [readfunc='read_call_handler'] [, writefunc='write_call_handler'] 
    [, validatorfunc='validate_handler' ])

See CREATE PROTOCOL for more information.
CREATE RESOURCE GROUP
Defines a new resource group.

```sql
CREATE RESOURCE GROUP name WITH (group_attribute=value [, ... ])
```

See `CREATE RESOURCE GROUP` for more information.

CREATE RESOURCE QUEUE
Defines a new resource queue.

```sql
CREATE RESOURCE QUEUE name WITH (queue_attribute=value [, ... ])
```

See `CREATE RESOURCE QUEUE` for more information.

CREATE ROLE
Defines a new database role (user or group).

```sql
CREATE ROLE name [[WITH] option [ ... ]]
```

See `CREATE ROLE` for more information.

CREATE RULE
Defines a new rewrite rule.

```sql
CREATE [OR REPLACE] RULE name AS ON event
TO table [WHERE condition]
DO [ALSO | INSTEAD] { NOTHING | command | (command; command ...
```}

See `CREATE RULE` for more information.

CREATE SCHEMA
Defines a new schema.

```sql
CREATE SCHEMA schema_name [AUTHORIZATION username]
[schema_element [ ... ]]

CREATE SCHEMA AUTHORIZATION rolename [schema_element [ ... ]]
```

See `CREATE SCHEMA` for more information.

CREATE SEQUENCE
Defines a new sequence generator.

```sql
CREATE [TEMPORARY | TEMP] SEQUENCE name
[INCREMENT [BY] value]
[MINVALUE minvalue | NO MINVALUE]
[MAXVALUE maxvalue | NO MAXVALUE]
[START [ WITH ] start]
[CACHE cache]
[[NO] CYCLE]
[OWNED BY { table.column | NONE }]
```

See `CREATE SEQUENCE` for more information.
**CREATE TABLE**

Defines a new table.

```
CREATE [[GLOBAL | LOCAL] {TEMPORARY | TEMP}] TABLE table_name ( 
    [ ( column_name data_type [ DEFAULT default_expr ] ]
    [column_constraint [ ... ] ]
    [ ENCODING ( storage_directive [, ... ] ) ]
    )
    | table_constraint
    | LIKE other_table {[INCLUDING | EXCLUDING]
    | [Defaults | CONSTRAINTS] ...}
    [, ... ] )
    [ INHERITS ( parent_table [, ... ] ) ]
    [ WITH { storage_parameter = value [, ... ] } ]
    [ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
    [ TABLESPACE tablespace ]
    [ DISTRIBUTED BY ( column, [ ... ] ) | DISTRIBUTED RANDOMLY ]
    [ PARTITION BY partition_type ( column )
    [ SUBPARTITION BY partition_type ( column ) ]
    [ SUBPARTITION TEMPLATE ( template_spec ) ]
    [...]
    ( partition_spec )
    | [ SUBPARTITION BY partition_type ( column ) ]
    [...]
    ( partition_spec
    [ ( subpartition_spec
    [ (...]
    ) ] )
    [...]
    )
```

See `CREATE TABLE` for more information.

**CREATE TABLE AS**

Defines a new table from the results of a query.

```
CREATE [ [[GLOBAL | LOCAL] {TEMPORARY | TEMP} ] TABLE table_name
    { ( column_name [, ... ] ) ]
    [ WITH { storage_parameter = value [, ... ] } ]
    [ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
    [ TABLESPACE tablespace ]
    AS query
    [ DISTRIBUTED BY ( column, [ ... ] ) | DISTRIBUTED RANDOMLY ]
```

See `CREATE TABLE AS` for more information.

**CREATE TABLESPACE**

Defines a new tablespace.

```
CREATE TABLESPACE tablespace_name [ OWNER username ]
    FILESPACE filespace_name
```

See `CREATE TABLESPACE` for more information.

**CREATE TYPE**

Defines a new data type.

```
CREATE TYPE name AS { attribute_name data_type [, ... ] }
```
CREATE TYPE name AS ENUM ( 'label' [, ... ] )

CREATE TYPE name (  
  INPUT = input_function,  
  OUTPUT = output_function  
  [, RECEIVE = receive_function]  
  [, SEND = send_function]  
  [, TYPMOD_IN = type_modifier_input_function ]  
  [, TYPMOD_OUT = type_modifier_output_function ]  
  [, INTERNALLength = {internalLength | VARIABLE}]  
  [, PASSEDBYVALUE]  
  [, ALIGNMENT = alignment]  
  [, STORAGE = storage]  
  [, DEFAULT = default]  
  [, ELEMENT = element]  
  [, DELIMITER = delimiter] )

CREATE TYPE name

See CREATE TYPE for more information.

CREATE USER

Defines a new database role with the LOGIN privilege by default.

CREATE USER name [[WITH] option [ ... ]]

See CREATE USER for more information.

CREATE VIEW

Defines a new view.

CREATE [OR REPLACE] [TEMP | TEMPORARY] VIEW name
  [ ( column_name [, ... ] ) ]
  AS query

See CREATE VIEW for more information.

DEALLOCATE

Deallocates a prepared statement.

DEALLOCATE [PREPARE] name

See DEALLOCATE for more information.

DECLARE

Defines a cursor.

DECLARE name [BINARY] [INSENSITIVE] [NO SCROLL] CURSOR
  [[WITH | WITHOUT] HOLD]
  FOR query [FOR READ ONLY]

See DECLARE for more information.
**DELETE**
Deletes rows from a table.

```
DELETE FROM [ONLY] table [[AS] alias]
  [USING usinglist]
  [WHERE condition | WHERE CURRENT OF cursor_name ]
```

See `DELETE` for more information.

**DISCARD**
Discards the session state.

```
DISCARD { ALL | PLANS | TEMPORARY | TEMP }
```

See `DISCARD` for more information.

**DROP AGGREGATE**
Removes an aggregate function.

```
DROP AGGREGATE [IF EXISTS] name (type [, ...] ) [CASCADE | RESTRICT]
```

See `DROP AGGREGATE` for more information.

**DO**
Executes an anonymous code block as a transient anonymous function.

```
DO [ LANGUAGE lang_name ] code
```

See `DO` for more information.

**DROP CAST**
Removes a cast.

```
DROP CAST [IF EXISTS] (sourcetype AS targettype) [CASCADE | RESTRICT]
```

See `DROP CAST` for more information.

**DROP CONVERSION**
Removes a conversion.

```
DROP CONVERSION [IF EXISTS] name [CASCADE | RESTRICT]
```

See `DROP CONVERSION` for more information.

**DROP DATABASE**
Removes a database.

```
DROP DATABASE [IF EXISTS] name
```

See `DROP DATABASE` for more information.
**DROP DOMAIN**
Removes a domain.

```
DROP DOMAIN [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

See *DROP DOMAIN* for more information.

**DROP EXTENSION**
Removes an extension from a Greenplum database.

```
DROP EXTENSION [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]
```

See *DROP EXTENSION* for more information.

**DROP EXTERNAL TABLE**
Removes an external table definition.

```
DROP EXTERNAL [WEB] TABLE [IF EXISTS] name [CASCADE | RESTRICT]
```

See *DROP EXTERNAL TABLE* for more information.

**DROP FILESPACE**
Removes a filespace.

```
DROP FILESPACE [IF EXISTS] filespacename
```

See *DROP FILESPACE* for more information.

**DROP FUNCTION**
Removes a function.

```
DROP FUNCTION [IF EXISTS] name ( [ [argmode] [argname] argtype [, ...] ] ) [CASCADE | RESTRICT]
```

See *DROP FUNCTION* for more information.

**DROP GROUP**
Removes a database role.

```
DROP GROUP [IF EXISTS] name [, ...]
```

See *DROP GROUP* for more information.

**DROP INDEX**
Removes an index.

```
DROP INDEX [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

See *DROP INDEX* for more information.
**DROP LANGUAGE**
Removes a procedural language.

```
DROP [PROCEDURAL] LANGUAGE [IF EXISTS] name [CASCADE | RESTRICT]
```

See *DROP LANGUAGE* for more information.

**DROP OPERATOR**
Removes an operator.

```
DROP OPERATOR [IF EXISTS] name ( {lefttype | NONE} ,
    {righttype | NONE} ) [CASCADE | RESTRICT]
```

See *DROP OPERATOR* for more information.

**DROP OPERATOR CLASS**
Removes an operator class.

```
DROP OPERATOR CLASS [IF EXISTS] name USING index_method [CASCADE | RESTRICT]
```

See *DROP OPERATOR CLASS* for more information.

**DROP OPERATOR FAMILY**
Removes an operator family.

```
DROP OPERATOR FAMILY [IF EXISTS] name USING index_method [CASCADE | RESTRICT]
```

See *DROP OPERATOR FAMILY* for more information.

**DROP OWNED**
Removes database objects owned by a database role.

```
DROP OWNED BY name [, ...] [CASCADE | RESTRICT]
```

See *DROP OWNED* for more information.

**DROP PROTOCOL**
Removes an external table data access protocol from a database.

```
DROP PROTOCOL [IF EXISTS] name
```

See *DROP PROTOCOL* for more information.

**DROP RESOURCE GROUP**
Removes a resource group.

```
DROP RESOURCE GROUP group_name
```

See *DROP RESOURCE GROUP* for more information.
DROP RESOURCE QUEUE
Removes a resource queue.

```
DROP RESOURCE QUEUE queue_name
```

See `DROP RESOURCE QUEUE` for more information.

DROP ROLE
Removes a database role.

```
DROP ROLE [IF EXISTS] name [, ...]
```

See `DROP ROLE` for more information.

DROP RULE
Removes a rewrite rule.

```
DROP RULE [IF EXISTS] name ON relation [CASCADE | RESTRICT]
```

See `DROP RULE` for more information.

DROP SCHEMA
Removes a schema.

```
DROP SCHEMA [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

See `DROP SCHEMA` for more information.

DROP SEQUENCE
Removes a sequence.

```
DROP SEQUENCE [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

See `DROP SEQUENCE` for more information.

DROP TABLE
Removes a table.

```
DROP TABLE [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

See `DROP TABLE` for more information.

DROP TABLESPACE
Removes a tablespace.

```
DROP TABLESPACE [IF EXISTS] tablesapce
```

See `DROP TABLESPACE` for more information.
DROP TYPE
Removes a data type.

```
DROP TYPE [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

See *DROP TYPE* for more information.

DROP USER
Removes a database role.

```
DROP USER [IF EXISTS] name [, ...]
```

See *DROP USER* for more information.

DROP VIEW
Removes a view.

```
DROP VIEW [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

See *DROP VIEW* for more information.

END
Commits the current transaction.

```
END [WORK | TRANSACTION]
```

See *END* for more information.

EXECUTE
Executes a prepared SQL statement.

```
EXECUTE name [ (parameter [, ...] ) ]
```

See *EXECUTE* for more information.

EXPLAIN
Shows the query plan of a statement.

```
EXPLAIN [ANALYZE] [VERBOSE] statement
```

See *EXPLAIN* for more information.

FETCH
Retrieves rows from a query using a cursor.

```
FETCH [ forward_direction { FROM | IN } ] cursoname
```

See *FETCH* for more information.
**GRANT**

Defines access privileges.

```
GRANT { {SELECT | INSERT | UPDATE | DELETE | REFERENCES | TRIGGER | TRUNCATE } [, ...] | ALL [PRIVILEGES] }
  ON [TABLE] tablename [, ...]
  TO { rolename | PUBLIC} [, ...] [WITH GRANT OPTION]

GRANT { {USAGE | SELECT | UPDATE} [, ...] | ALL [PRIVILEGES] }
  ON SEQUENCE sequencename [, ...]
  TO { rolename | PUBLIC } [, ...] [WITH GRANT OPTION]

GRANT { {CREATE | CONNECT | TEMPORARY | TEMP} [, ...] | ALL [PRIVILEGES] }
  ON DATABASE dbname [, ...]
  TO { rolename | PUBLIC} [, ...] [WITH GRANT OPTION]

GRANT { EXECUTE | ALL [PRIVILEGES] }
  ON FUNCTION funcname ( [ [argmode] argname argtype [, ...] ] [, ...]
  TO { rolename | PUBLIC} [, ...] [WITH GRANT OPTION]

GRANT { USAGE | ALL [PRIVILEGES] }
  ON LANGUAGE langname [, ...]
  TO { rolename | PUBLIC} [, ...] [WITH GRANT OPTION]

GRANT { {CREATE | USAGE} [, ...] | ALL [PRIVILEGES] }
  ON SCHEMA schemaname [, ...]
  TO { rolename | PUBLIC} [, ...] [WITH GRANT OPTION]

GRANT { CREATE | ALL [PRIVILEGES] }
  ON TABLESPACE tablespacename [, ...]
  TO { rolename | PUBLIC} [, ...] [WITH GRANT OPTION]

GRANT parent_role [, ...]
  TO member_role [, ...] [WITH ADMIN OPTION]

GRANT { SELECT | INSERT | ALL [PRIVILEGES] }
  ON PROTOCOL protocolname
  TO username
```

See **GRANT** for more information.

**INSERT**

Creates new rows in a table.

```
INSERT INTO table [( column [, ...] )]
{DEFAULT VALUES | VALUES ( {expression | DEFAULT} [, ...] )
 [, ...] | query}
```

See **INSERT** for more information.

**LOAD**

Loads or reloads a shared library file.

```
LOAD 'filename'
```

See **LOAD** for more information.
**LOCK**
Locks a table.

```
LOCK [TABLE] name [, ...] [IN lockmode MODE] [NOWAIT]
```

See *LOCK* for more information.

**MOVE**
Positions a cursor.

```
MOVE [ forward_direction {FROM | IN} ] cursorname
```

See *MOVE* for more information.

**PREPARE**
Prepare a statement for execution.

```
PREPARE name [ (datatype [, ...] ) ] AS statement
```

See *PREPARE* for more information.

**REASSIGN OWNED**
Changes the ownership of database objects owned by a database role.

```
REASSIGN OWNED BY old_role [, ...] TO new_role
```

See *REASSIGN OWNED* for more information.

**REINDEX**
Rebuilds indexes.

```
REINDEX {INDEX | TABLE | DATABASE | SYSTEM} name
```

See *REINDEX* for more information.

**RELEASE SAVEPOINT**
Destroys a previously defined savepoint.

```
RELEASE [SAVEPOINT] savepoint_name
```

See *RELEASE SAVEPOINT* for more information.

**RESET**
Restores the value of a system configuration parameter to the default value.

```
RESET configuration_parameter
RESET ALL
```

See *RESET* for more information.
REVOKE
Removes access privileges.

```
REVOKE [GRANT OPTION FOR] { {SELECT | INSERT | UPDATE | DELETE
| REFERENCES | TRIGGER | TRUNCATE } [, ...] | ALL [PRIVILEGES] }
ON [TABLE] tablename [, ...]
FROM { rolename | PUBLIC} [, ...]
[CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] { {USAGE | SELECT | UPDATE} [, ...]
| ALL [PRIVILEGES] }
ON SEQUENCE sequencename [, ...]
FROM { rolename | PUBLIC} [, ...]
[CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] { {CREATE | CONNECT
| TEMPORARY | TEMP} [, ...] | ALL [PRIVILEGES] }
ON DATABASE dbname [, ...]
FROM { rolename | PUBLIC} [, ...]
[CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] {EXECUTE | ALL [PRIVILEGES]}
ON FUNCTION funcname ( [[argmode] [argname] argtype
[, ...]] ) [, ...]
FROM { rolename | PUBLIC} [, ...]
[CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] {USAGE | ALL [PRIVILEGES]}
ON LANGUAGE langname [, ...]
FROM { rolename | PUBLIC} [, ...]
[CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] { {CREATE | USAGE} [, ...]
| ALL [PRIVILEGES] }
ON SCHEMA schemaname [, ...]
FROM { rolename | PUBLIC} [, ...]
[CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] { CREATE | ALL [PRIVILEGES] }
ON TABLESPACE tablespacename [, ...]
FROM { rolename | PUBLIC} [, ...]
[CASCADE | RESTRICT]

REVOKE [ADMIN OPTION FOR] parent_role [, ...]
FROM member_role [, ...]
[CASCADE | RESTRICT]
```

See `REVOKE` for more information.

ROLLBACK
Aborts the current transaction.

```
ROLLBACK [WORK | TRANSACTION]
```

See `ROLLBACK` for more information.
ROLLBACK TO SAVEPOINT
Rolls back the current transaction to a savepoint.

ROLLBACK [WORK | TRANSACTION] TO [SAVEPOINT] savepoint_name

See ROLLBACK TO SAVEPOINT for more information.

SAVEPOINT
Defines a new savepoint within the current transaction.

SAVEPOINT savepoint_name

See SAVEPOINT for more information.

SELECT
Retrieves rows from a table or view.

[ WITH [ RECURSIVE^1 ] with_query [, ...] ]
SELECT [ALL | DISTINCT [ON (expression [, ...])] ]
 * | expression [ [AS] output_name ] [, ...]
 FROM from_item [, ...]
 [WHERE condition]
 [GROUP BY grouping_element [, ...]]
 [HAVING condition [, ...]]
 [WINDOW window_name AS (window_specification)]
 [{UNION | INTERSECT | EXCEPT} ALL select]
 [ORDER BY expression [ASC | DESC | USING operator] [NULLS {FIRST | LAST}] [, ...]]
 [LIMIT {count | ALL}]
 [OFFSET start]
 [FOR {UPDATE | SHARE} OF table_name [, ...] NOWAIT ] [...]

See SELECT for more information.

SELECT INTO
Defines a new table from the results of a query.

[ WITH [ RECURSIVE^1 ] with_query [, ...] ]
SELECT [ALL | DISTINCT [ON ( expression [, ...] ) ]] * | expression [ [AS] output_name ] [, ...]
 INTO [TEMPORARY | TEMP] [TABLE] new_table
 FROM from_item [, ...]
 [WHERE condition]
 [GROUP BY expression [, ...]]
 [HAVING condition [, ...]]
 [{UNION | INTERSECT | EXCEPT} ALL select]
 [ORDER BY expression [ASC | DESC | USING operator] [NULLS {FIRST | LAST}] [, ...]]
 [LIMIT {count | ALL}]
 [OFFSET start]
 [FOR {UPDATE | SHARE} OF table_name [, ...] NOWAIT]
 [...]

See SELECT INTO for more information.
SET
Changes the value of a Greenplum Database configuration parameter.

```
SET [SESSION | LOCAL] configuration_parameter {TO | =} value | 'value' | DEFAULT
```

```
SET [SESSION | LOCAL] TIME ZONE {timezone | LOCAL | DEFAULT}
```

See `SET` for more information.

SET ROLE
Sets the current role identifier of the current session.

```
SET [SESSION | LOCAL] ROLE rolename
```

```
SET [SESSION | LOCAL] ROLE NONE
```

```
RESET ROLE
```

See `SET ROLE` for more information.

SET SESSION AUTHORIZATION
Sets the session role identifier and the current role identifier of the current session.

```
SET [SESSION | LOCAL] SESSION AUTHORIZATION rolename
```

```
SET [SESSION | LOCAL] SESSION AUTHORIZATION DEFAULT
```

```
RESET SESSION AUTHORIZATION
```

See `SET SESSION AUTHORIZATION` for more information.

SET TRANSACTION
Sets the characteristics of the current transaction.

```
SET TRANSACTION [transaction_mode] [READ ONLY | READ WRITE]
```

```
SET SESSION CHARACTERISTICS AS TRANSACTION transaction_mode [READ ONLY | READ WRITE]
```

See `SET TRANSACTION` for more information.

SHOW
Shows the value of a system configuration parameter.

```
SHOW configuration_parameter
```

```
SHOW ALL
```

See `SHOW` for more information.
START TRANSACTION
Starts a transaction block.

```
START TRANSACTION [SERIALIZABLE | READ COMMITTED | READ UNCOMMITTED]
[READ WRITE | READ ONLY]
```

See `START TRANSACTION` for more information.

TRUNCATE
Empties a table of all rows.

```
TRUNCATE [TABLE] name [, ...] [CASCADE | RESTRICT]
```

See `TRUNCATE` for more information.

UPDATE
Updates rows of a table.

```
UPDATE [ONLY] table [[AS] alias]
SET {column = {expression | DEFAULT} |
  (column [, ...]) = ((expression | DEFAULT) [, ...])}, ...
[FROM fromlist]
[WHERE condition | WHERE CURRENT OF cursor_name ]
```

See `UPDATE` for more information.

VACUUM
Garbage-collects and optionally analyzes a database.

```
VACUUM [FULL] [FREEZE] [VERBOSE] [table]
VACUUM [FULL] [FREEZE] [VERBOSE] ANALYZE
  [table [(column [, ... ])]]
```

See `VACUUM` for more information.

VALUES
Computes a set of rows.

```
VALUES ( expression [, ... ] ) [, ...]
[ORDER BY sort_expression [ASC | DESC | USING operator] [, ...]]
[LIMIT {count | ALL}] [OFFSET start]
```

See `VALUES` for more information.

ABORT
Aborts the current transaction.

Synopsis
```
ABORT [WORK | TRANSACTION]
```
**Description**

ABORT rolls back the current transaction and causes all the updates made by the transaction to be discarded. This command is identical in behavior to the standard SQL command ROLLBACK, and is present only for historical reasons.

**Parameters**

- **WORK**
- **TRANSACTION**

  Optional key words. They have no effect.

**Notes**

Use COMMIT to successfully terminate a transaction.

Issuing ABORT when not inside a transaction does no harm, but it will provoke a warning message.

**Compatibility**

This command is a Greenplum Database extension present for historical reasons. ROLLBACK is the equivalent standard SQL command.

**See Also**

BEGIN, COMMIT, ROLLBACK

---

**ALTER AGGREGATE**

Changes the definition of an aggregate function

**Synopsis**

```
ALTER AGGREGATE name ( type [ , ... ] ) RENAME TO new_name
ALTER AGGREGATE name ( type [ , ... ] ) OWNER TO new_owner
ALTER AGGREGATE name ( type [ , ... ] ) SET SCHEMA new_schema
```

**Description**

ALTER AGGREGATE changes the definition of an aggregate function.

You must own the aggregate function to use ALTER AGGREGATE. To change the schema of an aggregate function, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the aggregate function's schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the aggregate function. However, a superuser can alter ownership of any aggregate function anyway.)

**Parameters**

- **name**
  
  The name (optionally schema-qualified) of an existing aggregate function.

- **type**
  
  An input data type on which the aggregate function operates. To reference a zero-argument aggregate function, write * in place of the list of input data types.

- **new_name**
The new name of the aggregate function.

\texttt{new\_owner}

The new owner of the aggregate function.

\texttt{new\_schema}

The new schema for the aggregate function.

### Examples

To rename the aggregate function \texttt{myavg} for type \texttt{integer} to \texttt{my\_average}:

```sql
ALTER AGGREGATE myavg(integer) RENAME TO my_average;
```

To change the owner of the aggregate function \texttt{myavg} for type \texttt{integer} to \texttt{joe}:

```sql
ALTER AGGREGATE myavg(integer) OWNER TO joe;
```

To move the aggregate function \texttt{myavg} for type \texttt{integer} into schema \texttt{myschema}:

```sql
ALTER AGGREGATE myavg(integer) SET SCHEMA myschema;
```

### Compatibility

There is no \texttt{ALTER AGGREGATE} statement in the SQL standard.

### See Also

\texttt{CREATE AGGREGATE, DROP AGGREGATE}

\textbf{ALTER CONVERSION}

Changes the definition of a conversion.

### Synopsis

```
ALTER CONVERSION \textit{name} RENAME TO \textit{newname}
```

```
ALTER CONVERSION \textit{name} OWNER TO \textit{newowner}
```

### Description

\texttt{ALTER CONVERSION} changes the definition of a conversion.

You must own the conversion to use \texttt{ALTER CONVERSION}. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have \texttt{CREATE} privilege on the conversion’s schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the conversion. However, a superuser can alter ownership of any conversion anyway.)

### Parameters

\texttt{name}

The name (optionally schema-qualified) of an existing conversion.

\texttt{newname}

The new name of the conversion.

\texttt{newowner}
The new owner of the conversion.

**Examples**

To rename the conversion `iso_8859_1_to_utf8` to `latin1_to_unicode`:

```sql
ALTER CONVERSION iso_8859_1_to_utf8 RENAME TO latin1_to_unicode;
```

To change the owner of the conversion `iso_8859_1_to_utf8` to `joe`:

```sql
ALTER CONVERSION iso_8859_1_to_utf8 OWNER TO joe;
```

**Compatibility**

There is no `ALTER CONVERSION` statement in the SQL standard.

**See Also**

`CREATE CONVERSION`, `DROP CONVERSION`

---

**ALTER DATABASE**

Changes the attributes of a database.

**Synopsis**

```sql
ALTER DATABASE name [ WITH CONNECTION LIMIT connlimit ]
ALTER DATABASE name SET parameter { TO | = } { value | DEFAULT }
ALTER DATABASE name RESET parameter
ALTER DATABASE name RENAME TO newname
ALTER DATABASE name OWNER TO new_owner
```

**Description**

`ALTER DATABASE` changes the attributes of a database.

The first form changes the allowed connection limit for a database. Only the database owner or a superuser can change this setting.

The second and third forms change the session default for a configuration parameter for a Greenplum database. Whenever a new session is subsequently started in that database, the specified value becomes the session default value. The database-specific default overrides whatever setting is present in the server configuration file (`postgresql.conf`). Only the database owner or a superuser can change the session defaults for a database. Certain parameters cannot be set this way, or can only be set by a superuser.

The fourth form changes the name of the database. Only the database owner or a superuser can rename a database; non-superuser owners must also have the `CREATEDB` privilege. You cannot rename the current database. Connect to a different database first.

The fifth form changes the owner of the database. To alter the owner, you must own the database and also be a direct or indirect member of the new owning role, and you must have the `CREATEDB` privilege. (Note that superusers have all these privileges automatically.)
Parameters

**name**

The name of the database whose attributes are to be altered.

**connlimit**

The maximum number of concurrent connections possible. The default of -1 means there is no limitation.

**parameter value**

Set this database’s session default for the specified configuration parameter to the given value. If value is **DEFAULT** or, equivalently, **RESET** is used, the database-specific setting is removed, so the system-wide default setting will be inherited in new sessions. Use **RESET ALL** to clear all database-specific settings. See Server Configuration Parameters for information about server parameters. for information about all user-settable configuration parameters.

**newname**

The new name of the database.

**new_owner**

The new owner of the database.

Notes

It is also possible to set a configuration parameter session default for a specific role (user) rather than to a database. Role-specific settings override database-specific ones if there is a conflict. See **ALTER ROLE**.

Examples

To set the default schema search path for the **mydatabase** database:

```
ALTER DATABASE mydatabase SET search_path TO myschema, public, pg_catalog;
```

Compatibility

The **ALTER DATABASE** statement is a Greenplum Database extension.

See Also

**CREATE DATABASE**, **DROP DATABASE**, **SET**

**ALTER DOMAIN**

Changes the definition of a domain.

Synopsis

```
ALTER DOMAIN name { SET DEFAULT expression | DROP DEFAULT } 
ALTER DOMAIN name { SET | DROP } NOT NULL
ALTER DOMAIN name ADD domain_constraint
ALTER DOMAIN name DROP CONSTRAINT constraint_name [RESTRICT | CASCADE]
ALTER DOMAIN name OWNER TO new_owner
```
**Description**  

ALTER DOMAIN changes the definition of an existing domain. There are several sub-forms:

- **SET/DROP DEFAULT** — These forms set or remove the default value for a domain. Note that defaults only apply to subsequent INSERT commands. They do not affect rows already in a table using the domain.
- **SET/DROP NOT NULL** — These forms change whether a domain is marked to allow NULL values or to reject NULL values. You may only SET NOT NULL when the columns using the domain contain no null values.
- **ADD domain_constraint** — This form adds a new constraint to a domain using the same syntax as CREATE DOMAIN. This will only succeed if all columns using the domain satisfy the new constraint.
- **DROP CONSTRAINT** — This form drops constraints on a domain.
- **OWNER** — This form changes the owner of the domain to the specified user.
- **SET SCHEMA** — This form changes the schema of the domain. Any constraints associated with the domain are moved into the new schema as well.

You must own the domain to use ALTER DOMAIN. To change the schema of a domain, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the domain's schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the domain. However, a superuser can alter ownership of any domain anyway.)

**Parameters**

- **name**
  The name (optionally schema-qualified) of an existing domain to alter.

- **domain_constraint**
  New domain constraint for the domain.

- **constraint_name**
  Name of an existing constraint to drop.

- **CASCADE**
  Automatically drop objects that depend on the constraint.

- **RESTRICT**
  Refuse to drop the constraint if there are any dependent objects. This is the default behavior.

- **new_owner**
  The user name of the new owner of the domain.

- **new_schema**
  The new schema for the domain.

**Examples**

To add a NOT NULL constraint to a domain:

```sql
ALTER DOMAIN zipcode SET NOT NULL;
```

To remove a NOT NULL constraint from a domain:

```sql
ALTER DOMAIN zipcode DROP NOT NULL;
```
To add a check constraint to a domain:

```
ALTER DOMAIN zipcode ADD CONSTRAINT zipchk CHECK
(char_length(VALUE) = 5);
```

To remove a check constraint from a domain:

```
ALTER DOMAIN zipcode DROP CONSTRAINT zipchk;
```

To move the domain into a different schema:

```
ALTER DOMAIN zipcode SET SCHEMA customers;
```

**Compatibility**

ALTER DOMAIN conforms to the SQL standard, except for the OWNER and SET SCHEMA variants, which are Greenplum Database extensions.

**See Also**

CREATE DOMAIN, DROP DOMAIN

**ALTER EXTENSION**

Change the definition of an extension that is registered in a Greenplum database.

**Synopsis**

```
ALTER EXTENSION name UPDATE [ TO new_version ]
ALTER EXTENSION name SET SCHEMA new_schema
ALTER EXTENSION name ADD member_object
ALTER EXTENSION name DROP member_object
```

where member_object is:

```
ACCESS METHOD object_name |  
AGGREGATE aggregate_name ( aggregate_signature ) |  
CAST (source_type AS target_type) |  
COLLATION object_name |  
CONVERSION object_name |  
DOMAIN object_name |  
EVENT TRIGGER object_name |  
FOREIGN DATA WRAPPER object_name |  
FOREIGN TABLE object_name |  
FUNCTION function_name ( [ [ argmode ] [ argname ] argtype [, ...] ] ) |  
MATERIALIZED VIEW object_name |  
OPERATOR operator_name (left_type, right_type) |  
OPERATOR CLASS object_name USING index_method |  
OPERATOR FAMILY object_name USING index_method |  
[ PROCEDURAL ] LANGUAGE object_name |  
SCHEMA object_name |  
SEQUENCE object_name |  
SERVER object_name |  
TABLE object_name |  
TEXT SEARCH CONFIGURATION object_name |  
TEXT SEARCH DICTIONARY object_name |  
TEXT SEARCH PARSER object_name |  
TEXT SEARCH TEMPLATE object_name |  
TRANSFORM FOR type_name LANGUAGE lang_name |  
TYPE object_name |  
```
**Description**

`ALTER EXTENSION` changes the definition of an installed extension. These are the subforms:

**UPDATE**

This form updates the extension to a newer version. The extension must supply a suitable update script (or series of scripts) that can modify the currently-installed version into the requested version.

**SET SCHEMA**

This form moves the extension member objects into another schema. The extension must be relocatable.

**ADD member_object**

This form adds an existing object to the extension. This is useful in extension update scripts. The added object is treated as a member of the extension. The object can only be dropped by dropping the extension.

**DROP member_object**

This form removes a member object from the extension. This is mainly useful in extension update scripts. The object is not dropped, only disassociated from the extension.

See Packaging Related Objects into an Extension for more information about these operations.

You must own the extension to use `ALTER EXTENSION`. The `ADD` and `DROP` forms also require ownership of the object that is being added or dropped.

**Parameters**

- **name**
  
  The name of an installed extension.

- **new_version**
  
  The new version of the extension. The `new_version` can be either an identifier or a string literal. If not specified, the command attempts to update to the default version in the extension control file.

- **new_schema**
  
  The new schema for the extension.

- **object_name**
- **aggregate_name**
- **function_name**
- **operator_name**

  The name of an object to be added to or removed from the extension. Names of tables, aggregates, domains, foreign tables, functions, operators, operator classes, operator families, sequences, text search objects, types, and views can be schema-qualified.

- **source_type**

  The name of the source data type of the cast.
**target_type**

The name of the target data type of the cast.

**argmode**

The mode of a function or aggregate argument: **IN, OUT, INOUT, or VARIADIC**. The default is **IN**.

The command ignores the **OUT** arguments. Only the input arguments are required to determine the function identity. It is sufficient to list the **IN, INOUT, and VARIADIC** arguments.

**argname**

The name of a function or aggregate argument.

The command ignores argument names, since only the argument data types are required to determine the function identity.

**argtype**

The data type of a function or aggregate argument.

**left_type**

**right_type**

The data types (optionally schema-qualified) of the operator arguments. Specify **NONE** for the missing argument of a prefix or postfix operator.

**PROCEDURAL**

This is a noise word.

**type_name**

The name of the data type of the transform.

**lang_name**

The name of the language of the transform.

**Examples**

To update the hstore extension to version 2.0:

```
ALTER EXTENSION hstore UPDATE TO '2.0';
```

To change the schema of the hstore extension to **utils**:

```
ALTER EXTENSION hstore SET SCHEMA utils;
```

To add an existing function to the hstore extension:

```
ALTER EXTENSION hstore ADD FUNCTION populate_record(anyelement, hstore);
```

**Compatibility**

`ALTER EXTENSION` is a Greenplum Database extension.

**See Also**

`CREATE EXTENSION`, `DROP EXTENSION`
**ALTER EXTERNAL TABLE**

Changes the definition of an external table.

**Synopsis**

```
ALTER EXTERNAL TABLE name action [, ... ]
```

where *action* is one of:

- `ADD [COLUMN] new_column type`
- `DROP [COLUMN] column [RESTRICT|CASCADE]`
- `ALTER [COLUMN] column TYPE type [USING expression]`
- `OWNER TO new_owner`

**Description**

`ALTER EXTERNAL TABLE` changes the definition of an existing external table. These are the supported `ALTER EXTERNAL TABLE` actions:

- **ADD COLUMN** — Adds a new column to the external table definition.
- **DROP COLUMN** — Drops a column from the external table definition. If you drop readable external table columns, it only changes the table definition in Greenplum Database. The `CASCADE` keyword is required if anything outside the table depends on the column, such as a view that references the column.
- **ALTER COLUMN TYPE** — Changes the data type of a table column.
- **OWNER** — Changes the owner of the external table to the specified user.

Use the `ALTER TABLE` command to perform these actions on an external table.

- Set (change) the table schema.
- Rename the table.
- Rename a table column.

You must own the external table to use `ALTER EXTERNAL TABLE` or `ALTER TABLE`. To change the schema of an external table, you must also have `CREATE` privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the external table's schema. A superuser has these privileges automatically.

Changes to the external table definition with either `ALTER EXTERNAL TABLE` or `ALTER TABLE` do not affect the external data.

The `ALTER EXTERNAL TABLE` and `ALTER TABLE` commands cannot modify the type external table (read, write, web), the table `FORMAT` information, or the location of the external data. To modify this information, you must drop and recreate the external table definition.

**Parameters**

- `name`  
  The name (possibly schema-qualified) of an existing external table definition to alter.

- `column`  
  Name of an existing column.

- `new_column`  
  Name of a new column.

- `USING expression`
Optional if an implicit or assignment cast exists from the old column data type to new data type. The clause is required if there is no implicit or assignment cast.

The **USING** clause does not affect the external data.

**type**

Data type of the new column, or new data type for an existing column.

**new_owner**

The role name of the new owner of the external table.

**CASCADE**

Automatically drop objects that depend on the dropped column, such as a view that references the column.

**RESTRICT**

Refuse to drop the column or constraint if there are any dependent objects. This is the default behavior.

**Examples**

Add a new column to an external table definition:

```sql
ALTER EXTERNAL TABLE ext_expenses ADD COLUMN manager text;
```

Change the owner of an external table:

```sql
ALTER EXTERNAL TABLE ext_data OWNER TO jojo;
```

Change the data type of an external table:

```sql
ALTER EXTERNAL TABLE ext_leads ALTER COLUMN acct_code TYPE integer USING acct_code::integer
```

When altering the column data type from **text** to **integer**, the **USING** clause is required but does not affect the external data.

**Compatibility**

`ALTER EXTERNAL TABLE` is a Greenplum Database extension. There is no `ALTER EXTERNAL TABLE` statement in the SQL standard or regular PostgreSQL.

**See Also**

`CREATE EXTERNAL TABLE`, `DROP EXTERNAL TABLE`, `ALTER TABLE`

---

**ALTER FILESPACE**

Changes the definition of a filespace.

**Synopsis**

```sql
ALTER FILESPACE name RENAME TO newname
```

```sql
ALTER FILESPACE name OWNER TO newowner
```

**Description**

`ALTER FILESPACE` changes the definition of a filespace.
You must own the filespace to use `ALTER FILESPACE`. To alter the owner, you must also be a direct or indirect member of the new owning role (note that superusers have these privileges automatically).

**Parameters**

- **name**
  The name of an existing filespace.

- **newname**
  The new name of the filespace. The new name cannot begin with `pg_` or `gp_` (reserved for system filespaces).

- **newowner**
  The new owner of the filespace.

**Examples**

Rename filespace `myfs` to `fast_ssd`:

```
ALTER FILESPACE myfs RENAME TO fast_ssd;
```

Change the owner of tablespace `myfs`:

```
ALTER FILESPACE myfs OWNER TO dba;
```

**Compatibility**

There is no `ALTER FILESPACE` statement in the SQL standard or in PostgreSQL.

**See Also**

`DROP FILESPACE`, `gpfilespace` in the *Greenplum Database Utility Guide*

---

**ALTER FUNCTION**

Changes the definition of a function.

**Synopsis**

```
ALTER FUNCTION name ( [ [argmode] [argname] argtyp e [, ... ] ] )
  action [, ... ] [RESTRICT]
```

```
ALTER FUNCTION name ( [ [argmode] [argname] argtyp e [, ... ] ] )
  RENAME TO new_name
```

```
ALTER FUNCTION name ( [ [argmode] [argname] argtyp e [, ... ] ] )
  OWNER TO new_owner
```

```
ALTER FUNCTION name ( [ [argmode] [argname] argtyp e [, ... ] ] )
  SET SCHEMA new_schema
```

where `action` is one of:

- `CALLED ON NULL INPUT`
- `RETURNS NULL ON NULL INPUT`
- `STRICT`
- `IMMUTABLE` or `STABLE` or `VOLATILE`
- `[[EXTERNAL] SECURITY INVOKER` or `[[EXTERNAL] SECURITY DEFINER`
- `COST execution_cost`
- `SET configuration_parameter { TO | = } { value | DEFAULT }`
- `SET configuration_parameter FROM CURRENT`
Description

ALTER FUNCTION changes the definition of a function.

You must own the function to use ALTER FUNCTION. To change a function’s schema, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the function's schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the function. However, a superuser can alter ownership of any function anyway.)

Parameters

name
The name (optionally schema-qualified) of an existing function.

argmode
The mode of an argument: either IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that ALTER FUNCTION does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function’s identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

argname
The name of an argument. Note that ALTER FUNCTION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function’s identity.

argtype
The data type(s) of the function’s arguments (optionally schema-qualified), if any.

new_name
The new name of the function.

new_owner
The new owner of the function. Note that if the function is marked SECURITY DEFINER, it will subsequently execute as the new owner.

new_schema
The new schema for the function.

CALLED ON NULL INPUT
RETURNS NULL ON NULL INPUT
STRICT

CALLED ON NULL INPUT changes the function so that it will be invoked when some or all of its arguments are null. RETURNS NULL ON NULL INPUT or STRICT changes the function so that it is not invoked if any of its arguments are null; instead, a null result is assumed automatically. See CREATE FUNCTION for more information.

IMMUTABLE
STABLE
VOLATILE

Change the volatility of the function to the specified setting. See CREATE FUNCTION for details.

[ EXTERNAL ] SECURITY INVOKER
[ EXTERNAL ] SECURITY DEFINER
Change whether the function is a security definer or not. The key word `EXTERNAL` is ignored for SQL conformance. See `CREATE FUNCTION` for more information about this capability.

**COST** `execution_cost`

Change the estimated execution cost of the function. See `CREATE FUNCTION` for more information.

**configuration_parameter**

Set or change the value of a configuration parameter when the function is called. If `value` is `DEFAULT` or, equivalently, `RESET` is used, the function-local setting is removed, and the function executes with the value present in its environment. Use `RESET ALL` to clear all function-local settings. `SET FROM CURRENT` applies the session's current value of the parameter when the function is entered.

**RESTRICT**

Ignored for conformance with the SQL standard.

**Notes**

Greenplum Database has limitations on the use of functions defined as `STABLE` or `VOLATILE`. See `CREATE FUNCTION` for more information.

**Examples**

To rename the function `sqrt` for type `integer` to `square_root`:

```sql
ALTER FUNCTION sqrt(integer) RENAME TO square_root;
```

To change the owner of the function `sqrt` for type `integer` to `joe`:

```sql
ALTER FUNCTION sqrt(integer) OWNER TO joe;
```

To change the `schema` of the function `sqrt` for type `integer` to `math`:

```sql
ALTER FUNCTION sqrt(integer) SET SCHEMA math;
```

To adjust the search path that is automatically set for a function:

```sql
ALTER FUNCTION check_password(text) RESET search_path;
```

**Compatibility**

This statement is partially compatible with the `ALTER FUNCTION` statement in the SQL standard. The standard allows more properties of a function to be modified, but does not provide the ability to rename a function, make a function a security definer, or change the owner, schema, or volatility of a function. The standard also requires the `RESTRICT` key word, which is optional in Greenplum Database.

**See Also**

`CREATE FUNCTION`, `DROP FUNCTION`

**ALTER GROUP**

Changes a role name or membership.
Synopsis

ALTER GROUP groupname ADD USER username [, ... ]
ALTER GROUP groupname DROP USER username [, ... ]
ALTER GROUP groupname RENAME TO newname

Description

ALTER GROUP changes the attributes of a user group. This is an obsolete command, though still accepted for backwards compatibility, because users and groups are superseded by the more general concept of roles. See ALTER ROLE for more information.

The first two variants add users to a group or remove them from a group. Any role can play the part of groupname or username. The preferred method for accomplishing these tasks is to use GRANT and REVOKE.

Parameters

groupname
  The name of the group (role) to modify.

username
  Users (roles) that are to be added to or removed from the group. The users (roles) must already exist.

newname
  The new name of the group (role).

Examples

To add users to a group:

ALTER GROUP staff ADD USER karl, john;

To remove a user from a group:

ALTER GROUP workers DROP USER beth;

Compatibility

There is no ALTER GROUP statement in the SQL standard.

See Also

ALTER ROLE, GRANT, REVOKE

ALTER INDEX

Changes the definition of an index.

Synopsis

ALTER INDEX name RENAME TO new_name
ALTER INDEX name SET TABLESPACE tablespace_name
ALTER INDEX name SET ( FILLFACTOR = value )
ALTER INDEX name RESET ( FILLFACTOR )

Description
ALTER INDEX changes the definition of an existing index. There are several subforms:

• **RENAME** — Changes the name of the index. There is no effect on the stored data.
• **SET TABLESPACE** — Changes the index's tablespace to the specified tablespace and moves the data file(s) associated with the index to the new tablespace. See also `CREATE TABLESPACE`.
• **SET FILLFACTOR** — Changes the index-method-specific storage parameters for the index. The built-in index methods all accept a single parameter: `FILLFACTOR`. The fillfactor for an index is a percentage that determines how full the index method will try to pack index pages. For B-trees, leaf pages are filled to this percentage during initial index build, and also when extending the index at the right (largest key values). If pages subsequently become completely full, they will be split, leading to gradual degradation in the index's efficiency. B-trees use a default fillfactor of 90, but any value from 10 to 100 can be selected. If the table is static then fillfactor 100 is best to minimize the index's physical size, but for heavily updated tables a smaller fillfactor is better to minimize the need for page splits. The other index methods use fillfactor in different but roughly analogous ways; the default fillfactor varies between methods.
• **RESET FILLFACTOR** — Resets `FILLFACTOR` to the default. As with `SET`, a `REINDEX` may be needed to update the index entirely.

Parameters

- **name**
  The name (optionally schema-qualified) of an existing index to alter.
- **new_name**
  New name for the index.
- **tablespace_name**
  The tablespace to which the index will be moved.
- **FILLFACTOR**
  The fillfactor for an index is a percentage that determines how full the index method will try to pack index pages. For B-trees, leaf pages are filled to this percentage during initial index build, and also when extending the index at the right (largest key values). If pages subsequently become completely full, they will be split, leading to gradual degradation in the index's efficiency. B-trees use a default fillfactor of 90, but any value from 10 to 100 can be selected. If the table is static then fillfactor 100 is best to minimize the index's physical size, but for heavily updated tables a smaller fillfactor is better to minimize the need for page splits. The other index methods use fillfactor in different but roughly analogous ways; the default fillfactor varies between methods.

Notes

These operations are also possible using `ALTER TABLE`. Changing any part of a system catalog index is not permitted.

Examples

To rename an existing index:

```
ALTER INDEX distributors RENAME TO suppliers;
```

To move an index to a different tablespace:

```
ALTER INDEX distributors SET TABLESPACE fasttablespace;
```

To change an index's fill factor (assuming that the index method supports it):

```
ALTER INDEX distributors SET (fillfactor = 75);
```
REINDEX INDEX distributors;

Compatibility
ALTER INDEX is a Greenplum Database extension.

See Also
CREATE INDEX, REINDEX, ALTER TABLE

**ALTER LANGUAGE**
Changes the name of a procedural language.

**Synopsis**

```
ALTER LANGUAGE name RENAME TO newname
ALTER LANGUAGE name OWNER TO new_owner
```

**Description**
ALTER LANGUAGE changes the definition of a procedural language for a specific database. Definition changes supported include renaming the language or assigning a new owner. You must be superuser or the owner of the language to use ALTER LANGUAGE.

**Parameters**

- **name**
  Name of a language.

- **newname**
  The new name of the language.

- **new_owner**
  The new owner of the language.

**Compatibility**
There is no ALTER LANGUAGE statement in the SQL standard.

**See Also**
CREATE LANGUAGE, DROP LANGUAGE

**ALTER OPERATOR**
Changes the definition of an operator.

**Synopsis**

```
ALTER OPERATOR name ( {lefttype | NONE} , {righttype | NONE} )
OWNER TO newowner
```

**Description**
ALTER OPERATOR changes the definition of an operator. The only currently available functionality is to change the owner of the operator.
You must own the operator to use `ALTER OPERATOR`. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the operator’s schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the operator. However, a superuser can alter ownership of any operator anyway.)

### Parameters

**name**
The name (optionally schema-qualified) of an existing operator.

**lefttype**
The data type of the operator's left operand; write `NONE` if the operator has no left operand.

**righttype**
The data type of the operator's right operand; write `NONE` if the operator has no right operand.

**newowner**
The new owner of the operator.

### Examples

Change the owner of a custom operator `a @@ b` for type `text`:

```
ALTER OPERATOR @@ (text, text) OWNER TO joe;
```

### Compatibility

There is no `ALTEROPERATOR` statement in the SQL standard.

### See Also

`CREATE OPERATOR`, `DROP OPERATOR`  

### ALTER OPERATOR CLASS

Changes the definition of an operator class.

#### Synopsis

```
ALTER OPERATOR CLASS name USING index_method RENAME TO newname  
ALTER OPERATOR CLASS name USING index_method OWNER TO newowner  
```

#### Description

`ALTER OPERATOR CLASS` changes the definition of an operator class.

You must own the operator class to use `ALTER OPERATOR CLASS`. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have `CREATE` privilege on the operator class's schema. (These restrictions enforce that altering the owner does not do anything you could not do by dropping and recreating the operator class. However, a superuser can alter ownership of any operator class anyway.)

#### Parameters

**name**
The name (optionally schema-qualified) of an existing operator class.
index_method

The name of the index method this operator class is for.

newname

The new name of the operator class.

newowner

The new owner of the operator class

Compatibility

There is no ALTER OPERATOR CLASS statement in the SQL standard.

See Also

CREATE OPERATOR CLASS, DROP OPERATOR CLASS

ALTER OPERATOR FAMILY

Changes the definition of an operator family.

Synopsis

```sql
ALTER OPERATOR FAMILY name USING index_method ADD
 { OPERATOR strategy_number operator_name ( op_type, op_type ) [ RECHECK ]
 | FUNCTION support_number [ ( op_type [ , op_type ] ) ] funcname
 ( argument_type [ , ... ] )
 } [, ... ]

ALTER OPERATOR FAMILY name USING index_method DROP
 { OPERATOR strategy_number ( op_type, op_type )
 | FUNCTION support_number [ ( op_type [ , op_type ] )
 } [, ... ]

ALTER OPERATOR FAMILY name USING index_method RENAME TO newname

ALTER OPERATOR FAMILY name USING index_method OWNER TO newowner
```

Description

ALTER OPERATOR FAMILY changes the definition of an operator family. You can add operators and support functions to the family, remove them from the family, or change the family's name or owner.

When operators and support functions are added to a family with ALTER OPERATOR FAMILY, they are not part of any specific operator class within the family, but are just "loose" within the family. This indicates that these operators and functions are compatible with the family's semantics, but are not required for correct functioning of any specific index. (Operators and functions that are so required should be declared as part of an operator class, instead; see CREATE OPERATOR CLASS.) You can drop loose members of a family from the family at any time, but members of an operator class cannot be dropped without dropping the whole class and any indexes that depend on it. Typically, single-data-type operators and functions are part of operator classes because they are needed to support an index on that specific data type, while cross-data-type operators and functions are made loose members of the family.

You must be a superuser to use ALTER OPERATOR FAMILY. (This restriction is made because an erroneous operator family definition could confuse or even crash the server.)

ALTER OPERATOR FAMILY does not presently check whether the operator family definition includes all the operators and functions required by the index method, nor whether the operators and functions form a self-consistent set. It is the user's responsibility to define a valid operator family.

OPERATOR and FUNCTION clauses can appear in any order.
Parameters

**name**

The name (optionally schema-qualified) of an existing operator family.

**index_method**

The name of the index method this operator family is for.

**strategy_number**

The index method’s strategy number for an operator associated with the operator family.

**operator_name**

The name (optionally schema-qualified) of an operator associated with the operator family.

**op_type**

In an OPERATOR clause, the operand data type(s) of the operator, or NONE to signify a left-unary or right-unary operator. Unlike the comparable syntax in CREATE OPERATOR CLASS, the operand data types must always be specified. In an ADD FUNCTION clause, the operand data type(s) the function is intended to support, if different from the input data type(s) of the function. For B-tree and hash indexes it is not necessary to specify op_type since the function’s input data type(s) are always the correct ones to use. For GIN and GiST indexes it is necessary to specify the input data type the function is to be used with. In an DROP FUNCTION clause, the operand data type(s) the function is intended to support must be specified.

**RECHECK**

If present, the index is "lossy" for this operator, and so the rows retrieved using the index must be rechecked to verify that they actually satisfy the qualification clause involving this operator.

**support_number**

The index method’s support procedure number for a function associated with the operator family.

**funcname**

The name (optionally schema-qualified) of a function that is an index method support procedure for the operator family.

**argument_types**

The parameter data type(s) of the function.

**newname**

The new name of the operator family.

**newowner**

The new owner of the operator family.

Compatibility

There is no ALTER OPERATOR FAMILY statement in the SQL standard.

Notes

Notice that the DROP syntax only specifies the "slot" in the operator family, by strategy or support number and input data type(s). The name of the operator or function occupying the slot is not mentioned. Also, for DROP FUNCTION the type(s) to specify are the input data type(s) the function is intended to support; for GIN and GiST indexes this might have nothing to do with the actual input argument types of the function.

Because the index machinery does not check access permissions on functions before using them, including a function or operator in an operator family is tantamount to granting public execute permission on it. This is usually not an issue for the sorts of functions that are useful in an operator family.
The operators should not be defined by SQL functions. A SQL function is likely to be inlined into the calling query, which will prevent the optimizer from recognizing that the query matches an index.

**Examples**

The following example command adds cross-data-type operators and support functions to an operator family that already contains B-tree operator classes for data types int4 and int2:

```sql
ALTER OPERATOR FAMILY integer_ops USING btree ADD

-- int4 vs int2
OPERATOR 1 < (int4, int2) ,
OPERATOR 2 <= (int4, int2) ,
OPERATOR 3 = (int4, int2) ,
OPERATOR 4 >= (int4, int2) ,
OPERATOR 5 > (int4, int2) ,
FUNCTION 1 btint42cmp(int4, int2) ,

-- int2 vs int4
OPERATOR 1 < (int2, int4) ,
OPERATOR 2 <= (int2, int4) ,
OPERATOR 3 = (int2, int4) ,
OPERATOR 4 >= (int2, int4) ,
OPERATOR 5 > (int2, int4) ,
FUNCTION 1 btint24cmp(int2, int4) ;
```

To remove these entries:

```sql
ALTER OPERATOR FAMILY integer_ops USING btree DROP

-- int4 vs int2
OPERATOR 1 (int4, int2) ,
OPERATOR 2 (int4, int2) ,
OPERATOR 3 (int4, int2) ,
OPERATOR 4 (int4, int2) ,
OPERATOR 5 (int4, int2) ,
FUNCTION 1 (int4, int2) ,

-- int2 vs int4
OPERATOR 1 (int2, int4) ,
OPERATOR 2 (int2, int4) ,
OPERATOR 3 (int2, int4) ,
OPERATOR 4 (int2, int4) ,
OPERATOR 5 (int2, int4) ,
FUNCTION 1 (int2, int4) ;
```

**See Also**

CREATE OPERATOR FAMILY, DROP OPERATOR FAMILY, ALTER OPERATOR CLASS, CREATE OPERATOR CLASS, DROP OPERATOR CLASS

**ALTERT PROTOCOL**

Changes the definition of a protocol.

**Synopsis**

```
ALTER PROTOCOL name RENAME TO newname

ALTER PROTOCOL name OWNER TO newowner
```
Description

ALTER PROTOCOL changes the definition of a protocol. Only the protocol name or owner can be altered. You must own the protocol to use ALTER PROTOCOL. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on schema of the conversion.

These restrictions are in place to ensure that altering the owner only makes changes that could be made by dropping and recreating the protocol. Note that a superuser can alter ownership of any protocol.

Parameters

name
The name (optionally schema-qualified) of an existing protocol.

newname
The new name of the protocol.

newowner
The new owner of the protocol.

Examples

To rename the conversion GPDBauth to GPDB_authentication:

```
ALTER PROTOCOL GPDBauth RENAME TO GPDB_authentication;
```

To change the owner of the conversion GPDB_authentication to joe:

```
ALTER PROTOCOL GPDB_authentication OWNER TO joe;
```

Compatibility

There is no ALTER PROTOCOL statement in the SQL standard.

See Also

CREATE EXTERNAL TABLE, CREATE PROTOCOL

**ALTER RESOURCE GROUP**

Changes the limits of a resource group.

Synopsis

```
ALTER RESOURCE GROUP name SET group_attribute value
```

where group_attribute is one of:

- CONCURRENCY integer
- CPU_RATE_LIMIT integer
- MEMORY_LIMIT integer
- MEMORY_SHARED_QUOTA integer
- MEMORY_SPILL_RATIO integer
**Description**

ALTER RESOURCE GROUP changes the limits of a resource group. Only a superuser can alter a resource group.

You can set or reset the concurrency limit of a resource group that you create for roles to control the maximum number of active concurrent statements in that group. You can also reset the memory or CPU rate limit of a resource group to control the amount of memory or CPU resources that all queries submitted through the group can consume on each segment host.

When you alter the CPU limit of a resource group, the new limit is immediately applied.

When you alter a memory limit of a resource group that you create for roles, the new resource limit is immediately applied if current resource usage is less than or equal to the new value and there are no running transactions in the resource group. If the current resource usage exceeds the new memory limit value, or if there are running transactions in other resource groups that hold some of the resource, then Greenplum Database defers assigning the new limit until resource usage falls within the range of the new value.

When you increase the memory limit of a resource group that you create for external components, the new resource limit is phased in as system memory resources become available. If you decrease the memory limit of a resource group that you create for external components, the behavior is component-specific. For example, if you decrease the memory limit of a resource group that you create for a PL/Container runtime, queries in a running container may fail with an out of memory error.

You can alter one limit type in a single ALTER RESOURCE GROUP call.

**Parameters**

- **name**
  
  The name of the resource group to alter.

- **CONCURRENCY integer**
  
  The maximum number of concurrent transactions, including active and idle transactions, that are permitted for resource groups that you assign to roles. Any transactions submitted after the CONCURRENCY value limit is reached are queued. When a running transaction completes, the earliest queued transaction is executed.

  The CONCURRENCY value must be an integer in the range [0 .. max_connections]. The default CONCURRENCY value for a resource group that you create for roles is 20.

  **Note:** You cannot set the CONCURRENCY value for the admin_group to zero (0).

- **CPU_RATE_LIMIT integer**
  
  The percentage of CPU resources to allocate to this resource group. The minimum CPU percentage for a resource group is 1. The maximum is 100. The sum of the CPU_RATE_LIMITs of all resource groups defined in the Greenplum Database cluster must not exceed 100.

- **MEMORY_LIMIT integer**
  
  The percentage of memory resources to allocate to this resource group. The minimum memory percentage for a resource group is 1. The maximum is 100. The sum of the MEMORY_LIMITs of all resource groups defined in the Greenplum Database cluster must not exceed 100.

- **MEMORY_SHARED_QUOTA integer**
  
  The percentage of memory resources to share among transactions in the resource group. The minimum memory shared quota percentage for a resource group is 0. The maximum is 100. The default MEMORY_SHARED_QUOTA value is 20.

- **MEMORY_SPILL_RATIO integer**
The memory usage threshold for memory-intensive operators in a transaction issued in the resource group. The minimum memory spill ratio percentage for a resource group is 0. The maximum is 100. The default `MEMORY_SPILL_RATIO` value is 20.

**Notes**

Use `CREATE ROLE` or `ALTER ROLE` to assign a specific resource group to a role (user).

You cannot submit an `ALTER RESOURCE GROUP` command in an explicit transaction or sub-transaction.

**Examples**

Change the active transaction limit for a resource group:

```
ALTER RESOURCE GROUP rgroup1 SET CONCURRENCY 13;
```

Update the CPU limit for a resource group:

```
ALTER RESOURCE GROUP rgroup2 SET CPU_RATE_LIMIT 45;
```

Update the memory limit for a resource group:

```
ALTER RESOURCE GROUP rgroup3 SET MEMORY_LIMIT 30;
```

Increase the memory spill ratio for a resource group from the default:

```
ALTER RESOURCE GROUP rgroup4 SET MEMORY_SPILL_RATIO 25;
```

**Compatibility**

The `ALTER RESOURCE GROUP` statement is a Greenplum Database extension. This command does not exist in standard PostgreSQL.

**See Also**

`CREATE RESOURCE GROUP`, `DROP RESOURCE GROUP`, `CREATE ROLE`, `ALTER ROLE`
where queue_attribute is:

```
ACTIVE_STATEMENTS
MEMORY_LIMIT
MAX_COST
COST_OVERCOMMIT
MIN_COST
```

Note: A resource queue must have either an active STATEMENTS or a MAX_COST value. Do not remove both these queue_attributes from a resource queue.

**Description**

`ALTER RESOURCE QUEUE` changes the limits of a resource queue. Only a superuser can alter a resource queue. A resource queue must have either an ACTIVE_STATEMENTS or a MAX_COST value (or it can have both). You can also set or reset priority for a resource queue to control the relative share of available CPU resources used by queries associated with the queue, or memory limit of a resource queue to control the amount of memory that all queries submitted through the queue can consume on a segment host.

`ALTER RESOURCE QUEUE WITHOUT` removes the specified limits on a resource that were previously set. A resource queue must have either an ACTIVE_STATEMENTS or a MAX_COST value. Do not remove both these queue_attributes from a resource queue.

**Parameters**

`name`

The name of the resource queue whose limits are to be altered.

**ACTIVE_STATEMENTS** `integer`

The number of active statements submitted from users in this resource queue allowed on the system at any one time. The value for ACTIVE_STATEMENTS should be an integer greater than 0. To reset ACTIVE_STATEMENTS to have no limit, enter a value of -1.

**MEMORY_LIMIT** `'memory_units'`

Sets the total memory quota for all statements submitted from users in this resource queue. Memory units can be specified in kB, MB or GB. The minimum memory quota for a resource queue is 10MB. There is no maximum; however the upper boundary at query execution time is limited by the physical memory of a segment host. The default value is no limit (-1).

**MAX_COST** `float`

The total query optimizer cost of statements submitted from users in this resource queue allowed on the system at any one time. The value for MAX_COST is specified as a floating point number (for example 100.0) or can also be specified as an exponent (for example 1e+2). To reset MAX_COST to have no limit, enter a value of -1.0.

**COST_OVERCOMMIT** `boolean`

If a resource queue is limited based on query cost, then the administrator can allow cost overcommit (COST_OVERCOMMIT=TRUE, the default). This means that a query that exceeds the allowed cost threshold will be allowed to run but only when the system is idle. If COST_OVERCOMMIT=FALSE is specified, queries that exceed the cost limit will always be rejected and never allowed to run.

**MIN_COST** `float`

Queries with a cost under this limit will not be queued and run immediately. Cost is measured in units of disk page fetches; 1.0 equals one sequential disk page read. The value for MIN_COST is specified as a floating point number (for example 100.0) or can also be specified as an exponent (for example 1e+2). To reset MIN_COST to have no limit, enter a value of -1.0.
PRIORITY={MIN|LOW|MEDIUM|HIGH|MAX}

Sets the priority of queries associated with a resource queue. Queries or statements in
queues with higher priority levels will receive a larger share of available CPU resources
in case of contention. Queries in low-priority queues may be delayed while higher priority
queries are executed.

Notes

GPORCA and the legacy Greenplum Database query optimizer utilize different query costing models and
may compute different costs for the same query. The Greenplum Database resource queue resource
management scheme neither differentiates nor aligns costs between GPORCA and the legacy optimizer; it
uses the literal cost value returned from the optimizer to throttle queries.

When resource queue-based resource management is active, use the MEMORY_LIMIT and
ACTIVE_STATEMENTS limits for resource queues rather than configuring cost-based limits. Even when
using GPORCA, Greenplum Database may fall back to using the legacy query optimizer for certain
queries, so using cost-based limits can lead to unexpected results.

Examples

Change the active query limit for a resource queue:

```
ALTER RESOURCE QUEUE myqueue WITH (ACTIVE_STATEMENTS=20);
```

Change the memory limit for a resource queue:

```
ALTER RESOURCE QUEUE myqueue WITH (MEMORY_LIMIT='2GB');
```

Reset the maximum and minimum query cost limit for a resource queue to no limit:

```
ALTER RESOURCE QUEUE myqueue WITH (MAX_COST=-1.0,
MIN_COST=-1.0);
```

Reset the query cost limit for a resource queue to $3^{10}$ (or 30000000000.0) and do not allow overcommit:

```
ALTER RESOURCE QUEUE myqueue WITH (MAX_COST=3e+10,
COST_OVERCOMMIT=FALSE);
```

Reset the priority of queries associated with a resource queue to the minimum level:

```
ALTER RESOURCE QUEUE myqueue WITH (PRIORITY=MIN);
```

Remove the MAX_COST and MEMORY_LIMIT limits from a resource queue:

```
ALTER RESOURCE QUEUE myqueue WITHOUT (MAX_COST, MEMORY_LIMIT);
```

Compatibility

The ALTER RESOURCE QUEUE statement is a Greenplum Database extension. This command does not
exist in standard PostgreSQL.

See Also

CREATE RESOURCE QUEUE, DROP RESOURCE QUEUE, CREATE ROLE, ALTER ROLE

ALTER ROLE

Changes a database role (user or group).
Synopsis

ALTER ROLE name RENAME TO newname
ALTER ROLE name SET config_parameter {TO | =} {value | DEFAULT}
ALTER ROLE name RESET config_parameter
ALTER ROLE name RESOURCE QUEUE {queue_name | NONE}
ALTER ROLE name RESOURCE GROUP {group_name | NONE}
ALTER ROLE name [ [WITH] option [ ... ] ]

where option can be:

- SUPERUSER | NOSUPERUSER
- CREATEDB | NOCREATEDB
- CREATEROLE | NOCREATEROLE
- CREATEUSER | NOCREATEUSER
- CREATEEXTABLE | NOCREATEEXTABLE
  [ ( attribute='value'[, ...] ) ]
  where attributes and value are:
  - type='readable'|'writable'
  - protocol='gpfdist'|'http'
- INHERIT | NOINHERIT
- LOGIN | NOLOGIN
- CONNECTION LIMIT connlimit
- [ENCRYPTED | UNENCRYPTED] PASSWORD 'password'
- VALID UNTIL 'timestamp'
  [ DENY deny_point ]
  [ DENY BETWEEN deny_point AND deny_point]
  [ DROP DENY FOR deny_point ]

Description

ALTER ROLE changes the attributes of a Greenplum Database role. There are several variants of this command:

- **RENAME** — Changes the name of the role. Database superusers can rename any role. Roles having CREATEROLE privilege can rename non-superuser roles. The current session user cannot be renamed (connect as a different user to rename a role). Because MD5-encrypted passwords use the role name as cryptographic salt, renaming a role clears its password if the password is MD5-encrypted.

- **SET | RESET** — Changes a role's session default for a specified configuration parameter. Whenever the role subsequently starts a new session, the specified value becomes the session default, overriding whatever setting is present in server configuration file (postgresql.conf). For a role without LOGIN privilege, session defaults have no effect. Ordinary roles can change their own session defaults. Superusers can change anyone's session defaults. Roles having CREATEROLE privilege can change defaults for non-superuser roles. See the Greenplum Database Administrator Guide for information about all user-settable configuration parameters.

- **RESOURCE QUEUE** — Assigns the role to a resource queue. The role would then be subject to the limits assigned to the resource queue when issuing queries. Specify NONE to assign the role to the default resource queue. A role can only belong to one resource queue. For a role without LOGIN privilege, resource queues have no effect. See CREATE RESOURCE QUEUE for more information.

- **RESOURCE GROUP** — Assigns a resource group to the role. The role would then be subject to the concurrent transaction, memory, and CPU limits configured for the resource group. You can assign a single resource group to one or more roles. You cannot assign a resource group that you create for an external component to a role. See CREATE RESOURCE GROUP for additional information.
• **WITH option** — Changes many of the role attributes that can be specified in `CREATE ROLE`. Attributes not mentioned in the command retain their previous settings. Database superusers can change any of these settings for any role. Roles having `CREATEROLE` privilege can change any of these settings, but only for non-superuser roles. Ordinary roles can only change their own password.

**Parameters**

`name`

The name of the role whose attributes are to be altered.

`newname`

The new name of the role.

`config_parameter=value`

Set this role's session default for the specified configuration parameter to the given value. If value is `DEFAULT` or if `RESET` is used, the role-specific variable setting is removed, so the role will inherit the system-wide default setting in new sessions. Use `RESET ALL` to clear all role-specific settings. See `SET` and `Server Configuration Parameters` for information about user-settable configuration parameters.

`group_name`

The name of the resource group to assign to this role. Specifying the `group_name` `NONE` removes the role's current resource group assignment and assigns a default resource group based on the role's capability. `SUPERUSER` roles are assigned the `admin_group` resource group, while the `default_group` resource group is assigned to non-admin roles.

You cannot assign a resource group that you create for an external component to a role.

`queue_name`

The name of the resource queue to which the user-level role is to be assigned. Only roles with `LOGIN` privilege can be assigned to a resource queue. To unassign a role from a resource queue and put it in the default resource queue, specify `NONE`. A role can only belong to one resource queue.

`SUPERUSER | NOSUPERUSER`

`CREATEDB | NOCREATEDB`

`CREATEROLE | NOCREATEROLE`

`CREATEUSER | NOCREATEUSER`

`CREATEUSER` and `NOCREATEUSER` are obsolete, but still accepted, spellings of `SUPERUSER` and `NOSUPERUSER`. Note that they are not equivalent to the `CREATEROLE` and `NOCREATEROLE` clauses.

`CREATEEXTTABLE | NOCREATEEXTTABLE` [[attribute='value']]

If `CREATEEXTTABLE` is specified, the role being defined is allowed to create external tables. The default `type` is `readable` and the default `protocol` is `gpfdist` if not specified. `NOCREATEEXTTABLE` (the default) denies the role the ability to create external tables. Note that external tables that use the `file` or `execute` protocols can only be created by superusers.

`INHERIT | NOINHERIT`

`LOGIN | NOLOGIN`

`CONNECTION LIMIT connlimit`

`PASSWORD password`

`ENCRYPTED | UNENCRYPTED`

`VALID UNTIL 'timestamp'`

These clauses alter role attributes originally set by `CREATE ROLE`.

`DENY deny_point`

`DENY BETWEEN deny_point AND deny_point`
The **DENY** and **DENY BETWEEN** keywords set time-based constraints that are enforced at login. **DENY** sets a day or a day and time to deny access. **DENY BETWEEN** sets an interval during which access is denied. Both use the parameter **deny_point** that has following format:

```
DAY day [ TIME 'time' ]
```

The two parts of the **deny_point** parameter use the following formats:

For day:

```
{ 'Sunday' | 'Monday' | 'Tuesday' | 'Wednesday' | 'Thursday' | 'Friday' | 'Saturday' | 0-6 }
```

For time:

```
{ 00-23 : 00-59 | 01-12 : 00-59 { AM | PM } }
```

The **DENY BETWEEN** clause uses two **deny_point** parameters.

```
DENY BETWEEN deny_point AND deny_point
```

For more information about time-based constraints and examples, see "Managing Roles and Privileges" in the *Greenplum Database Administrator Guide*.

**DROP DENY FOR** **deny_point**

The **DROP DENY FOR** clause removes a time-based constraint from the role. It uses the **deny_point** parameter described above.

For more information about time-based constraints and examples, see "Managing Roles and Privileges" in the *Greenplum Database Administrator Guide*.

**Notes**

Use **GRANT** and **REVOKE** for adding and removing role memberships.

Caution must be exercised when specifying an unencrypted password with this command. The password will be transmitted to the server in clear text, and it might also be logged in the client's command history or the server log. The **psql** command-line client contains a meta-command **\password** that can be used to safely change a role's password.

It is also possible to tie a session default to a specific database rather than to a role. Role-specific settings override database-specific ones if there is a conflict. See **ALTER DATABASE**.

**Examples**

Change the password for a role:

```
ALTER ROLE daria WITH PASSWORD 'passwd123';
```

Change a password expiration date:

```
ALTER ROLE scott VALID UNTIL 'May 4 12:00:00 2015 +1';
```

Make a password valid forever:

```
ALTER ROLE luke VALID UNTIL 'infinity';
```
Give a role the ability to create other roles and new databases:

ALTER ROLE joelle CREATEROLE CREATEDB;

Give a role a non-default setting of the maintenance_work_mem parameter:

ALTER ROLE admin SET maintenance_work_mem = 100000;

Assign a role to a resource queue:

ALTER ROLE sammy RESOURCE QUEUE poweruser;

Give a role permission to create writable external tables:

ALTER ROLE load CREATEEXTTABLE (type='writable');

Alter a role so it does not allow login access on Sundays:

ALTER ROLE user3 DENY DAY 'Sunday';

Alter a role to remove the constraint that does not allow login access on Sundays:

ALTER ROLE user3 DROP DENY FOR DAY 'Sunday';

Assign a new resource group to a role:

ALTER ROLE parttime_user RESOURCE GROUP rg_light;

### Compatibility

The `ALTER ROLE` statement is a Greenplum Database extension.

### See Also

- `CREATE ROLE`, `DROP ROLE`, `SET`, `CREATE RESOURCE GROUP`, `CREATE RESOURCE QUEUE`, `GRANT`, `REVOKE`

### ALTER SCHEMA

Changes the definition of a schema.

#### Synopsis

- `ALTER SCHEMA name RENAME TO newname`
- `ALTER SCHEMA name OWNER TO newowner`

#### Description

`ALTER SCHEMA` changes the definition of a schema.

You must own the schema to use `ALTER SCHEMA`. To rename a schema you must also have the `CREATE` privilege for the database. To alter the owner, you must also be a direct or indirect member of the new owning role, and you must have the `CREATE` privilege for the database. Note that superusers have all these privileges automatically.
Parameters

name
The name of an existing schema.

newname
The new name of the schema. The new name cannot begin with pg_, as such names are reserved for system schemas.

newowner
The new owner of the schema.

Compatibility
There is no ALTER SCHEMA statement in the SQL standard.

See Also
CREATE SCHEMA, DROP SCHEMA

ALTER SEQUENCE
Changes the definition of a sequence generator.

Synopsis

```
ALTER SEQUENCE name [INCREMENT [ BY ] increment]
[MINVALUE minvalue | NO MINVALUE]
[MAXVALUE maxvalue | NO MAXVALUE]
[RESTART [ WITH ] start]
[CACHE cache] [[ NO ] CYCLE]
[OWNED BY {table.column | NONE}]
```

```
ALTER SEQUENCE name RENAME TO new_name

ALTER SEQUENCE name SET SCHEMA new_schema
```

Description

ALTER SEQUENCE changes the parameters of an existing sequence generator. Any parameters not specifically set in the ALTER SEQUENCE command retain their prior settings.

You must own the sequence to use ALTER SEQUENCE. To change a sequence's schema, you must also have CREATE privilege on the new schema. Note that superusers have all these privileges automatically.

Parameters

name
The name (optionally schema-qualified) of a sequence to be altered.

increment
The clause INCREMENT BY increment is optional. A positive value will make an ascending sequence, a negative one a descending sequence. If unspecified, the old increment value will be maintained.

minvalue
NO MINVALUE
The optional clause MINVALUE minvalue determines the minimum value a sequence can generate. If NO MINVALUE is specified, the defaults of 1 and -263-1 for ascending and
descending sequences, respectively, will be used. If neither option is specified, the current minimum value will be maintained.

**maxvalue**

**NO MAXVALUE**

The optional clause `MAXVALUE maxvalue` determines the maximum value for the sequence. If `NO MAXVALUE` is specified, the defaults are 263-1 and -1 for ascending and descending sequences, respectively, will be used. If neither option is specified, the current maximum value will be maintained.

**start**

The optional clause `RESTART WITH start` changes the current value of the sequence. Altering the sequence in this manner is equivalent to calling the `setval(sequence, start_val, is_called)` function with `is_called = false`. The first `nextval()` call after you alter the sequence start value does not increment the sequence and returns `start`.

**cache**

The clause `CACHE cache` enables sequence numbers to be preallocated and stored in memory for faster access. The minimum value is 1 (only one value can be generated at a time, i.e., no cache). If unspecified, the old cache value will be maintained.

**CYCLE**

The optional `CYCLE` key word may be used to enable the sequence to wrap around when the `maxvalue` or `minvalue` has been reached by an ascending or descending sequence. If the limit is reached, the next number generated will be the respective `minvalue` or `maxvalue`.

**NO CYCLE**

If the optional `NO CYCLE` key word is specified, any calls to `nextval()` after the sequence has reached its maximum value will return an error. If neither `CYCLE` or `NO CYCLE` are specified, the old cycle behavior will be maintained.

**OWNED BY table.column**

**OWNED BY NONE**

The `OWNED BY` option causes the sequence to be associated with a specific table column, such that if that column (or its whole table) is dropped, the sequence will be automatically dropped as well. If specified, this association replaces any previously specified association for the sequence. The specified table must have the same owner and be in the same schema as the sequence. Specifying `OWNED BY NONE` removes any existing table column association.

**new_name**

The new name for the sequence.

**new_schema**

The new schema for the sequence.

**Notes**

To avoid blocking of concurrent transactions that obtain numbers from the same sequence, `ALTER SEQUENCE`'s effects on the sequence generation parameters are never rolled back; those changes take effect immediately and are not reversible. However, the `OWNED BY`, `RENAME TO`, and `SET SCHEMA` clauses are ordinary catalog updates and can be rolled back.

`ALTER SEQUENCE` will not immediately affect `nextval()` results in sessions, other than the current one, that have preallocated (cached) sequence values. They will use up all cached values prior to noticing the changed sequence generation parameters. The current session will be affected immediately.
Some variants of `ALTER TABLE` can be used with sequences as well. For example, to rename a sequence use `ALTER TABLE RENAME`.

**Examples**

Restart a sequence called `serial` at 105:

```
ALTER SEQUENCE serial RESTART WITH 105;
```

**Compatibility**

`ALTER SEQUENCE` conforms to the SQL standard, except for the `OWNED BY`, `RENAME TO`, and `SET SCHEMA` clauses, which are Greenplum Database extensions.

**See Also**

`CREATE SEQUENCE`, `DROP SEQUENCE`, `ALTER TABLE`

---

**ALTER TABLE**

Changes the definition of a table.

**Synopsis**

```
ALTER TABLE [ONLY] name RENAME [COLUMN] column TO new_column

ALTER TABLE name RENAME TO new_name

ALTER TABLE name SET SCHEMA new_schema

ALTER TABLE [ONLY] name SET
    DISTRIBUTED BY (column, [ ... ] )
    | DISTRIBUTED RANDOMLY
    | WITH (REORGANIZE=true|false)

ALTER TABLE [ONLY] name action [, ... ]

ALTER TABLE name
    [ ALTER PARTITION { partition_name | FOR (RANK(number))
    | FOR (value) } partition_action [...] ]

WHERE action is one of:

```
ADD [COLUMN] column_name type [ DEFAULT default_expr ]
    [column_constraint [ ... ]]
    [ ENCODING ( storage_directive [,...] ) ]
DROP [COLUMN] column [RESTRICT | CASCADE]
ALTER [COLUMN] column TYPE type [USING expression]
ALTER [COLUMN] column SET DEFAULT expression
ALTER [COLUMN] column DROP DEFAULT
ALTER [COLUMN] column { SET | DROP } NOT NULL
ALTER [COLUMN] column SET STATISTICS integer
ADD table_constraint
DROP CONSTRAINT constraint_name [RESTRICT | CASCADE]
DISABLE TRIGGER [trigger_name | ALL | USER]
ENABLE TRIGGER [trigger_name | ALL | USER]
CLUSTER ON index_name
SET WITHOUT CLUSTER
SET WITHOUT OIDS
```
SET (FILLFACTOR = value)
RESET (FILLFACTOR)
INHERIT parent_table
NO INHERIT parent_table
OWNER TO new_owner
SET TABLESPACE new_tablespace

where partition_action is one of:

ALTER DEFAULT PARTITION
DROP DEFAULT PARTITION [IF EXISTS]
DROP PARTITION [IF EXISTS] { partition_name | FOR (RANK(number)) | FOR (value) } [CASCADE]
TRUNCATE DEFAULT PARTITION
TRUNCATE PARTITION { partition_name | FOR (RANK(number)) | FOR (value) } TO new_partition_name
RENAME DEFAULT PARTITION TO new_partition_name
RENAME PARTITION { partition_name | FOR (RANK(number)) | FOR (value) } TO new_partition_name
ADD DEFAULT PARTITION name [ ( subpartition_spec ) ]
ADD PARTITION { partition_name } partition_element [ ( subpartition_spec ) ]
EXCHANGE PARTITION { partition_name | FOR (RANK(number)) | FOR (value) } WITH TABLE table_name
[ WITH | WITHOUT VALIDATION ]
EXCHANGE DEFAULT PARTITION WITH TABLE table_name
[ WITH | WITHOUT VALIDATION ]
SET SUBPARTITION TEMPLATE ( subpartition_spec )
SPLIT DEFAULT PARTITION
{ AT ( list_value )
 | START ([ datatype ] range_value) [ INCLUSIVE | EXCLUSIVE ]
 | END ([ datatype ] range_value) [ INCLUSIVE | EXCLUSIVE ]
 [ INTO ( PARTITION new_partition_name,
 | PARTITION default_partition_name ) ]
}
SPLIT PARTITION { partition_name | FOR (RANK(number)) | FOR (value) } AT ( value )
[ INTO ( PARTITION partition_name, PARTITION partition_name ) ]

where partition_element is:

VALUES ( list_value [, ... ] )
 | START ([ datatype ] 'start_value') [ INCLUSIVE | EXCLUSIVE ]
 | END ([ datatype ] 'end_value') [ INCLUSIVE | EXCLUSIVE ]
 | [ WITH ( partition_storage_parameter=value [, ... ] ) ]
 | TABLESPACE tablespace ]

where subpartition_spec is:

subpartition_element [ , ... ]

and subpartition_element [ , ... ] is:

DEFAULT SUBPARTITION subpartition_name
 | [ SUBPARTITION subpartition_name ] VALUES ( list_value [, ... ] )
 | [ SUBPARTITION subpartition_name ]
START ([ datatype ] 'start_value') [ INCLUSIVE | EXCLUSIVE ]
END ([ datatype ] 'end_value') [ INCLUSIVE | EXCLUSIVE ]
[ EVERY ( [ number | datatype ] 'interval_value') ]
[ SUBPARTITION subpartition_name ]
END ([ datatype ] 'end_value') [ INCLUSIVE | EXCLUSIVE ]
[ EVERY ( [ number | datatype ] 'interval_value') ]
[ WITH ( partition_storage_parameter=value [, ... ] ) ]
[ TABLESPACE tablespace ]

where storage_parameter is:

- APPENDONLY={TRUE|FALSE}
- BLOCKSIZE={8192-2097152}
- ORIENTATION={COLUMN|ROW}
- COMPRESSTYPE={ZLIB|QUICKLZ|RLE_TYPE|NONE}
- COMPRESSLEVEL={0-9}
- FILLFACTOR={10-100}
- OIDS [=TRUE|FALSE]

**Description**

**ALTER TABLE** changes the definition of an existing table. There are several subforms:

- **ADD COLUMN** — Adds a new column to the table, using the same syntax as **CREATE TABLE**. The **ENCODING** clause is valid only for append-optimized, column-oriented tables.

- **DROP COLUMN** — Drops a column from a table. Note that if you drop table columns that are being used as the Greenplum Database distribution key, the distribution policy for the table will be changed to **DISTRIBUTED RANDOMLY**. Indexes and table constraints involving the column will be automatically dropped as well. You will need to say **CASCADE** if anything outside the table depends on the column (such as views).

- **ALTER COLUMN TYPE** — Changes the data type of a column of a table. Note that you cannot alter column data types that are being used as distribution or partitioning keys. Indexes and simple table constraints involving the column will be automatically converted to use the new column type by reparsing the originally supplied expression. The optional **USING** clause specifies how to compute the new column value from the old. If omitted, the default conversion is the same as an assignment cast from old data type to new. A **USING** clause must be provided if there is no implicit or assignment cast from old to new type.

- **SET/DROP DEFAULT** — Sets or removes the default value for a column. The default values only apply to subsequent **INSERT** commands. They do not cause rows already in the table to change. Defaults may also be created for views, in which case they are inserted into statements on the view before the view’s **ON INSERT** rule is applied.

- **SET/DROP NOT NULL** — Changes whether a column is marked to allow null values or to reject null values. You can only use **SET NOT NULL** when the column contains no null values.

- **SET STATISTICS** — Sets the per-column statistics-gathering target for subsequent **ANALYZE** operations. The target can be set in the range 1 to 1000, or set to -1 to revert to using the system default statistics target (**default_statistics_target**).

- **ADD table_constraint** — Adds a new constraint to a table (not just a partition) using the same syntax as **CREATE TABLE**.

- **DROP CONSTRAINT** — Drops the specified constraint on a table.

- **DISABLE/ENABLE TRIGGER** — Disables or enables trigger(s) belonging to the table. A disabled trigger is still known to the system, but is not executed when its triggering event occurs. For a deferred trigger, the enable status is checked when the event occurs, not when the trigger function is actually executed. One may disable or enable a single trigger specified by name, or all triggers on the table, or only user-created triggers. Disabling or enabling constraint triggers requires superuser privileges.

  **Note:** Triggers are not supported in Greenplum Database. Triggers in general have very limited functionality due to the parallelism of Greenplum Database.

- **CLUSTER ON/SET WITHOUT CLUSTER** — Selects or removes the default index for future **CLUSTER** operations. It does not actually re-cluster the table. Note that **CLUSTER** is not the recommended way to physically reorder a table in Greenplum Database because it takes so long. It is better to recreate the table with **CREATE TABLE AS** and order it by the index column(s).

  **Note:** **CLUSTER ON** is not supported on append-optimized tables.
- **SET WITHOUT OIDS** — Removes the OID system column from the table. Note that there is no variant of ALTER TABLE that allows OIDs to be restored to a table once they have been removed.

- **SET ( FILLFACTOR = value ) / RESET (FILLFACTOR)** — Changes the fillfactor for the table. The fillfactor for a table is a percentage between 10 and 100. 100 (complete packing) is the default. When a smaller fillfactor is specified, INSERT operations pack table pages only to the indicated percentage; the remaining space on each page is reserved for updating rows on that page. This gives UPDATE a chance to place the updated copy of a row on the same page as the original, which is more efficient than placing it on a different page. For a table whose entries are never updated, complete packing is the best choice, but in heavily updated tables smaller fillfactors are appropriate. Note that the table contents will not be modified immediately by this command. You will need to rewrite the table to get the desired effects.

- **SET DISTRIBUTED** — Changes the distribution policy of a table. Changes to a hash distribution policy will cause the table data to be physically redistributed on disk, which can be resource intensive.

- **INHERIT parent_table / NO INHERIT parent_table** — Adds or removes the target table as a child of the specified parent table. Queries against the parent will include records of its child table. To be added as a child, the target table must already contain all the same columns as the parent (it could have additional columns, too). The columns must have matching data types, and if they have NOTNULL constraints in the parent then they must also have NOT NULL constraints in the child. There must also be matching child-table constraints for all CHECK constraints of the parent.

- **OWNER** — Changes the owner of the table, sequence, or view to the specified user.

- **SET TABLESPACE** — Changes the table's tablespace to the specified tablespace and moves the data file(s) associated with the table to the new tablespace. Indexes on the table, if any, are not moved; but they can be moved separately with additional SET TABLESPACE commands. See also CREATE TABLESPACE. If changing the tablespace of a partitioned table, all child table partitions will also be moved to the new tablespace.

- **RENAME** — Changes the name of a table (or an index, sequence, or view) or the name of an individual column in a table. There is no effect on the stored data. Note that Greenplum Database distribution key columns cannot be renamed.

- **SET SCHEMA** — Moves the table into another schema. Associated indexes, constraints, and sequences owned by table columns are moved as well.

- **ALTER PARTITION | DROP PARTITION | RENAME PARTITION | TRUNCATE PARTITION | ADD PARTITION | SPLIT PARTITION | EXCHANGE PARTITION | SET SUBPARTITION TEMPLATE** — Changes the structure of a partitioned table. In most cases, you must go through the parent table to alter one of its child table partitions.

  **Note:** If you add a partition to a table that has subpartition encodings, the new partition inherits the storage directives for the subpartitions. For more information about the precedence of compression settings, see "Using Compression" in the Greenplum Database Administrator Guide.

You must own the table to use ALTER TABLE. To change the schema of a table, you must also have CREATE privilege on the new schema. To add the table as a new child of a parent table, you must own the parent table as well. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the table's schema. A superuser has these privileges automatically.

  **Note:** Memory usage increases significantly when a table has many partitions, if a table has compression, or if the blocksize for a table is large. If the number of relations associated with the table is large, this condition can force an operation on the table to use more memory. For example, if the table is a CO table and has a large number of columns, each column is a relation. An operation like ALTER TABLE ALTER COLUMN opens all the columns in the table allocates associated buffers. If a CO table has 40 columns and 100 partitions, and the columns are compressed and the blocksize is 2 MB (with a system factor of 3), the system attempts to allocate 24 GB, that is (40 \times 100) \times (2 \times 3) MB or 24 GB.

**Parameters**

**ONLY**
Only perform the operation on the table name specified. If the `ONLY` keyword is not used, the operation will be performed on the named table and any child table partitions associated with that table.

**name**

The name (possibly schema-qualified) of an existing table to alter. If `ONLY` is specified, only that table is altered. If `ONLY` is not specified, the table and all its descendant tables (if any) are updated.

**Note:** Constraints can only be added to an entire table, not to a partition. Because of that restriction, the `name` parameter can only contain a table name, not a partition name.

**column**

Name of a new or existing column. Note that Greenplum Database distribution key columns must be treated with special care. Altering or dropping these columns can change the distribution policy for the table.

**new_column**

New name for an existing column.

**new_name**

New name for the table.

**type**

Data type of the new column, or new data type for an existing column. If changing the data type of a Greenplum distribution key column, you are only allowed to change it to a compatible type (for example, `text` to `varchar` is OK, but `text` to `int` is not).

**table_constraint**

New table constraint for the table. Note that foreign key constraints are currently not supported in Greenplum Database. Also a table is only allowed one unique constraint and the uniqueness must be within the Greenplum Database distribution key.

**constraint_name**

Name of an existing constraint to drop.

**CASCADE**

Automatically drop objects that depend on the dropped column or constraint (for example, views referencing the column).

**RESTRICT**

Refuse to drop the column or constraint if there are any dependent objects. This is the default behavior.

**trigger_name**

Name of a single trigger to disable or enable. Note that Greenplum Database does not support triggers.

**ALL**

Disable or enable all triggers belonging to the table including constraint related triggers. This requires superuser privilege.

**USER**

Disable or enable all user-created triggers belonging to the table.

**index_name**

The index name on which the table should be marked for clustering. Note that `CLUSTER` is not the recommended way to physically reorder a table in Greenplum Database because it takes so long. It is better to recreate the table with `CREATE TABLE AS` and order it by the index column(s).
**FILLFACTOR**

Set the fillfactor percentage for a table.

**value**

The new value for the FILLFACTOR parameter, which is a percentage between 10 and 100. 100 is the default.

**DISTRICTED BY (column) | DISTRICTED RANDOMLY**

Specifies the distribution policy for a table. Changing a hash distribution policy will cause the table data to be physically redistributed on disk, which can be resource intensive. If you declare the same hash distribution policy or change from hash to random distribution, data will not be redistributed unless you declare SET WITH (REORGANIZE=true).

**REORGANIZE=true|false**

Use REORGANIZE=true when the hash distribution policy has not changed or when you have changed from a hash to a random distribution, and you want to redistribute the data anyways.

**parent_table**

A parent table to associate or de-associate with this table.

**new_owner**

The role name of the new owner of the table.

**new_tablespace**

The name of the tablespace to which the table will be moved.

**new_schema**

The name of the schema to which the table will be moved.

**parent_table_name**

When altering a partitioned table, the name of the top-level parent table.

**ALTER [DEFAULT] PARTITION**

If altering a partition deeper than the first level of partitions, the ALTER PARTITION clause is used to specify which subpartition in the hierarchy you want to alter.

**DROP [DEFAULT] PARTITION**

Drops the specified partition. If the partition has subpartitions, the subpartitions are automatically dropped as well.

**TRUNCATE [DEFAULT] PARTITION**

Truncates the specified partition. If the partition has subpartitions, the subpartitions are automatically truncated as well.

**RENAME [DEFAULT] PARTITION**

Changes the partition name of a partition (not the relation name). Partitioned tables are created using the naming convention: `<parentname>_<level>_prt_<partition_name>`.

**ADD DEFAULT PARTITION**

Adds a default partition to an existing partition design. When data does not match to an existing partition, it is inserted into the default partition. Partition designs that do not have a default partition will reject incoming rows that do not match to an existing partition. Default partitions must be given a name.

**ADD PARTITION**

**partition_element** - Using the existing partition type of the table (range or list), defines the boundaries of new partition you are adding.

**name** - A name for this new partition.

**VALUES** - For list partitions, defines the value(s) that the partition will contain.
**START** - For range partitions, defines the starting range value for the partition. By default, start values are **INCLUSIVE**. For example, if you declared a start date of '2016-01-01', then the partition would contain all dates greater than or equal to '2016-01-01'. Typically the data type of the **START** expression is the same type as the partition key column. If that is not the case, then you must explicitly cast to the intended data type.

**END** - For range partitions, defines the ending range value for the partition. By default, end values are **EXCLUSIVE**. For example, if you declared an end date of '2016-02-01', then the partition would contain all dates less than but not equal to '2016-02-01'. Typically the data type of the **END** expression is the same type as the partition key column. If that is not the case, then you must explicitly cast to the intended data type.

**WITH** - Sets the table storage options for a partition. For example, you may want older partitions to be append-optimized tables and newer partitions to be regular heap tables. See **CREATE TABLE** for a description of the storage options.

**TABLESPACE** - The name of the tablespace in which the partition is to be created.

**subpartition_spec** - Only allowed on partition designs that were created without a subpartition template. Declares a subpartition specification for the new partition you are adding. If the partitioned table was originally defined using a subpartition template, then the template will be used to generate the subpartitions automatically.

**EXCHANGE [DEFAULT] PARTITION**

Exchanges another table into the partition hierarchy into the place of an existing partition. In a multi-level partition design, you can only exchange the lowest level partitions (those that contain data).

The Greenplum Database server configuration parameter **gp_enable_exchange_default_partition** controls availability of the **EXCHANGE DEFAULT PARTITION** clause. The default value for the parameter is **off**. The clause is not available and Greenplum Database returns an error if the clause is specified in an **ALTER TABLE** command. For information about the parameter, see **Server Configuration Parameters**.

**Warning:** Before you exchange the default partition, you must ensure the data in the table to be exchanged, the new default partition, is valid for the default partition. For example, the data in the new default partition must not contain data that would be valid in other leaf child partitions of the partitioned table. Otherwise, queries against the partitioned table with the exchanged default partition that are executed by GPORCA might return incorrect results.

**WITH TABLE** *table_name* - The name of the table you are swapping into the partition design. You can exchange a table where the table data is stored in the database. For example, the table is created with the **CREATE TABLE** command.

With the **EXCHANGE PARTITION** clause, you can also exchange a readable external table (created with the **CREATE EXTERNAL TABLE** command) into the partition hierarchy in the place of an existing leaf child partition. If you specify a readable external table, you must also specify the **WITHOUT VALIDATION** clause to skip table validation against the **CHECK** constraint of the partition you are exchanging.

Exchanging a leaf child partition with an external table is not supported if the partitioned table contains a column with a check constraint or a **NOT NULL** constraint.

**WITH | WITHOUT VALIDATION** - Validates that the data in the table matches the **CHECK** constraint of the partition you are exchanging. The default is to validate the data against the **CHECK** constraint.

**Warning:** If you specify the **WITHOUT VALIDATION** clause, you must ensure that the data in table that you are exchanging for an existing child leaf partition
is valid against the CHECK constraints on the partition. Otherwise, queries against the partitioned table might return incorrect results.

**SET SUBPARTITION TEMPLATE**

Modifies the subpartition template for an existing partition. After a new subpartition template is set, all new partitions added will have the new subpartition design (existing partitions are not modified).

**SPLIT DEFAULT PARTITION**

Splits a default partition. In a multi-level partition, only a range partition can be split, not a list partition, and you can only split the lowest level default partitions (those that contain data). Splitting a default partition creates a new partition containing the values specified and leaves the default partition containing any values that do not match to an existing partition.

- **AT** - For list partitioned tables, specifies a single list value that should be used as the criteria for the split.
- **START** - For range partitioned tables, specifies a starting value for the new partition.
- **END** - For range partitioned tables, specifies an ending value for the new partition.
- **INTO** - Allows you to specify a name for the new partition. When using the **INTO** clause to split a default partition, the second partition name specified should always be that of the existing default partition. If you do not know the name of the default partition, you can look it up using the `pg_partitions` view.

**SPLIT PARTITION**

Splits an existing partition into two partitions. In a multi-level partition, only a range partition can be split, not a list partition, and you can only split the lowest level partitions (those that contain data).

- **AT** - Specifies a single value that should be used as the criteria for the split. The partition will be divided into two new partitions with the split value specified being the starting range for the *latter* partition.
- **INTO** - Allows you to specify names for the two new partitions created by the split.

**partition_name**

The given name of a partition.

**FOR (RANK(number))**

For range partitions, the rank of the partition in the range.

**FOR ('value')**

Specifies a partition by declaring a value that falls within the partition boundary specification. If the value declared with **FOR** matches to both a partition and one of its subpartitions (for example, if the value is a date and the table is partitioned by month and then by day), then **FOR** will operate on the first level where a match is found (for example, the monthly partition). If your intent is to operate on a subpartition, you must declare so as follows: `ALTER TABLE name ALTER PARTITION FOR ('2016-10-01') DROP PARTITION FOR ('2016-10-01');`

**Notes**

The table name specified in the **ALTER TABLE** command cannot be the name of a partition within a table.

Take special care when altering or dropping columns that are part of the Greenplum Database distribution key as this can change the distribution policy for the table.

Greenplum Database does not currently support foreign key constraints. For a unique constraint to be enforced in Greenplum Database, the table must be hash-distributed (not **DISTRIBUTED RANDOMLY**),
and all of the distribution key columns must be the same as the initial columns of the unique constraint columns.

Adding a CHECK or NOT NULL constraint requires scanning the table to verify that existing rows meet the constraint.

When a column is added with ADD COLUMN, all existing rows in the table are initialized with the column's default value, or NULL if no DEFAULT clause is specified. Adding a column with a non-null default or changing the type of an existing column will require the entire table to be rewritten. This may take a significant amount of time for a large table; and it will temporarily require double the disk space.

You can specify multiple changes in a single ALTER TABLE command, which will be done in a single pass over the table.

The DROP COLUMN form does not physically remove the column, but simply makes it invisible to SQL operations. Subsequent insert and update operations in the table will store a null value for the column. Thus, dropping a column is quick but it will not immediately reduce the on-disk size of your table, as the space occupied by the dropped column is not reclaimed. The space will be reclaimed over time as existing rows are updated.

The fact that ALTERTYPE requires rewriting the whole table is sometimes an advantage, because the rewriting process eliminates any dead space in the table. For example, to reclaim the space occupied by a dropped column immediately, the fastest way is: ALTER TABLE table ALTER COLUMN anycol TYPE sametype; where anycol is any remaining table column and sametype is the same type that column already has. This results in no semantically-visible change in the table, but the command forces rewriting, which gets rid of no-longer-useful data.

If a table is partitioned or has any descendant tables, it is not permitted to add, rename, or change the type of a column in the parent table without doing the same to the descendants. This ensures that the descendants always have columns matching the parent.

To see the structure of a partitioned table, you can use the view pg_partitions. This view can help identify the particular partitions you may want to alter.

A recursive DROP COLUMN operation will remove a descendant table's column only if the descendant does not inherit that column from any other parents and never had an independent definition of the column. A nonrecursive DROP COLUMN (ALTER TABLE ONLY ... DROP COLUMN) never removes any descendant columns, but instead marks them as independently defined rather than inherited.

The TRIGGER, CLUSTER, OWNER, and TABLESPACE actions never recurse to descendant tables; that is, they always act as though ONLY were specified. Adding a constraint can recurse only for CHECK constraints.

These ALTER PARTITION operations are supported if no data is changed on a partitioned table that contains a leaf child partition that has been exchanged to use an external table. Otherwise, an error is returned.

• Adding or dropping a column.
• Changing the data type of column.

These ALTER PARTITION operations are not supported for a partitioned table that contains a leaf child partition that has been exchanged to use an external table:

• Setting a subpartition template.
• Altering the partition properties.
• Creating a default partition.
• Setting a distribution policy.
• Setting or dropping a NOT NULL constraint of column.
• Adding or dropping constraints.
• Splitting an external partition.

Changing any part of a system catalog table is not permitted.
Examples

Add a column to a table:

```
ALTER TABLE distributors ADD COLUMN address varchar(30);
```

Rename an existing column:

```
ALTER TABLE distributors RENAME COLUMN address TO city;
```

Rename an existing table:

```
ALTER TABLE distributors RENAME TO suppliers;
```

Add a not-null constraint to a column:

```
ALTER TABLE distributors ALTER COLUMN street SET NOT NULL;
```

Add a check constraint to a table:

```
ALTER TABLE distributors ADD CONSTRAINT zipchk CHECK
(char_length(zipcode) = 5);
```

Move a table to a different schema:

```
ALTER TABLE myschema.distributors SET SCHEMA yourschema;
```

Add a new partition to a partitioned table:

```
ALTER TABLE sales ADD PARTITION
START (date '2017-02-01') INCLUSIVE
END (date '2017-03-01') EXCLUSIVE;
```

Add a default partition to an existing partition design:

```
ALTER TABLE sales ADD DEFAULT PARTITION other;
```

Rename a partition:

```
ALTER TABLE sales RENAME PARTITION FOR ('2016-01-01') TO jan08;
```

Drop the first (oldest) partition in a range sequence:

```
ALTER TABLE sales DROP PARTITION FOR (RANK(1));
```

Exchange a table into your partition design:

```
ALTER TABLE sales EXCHANGE PARTITION FOR ('2016-01-01') WITH
TABLE jan08;
```

Split the default partition (where the existing default partition's name is other) to add a new monthly partition for January 2017:

```
ALTER TABLE sales SPLIT DEFAULT PARTITION
START ('2017-01-01') INCLUSIVE
END ('2017-02-01') EXCLUSIVE
INTO (PARTITION jan09, PARTITION other);
```
Split a monthly partition into two with the first partition containing dates January 1-15 and the second partition containing dates January 16-31:

```
ALTER TABLE sales SPLIT PARTITION FOR ('2016-01-01') AT ('2016-01-16') INTO (PARTITION jan081to15, PARTITION jan0816to31);
```

**Compatibility**

The `ADD`, `DROP`, and `SET DEFAULT` forms conform with the SQL standard. The other forms are Greenplum Database extensions of the SQL standard. Also, the ability to specify more than one manipulation in a single `ALTER TABLE` command is an extension.

`ALTER TABLE DROP COLUMN` can be used to drop the only column of a table, leaving a zero-column table. This is an extension of SQL, which disallows zero-column tables.

**See Also**

`CREATE TABLE`, `DROP TABLE`

### ALTER TABLESPACE

Changes the definition of a tablespace.

**Synopsis**

```
ALTER TABLESPACE name RENAME TO newname
ALTER TABLESPACE name OWNER TO newowner
```

**Description**

`ALTER TABLESPACE` changes the definition of a tablespace.

You must own the tablespace to use `ALTER TABLESPACE`. To alter the owner, you must also be a direct or indirect member of the new owning role. (Note that superusers have these privileges automatically.)

**Parameters**

- **name**
  The name of an existing tablespace.

- **newname**
  The new name of the tablespace. The new name cannot begin with `pg_` or `gp_` (reserved for system tablespaces).

- **newowner**
  The new owner of the tablespace.

**Examples**

- **Rename tablespace index_space to fast_raid:**
  
  ```
  ALTER TABLESPACE index_space RENAME TO fast_raid;
  ```

- **Change the owner of tablespace index_space:**
  
  ```
  ALTER TABLESPACE index_space OWNER TO mary;
  ```
ALTER TYPE

Changes the definition of a data type.

Synopsis

```
ALTER TYPE name
    OWNER TO new_owner | SET SCHEMA new_schema
```

Description

ALTER TYPE changes the definition of an existing type. You can change the owner and the schema of a type.

You must own the type to use ALTER TYPE. To change the schema of a type, you must also have CREATE privilege on the new schema. To alter the owner, you must also be a direct or indirect member of the new owning role, and that role must have CREATE privilege on the type's schema. (These restrictions enforce that altering the owner does not do anything that could be done by dropping and recreating the type. However, a superuser can alter ownership of any type.)

Parameters

- **name**: The name (optionally schema-qualified) of an existing type to alter.
- **new_owner**: The user name of the new owner of the type.
- **new_schema**: The new schema for the type.

Examples

To change the owner of the user-defined type `email` to `joe`:

```
ALTER TYPE email OWNER TO joe;
```

To change the schema of the user-defined type `email` to `customers`:

```
ALTER TYPE email SET SCHEMA customers;
```

Compatibility

There is no ALTER TYPE statement in the SQL standard.

See Also

CREATE TYPE, DROP TYPE
**ALTER USER**

Changes the definition of a database role (user).

**Synopsis**

```sql
ALTER USER name RENAME TO newname

ALTER USER name SET config_parameter {TO | =} {value | DEFAULT}

ALTER USER name RESET config_parameter

ALTER USER name RESOURCE QUEUE {queue_name | NONE}

ALTER USER name RESOURCE GROUP {group_name | NONE}

ALTER USER name [ [WITH] option [ ... ] ]
```

where option can be:

- SUPERUSER | NOSUPERUSER
- CREATEDB | NOCREATEDB
- CREATEROLE | NOCREATEROLE
- CREATEUSER | NOCREATEUSER
- CREATEEXTTABLE | NOCREATEEXTTABLE
- [ ( attribute='value'[, ...] ) ]
  where attributes and value are:
  - type='readable'|'writable'
  - protocol='gpfdist'|'http'
- INHERIT | NOINHERIT
- LOGIN | NOLOGIN
- CONNECTION LIMIT connlimit
- [ENCRYPTED | UNENCRYPTED] PASSWORD 'password'
- VALID UNTIL 'timestamp'
- [ DENY deny_point ]
- [ DROP DENY FOR deny_point ]

**Description**

ALTER USER is an alias for ALTER ROLE. See ALTER ROLE for more information.

**Compatibility**

The ALTER USER statement is a Greenplum Database extension. The SQL standard leaves the definition of users to the implementation.

**See Also**

ALTER ROLE

**ALTER VIEW**

Changes the definition of a view.
Synopsis

ALTER VIEW name RENAME TO newname

Description

ALTER VIEW changes the definition of a view. The only currently available functionality is to rename the view. To execute this command you must be the owner of the view.

Parameters

name

The (optionally schema-qualified) name of an existing filespace.

newname

The new name of the view.

Notes

Some variants of ALTER TABLE can be used with views as well; for example, to rename a view, it is also possible to use ALTER TABLE RENAME. To change the schema or owner of a view, you currently must use ALTER TABLE.

Examples

Rename the view myview to newview:

ALTER VIEW myview RENAME TO newview;

Change the owner of tablespace myfs:

ALTER FILESPACE myfs OWNER TO dba;

Compatibility

ALTER VIEW is a Greenplum Database extension of the SQL standard.

See Also

CREATE VIEW, DROP VIEW in the Greenplum Database Utility Guide

ANALYZE

Collects statistics about a database.

Synopsis

ANALYZE [VERBOSE] [ROOTPARTITION [ALL] ]
[ table [ (column [, ...] ) ] ]

Description

ANALYZE collects statistics about the contents of tables in the database, and stores the results in the system table pg_statistic. Subsequently, Greenplum Database uses these statistics to help determine the most efficient execution plans for queries.
With no parameter, `ANALYZE` collects statistics for every table in the current database. You can specify a table name to collect statistics for a single table. You can specify a set of column names, in which case the statistics only for those columns are collected.

`ANALYZE` does not collect statistics on external tables.

**Important:** If you intend to execute queries on partitioned tables with GPORCA enabled (the default), then you must collect statistics on the root partition of the partitioned table with the `ANALYZE ROOTPARTITION` command. For information about GPORCA, see “Querying Data” in the *Greenplum Database Administrator Guide*.

**Note:** You can also use the Greenplum Database utility `analyzedb` to update table statistics. The `analyzedb` utility can update statistics for multiple tables concurrently. The utility can also check table statistics and update statistics only if the statistics are not current or do not exist. For information about the utility, see the *Greenplum Database Utility Guide*.

### Parameters

**ROOTPARTITION [ALL]**

Collect statistics only on the root partition of partitioned tables based on the data in the partitioned table. Statistics are not collected on the leaf child partitions, the data is only sampled. When you specify `ROOTPARTITION`, you must specify either `ALL` or the name of a partitioned table.

If you specify `ALL` with `ROOTPARTITION`, Greenplum Database collects statistics for the root partition of all partitioned tables in the database. If there are no partitioned tables in the database, a message stating that there are no partitioned tables is returned. For tables that are not partitioned tables, statistics are not collected.

If you specify a table name with `ROOTPARTITION` and the table is not a partitioned table, no statistics are collected for the table and a warning message is returned.

The `ROOTPARTITION` clause is not valid with `VACUUM ANALYZE`. The command `VACUUM ANALYZE` returns an error.

The time to run `ANALYZE` `ROOTPARTITION` is similar to the time to analyze a non-partitioned table with the same data since `ANALYZE` `ROOTPARTITION` only samples the leaf child partition data.

For the partitioned table `sales_curr_yr`, this example command collects statistics only on the root partition of the partitioned table. `ANALYZE` `ROOTPARTITION` `sales_curr_yr`;

This example `ANALYZE` command collects statistics on the root partition of all the partitioned tables in the database.

```
ANALYZE ROOTPARTITION ALL;
```

**VERBOSE**

Enables display of progress messages. Enables display of progress messages. When specified, `ANALYZE` emits this information

- The table that is being processed.
- The query that is executed to generate the sample table.
- The column for which statistics is being computed.
- The queries that are issued to collect the different statistics for a single column.
- The statistics that are generated.

**table**

The name (possibly schema-qualified) of a specific table to analyze. Defaults to all tables in the current database.

**column**
The name of a specific column to analyze. Defaults to all columns.

Notes

It is a good idea to run ANALYZE periodically, or just after making major changes in the contents of a table. Accurate statistics helps Greenplum Database choose the most appropriate query plan, and thereby improve the speed of query processing. A common strategy is to run VACUUM and ANALYZE once a day during a low-usage time of day.

ANALYZE requires SHARE UPDATE EXCLUSIVE lock on the target table. This lock conflicts with these locks: SHARE UPDATE EXCLUSIVE, SHARE, SHARE ROW EXCLUSIVE, EXCLUSIVE, ACCESS EXCLUSIVE.

For a partitioned table, specifying which portion of the table to analyze, the root partition or subpartitions (leaf child tables) can be useful if the partitioned table has large number of partitions that have been analyzed and only a few leaf child tables have changed.

- When you run ANALYZE on the root partitioned table, statistics are collected for all the leaf child tables (the lowest-level tables in the hierarchy of child tables created by Greenplum Database for use by the partitioned table).
- When you run ANALYZE on a leaf child table, statistics are collected only for that leaf child table. When you run ANALYZE on a child table that is not a leaf child table, statistics are not collected.

For example, you can create a partitioned table with partitions for the years 2006 to 2016 and subpartitions for each month in each year. If you run ANALYZE on the child table for the year 2013 no statistics are collected. If you run ANALYZE on the leaf child table for March of 2013, statistics are collected only for that leaf child table.

Note: When you create a partitioned table with the CREATE TABLE command, Greenplum Database creates the table that you specify (the root partition or parent table), and also creates a hierarchy of tables based on the partition hierarchy that you specified (the child tables). Partitioned tables, child tables and their inheritance level relationships are tracked in the system view pg_partitions.

For a partitioned table that contains a leaf child partition that has been exchanged to use an external table, ANALYZE does not collect statistics for the external table partition:

- If ANALYZE [ROOTPARTITION] is run, external table partitions are not sampled and root table statistics do not include external table partition.
- If ANALYZE is run on an external table partition, the partition is not analyzed.
- If the VERBOSE clause is specified, an informational message is displayed: skipping external table.

The Greenplum Database server configuration parameter optimizer_analyze_root_partition affects when statistics are collected on the root partition of a partitioned table. If the parameter is enabled, statistics are also collected on the root partition when you run ANALYZE (without the ROOTPARTITION keyword) and specify the root partition.

The statistics collected by ANALYZE usually include a list of some of the most common values in each column and a histogram showing the approximate data distribution in each column. One or both of these may be omitted if ANALYZE deems them uninteresting (for example, in a unique-key column, there are no common values) or if the column data type does not support the appropriate operators.

For large tables, ANALYZE takes a random sample of the table contents, rather than examining every row. This allows even very large tables to be analyzed in a small amount of time. Note, however, that the statistics are only approximate, and will change slightly each time ANALYZE is run, even if the actual table contents did not change. This may result in small changes in the planner's estimated costs shown by EXPLAIN. In rare situations, this non-determinism will cause the query optimizer to choose a different query plan between runs of ANALYZE. To avoid this, raise the amount of statistics collected by ANALYZE by adjusting the default_statistics_target configuration parameter, or on a column-by-column basis by setting the per-column statistics target with ALTER TABLE ... ALTER COLUMN ... SET
**STATISTICS** (see ALTER TABLE). The target value sets the maximum number of entries in the most-common-value list and the maximum number of bins in the histogram. The default target value is 100, but this can be adjusted up or down to trade off accuracy of planner estimates against the time taken for ANALYZE and the amount of space occupied in pg_statistic. In particular, setting the statistics target to zero disables collection of statistics for that column. It may be useful to do that for columns that are never used as part of the WHERE, GROUP BY, or ORDER BY clauses of queries, since the planner will have no use for statistics on such columns.

The largest statistics target among the columns being analyzed determines the number of table rows sampled to prepare the statistics. Increasing the target causes a proportional increase in the time and space needed to do ANALYZE.

When Greenplum Database performs an ANALYZE operation to collect statistics for a table and detects that all the sampled table data pages are empty (do not contain valid data), Greenplum Database displays a message that a VACUUM FULL operation should be performed. If the sampled pages are empty, the table statistics will be inaccurate. Pages become empty after a large number of changes to the table, for example deleting a large number of rows. A VACUUM FULL operation removes the empty pages and allows an ANALYZE operation to collect accurate statistics.

If there are no statistics for the table, the server configuration parameter `gp_enable_relsize_collection` controls whether the legacy query optimizer uses a default statistics file or estimates the size of a table using the `pg_relation_size` function. By default, the legacy optimizer uses the default statistics file to estimate the number of rows if statistics are not available.

**Examples**

Collect statistics for the table `mytable`:

```
ANALYZE mytable;
```

**Compatibility**

There is no ANALYZE statement in the SQL standard.

**See Also**

ALTER TABLE, EXPLAIN, VACUUM, analyzedb utility in the Greenplum Database Utility Guide.

---

**BEGIN**

Starts a transaction block.

**Synopsis**

```
BEGIN [WORK | TRANSACTION] [transaction_mode] [READ ONLY | READ WRITE]
```

where `transaction_mode` is one of:

- ISOLATION LEVEL | {SERIALIZABLE | READ COMMITTED | READ UNCOMMITTED}

**Description**

BEGIN initiates a transaction block, that is, all statements after a BEGIN command will be executed in a single transaction until an explicit COMMIT or ROLLBACK is given. By default (without BEGIN), Greenplum Database executes transactions in autocommit mode, that is, each statement is executed in its own transaction and a commit is implicitly performed at the end of the statement (if execution was successful, otherwise a rollback is done).
Statements are executed more quickly in a transaction block, because transaction start/commit requires significant CPU and disk activity. Execution of multiple statements inside a transaction is also useful to ensure consistency when making several related changes: other sessions will be unable to see the intermediate states wherein not all the related updates have been done.

If the isolation level or read/write mode is specified, the new transaction has those characteristics, as if `SET TRANSACTION` was executed.

**Parameters**

- **WORK**
- **TRANSACTION**
  
  Optional key words. They have no effect.

- **SERIALIZABLE**
- **READ COMMITTED**
- **READ UNCOMMITTED**

The SQL standard defines four transaction isolation levels: `READ COMMITTED`, `READ UNCOMMITTED`, and `REPEATABLE READ`. The default behavior is that a statement can only see rows committed before it began (`READ COMMITTED`). In Greenplum Database `READ UNCOMMITTED` is treated the same as `READ COMMITTED`. `REPEATABLE READ` is not supported; use `SERIALIZABLE` if this behavior is required. `SERIALIZABLE` is the strictest transaction isolation. This level emulates serial transaction execution, as if transactions had been executed one after another, serially, rather than concurrently. Applications using this level must be prepared to retry transactions due to serialization failures.

- **READ WRITE**
- **READ ONLY**

  Determines whether the transaction is read/write or read-only. Read/write is the default. When a transaction is read-only, the following SQL commands are disallowed: `INSERT`, `UPDATE`, `DELETE`, and `COPY FROM` if the table they would write to is not a temporary table; all `CREATE`, `ALTER`, and `DROP` commands; `GRANT`, `REVOKE`, `TRUNCATE`; and `EXPLAIN ANALYZE` and `EXECUTE` if the command they would execute is among those listed.

**Notes**

- `START TRANSACTION` has the same functionality as `BEGIN`.

  Use `COMMIT` or `ROLLBACK` to terminate a transaction block.

  Issuing `BEGIN` when already inside a transaction block will provoke a warning message. The state of the transaction is not affected. To nest transactions within a transaction block, use savepoints (see `SAVEPOINT`).

**Examples**

To begin a transaction block:

```sql
BEGIN;
```

To begin a transaction block with the serializable isolation level:

```sql
BEGIN TRANSACTION ISOLATION LEVEL SERIALIZABLE;
```

**Compatibility**

- `BEGIN` is a Greenplum Database language extension. It is equivalent to the SQL-standard command `START TRANSACTION`.
Incidentally, the `BEGIN` key word is used for a different purpose in embedded SQL. You are advised to be careful about the transaction semantics when porting database applications.

**See Also**

`COMMIT`, `ROLLBACK`, `START TRANSACTION`, `SAVEPOINT`

**CHECKPOINT**

Forces a transaction log checkpoint.

**Synopsis**

```
CHECKPOINT
```

**Description**

Write-Ahead Logging (WAL) puts a checkpoint in the transaction log every so often. The automatic checkpoint interval is set per Greenplum Database segment instance by the server configuration parameters `checkpoint_segments` and `checkpoint_timeout`. The `CHECKPOINT` command forces an immediate checkpoint when the command is issued, without waiting for a scheduled checkpoint.

A checkpoint is a point in the transaction log sequence at which all data files have been updated to reflect the information in the log. All data files will be flushed to disk.

Only superusers may call `CHECKPOINT`. The command is not intended for use during normal operation.

**Compatibility**

The `CHECKPOINT` command is a Greenplum Database language extension.

**CLOSE**

Closes a cursor.

**Synopsis**

```
CLOSE cursor_name
```

**Description**

`CLOSE` frees the resources associated with an open cursor. After the cursor is closed, no subsequent operations are allowed on it. A cursor should be closed when it is no longer needed.

Every non-holdable open cursor is implicitly closed when a transaction is terminated by `COMMIT` or `ROLLBACK`. A holdable cursor is implicitly closed if the transaction that created it aborts via `ROLLBACK`. If the creating transaction successfully commits, the holdable cursor remains open until an explicit `CLOSE` is executed, or the client disconnects.

**Parameters**

`cursor_name`

The name of an open cursor to close.

**Notes**

Greenplum Database does not have an explicit `OPEN` cursor statement. A cursor is considered open when it is declared. Use the `DECLARE` statement to declare (and open) a cursor.
You can see all available cursors by querying the `pg_cursors` system view.

**Examples**

Close the cursor `portala`:

```
CLOSE portala;
```

**Compatibility**

`CLOSE` is fully conforming with the SQL standard.

**See Also**

`DECLARE, FETCH, MOVE`

**CLUSTER**

Physically reorders a heap storage table on disk according to an index. Not a recommended operation in Greenplum Database.

**Synopsis**

```
CLUSTER indexname ON tablename

CLUSTER tablename

CLUSTER
```

**Description**

`CLUSTER` orders a heap storage table based on an index. `CLUSTER` is not supported on append-optimized storage tables. Clustering an index means that the records are physically ordered on disk according to the index information. If the records you need are distributed randomly on disk, then the database has to seek across the disk to get the records requested. If those records are stored more closely together, then the fetching from disk is more sequential. A good example for a clustered index is on a date column where the data is ordered sequentially by date. A query against a specific date range will result in an ordered fetch from the disk, which leverages faster sequential access.

Clustering is a one-time operation: when the table is subsequently updated, the changes are not clustered. That is, no attempt is made to store new or updated rows according to their index order. If one wishes, one can periodically recluster by issuing the command again.

When a table is clustered using this command, Greenplum Database remembers on which index it was clustered. The form `CLUSTER tablename` reclusters the table on the same index that it was clustered before. `CLUSTER` without any parameter reclusters all previously clustered tables in the current database that the calling user owns, or all tables if called by a superuser. This form of `CLUSTER` cannot be executed inside a transaction block.

When a table is being clustered, an `ACCESS EXCLUSIVE` lock is acquired on it. This prevents any other database operations (both reads and writes) from operating on the table until the `CLUSTER` is finished.

**Parameters**

*indexname*

The name of an index.

*tablename*

The name (optionally schema-qualified) of a table.
Notes

In cases where you are accessing single rows randomly within a table, the actual order of the data in the table is unimportant. However, if you tend to access some data more than others, and there is an index that groups them together, you will benefit from using CLUSTER. If you are requesting a range of indexed values from a table, or a single indexed value that has multiple rows that match, CLUSTER will help because once the index identifies the table page for the first row that matches, all other rows that match are probably already on the same table page, and so you save disk accesses and speed up the query.

During the cluster operation, a temporary copy of the table is created that contains the table data in the index order. Temporary copies of each index on the table are created as well. Therefore, you need free space on disk at least equal to the sum of the table size and the index sizes.

Because the query optimizer records statistics about the ordering of tables, it is advisable to run ANALYZE on the newly clustered table. Otherwise, the planner may make poor choices of query plans.

There is another way to cluster data. The CLUSTER command reorders the original table by scanning it using the index you specify. This can be slow on large tables because the rows are fetched from the table in index order, and if the table is disordered, the entries are on random pages, so there is one disk page retrieved for every row moved. (Greenplum Database has a cache, but the majority of a big table will not fit in the cache.) The other way to cluster a table is to use a statement such as:

```
CREATE TABLE newtable AS SELECT * FROM table ORDER BY column;
```

This uses the Greenplum Database sorting code to produce the desired order, which is usually much faster than an index scan for disordered data. Then you drop the old table, use ALTER TABLE ... RENAME to rename newtable to the old name, and recreate the table's indexes. The big disadvantage of this approach is that it does not preserve OIDs, constraints, granted privileges, and other ancillary properties of the table — all such items must be manually recreated. Another disadvantage is that this way requires a sort temporary file about the same size as the table itself, so peak disk usage is about three times the table size instead of twice the table size.

Note: CLUSTER is not supported with append-optimized tables.

Examples

Cluster the table employees on the basis of its index emp_ind:

```
CLUSTER emp_ind ON emp;
```

Cluster a large table by recreating it and loading it in the correct index order:

```
CREATE TABLE newtable AS SELECT * FROM table ORDER BY column;
DROP table;
ALTER TABLE newtable RENAME TO table;
CREATE INDEX column_ix ON table (column);
VACUUM ANALYZE table;
```

Compatibility

There is no CLUSTER statement in the SQL standard.

See Also

CREATE TABLE AS, CREATE INDEX

COMMENT

Defines or change the comment of an object.
Synopsis

```sql
COMMENT ON

{ TABLE object_name |
  COLUMN table_name.column_name |
  AGGREGATE agg_name (agg_type [, ...]) |
  CAST (sourcetype AS targettype) |
  CONSTRAINT constraint_name ON table_name |
  CONVERSION object_name |
  DATABASE object_name |
  DOMAIN object_name |
  FILESPACE object_name |
  FUNCTION func_name ([[argmode] [argname] argtype [, ...]]) |
  INDEX object_name |
  LARGE OBJECT large_object_oid |
  OPERATOR op (leftoperand_type , rightoperand_type) |
  OPERATOR CLASS object_name USING index_method |
  [PROCEDURAL] LANGUAGE object_name |
  RESOURCE QUEUE object_name |
  ROLE object_name |
  RULE rule_name ON table_name |
  SCHEMA object_name |
  SEQUENCE object_name |
  TABLESPACE object_name |
  TRIGGER trigger_name ON table_name |
  TYPE object_name |
  VIEW object_name |

IS 'text'
```

Description

`COMMENT` stores a comment about a database object. To modify a comment, issue a new `COMMENT` command for the same object. Only one comment string is stored for each object. To remove a comment, write `NULL` in place of the text string. Comments are automatically dropped when the object is dropped.

Comments can be easily retrieved with the psql meta-commands `\dd`, `\d+`, and `\l+`. Other user interfaces to retrieve comments can be built atop the same built-in functions that psql uses, namely `obj_description`, `col_description`, and `shobj_description`.

Parameters

- `object_name`
- `table_name.column_name`
- `agg_name`
- `constraint_name`
- `func_name`
- `op`
- `rule_name`
- `trigger_name`

  The name of the object to be commented. Names of tables, aggregates, domains, functions, indexes, operators, operator classes, sequences, types, and views may be schema-qualified.

  **Note:** Greenplum Database does not support triggers.

- `agg_type`

  An input data type on which the aggregate function operates. To reference a zero-argument aggregate function, write `*` in place of the list of input data types.

- `sourcetype`

  The name of the source data type of the cast.
**targettype**

The name of the target data type of the cast.

**argmode**

The mode of a function argument: either IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that COMMENT ON FUNCTION does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

**argname**

The name of a function argument. Note that COMMENT ON FUNCTION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

**argtype**

The data type(s) of the function's arguments (optionally schema-qualified), if any.

**large_object_oid**

The OID of the large object.

**PROCEDURAL**

This is a noise word.

**text**

The new comment, written as a string literal; or NULL to drop the comment.

**Notes**

There is presently no security mechanism for comments: any user connected to a database can see all the comments for objects in that database (although only superusers can change comments for objects that they do not own). For shared objects such as databases, roles, and tablespaces comments are stored globally and any user connected to any database can see all the comments for shared objects. Therefore, do not put security-critical information in comments.

**Examples**

Attach a comment to the table mytable:

```sql
COMMENT ON TABLE mytable IS 'This is my table.';
```

Remove it again:

```sql
COMMENT ON TABLE mytable IS NULL;
```

**Compatibility**

There is no COMMENT statement in the SQL standard.

**COMMIT**

Commits the current transaction.

**Synopsis**

```sql
COMMIT [WORK | TRANSACTION]
```
Description

**COMMIT** commits the current transaction. All changes made by the transaction become visible to others and are guaranteed to be durable if a crash occurs.

Parameters

**WORK**
**TRANSACTION**

Optional key words. They have no effect.

Notes

Use **ROLLBACK** to abort a transaction.

Issuing **COMMIT** when not inside a transaction does no harm, but it will provoke a warning message.

Examples

To commit the current transaction and make all changes permanent:

```sql
COMMIT;
```

Compatibility

The SQL standard only specifies the two forms **COMMIT** and **COMMIT WORK**. Otherwise, this command is fully conforming.

See Also

**BEGIN**, **END**, **START TRANSACTION**, **ROLLBACK**

**COPY**

Copies data between a file and a table.

Synopsis

```sql
COPY table [(column [, ...])] FROM ('file' | PROGRAM 'command' | STDIN) 
[ [WITH] 
  [ON SEGMENT]
  [BINARY]
  [OIDS]
  [HEADER]
  [DELIMITER [ AS ] 'delimiter']
  [NULL [ AS ] 'null string']
  [ESCAPE [ AS ] 'escape' [ 'OFF']]
  [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
  [CSV [QUOTE [ AS ] 'quote']
   [FORCE NOT NULL column [, ...]]
  [FILL MISSING FIELDS]
  [[LOG ERRORS]
   SEGMENT REJECT LIMIT count [ROWS | PERCENT] ]
] TO ('file' | PROGRAM 'command' | STDOUT)
[ 
] [WITH]
[ON SEGMENT]
[BINARY]
[OIDS]
```

```sql
COPY (table [(column [, ...])] | (query)) TO ('file' | PROGRAM 'command' | STDOUT)
[ [WITH] 
  [ON SEGMENT]
  [BINARY]
  [OIDS]
] ```
**Description**

COPY moves data between Greenplum Database tables and standard file-system files. COPY TO copies the contents of a table to a file (or multiple files based on the segment ID if copying ON SEGMENT), while COPY FROM copies data from a file to a table (appending the data to whatever is in the table already). COPY TO can also copy the results of a SELECT query.

If a list of columns is specified, COPY will only copy the data in the specified columns to or from the file. If there are any columns in the table that are not in the column list, COPY FROM will insert the default values for those columns.

COPY with a file name instructs the Greenplum Database master host to directly read from or write to a file. The file must be accessible to the master host and the name must be specified from the viewpoint of the master host.

When COPY is used with the ON SEGMENT clause, the copy TO causes segments to create individual segment-oriented files, which remain on the segment hosts. The file argument for ON SEGMENT takes the string literal <SEGID> (required) and uses either the absolute path or the <SEG DATA_DIR> string literal. When the COPY operation is run, the segment IDs and the paths of the segment data directories are substituted for the string literal values.

The ON SEGMENT clause allows you to copy table data to files on segment hosts for use in operations such as migrating data between clusters or performing a backup. Segment data created by the ON SEGMENT clause can be restored by tools such as gpfdist, which is useful for high speed data loading.

**Warning:** Use of the ON SEGMENT clause is recommended for expert users only.

When STDIN or STDOUT is specified, data is transmitted via the connection between the client and the master. STDIN and STDOUT cannot be used with the ON SEGMENT clause.

If SEGMENT REJECT LIMIT is used, then a COPY FROM operation will operate in single row error isolation mode. In this release, single row error isolation mode only applies to rows in the input file with format errors — for example, extra or missing attributes, attributes of a wrong data type, or invalid client encoding sequences. Constraint errors such as violation of a NOT NULL, CHECK, or UNIQUE constraint will still be handled in 'all-or-nothing' input mode. The user can specify the number of error rows acceptable (on a per-segment basis), after which the entire COPY FROM operation will be aborted and no rows will be loaded. The count of error rows is per-segment, not per entire load operation. If the per-segment reject limit is not reached, then all rows not containing an error will be loaded and any error rows discarded. To keep error rows for further examination, specify the LOG ERRORS clause to capture error log information. The error information and the row is stored internally in Greenplum Database.

**Outputs**

On successful completion, a COPY command returns a command tag of the form, where `count` is the number of rows copied:

```
COPY count
```

If running a COPY FROM command in single row error isolation mode, the following notice message will be returned if any rows were not loaded due to format errors, where `count` is the number of rows rejected:

```
NOTICE: Rejected count badly formatted rows.
```
**Parameters**

**table**

The name (optionally schema-qualified) of an existing table.

**column**

An optional list of columns to be copied. If no column list is specified, all columns of the table will be copied.

When copying in text format, the default, a row of data in a column of type `bytea` can be up to 256MB.

**query**

A `SELECT` or `VALUES` command whose results are to be copied. Note that parentheses are required around the query.

**file**

The absolute path name of the input or output file.

**PROGRAM 'command'**

Specify a command to execute. The `command` must be specified from the viewpoint of the Greenplum Database master host system, and must be executable by the Greenplum Database administrator user (`gpadmin`). The `COPY FROM` command reads the input from the standard output of the command, and for the `COPY TO` command, the output is written to the standard input of the command.

The command is invoked by a shell. When passing arguments to the shell, strip or escape any special characters that have a special meaning for the shell. For security reasons, it is best to use a fixed command string, or at least avoid passing any user input in the string.

When `ON SEGMENT` is specified, the command must be executable on all Greenplum Database primary segment hosts by the Greenplum Database administrator user (`gpadmin`). The command is executed by each Greenplum segment instance. The `<SEGID>` is required in the `command`.

See the `ON SEGMENT` clause for information about command syntax requirements and the data that is copied when the clause is specified.

**STDIN**

Specifies that input comes from the client application. The `ON SEGMENT` clause is not supported with `STDIN`.

**STDOUT**

Specifies that output goes to the client application. The `ON SEGMENT` clause is not supported with `STDOUT`.

**ON SEGMENT**

Specify individual, segment data files on the segment hosts. Each file contains the table data that is managed by the primary segment instance. For example, when copying data to files from a table with a `COPY TO...ON SEGMENT` command, the command creates a file on the segment host for each segment instance on the host. Each file contains the table data that is managed by the segment instance.

The `COPY` command does not copy data from or to mirror segment instances and segment data files.

The keywords `STDIN` and `STDOUT` are not supported with `ON SEGMENT`.

The `<SEG_DATA_DIR>` and `<SEGID>` string literals are used to specify an absolute path and file name with the following syntax:

```sql
COPY table [TO|FROM] 'SEG_DATA_DIR>/gpdumpname<SEGID>_suffix' ON SEGMENT;
```
**<SEG_DATA_DIR>**

The string literal representing the absolute path of the segment instance data directory for ON SEGMENT copying. The angle brackets (< and >) are part of the string literal used to specify the path. COPY replaces the string literal with the segment path(s) when COPY is run. An absolute path can be used in place of the <SEG_DATA_DIR> string literal.

**<SEGID>**

The string literal representing the content ID number of the segment instance to be copied when copying ON SEGMENT. <SEGID> is a required part of the file name when ON SEGMENT is specified. The angle brackets are part of the string literal used to specify the file name.

With COPY TO, the string literal is replaced by the content ID of the segment instance when the COPY command is run.

With COPY FROM, specify the segment instance content ID in the name of the file and place that file on the segment instance host. There must be a file for each primary segment instance on each host. When the COPY FROM command is run, the data is copied from the file to the segment instance.

When the PROGRAM command clause is specified, the <SEGID> string literal is required in the command, the <SEG_DATA_DIR> string literal is optional. See Examples.

For a COPY FROM...ON SEGMENT command, the table distribution policy is checked when data is copied into the table. By default, an error is returned if a data row violates the table distribution policy. You can disable the distribution policy check with the server configuration parameter gp_enable_segment_copy_checking. See Notes.

**BINARY**

Causes all data to be stored or read in binary format rather than as text. You cannot specify the DELIMITER, NULL, or CSV options in binary mode. See Binary Format.

When copying in binary format, a row of data can be up to 1GB.

**OIDS**

Specifies copying the OID for each row. (An error is raised if OIDS is specified for a table that does not have OIDs, or in the case of copying a query.)

**delimiter**

The single ASCII character that separates columns within each row (line) of the file. The default is a tab character in text mode, a comma in CSV mode.

**null string**

The string that represents a null value. The default is \\N (backslash-N) in text mode, and a empty value with no quotes in CSV mode. You might prefer an empty string even in text mode for cases where you don't want to distinguish nulls from empty strings. When using COPY FROM, any data item that matches this string will be stored as a null value, so you should make sure that you use the same string as you used with COPY TO.

**escape**

Specifies the single character that is used for C escape sequences (such as \n,\t,\100, and so on) and for quoting data characters that might otherwise be taken as row or column delimiters. Make sure to choose an escape character that is not used anywhere in your actual column data. The default escape character is \ (backslash) for text files or " (double quote) for CSV files, however it is possible to specify any other character to represent an escape. It is also possible to disable escaping on text-formatted files by specifying the value 'OFF' as the escape value. This is very useful for data such as web log data that has many embedded backslashes that are not intended to be escapes.

**NEWLINE**
Specifies the newline used in your data files — **LF** (Line feed, 0x0A), **CR** (Carriage return, 0x0D), or **CRLF** (Carriage return plus line feed, 0x0D 0x0A). If not specified, a Greenplum Database segment will detect the newline type by looking at the first row of data it receives and using the first newline type encountered.

**CSV**

Selects Comma Separated Value (CSV) mode. See **CSV Format**.

**HEADER**

Specifies that a file contains a header line with the names of each column in the file. On output, the first line contains the column names from the table, and on input, the first line is ignored.

**quote**

Specifies the quotation character in CSV mode. The default is double-quote.

**FORCE QUOTE**

In CSV COPY TO mode, forces quoting to be used for all non-NULL values in each specified column. NULL output is never quoted.

**FORCE NOT NULL**

In CSV COPY FROM mode, process each specified column as though it were quoted and hence not a NULL value. For the default null string in CSV mode (nothing between two delimiters), this causes missing values to be evaluated as zero-length strings.

**FILL MISSING FIELDS**

In COPY FROM mode for both TEXT and CSV, specifying FILL MISSING FIELDS will set missing trailing field values to NULL (instead of reporting an error) when a row of data has missing data fields at the end of a line or row. Blank rows, fields with a NOT NULL constraint, and trailing delimiters on a line will still report an error.

**LOG ERRORS**

This is an optional clause that can precede a SEGMENT REJECT LIMIT clause to capture error log information about rows with formatting errors.

Error log information is stored internally and is accessed with the Greenplum Database built-in SQL function **gp_read_error_log()**.

See **Notes** for information about the error log information and built-in functions for viewing and managing error log information.

**SEGMENT REJECT LIMIT count [ROWS | PERCENT]**

Runs a COPY FROM operation in single row error isolation mode. If the input rows have format errors they will be discarded provided that the reject limit count is not reached on any Greenplum Database segment instance during the load operation. The reject limit count can be specified as number of rows (the default) or percentage of total rows (1-100). If PERCENT is used, each segment starts calculating the bad row percentage only after the number of rows specified by the parameter **gp_reject_percent_threshold** has been processed. The default for **gp_reject_percent_threshold** is 300 rows. Constraint errors such as violation of a NOT NULL, CHECK, or UNIQUE constraint will still be handled in 'all-or-nothing' input mode. If the limit is not reached, all good rows will be loaded and any error rows discarded.

**Note:** Greenplum Database limits the initial number of rows that can contain formatting errors if the SEGMENT REJECT LIMIT is not triggered first or is not specified. If the first 1000 rows are rejected, the COPY operation is stopped and rolled back.

The limit for the number of initial rejected rows can be changed with the Greenplum Database server configuration parameter
gp_initial_bad_row_limit. See Server Configuration Parameters for information about the parameter.

**IGNORE EXTERNAL PARTITIONS**

When copying data from partitioned tables, data are not copied from leaf child partitions that are external tables. A message is added to the log file when data are not copied.

If this clause is not specified and Greenplum Database attempts to copy data from a leaf child partition that is an external table, an error is returned.

See the next section "Notes" for information about specifying an SQL query to copy data from leaf child partitions that are external tables.

**Notes**

*COPY* can only be used with tables, not with external tables or views. However, you can write *COPY* (SELECT * FROM viewname) TO ...

When the **ON SEGMENT** clause is specified, the *COPY* command does not support specifying a SELECT statement in the *COPY TO* command. For example, this command is not supported.

```
COPY (SELECT * FROM testtbl) TO '/tmp/mytst<SEGID>' ON SEGMENT
```

To copy data from a partitioned table with a leaf child partition that is an external table, use an SQL query to copy the data. For example, if the table *my_sales* contains a with a leaf child partition that is an external table, this command *COPY my_sales TO stdout* returns an error. This command sends the data to stdout:

```
COPY (SELECT * from my_sales ) TO stdout
```

The **BINARY** key word causes all data to be stored/read as binary format rather than as text. It is somewhat faster than the normal text mode, but a binary-format file is less portable across machine architectures and Greenplum Database versions. Also, you cannot run *COPY FROM* in single row error isolation mode if the data is in binary format.

You must have **SELECT** privilege on the table whose values are read by *COPY TO*, and insert privilege on the table into which values are inserted by *COPY FROM*.

Files named in a *COPY* command are read or written directly by the database server, not by the client application. Therefore, they must reside on or be accessible to the Greenplum Database master host machine, not the client. They must be accessible to and readable or writable by the Greenplum Database system user (the user ID the server runs as), not the client. *COPY* naming a file is only allowed to database superusers, since it allows reading or writing any file that the server has privileges to access.

*COPY FROM* will invoke any triggers and check constraints on the destination table. However, it will not invoke rewrite rules. Note that in this release, violations of constraints are not evaluated for single row error isolation mode.

*COPY* input and output is affected by **DateStyle**. To ensure portability to other Greenplum Database installations that might use non-default **DateStyle** settings, **DateStyle** should be set to ISO before using *COPY TO*.

When copying XML data from a file in text mode, the server configuration parameter **xmloption** affects the validation of the XML data that is copied. If the value is **content** (the default), XML data is validated as an XML content fragment. If the parameter value is **document**, XML data is validated as an XML document. If the XML data is not valid, *COPY* returns an error.

By default, *COPY* stops operation at the first error. This should not lead to problems in the event of a *COPY TO*, but the target table will already have received earlier rows in a *COPY FROM*. These rows will not be visible or accessible, but they still occupy disk space. This may amount to a considerable amount of wasted disk space if the failure happened well into a large *COPY FROM* operation. You may wish to invoke
VACUUM to recover the wasted space. Another option would be to use single row error isolation mode to filter out error rows while still loading good rows.

When a COPY FROM...ON SEGMENT command is run, the server configuration parameter gp_enable_segment_copy_checking controls whether the table distribution policy (from the table DISTRIBUTED clause) is checked when data is copied into the table. The default is to check the distribution policy. An error is returned if the row of data violates the distribution policy for the segment instance. For a partitioned table, if the distribution policy of the child leaf partitioned table is not the same as the root table, an error is returned for all data. For information about the parameter, see Server Configuration Parameters.

Data from a table that is generated by a COPY TO...ON SEGMENT command can be used to restore table data with COPY FROM...ON SEGMENT. However, data restored to the segments is distributed according to the table distribution policy at the time the files were generated with the COPY TO command. The COPY command might return table distribution policy errors, if you attempt to restore table data and the table distribution policy was changed after the COPY FROM...ON SEGMENT was run.

Note: If you run COPY FROM...ON SEGMENT and the server configuration parameter gp_enable_segment_copy_checking is false, manual redistribution of table data might be required. See the ALTER TABLE clause WITH REORGANIZE.

When you specify the LOG ERRORS clause, Greenplum Database captures errors that occur while reading the external table data. You can view and manage the captured error log data.

• Use the built-in SQL function gp_read_error_log('table_name'). It requires SELECT privilege on table_name. This example displays the error log information for data loaded into table ext_expenses with a COPY command:

```sql
SELECT * from gp_read_error_log('ext_expenses');
```

For information about the error log format, see Viewing Bad Rows in the Error Log in the Greenplum Database Administrator Guide.

The function returns FALSE if table_name does not exist.

• If error log data exists for the specified table, the new error log data is appended to existing error log data. The error log information is not replicated to mirror segments.

• Use the built-in SQL function gp_truncate_error_log('table_name') to delete the error log data for table_name. It requires the table owner privilege This example deletes the error log information captured when moving data into the table ext_expenses:

```sql
SELECT gp_truncate_error_log('ext_expenses');
```

The function returns FALSE if table_name does not exist.

Specify the * wildcard character to delete error log information for existing tables in the current database. Specify the string *.* to delete all database error log information, including error log information that was not deleted due to previous database issues. If * is specified, database owner privilege is required. If *.* is specified, operating system super-user privilege is required.

When a Greenplum Database user who is not a superuser runs a COPY command, the command can be controlled by a resource queue. The resource queue must be configured with the ACTIVE_STATEMENTS parameter that specifies a maximum limit on the number of queries that can be executed by roles assigned to that queue. Greenplum Database does not apply a cost value or memory value to a COPY command, resource queues with only cost or memory limits do not affect the running of COPY commands.

A non-superuser can run only these types of COPY commands:

• COPY FROM command where the source is stdin
• COPY TO command where the destination is stdout
For information about resource queues, see "Resource Management with Resource Queues" in the Greenplum Database Administrator Guide.

**File Formats**

File formats supported by COPY.

**Text Format**

When COPY is used without the BINARY or CSV options, the data read or written is a text file with one line per table row. Columns in a row are separated by the delimiter character (tab by default). The column values themselves are strings generated by the output function, or acceptable to the input function, of each attribute's data type. The specified null string is used in place of columns that are null. COPY FROM will raise an error if any line of the input file contains more or fewer columns than are expected. If OIDS is specified, the OID is read or written as the first column, preceding the user data columns.

The data file has two reserved characters that have special meaning to COPY:

- The designated delimiter character (tab by default), which is used to separate fields in the data file.
- A UNIX-style line feed (\n or 0x0a), which is used to designate a new row in the data file. It is strongly recommended that applications generating COPY data convert data line feeds to UNIX-style line feeds rather than Microsoft Windows style carriage return line feeds (\r\n or 0x0a 0x0d).

If your data contains either of these characters, you must escape the character so COPY treats it as data and not as a field separator or new row.

By default, the escape character is a \ (backslash) for text-formatted files and a " (double quote) for csv-formatted files. If you want to use a different escape character, you can do so using the ESCAPE AS clause. Make sure to choose an escape character that is not used anywhere in your data file as an actual data value. You can also disable escaping in text-formatted files by using ESCAPE 'OFF'.

For example, suppose you have a table with three columns and you want to load the following three fields using COPY.

- percentage sign = %
- vertical bar = |
- backslash = \ 

Your designated delimiter character is | (pipe character), and your designated escape character is * (asterisk). The formatted row in your data file would look like this:

```
percentage sign = % | vertical bar = *| | backslash = \ 
```

Notice how the pipe character that is part of the data has been escaped using the asterisk character (*). Also notice that we do not need to escape the backslash since we are using an alternative escape character.

The following characters must be preceded by the escape character if they appear as part of a column value: the escape character itself, newline, carriage return, and the current delimiter character. You can specify a different escape character using the ESCAPE AS clause.

**CSV Format**

This format is used for importing and exporting the Comma Separated Value (CSV) file format used by many other programs, such as spreadsheets. Instead of the escaping used by Greenplum Database standard text mode, it produces and recognizes the common CSV escaping mechanism.

The values in each record are separated by the DELIMITER character. If the value contains the delimiter character, the QUOTE character, the ESCAPE character (which is double quote by default), the NULL string, a carriage return, or line feed character, then the whole value is prefixed and suffixed by the QUOTE character. You can also use FORCE QUOTE to force quotes when outputting non-NULL values in specific columns.
The CSV format has no standard way to distinguish a NULL value from an empty string. Greenplum Database COPY handles this by quoting. A NULL is output as the NULL string and is not quoted, while a data value matching the NULL string is quoted. Therefore, using the default settings, a NULL is written as an unquoted empty string, while an empty string is written with double quotes (""). Reading values follows similar rules. You can use FORCE NOT NULL to prevent NULL input comparisons for specific columns.

Because backslash is not a special character in the CSV format, \., the end-of-data marker, could also appear as a data value. To avoid any misinterpretation, a \ . data value appearing as a lone entry on a line is automatically quoted on output, and on input, if quoted, is not interpreted as the end-of-data marker. If you are loading a file created by another application that has a single unquoted column and might have a value of \ ., you might need to quote that value in the input file.

Note: In CSV mode, all characters are significant. A quoted value surrounded by white space, or any characters other than DELIMITER, will include those characters. This can cause errors if you import data from a system that pads CSV lines with white space out to some fixed width. If such a situation arises you might need to preprocess the CSV file to remove the trailing white space, before importing the data into Greenplum Database.

CSV mode will both recognize and produce CSV files with quoted values containing embedded carriage returns and line feeds. Thus the files are not strictly one line per table row like text-mode files

Note: Many programs produce strange and occasionally perverse CSV files, so the file format is more a convention than a standard. Thus you might encounter some files that cannot be imported using this mechanism, and COPY might produce files that other programs cannot process.

Binary Format

The BINARY format consists of a file header, zero or more tuples containing the row data, and a file trailer. Headers and data are in network byte order.

- File Header — The file header consists of 15 bytes of fixed fields, followed by a variable-length header extension area. The fixed fields are:
  - Signature — 11-byte sequence PGCOPY\n\377\r\n\0 — note that the zero byte is a required part of the signature. (The signature is designed to allow easy identification of files that have been munged by a non-8-bit-clean transfer. This signature will be changed by end-of-line-translation filters, dropped zero bytes, dropped high bits, or parity changes.)
  - Flags field — 32-bit integer bit mask to denote important aspects of the file format. Bits are numbered from 0 (LSB) to 31 (MSB). Note that this field is stored in network byte order (most significant byte first), as are all the integer fields used in the file format. Bits 16-31 are reserved to denote critical file format issues; a reader should abort if it finds an unexpected bit set in this range. Bits 0-15 are reserved to signal backwards-compatible format issues; a reader should simply ignore any unexpected bits set in this range. Currently only one flag is defined, and the rest must be zero (Bit 16: 1 if data has OIDs, 0 if not).
  - Header extension area length — 32-bit integer, length in bytes of remainder of header, not including self. Currently, this is zero, and the first tuple follows immediately. Future changes to the format might allow additional data to be present in the header. A reader should silently skip over any header extension data it does not know what to do with. The header extension area is envisioned to contain a sequence of self-identifying chunks. The flags field is not intended to tell readers what is in the extension area. Specific design of header extension contents is left for a later release.
  - Tuples — Each tuple begins with a 16-bit integer count of the number of fields in the tuple. (Presently, all tuples in a table will have the same count, but that might not always be true.) Then, repeated for each field in the tuple, there is a 32-bit length word followed by that many bytes of field data. (The length word does not include itself, and can be zero.) As a special case, -1 indicates a NULL field value. No value bytes follow in the NULL case.

There is no alignment padding or any other extra data between fields.
Presently, all data values in a COPY BINARY file are assumed to be in binary format (format code one). It is anticipated that a future extension may add a header field that allows per-column format codes to be specified.

If OIDs are included in the file, the OID field immediately follows the field-count word. It is a normal field except that it is not included in the field-count. In particular it has a length word — this will allow handling of 4-byte vs. 8-byte OIDs without too much pain, and will allow OIDs to be shown as null if that ever proves desirable.

- **File Trailer** — The file trailer consists of a 16-bit integer word containing -1. This is easily distinguished from a tuple’s field-count word. A reader should report an error if a field-count word is neither -1 nor the expected number of columns. This provides an extra check against somehow getting out of sync with the data.

**Examples**

Copy a table to the client using the vertical bar (|) as the field delimiter:

```sql
COPY country TO STDOUT WITH DELIMITER '|';
```

Copy data from a file into the `country` table:

```sql
COPY country FROM '/home/usr1/sql/country_data';
```

Copy into a file just the countries whose names start with 'A':

```sql
COPY (SELECT * FROM country WHERE country_name LIKE 'A%') TO '/home/usr1/sql/a_list_countries.copy';
```

Copy data from a file into the `sales` table using single row error isolation mode and log errors:

```sql
COPY sales FROM '/home/usr1/sql/sales_data' LOG ERRORS SEGMENT REJECT LIMIT 10 ROWS;
```

To copy segment data for later use, use the ON SEGMENT clause. Use of the COPY TO ON SEGMENT command takes the form:

```sql
COPY table TO '<SEG_DATA_DIR>/gpdumpname<SEGID>_suffix' ON SEGMENT;
```

The `<SEGID>` is required. However, you can substitute an absolute path for the `<SEG_DATA_DIR>` string literal in the path.

When you pass in the string literal `<SEG_DATA_DIR>` and `<SEGID>` to COPY, COPY will fill in the appropriate values when the operation is run.

For example, if you have `mytable` with the segments and mirror segments like this:

<table>
<thead>
<tr>
<th>contentid</th>
<th>dbid</th>
<th>file segment location</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>/home/usr1/data1/gpsegdir0</td>
</tr>
<tr>
<td>0</td>
<td>3</td>
<td>/home/usr1/data_mirror1/gpsegdir0</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>/home/usr1/data2/gpsegdir1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>/home/usr1/data_mirror2/gpsegdir1</td>
</tr>
</tbody>
</table>

running the command:

```sql
COPY mytable TO '<SEG_DATA_DIR>/gpbackup<SEGID>.txt' ON SEGMENT;
```

would result in the following files:

```
/home/usr1/data1/gpsegdir0/gpbackup0.txt
```
The content ID in the first column is the identifier inserted into the file path (for example, gpsegdir0/gpbackup0.txt above) Files are created on the segment hosts, rather than on the master, as they would be in a standard COPY operation. No data files are created for the mirror segments when using ON SEGMENT copying.

If an absolute path is specified, instead of <SEG_DATA_DIR>, such as in the statement

```sql
COPY mytable TO '/tmp/gpdir/gpbackup_<SEGID>.txt' ON SEGMENT;
```

files would be placed in /tmp/gpdir on every segment. The gpfdist tool can also be used to restore data files generated with COPY TO with the ON SEGMENT option if redistribution is necessary.

**Note:** Tools such as gpfdist can be used to restore data. The backup/restore tools will not work with files that were manually generated with COPY TO ON SEGMENT.

This example copies the data from the lineitem table and uses the PROGRAM clause to add the data to the /tmp/lineitem_program.csv file with cat utility. The file is placed on the Greenplum Database master.

```sql
COPY LINEITEM TO PROGRAM 'cat > /tmp/lineitem.csv' CSV;
```

This example uses the PROGRAM and ON SEGMENT clauses to copy data to files on the segment hosts. On the segment hosts, the COPY command replaces <SEGID> with the segment content ID to create a file for each segment instance on the segment host.

```sql
COPY LINEITEM TO PROGRAM 'cat > /tmp/lineitem_program<SEGID>.csv' ON SEGMENT CSV;
```

This example uses the PROGRAM and ON SEGMENT clauses to copy data from files on the segment hosts. The COPY command replaces <SEGID> with the segment content ID when copying data from the files. On the segment hosts, there must be a file for each segment instance where the file name contains the segment content ID on the segment host.

```sql
COPY LINEITEM_4 FROM PROGRAM 'cat /tmp/lineitem_program<SEGID>.csv' ON SEGMENT CSV;
```

**Compatibility**

There is no COPY statement in the SQL standard.

**See Also**

CREATE EXTERNAL TABLE

**CREATE AGGREGATE**

Defines a new aggregate function.

**Synopsis**

```sql
CREATE [ORDERED] AGGREGATE name (input_data_type [ , ... ]) 
  ( SFUNC = sfunc, 
    STYPE = state_data_type 
    [, PREFUNC = prefunc] 
    [, FINALFUNC = ffunc] 
    [, INITCOND = initial_condition]
```
Description

`CREATE AGGREGATE` defines a new aggregate function. Some basic and commonly-used aggregate functions such as `count`, `min`, `max`, `sum`, `avg` and so on are already provided in Greenplum Database. If one defines new types or needs an aggregate function not already provided, then `CREATE AGGREGATE` can be used to provide the desired features.

An aggregate function is identified by its name and input data types. Two aggregate functions in the same schema can have the same name if they operate on different input types. The name and input data types of an aggregate function must also be distinct from the name and input data types of every ordinary function in the same schema.

An aggregate function is made from one, two or three ordinary functions (all of which must be `IMMUTABLE` functions):

- A state transition function `sfunc`
- An optional preliminary segment-level calculation function `prefunc`
- An optional final calculation function `ffunc`

These functions are used as follows:

- `sfunc( internal-state, next-data-values ) ---> next-internal-state`
- `prefunc( internal-state, internal-state ) ---> next-internal-state`
- `ffunc( internal-state ) ---> aggregate-value`

You can specify `PREFUNC` as method for optimizing aggregate execution. By specifying `PREFUNC`, the aggregate can be executed in parallel on segments first and then on the master. When a two-level execution is performed, `SFUNC` is executed on the segments to generate partial aggregate results, and `PREFUNC` is executed on the master to aggregate the partial results from segments. If single-level aggregation is performed, all the rows are sent to the master and `sfunc` is applied to the rows.

Single-level aggregation and two-level aggregation are equivalent execution strategies. Either type of aggregation can be implemented in a query plan. When you implement the functions `prefunc` and `sfunc`, you must ensure that the invocation of `sfunc` on the segment instances followed by `prefunc` on the master produce the same result as single-level aggregation that sends all the rows to the master and then applies only the `sfunc` to the rows.

Greenplum Database creates a temporary variable of data type `stype` to hold the current internal state of the aggregate function. At each input row, the aggregate argument values are calculated and the state transition function is invoked with the current state value and the new argument values to calculate a new internal state value. After all the rows have been processed, the final function is invoked once to calculate the aggregate return value. If there is no final function then the ending state value is returned as-is.

An aggregate function can provide an optional initial condition, an initial value for the internal state value. This is specified and stored in the database as a value of type text, but it must be a valid external representation of a constant of the state value data type. If it is not supplied then the state value starts out `NULL`.

If the state transition function is declared `STRICT`, then it cannot be called with `NULL` inputs. With such a transition function, aggregate execution behaves as follows. Rows with any null input values are ignored (the function is not called and the previous state value is retained). If the initial state value is `NULL`, then at the first row with all non-null input values, the first argument value replaces the state value, and the transition function is invoked at subsequent rows with all non-null input values. This is useful for implementing aggregates like `max`. Note that this behavior is only available when `state_data_type` is the same as the first `input_data_type`. When these types are different, you must supply a non-null initial condition or use a nonstrict transition function.
If the state transition function is not declared `STRICT`, then it will be called unconditionally at each input row, and must deal with `NULL` inputs and `NULL` transition values for itself. This allows the aggregate author to have full control over the aggregate handling of `NULL` values.

If the final function is declared `STRICT`, then it will not be called when the ending state value is `NULL`; instead a `NULL` result will be returned automatically. (This is the normal behavior of `STRICT` functions.) In any case the final function has the option of returning a `NULL` value. For example, the final function for `avg` returns `NULL` when it sees there were zero input rows.

Single argument aggregate functions, such as `min` or `max`, can sometimes be optimized by looking into an index instead of scanning every input row. If this aggregate can be so optimized, indicate it by specifying a sort operator. The basic requirement is that the aggregate must yield the first element in the sort ordering induced by the operator; in other words:

```
SELECT agg(col) FROM tab;
```

must be equivalent to:

```
SELECT col FROM tab ORDER BY col USING sortop LIMIT 1;
```

Further assumptions are that the aggregate function ignores `NULL` inputs, and that it delivers a `NULL` result if and only if there were no non-null inputs. Ordinarily, a data type's `<` operator is the proper sort operator for `MIN`, and `>` is the proper sort operator for `MAX`. Note that the optimization will never actually take effect unless the specified operator is the "less than" or "greater than" strategy member of a B-tree index operator class.

**Ordered Aggregates**

If the optional qualification `ORDERED` appears, the created aggregate function is an *ordered aggregate*. In this case, the preliminary aggregation function, `prefunc` cannot be specified.

An ordered aggregate is called with the following syntax.

```
name ( arg [ , ... ] [ORDER BY sortspec [ , ...] ] )
```

If the optional `ORDER BY` is omitted, a system-defined ordering is used. The transition function `sfunc` of an ordered aggregate function is called on its input arguments in the specified order and on a single segment. There is a new column `aggordered` in the `pg_aggregate` table to indicate the aggregate function is defined as an ordered aggregate.

**Parameters**

- **name**
  - The name (optionally schema-qualified) of the aggregate function to create.

- **input_data_type**
  - An input data type on which this aggregate function operates. To create a zero-argument aggregate function, write `*` in place of the list of input data types. An example of such an aggregate is `count(*)`.

- **sfunc**
  - The name of the state transition function to be called for each input row. For an N-argument aggregate function, the `sfunc` must take N+1 arguments, the first being of type `state_data_type` and the rest matching the declared input data types of the aggregate. The function must return a value of type `state_data_type`. This function takes the current state value and the current input data values, and returns the next state value.

- **state_data_type**
  - The data type for the aggregate state value.

- **prefunc**
  - **The data type for the aggregate state value.**
The name of a preliminary aggregation function. This is a function of two arguments, both of type `state_data_type`. It must return a value of `state_data_type`. A preliminary function takes two transition state values and returns a new transition state value representing the combined aggregation. In Greenplum Database, if the result of the aggregate function is computed in a segmented fashion, the preliminary aggregation function is invoked on the individual internal states in order to combine them into an ending internal state.

Note that this function is also called in hash aggregate mode within a segment. Therefore, if you call this aggregate function without a preliminary function, hash aggregate is never chosen. Since hash aggregate is efficient, consider defining preliminary function whenever possible.

`ffunc`

The name of the final function called to compute the aggregate result after all input rows have been traversed. The function must take a single argument of type `state_data_type`. The return data type of the aggregate is defined as the return type of this function. If `ffunc` is not specified, then the ending state value is used as the aggregate result, and the return type is `state_data_type`.

`initial_condition`

The initial setting for the state value. This must be a string constant in the form accepted for the data type `state_data_type`. If not specified, the state value starts out NULL.

`sort_operator`

The associated sort operator for a MIN- or MAX-like aggregate function. This is just an operator name (possibly schema-qualified). The operator is assumed to have the same input data types as the aggregate function (which must be a single-argument aggregate function).

**Notes**

The ordinary functions used to define a new aggregate function must be defined first. Note that in this release of Greenplum Database, it is required that the `sfunc`, `ffunc`, and `prefunc` functions used to create the aggregate are defined as IMMUTABLE.

If a user-defined aggregate is used in a window expression, a `prefunc` function must be defined for the aggregate.

If the value of the Greenplum Database server configuration parameter `gp_enable_multiphase_agg` is off, only single-level aggregation is performed.

Any compiled code (shared library files) for custom functions must be placed in the same location on every host in your Greenplum Database array (master and all segments). This location must also be in the `LD_LIBRARY_PATH` so that the server can locate the files.

**Example**

The following simple example creates an aggregate function that computes the sum of two columns.

Before creating the aggregate function, create two functions that are used as the `SFUNC` and `PREFUNC` functions of the aggregate function.

This function is specified as the `SFUNC` function in the aggregate function.

```sql
CREATE FUNCTION mysfunc_accum(numeric, numeric, numeric) RETURNS numeric
AS 'select $1 + $2 + $3'
LANGUAGE SQL
IMMUTABLE
RETURNS NULL ON NULL INPUT;
```
This function is specified as the `PREFUNC` function in the aggregate function.

```sql
CREATE FUNCTION mypre_accum(numeric, numeric )
RETURNS numeric
AS 'select $1 + $2'
LANGUAGE SQL
IMMUTABLE
RETURNS NULL ON NULL INPUT;
```

This `CREATE AGGREGATE` command creates the aggregate function that adds two columns.

```sql
CREATE AGGREGATE agg_prefunc(numeric, numeric) (  
 SFUNC = mysfunc_accum,  
 STYPE = numeric,  
 PREFUNC = mypre_accum,  
 INITCOND = 0 );
```

The following commands create a table, adds some rows, and runs the aggregate function.

```sql
create table t1 (a int, b int) DISTRIBUTED BY (a);
insert into t1 values
    (10, 1),
    (20, 2),
    (30, 3);
select agg_prefunc(a, b) from t1;
```

This `EXPLAIN` command shows two phase aggregation.

```sql
explain select agg_prefunc(a, b) from t1;
```

**QUERY PLAN**

```
Aggregate (cost=1.10..1.11 rows=1 width=32)
   -> Gather Motion 2:1 (slice1; segments: 2) (cost=1.04..1.08 rows=1 width=32)
      -> Aggregate (cost=1.04..1.05 rows=1 width=32)
         -> Seq Scan on t1 (cost=0.00..1.03 rows=2 width=8)
(4 rows)
```

**Compatibility**

`CREATE AGGREGATE` is a Greenplum Database language extension. The SQL standard does not provide for user-defined aggregate functions.

**See Also**

`ALTER AGGREGATE, DROP AGGREGATE, CREATE FUNCTION`

**CREATE CAST**

Defines a new cast.

**Synopsis**

```sql
CREATE CAST (sourcetype AS targettype)  
    WITH FUNCTION funcname (argtypes)  
    [AS ASSIGNMENT | AS IMPLICIT]

CREATE CAST (sourcetype AS targettype) WITHOUT FUNCTION
```
CREATE CAST defines a new cast. A cast specifies how to perform a conversion between two data types. For example,

```
SELECT CAST(42 AS text);
```

converts the integer constant 42 to type text by invoking a previously specified function, in this case `text(int4)` If no suitable cast has been defined, the conversion fails.

Two types may be binary compatible, which means that they can be converted into one another without invoking any function. This requires that corresponding values use the same internal representation. For instance, the types text and varchar are binary compatible.

By default, a cast can be invoked only by an explicit cast request, that is an explicit CAST(x AS typename) or x::typename construct.

If the cast is marked AS ASSIGNMENT then it can be invoked implicitly when assigning a value to a column of the target data type. For example, supposing that foo.f1 is a column of type text, then:

```
INSERT INTO foo (f1) VALUES (42);
```

will be allowed if the cast from type integer to type text is marked AS ASSIGNMENT, otherwise not. The term assignment cast is typically used to describe this kind of cast.

If the cast is marked AS IMPLICIT then it can be invoked implicitly in any context, whether assignment or internally in an expression. The term implicit cast is typically used to describe this kind of cast. For example, since || takes text operands,

```
SELECT 'The time is ' || now();
```

will be allowed only if the cast from type timestamp to text is marked AS IMPLICIT. Otherwise, it will be necessary to write the cast explicitly, for example

```
SELECT 'The time is ' || CAST(now() AS text);
```

It is wise to be conservative about marking casts as implicit. An overabundance of implicit casting paths can cause Greenplum Database to choose surprising interpretations of commands, or to be unable to resolve commands at all because there are multiple possible interpretations. A good rule of thumb is to make a cast implicitly invokable only for information-preserving transformations between types in the same general type category. For example, the cast from int2 to int4 can reasonably be implicit, but the cast from float8 to int4 should probably be assignment-only. Cross-type-category casts, such as text to int4, are best made explicit-only.

To be able to create a cast, you must own the source or the target data type. To create a binary-compatible cast, you must be superuser.

### Parameters

**sourcetype**

The name of the source data type of the cast.

**targettype**

The name of the target data type of the cast.

**funcname(argtypes)**
The function used to perform the cast. The function name may be schema-qualified. If it is not, the function will be looked up in the schema search path. The function's result data type must match the target type of the cast.

Cast implementation functions may have one to three arguments. The first argument type must be identical to the cast's source type. The second argument, if present, must be type `integer`; it receives the type modifier associated with the destination type, or `-1` if there is none. The third argument, if present, must be type `boolean`; it receives `true` if the cast is an explicit cast, `false` otherwise. The SQL specification demands different behaviors for explicit and implicit casts in some cases. This argument is supplied for functions that must implement such casts. It is not recommended that you design your own data types this way.

Ordinarily a cast must have different source and target data types. However, it is allowed to declare a cast with identical source and target types if it has a cast implementation function with more than one argument. This is used to represent type-specific length coercion functions in the system catalogs. The named function is used to coerce a value of the type to the type modifier value given by its second argument. (Since the grammar presently permits only certain built-in data types to have type modifiers, this feature is of no use for user-defined target types.)

When a cast has different source and target types and a function that takes more than one argument, it represents converting from one type to another and applying a length coercion in a single step. When no such entry is available, coercion to a type that uses a type modifier involves two steps, one to convert between data types and a second to apply the modifier.

**WITHOUT FUNCTION**
Indicates that the source type and the target type are binary compatible, so no function is required to perform the cast.

**AS ASSIGNMENT**
Indicates that the cast may be invoked implicitly in assignment contexts.

**AS IMPLICIT**
Indicates that the cast may be invoked implicitly in any context.

**Notes**
Note that in this release of Greenplum Database, user-defined functions used in a user-defined cast must be defined as `IMMUTABLE`. Any compiled code (shared library files) for custom functions must be placed in the same location on every host in your Greenplum Database array (master and all segments). This location must also be in the `LD_LIBRARY_PATH` so that the server can locate the files.

Remember that if you want to be able to convert types both ways you need to declare casts both ways explicitly.

It is recommended that you follow the convention of naming cast implementation functions after the target data type, as the built-in cast implementation functions are named. Many users are used to being able to cast data types using a function-style notation, that is `typename(x)`.

**Examples**
To create a cast from type `text` to type `int4` using the function `int4(text)` (This cast is already predefined in the system.):

```sql
CREATE CAST (text AS int4) WITH FUNCTION int4(text);
```
Compatibility

The `CREATE CAST` command conforms to the SQL standard, except that SQL does not make provisions for binary-compatible types or extra arguments to implementation functions. `AS IMPLICIT` is a Greenplum Database extension, too.

See Also

`CREATE FUNCTION`, `CREATE TYPE`, `DROP CAST`

CREATE CONVERSION

Defines a new encoding conversion.

Synopsis

```
CREATE [DEFAULT] CONVERSION name FOR source_encoding TO dest_encoding FROM funcname
```

Description

`CREATE CONVERSION` defines a new conversion between character set encodings. Conversion names may be used in the `convert` function to specify a particular encoding conversion. Also, conversions that are marked `DEFAULT` can be used for automatic encoding conversion between client and server. For this purpose, two conversions, from encoding A to B and from encoding B to A, must be defined.

To create a conversion, you must have `EXECUTE` privilege on the function and `CREATE` privilege on the destination schema.

Parameters

**DEFAULT**

Indicates that this conversion is the default for this particular source to destination encoding. There should be only one default encoding in a schema for the encoding pair.

**name**

The name of the conversion. The conversion name may be schema-qualified. If it is not, the conversion is defined in the current schema. The conversion name must be unique within a schema.

**source_encoding**

The source encoding name.

**dest_encoding**

The destination encoding name.

**funcname**

The function used to perform the conversion. The function name may be schema-qualified. If it is not, the function will be looked up in the path. The function must have the following signature:

```
conv_proc(
    Integer,  -- source encoding ID
    integer,  -- destination encoding ID
    cstring,  -- source string (null terminated C string)
    internal,  -- destination (fill with a null terminated C string)
    integer,  -- source string length
    ) RETURNS void;
```
Notes
Note that in this release of Greenplum Database, user-defined functions used in a user-defined conversion must be defined as IMMUTABLE. Any compiled code (shared library files) for custom functions must be placed in the same location on every host in your Greenplum Database array (master and all segments). This location must also be in the LD_LIBRARY_PATH so that the server can locate the files.

Examples
To create a conversion from encoding UTF8 to LATIN1 using myfunc:

```
CREATE CONVERSION myconv FOR 'UTF8' TO 'LATIN1' FROM myfunc;
```

Compatibility
There is no CREATE CONVERSION statement in the SQL standard.

See Also
ALTER CONVERSION, CREATE FUNCTION, DROP CONVERSION

CREATE DATABASE
Creates a new database.

Synopsis

```
CREATE DATABASE name [ [WITH] [OWNER [=] dbowner] 
[TEMPLATE [=] template] 
[ENCODING [=] encoding] 
[TABLESPACE [=] tablespace] 
[CONNECTION LIMIT [=] connlimit ] ]
```

Description
CREATE DATABASE creates a new database. To create a database, you must be a superuser or have the special CREATEDB privilege.

The creator becomes the owner of the new database by default. Superusers can create databases owned by other users by using the OWNER clause. They can even create databases owned by users with no special privileges. Non-superusers with CREATEDB privilege can only create databases owned by themselves.

By default, the new database will be created by cloning the standard system database template1. A different template can be specified by writing TEMPLATE name. In particular, by writing TEMPLATE template0, you can create a clean database containing only the standard objects predefined by Greenplum Database. This is useful if you wish to avoid copying any installation-local objects that may have been added to template1.

Parameters

name
The name of a database to create.

dbo
The name of the database user who will own the new database, or DEFAULT to use the default owner (the user executing the command).

template
The name of the template from which to create the new database, or `DEFAULT` to use the default template (`template1`).

**encoding**
Character set encoding to use in the new database. Specify a string constant (such as `'SQL_ASCII'`), an integer encoding number, or `DEFAULT` to use the default encoding. For more information, see [Character Set Support](#).

**tablespace**
The name of the tablespace that will be associated with the new database, or `DEFAULT` to use the template database's tablespace. This tablespace will be the default tablespace used for objects created in this database.

**conllimit**
The maximum number of concurrent connections possible. The default of -1 means there is no limitation.

### Notes

CREATE DATABASE cannot be executed inside a transaction block.

When you copy a database by specifying its name as the template, no other sessions can be connected to the template database while it is being copied. New connections to the template database are locked out until CREATE DATABASE completes.

The **CONNECTION LIMIT** is not enforced against superusers.

### Examples

To create a new database:

```
CREATE DATABASE gpdb;
```

To create a database `sales` owned by user `salesapp` with a default tablespace of `salesspace`:

```
CREATE DATABASE sales OWNER salesapp TABLESPACE salesspace;
```

To create a database `music` which supports the ISO-8859-1 character set:

```
CREATE DATABASE music ENCODING 'LATIN1';
```

### Compatibility

There is no CREATE DATABASE statement in the SQL standard. Databases are equivalent to catalogs, whose creation is implementation-defined.

### See Also

`ALTER DATABASE`, `DROP DATABASE`

---

**CREATE DOMAIN**

Defines a new domain.

### Synopsis

```
CREATE DOMAIN name [AS] data_type [DEFAULT expression]
[CONSTRAINT constraint_name]
[ NOT NULL ]
```
Description

CREATE DOMAIN creates a new domain. A domain is essentially a data type with optional constraints (restrictions on the allowed set of values). The user who defines a domain becomes its owner. The domain name must be unique among the data types and domains existing in its schema.

Domains are useful for abstracting common constraints on fields into a single location for maintenance. For example, several tables might contain email address columns, all requiring the same CHECK constraint to verify the address syntax. It is easier to define a domain rather than setting up a column constraint for each table that has an email column.

Parameters

name
The name (optionally schema-qualified) of a domain to be created.

data_type
The underlying data type of the domain. This may include array specifiers.

DEFAULT expression
Specifies a default value for columns of the domain data type. The value is any variable-free expression (but subqueries are not allowed). The data type of the default expression must match the data type of the domain. If no default value is specified, then the default value is the null value. The default expression will be used in any insert operation that does not specify a value for the column. If a default value is defined for a particular column, it overrides any default associated with the domain. In turn, the domain default overrides any default value associated with the underlying data type.

CONSTRAINT constraint_name
An optional name for a constraint. If not specified, the system generates a name.

NOT NULL
Values of this domain are not allowed to be null.

NULL
Values of this domain are allowed to be null. This is the default. This clause is only intended for compatibility with nonstandard SQL databases. Its use is discouraged in new applications.

CHECK (expression)
CHECK clauses specify integrity constraints or tests which values of the domain must satisfy. Each constraint must be an expression producing a Boolean result. It should use the keyword VALUE to refer to the value being tested. Currently, CHECK expressions cannot contain subqueries nor refer to variables other than VALUE.

Examples

Create the us_zip_code data type. A regular expression test is used to verify that the value looks like a valid US zip code.

```
CREATE DOMAIN us_zip_code AS TEXT CHECK
( VALUE ~ '^[\d(5)\$' OR VALUE ~ '^[\d(5)-\d(4)\$' );
```

Compatibility

CREATE DOMAIN conforms to the SQL standard.
CREATE EXTENSION

Registers an extension in a Greenplum database.

Synopsis

```
CREATE EXTENSION [ IF NOT EXISTS ] extension_name 
[ WITH ] [ SCHEMA schema_name ]
[ VERSION version ]
[ FROM old_version ]
[ CASCADE ]
```

Description

CREATE EXTENSION loads a new extension into the current database. There must not be an extension of the same name already loaded.

Loading an extension essentially amounts to running the extension script file. The script typically creates new SQL objects such as functions, data types, operators and index support methods. The CREATE EXTENSION command also records the identities of all the created objects, so that they can be dropped again if DROP EXTENSION is issued.

Loading an extension requires the same privileges that would be required to create the component extension objects. For most extensions this means superuser or database owner privileges are required. The user who runs CREATE EXTENSION becomes the owner of the extension for purposes of later privilege checks, as well as the owner of any objects created by the extension script.

Parameters

**IF NOT EXISTS**

Do not throw an error if an extension with the same name already exists. A notice is issued in this case. There is no guarantee that the existing extension is similar to the extension that would have been installed.

**extension_name**

The name of the extension to be installed. The name must be unique within the database. An extension is created from the details in the extension control file `SHAREDIR/extension/extension_name.control`.

`SHAREDIR` is the installation shared-data directory, for example `/usr/local/greenplum-db/share/postgresql`. The command `pg_config --sharedir` displays the directory.

**SCHEMA schema_name**

The name of the schema in which to install the extension objects. This assumes that the extension allows its contents to be relocated. The named schema must already exist. If not specified, and the extension control file does not specify a schema, the current default object creation schema is used.

If the extension specifies a schema parameter in its control file, then that schema cannot be overridden with a SCHEMA clause. Normally, an error is raised if a SCHEMA clause is given and it conflicts with the extension schema parameter. However, if the CASCADE clause is also given, then schema_name is ignored when it conflicts. The given schema_name is used for the installation of any needed extensions that do not a specify schema in their control files.

See Also

ALTER DOMAIN, DROP DOMAIN
The extension itself is not within any schema: extensions have unqualified names that must be unique within the database. But objects belonging to the extension can be within a schema.

**VERSION version**

The version of the extension to install. This can be written as either an identifier or a string literal. The default version is value that is specified in the extension control file.

**FROM old_version**

Specify **FROM old_version** only if you are attempting to install an extension that replaces an old-style module that is a collection of objects that is not packaged into an extension. If specified, **CREATE EXTENSION** runs an alternative installation script that absorbs the existing objects into the extension, instead of creating new objects. Ensure that **SCHEMA** clause specifies the schema containing these pre-existing objects.

The value to use for **old_version** is determined by the extension author, and might vary if there is more than one version of the old-style module that can be upgraded into an extension. For the standard additional modules supplied with pre-9.1 PostgreSQL, specify **unpacked** for the **old_version** when updating a module to extension style.

**CASCADE**

Automatically install dependant extensions are not already installed. Dependant extensions are checked recursively and those dependencies are also installed automatically. If the **SCHEMA** clause is specified, the schema applies to the extension and all dependant extensions that are installed. Other options that are specified are not applied to the automatically-installed dependant extensions. In particular, default versions are always selected when installing dependant extensions.

**Notes**

The extensions currently available for loading can be identified from the **pg_available_extensions** or **pg_available_extension_versions** system views.

Before you use **CREATE EXTENSION** to load an extension into a database, the supporting extension files must be installed including an extension control file and at least one least one SQL script file. The support files must be installed in the same location on all Greenplum Database hosts. For information about creating new extensions, see PostgreSQL information about **Packaging Related Objects into an Extension**.

**Compatibility**

**CREATE EXTENSION** is a Greenplum Database extension.

**See Also**

**ALTER EXTENSION, DROP EXTENSION**

**CREATE EXTERNAL TABLE**

Defines a new external table.

**Synopsis**

```
CREATE [READABLE] EXTERNAL TABLE table_name
  ( column name data type [, ...] | LIKE other_table )
  LOCATION ('file://seghost[:port]/path/file'[, ...])
  | ('gpfdist://filehost[:port]/file_pattern[#transform=trans_name]'[, ...])
```
CREATE [READABLE] EXTERNAL WEB TABLE table_name
  (column_name data_type [, ...] | LIKE other_table)
  LOCATION ('http://webhost[:port]/path/file' [, ...])
  | EXECUTE 'command' [ON ALL
  | MASTER
  | number_of_segments
  | HOST ['segment_hostname']
  | SEGMENT segment_id ]

FORMAT 'TEXT'
  [ [HEADER]
    [DELIMITER [AS] 'delimiter' | 'OFF']
    [NULL [AS] 'null string']
    [ESCAPE [AS] 'escape' | 'OFF']
    [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
    [FILL MISSING FIELDS] ]
  | 'CSV'
  [ [HEADER]
    [QUOTE [AS] 'quote']
    [DELIMITER [AS] 'delimiter']
    [NULL [AS] 'null string']
    [FORCE NOT NULL column [, ...]]
    [ESCAPE [AS] 'escape']
    [NEWLINE [ AS ] 'LF' | 'CR' | 'CRLF']
    [FILL MISSING FIELDS] ]
  | 'AVRO'
  | 'PARQUET'
  | 'CUSTOM' (Formatter=<formatter specifications>)
  [ ENCODING 'encoding' ]
  [ [LOG ERRORS] SEGMENT REJECT LIMIT count
    [ROWS | PERCENT] ]

CREATE WRITABLE EXTERNAL TABLE table_name
  (column_name data_type [, ...] | LIKE other_table)
  LOCATION('gpfdist://outputhost[:port]/filename[#transform=trans_name]
     [, ...])
CREATE WRITABLE EXTERNAL TABLE table_name
( column_name data_type [, ... ] | LIKE other_table )
LOCATION('s3://S3_endpoint[:port]/bucket_name/[S3_prefix]
[region=S3-region]
[config=config_file'])
[ON MASTER]
FORMAT 'TEXT'

| ( [DELIMITER [AS] 'delimiter']
  [NULL [AS] 'null string']
  [ESCAPE [AS] 'escape' | 'OFF'] ))
| 'CSV'
  [[ [QUOTE [AS] 'quote']
  [DELIMITER [AS] 'delimiter']
  [NULL [AS] 'null string']
  [FORCE QUOTE column [, ...]] ]
  [ESCAPE [AS] 'escape'] ])
| 'AVRO'
| 'PARQUET'

| 'CUSTOM' (Formatter=<formatter specifications>)
[ ENCODING 'write_encoding' ]
[ DISTRIBUTED BY (column, [ ... ] ) | DISTRIBUTED RANDOMLY ]

CREATE WRITABLE EXTERNAL WEB TABLE table_name
( column_name data_type [, ... ] | LIKE other_table )
EXECUTE 'command' [ON ALL]
FORMAT 'TEXT'

| ( [DELIMITER [AS] 'delimiter']
  [NULL [AS] 'null string']
  [ESCAPE [AS] 'escape' | 'OFF'] ))
| 'CSV'
  [[ [QUOTE [AS] 'quote']
  [DELIMITER [AS] 'delimiter']
  [NULL [AS] 'null string']
  [FORCE QUOTE column [, ...]] ]
  [ESCAPE [AS] 'escape'] ])

CREATE EXTERNAL TABLE or CREATE EXTERNAL WEB TABLE creates a new readable external table
definition in Greenplum Database. Readable external tables are typically used for fast, parallel data
loading. Once an external table is defined, you can query its data directly (and in parallel) using SQL
commands. For example, you can select, join, or sort external table data. You can also create views for external tables. DML operations (UPDATE, INSERT, DELETE, or TRUNCATE) are not allowed on readable external tables, and you cannot create indexes on readable external tables.

CREATE WRITABLE EXTERNAL TABLE or CREATE WRITABLE EXTERNAL WEB TABLE creates a new writable external table definition in Greenplum Database. Writable external tables are typically used for unloading data from the database into a set of files or named pipes. Writable external tables can also be used to output data to an executable program. Writable external tables can also be used as output targets for Greenplum parallel MapReduce calculations. Once a writable external table is defined, data can be selected from database tables and inserted into the writable external table. Writable external tables only allow INSERT operations – SELECT, UPDATE, DELETE or TRUNCATE are not allowed.

The main difference between regular external tables and external web tables is their data sources. Regular readable external tables access static flat files, whereas external web tables access dynamic data sources – either on a web server or by executing OS commands or scripts.

**Parameters**

**READABLE | WRITABLE**

Specifies the type of external table, readable being the default. Readable external tables are used for loading data into Greenplum Database. Writable external tables are used for unloading data.

**WEB**

Creates a readable or writable external web table definition in Greenplum Database. There are two forms of readable external web tables – those that access files via the http:// protocol or those that access data by executing OS commands. Writable external web tables output data to an executable program that can accept an input stream of data. External web tables are not rescannable during query execution.

The s3 protocol does not support external web tables. You can, however, create an external web table that executes a third-party tool to read data from or write data to S3 directly.

**table_name**

The name of the new external table.

**column_name**

The name of a column to create in the external table definition. Unlike regular tables, external tables do not have column constraints or default values, so do not specify those.

**LIKE other_table**

The LIKE clause specifies a table from which the new external table automatically copies all column names, data types and Greenplum distribution policy. If the original table specifies any column constraints or default column values, those will not be copied over to the new external table definition.

**data_type**

The data type of the column.

**LOCATION ('protocol://host[:port]/path/file' [, ...])**

If you use the gphdfs protocol to read or write a file to a Hadoop file system (HDFS), refer to Specify gphdfs Protocol in an External Table Definition for additional information about the gphdfs protocol LOCATION clause syntax.

If you use the pxf protocol to access an external data source, refer to the Creating an External Table Using PXF documentation for detailed information about the pxf protocol LOCATION clause syntax.

If you use the s3 protocol to read or write to S3, refer to About the S3 Protocol URL for additional information about the s3 protocol LOCATION clause syntax.
For readable external tables, specifies the URI of the external data source(s) to be used to populate the external table or web table. Regular readable external tables allow the gpfdist or file protocols. External web tables allow the http protocol. If port is omitted, port 8080 is assumed for http and gpfdist protocols, and port 9000 for the gphdfs protocol. If using the gpfdist protocol, the path is relative to the directory from which gpfdist is serving files (the directory specified when you started the gpfdist program). Also, gpfdist can use wildcards or other C-style pattern matching (for example, a whitespace character is `[:space:]`) to denote multiple files in a directory. For example:

```
'gpfdist://filehost:8081/*'
'gpfdist://masterhost:8081/my_load_file'
'file://seghost1/dbfast1/external/myfile.txt'
'http://intranet.example.com/finance/expenses.csv'
```

For writable external tables, specifies the URI location of the gpfdist process or S3 protocol that will collect data output from the Greenplum segments and write it to one or more named files. For gpfdist the path is relative to the directory from which gpfdist is serving files (the directory specified when you started the gpfdist program). If multiple gpfdist locations are listed, the segments sending data will be evenly divided across the available output locations. For example:

```
'gpfdist://outputhost:8081/data1.out,'
'gpfdist://outputhost:8081/data2.out'
```

With two gpfdist locations listed as in the above example, half of the segments would send their output data to the data1.out file and the other half to the data2.out file.

With the option `#transform=trans_name`, you can specify a transform to apply when loading or extracting data. The `trans_name` is the name of the transform in the YAML configuration file you specify with the `gpfdist` utility. For information about specifying a transform, see `gpfdist` in the Greenplum Utility Guide.

**ON MASTER**

Restricts all table-related operations to the Greenplum master segment. Permitted only on readable and writable external tables created with the s3 or custom protocols. The gpfdist, gpfdists, gphdfs, pxf, and file protocols do not support **ON MASTER**.

**Note:** Be aware of potential resource impacts when reading from or writing to external tables you create with the **ON MASTER** clause. You may encounter performance issues when you restrict table operations solely to the Greenplum master segment.

**EXECUTE 'command' [ON ...]**

Allowed for readable external web tables or writable external tables only. For readable external web tables, specifies the OS command to be executed by the segment instances. The command can be a single OS command or a script. The **ON** clause is used to specify which segment instances will execute the given command.

- **ON ALL** is the default. The command will be executed by every active (primary) segment instance on all segment hosts in the Greenplum Database system. If the command executes a script, that script must reside in the same location on all of the segment hosts and be executable by the Greenplum superuser (`gpadmin`).
- **ON MASTER** runs the command on the master host only.

**Note:** Logging is not supported for external web tables when the **ON MASTER** clause is specified.

- **ON number** means the command will be executed by the specified number of segments. The particular segments are chosen randomly at runtime by the Greenplum
Database system. If the command executes a script, that script must reside in the same location on all of the segment hosts and be executable by the Greenplum superuser (gpadmin).

- HOST means the command will be executed by one segment on each segment host (once per segment host), regardless of the number of active segment instances per host.
- HOST segment_hostname means the command will be executed by all active (primary) segment instances on the specified segment host.
- SEGMENT segment_id means the command will be executed only once by the specified segment. You can determine a segment instance's ID by looking at the content number in the system catalog table gp_segment_configuration. The content ID of the Greenplum Database master is always -1.

For writable external tables, the command specified in the EXECUTE clause must be prepared to have data piped into it. Since all segments that have data to send will write their output to the specified command or program, the only available option for the ON clause is ON ALL.

FORMAT 'TEXT | CSV | AVRO | PARQUET' (options)

When the FORMAT clause identifies delimited text (TEXT) or comma separated values (CSV) format, formatting options are similar to those available with the PostgreSQL COPY command. If the data in the file does not use the default column delimiter, escape character, null string and so on, you must specify the additional formatting options so that the data in the external file is read correctly by Greenplum Database. For information about using a custom format, see "Loading and Unloading Data" in the Greenplum Database Administrator Guide.

The AVRO and PARQUET formats are supported only when you specify the gphdfs protocol. Refer to Accessing HDFS Data with gphdfs for detailed information about the gphdfs protocol FORMAT clause syntax.

If you use the pxfs protocol to access an external data source, refer to the PXF Creating an External Table Using PXF documentation for detailed information about the pxfs protocol FORMAT clause syntax.

FORMAT 'CUSTOM' (formatter=formatter_specification)

Specifies a custom data format. The formatter_specification specifies the function to use to format the data, followed by comma-separated parameters to the formatter function. The length of the formatter specification, the string including Formatter=, can be up to approximately 50K bytes.

If you use the pxfs protocol to access an external data source, refer to the PXF Creating an External Table Using PXF documentation for detailed information about the pxfs protocol FORMAT clause syntax.

For general information about using a custom format, see "Loading and Unloading Data" in the Greenplum Database Administrator Guide.

DELIMITER

Specifies a single ASCII character that separates columns within each row (line) of data. The default is a tab character in TEXT mode, a comma in CSV mode. In TEXT mode for readable external tables, the delimiter can be set to OFF for special use cases in which unstructured data is loaded into a single-column table.

For the s3 protocol, the delimiter cannot be a newline character (\n) or a carriage return character (\r).

NULL

Specifies the string that represents a NULL value. The default is \N (backslash-N) in TEXT mode, and an empty value with no quotations in CSV mode. You might prefer an empty
string even in TEXT mode for cases where you do not want to distinguish NULL values from empty strings. When using external and web tables, any data item that matches this string will be considered a NULL value.

As an example for the text format, this FORMAT clause can be used to specify that the string of two single quotes ('') is a NULL value.

```sql
FORMAT 'text' (delimiter ',' null '\''\''\'' )
```

**ESCAPE**

Specifies the single character that is used for C escape sequences (such as \n, \t, \000, and so on) and for escaping data characters that might otherwise be taken as row or column delimiters. Make sure to choose an escape character that is not used anywhere in your actual column data. The default escape character is a \ (backslash) for text-formatted files and a " (double quote) for csv-formatted files, however it is possible to specify another character to represent an escape. It is also possible to disable escaping in text-formatted files by specifying the value 'OFF' as the escape value. This is very useful for data such as text-formatted web log data that has many embedded backslashes that are not intended to be escapes.

**NEWLINE**

Specifies the newline used in your data files — LF (Line feed, 0x0A), CR (Carriage return, 0x0D), or CRLF (Carriage return plus line feed, 0x0D 0x0A). If not specified, a Greenplum Database segment will detect the newline type by looking at the first row of data it receives and using the first newline type encountered.

**HEADER**

For readable external tables, specifies that the first line in the data file(s) is a header row (contains the names of the table columns) and should not be included as data for the table. If using multiple data source files, all files must have a header row.

For the s3 protocol, the column names in the header row cannot contain a newline character (\n) or a carriage return (\r).

The pxf protocol does not support the HEADER formatting option.

**QUOTE**

Specifies the quotation character for CSV mode. The default is double-quote (").

**FORCE NOT NULL**

In CSV mode, processes each specified column as though it were quoted and hence not a NULL value. For the default null string in CSV mode (nothing between two delimiters), this causes missing values to be evaluated as zero-length strings.

**FORCE QUOTE**

In CSV mode for writable external tables, forces quoting to be used for all non-NULL values in each specified column. NULL output is never quoted.

**FILL MISSING FIELDS**

In both TEXT and CSV mode for readable external tables, specifying FILL MISSING FIELDS will set missing trailing field values to NULL (instead of reporting an error) when a row of data has missing data fields at the end of a line or row. Blank rows, fields with a NOT NULL constraint, and trailing delimiters on a line will still report an error.

**ENCODING 'encoding'**

Character set encoding to use for the external table. Specify a string constant (such as 'SQL_ASCII'), an integer encoding number, or DEFAULT to use the default client encoding. See Character Set Support.

**LOG ERRORS**
This is an optional clause that can precede a `SEGMENT REJECT LIMIT` clause to log information about rows with formatting errors. The error log information is stored internally and is accessed with the Greenplum Database built-in SQL function `gp_read_error_log()`.

See *Notes* for information about the error log information and built-in functions for viewing and managing error log information.

**SEGMENT REJECT LIMIT count [ROWS | PERCENT]**

Runs a `COPY FROM` operation in single row error isolation mode. If the input rows have format errors they will be discarded provided that the reject limit count is not reached on any Greenplum segment instance during the load operation. The reject limit count can be specified as number of rows (the default) or percentage of total rows (1-100). If `PERCENT` is used, each segment starts calculating the bad row percentage only after the number of rows specified by the parameter `gp_reject_percent_threshold` has been processed. The default for `gp_reject_percent_threshold` is 300 rows. Constraint errors such as violation of a `NOT NULL`, `CHECK`, or `UNIQUE` constraint will still be handled in "all-or-nothing" input mode. If the limit is not reached, all good rows will be loaded and any error rows discarded.

**Note:** When reading an external table, Greenplum Database limits the initial number of rows that can contain formatting errors if the `SEGMENT REJECT LIMIT` is not triggered first or is not specified. If the first 1000 rows are rejected, the `COPY` operation is stopped and rolled back.

The limit for the number of initial rejected rows can be changed with the Greenplum Database server configuration parameter `gp_initial_bad_row_limit`. See *Server Configuration Parameters* for information about the parameter.

**DISTRIBUTED BY (column, [ ... ] )**

**DISTRIBUTED RANDOMLY**

Used to declare the Greenplum Database distribution policy for a writable external table. By default, writable external tables are distributed randomly. If the source table you are exporting data from has a hash distribution policy, defining the same distribution key column(s) for the writable external table will improve unload performance by eliminating the need to move rows over the interconnect. When you issue an unload command such as `INSERT INTO wex_table SELECT * FROM source_table`, the rows that are unloaded can be sent directly from the segments to the output location if the two tables have the same hash distribution policy.

**Examples**

Start the `gpfdist` file server program in the background on port 8081 serving files from directory `/var/data/staging`:

```
gpfdist -p 8081 -d /var/data/staging -l /home/gpadmin/log &
```

Create a readable external table named `ext_customer` using the `gpfdist` protocol and any text formatted files (*.txt) found in the `gpfdist` directory. The files are formatted with a pipe (|) as the column delimiter and an empty space as `NULL`. Also access the external table in single row error isolation mode:

```
CREATE EXTERNAL TABLE ext_customer
  (id int, name text, sponsor text)
  LOCATION ( 'gpfdist://filehost:8081/*.txt' )
  FORMAT 'TEXT' ( DELIMITER '|' NULL ' ')
  LOG ERRORS SEGMENT REJECT LIMIT 5;
```
Create the same readable external table definition as above, but with CSV formatted files:

```sql
CREATE EXTERNAL TABLE ext_customer
(id int, name text, sponsor text)
LOCATION ( 'gpfdist://filehost:8081/*.csv' )
FORMAT 'CSV' ( DELIMITER ',' );
```

Create a readable external table named ext_expenses using the file protocol and several CSV formatted files that have a header row:

```sql
CREATE EXTERNAL TABLE ext_expenses (name text, date date, amount float4, category text, description text)
LOCATION ( 'file://seghost1/dbfast/external/expenses1.csv',
'file://seghost1/dbfast/external/expenses2.csv',
'file://seghost2/dbfast/external/expenses3.csv',
'file://seghost2/dbfast/external/expenses4.csv',
'file://seghost3/dbfast/external/expenses5.csv',
'file://seghost3/dbfast/external/expenses6.csv' )
FORMAT 'CSV' ( HEADER );
```

Create a readable external web table that executes a script once per segment host:

```sql
CREATE EXTERNAL WEB TABLE log_output (linenum int, message text) EXECUTE '/var/load_scripts/get_log_data.sh' ON HOST
FORMAT 'TEXT' (DELIMITER '|');
```

Create a writable external table named sales_out that uses gpfdist to write output data to a file named sales.out. The files are formatted with a pipe (|) as the column delimiter and an empty space as NULL.

```sql
CREATE WRITABLE EXTERNAL TABLE sales_out (LIKE sales)
LOCATION ('gpfdist://etl1:8081/sales.out')
FORMAT 'TEXT' ( DELIMITER '|' NULL ' ')
DISTRIBUTED BY (txn_id);
```

Create a writable external web table that pipes output data received by the segments to an executable script named to_adreport_etl.sh:

```sql
CREATE WRITABLE EXTERNAL WEB TABLE campaign_out
(LIKE campaign)
EXECUTE '/var/unload_scripts/to_adreport_etl.sh'
FORMAT 'TEXT' (DELIMITER '|');
```

Use the writable external table defined above to unload selected data:

```sql
INSERT INTO campaign_out SELECT * FROM campaign WHERE customer_id=123;
```

**Notes**

When you specify the LOG ERRORS clause, Greenplum Database captures errors that occur while reading the external table data. You can view and manage the captured error log data.

- Use the built-in SQL function `gp_read_error_log('table_name')`. It requires SELECT privilege on `table_name`. This example displays the error log information for data loaded into table ext_expenses with a COPY command:

```sql
SELECT * from gp_read_error_log('ext_expenses');
```
For information about the error log format, see Viewing Bad Rows in the Error Log in the Greenplum Database Administrator Guide.

The function returns FALSE if table_name does not exist.

- If error log data exists for the specified table, the new error log data is appended to existing error log data. The error log information is not replicated to mirror segments.
- Use the built-in SQL function gp_truncate_error_log('table_name') to delete the error log data for table_name. It requires the table owner privilege. This example deletes the error log information captured when moving data into the table ext_expenses:

```sql
SELECT gp_truncate_error_log('ext_expenses');
```

The function returns FALSE if table_name does not exist.

Specify the * wildcard character to delete error log information for existing tables in the current database. Specify the string *.* to delete all database error log information, including error log information that was not deleted due to previous database issues. If * is specified, database owner privilege is required. If *.* is specified, operating system super-user privilege is required.

When multiple Greenplum Database external tables are defined with the gpfdist, gpfdists, or file protocol and access the same named pipe a Linux system, Greenplum Database restricts access to the named pipe to a single reader. An error is returned if a second reader attempts to access the named pipe.

**Compatibility**

CREATE EXTERNAL TABLE is a Greenplum Database extension. The SQL standard makes no provisions for external tables.

**See Also**

CREATE TABLE AS, CREATE TABLE, COPY, SELECT INTO, INSERT

### CREATE FUNCTION

Defines a new function.

**Synopsis**

```sql
CREATE [OR REPLACE] FUNCTION name
   ( [ [ argmode ] [ argname ] argtype [ { DEFAULT | = } defexpr ] [, ...] ] )
   [ RETURNS { [ SETOF ] rettype
   | TABLE ([[ argname argtype | LIKE other table ]
   [, ...]])
   ] ]
   { LANGUAGE langname
   | IMMUTABLE | STABLE | VOLATILE
   | CALLED ON NULL INPUT | RETURNS NULL ON NULL INPUT | STRICT
   | [EXTERNAL] SECURITY INVOKER | [EXTERNAL] SECURITY DEFINE
   | COST execution_cost
   | SET configuration_parameter { TO value | = value | FROM CURRENT }
   | AS 'definition'
   | AS 'obj_file', 'link_symbol' } ... 
   [ WITH ({{ DESCRIBE = describe_function
   } [, ...] } ]
```

**Description**

CREATE FUNCTION defines a new function. CREATE OR REPLACE FUNCTION will either create a new function, or replace an existing definition.
The name of the new function must not match any existing function with the same argument types in the same schema. However, functions of different argument types may share a name (overloading).

To update the definition of an existing function, use `CREATE OR REPLACE FUNCTION`. It is not possible to change the name or argument types of a function this way (this would actually create a new, distinct function). Also, `CREATE OR REPLACE FUNCTION` will not let you change the return type of an existing function. To do that, you must drop and recreate the function. If you drop and then recreate a function, you will have to drop existing objects (rules, views, triggers, and so on) that refer to the old function. Use `CREATE OR REPLACE FUNCTION` to change a function definition without breaking objects that refer to the function.

For more information about creating functions, see the `User Defined Functions` section of the PostgreSQL documentation.

**Limited Use of VOLATILE and STABLE Functions**

To prevent data from becoming out-of-sync across the segments in Greenplum Database, any function classified as `STABLE` or `VOLATILE` cannot be executed at the segment level if it contains SQL or modifies the database in any way. For example, functions such as `random()` or `timeofday()` are not allowed to execute on distributed data in Greenplum Database because they could potentially cause inconsistent data between the segment instances.

To ensure data consistency, `VOLATILE` and `STABLE` functions can safely be used in statements that are evaluated on and execute from the master. For example, the following statements are always executed on the master (statements without a `FROM` clause):

```sql
SELECT setval('myseq', 201);
SELECT foo();
```

In cases where a statement has a `FROM` clause containing a distributed table and the function used in the `FROM` clause simply returns a set of rows, execution may be allowed on the segments:

```sql
SELECT * FROM foo();
```

One exception to this rule are functions that return a table reference (`rangeFuncs`) or functions that use the `refCursor` data type. Note that you cannot return a `refcursor` from any kind of function in Greenplum Database.

**Parameters**

- **name**
  The name (optionally schema-qualified) of the function to create.

- **argmode**
  The mode of an argument: either `IN`, `OUT`, `INOUT`, or `VARIADIC`. Only `OUT` arguments can follow an argument declared as `VARIADIC`. If omitted, the default is `IN`.

- **argname**
  The name of an argument. Some languages (currently only PL/pgSQL) let you use the name in the function body. For other languages the name of an input argument is just extra documentation. But the name of an output argument is significant, since it defines the column name in the result row type. (If you omit the name for an output argument, the system will choose a default column name.)

- **argtype**
  The data type(s) of the function's arguments (optionally schema-qualified), if any. The argument types may be base, composite, or domain types, or may reference the type of a table column.
Depending on the implementation language it may also be allowed to specify pseudotypes such as cstring. Pseudotypes indicate that the actual argument type is either incompletely specified, or outside the set of ordinary SQL data types.

The type of a column is referenced by writing `tablename.columnname%TYPE`. Using this feature can sometimes help make a function independent of changes to the definition of a table.

**defexpr**

An expression to be used as the default value if the parameter is not specified. The expression must be coercible to the argument type of the parameter. Only IN and INOUT parameters can have a default value. Each input parameter in the argument list that follows a parameter with a default value must have a default value as well.

**rettype**

The return data type (optionally schema-qualified). The return type can be a base, composite, or domain type, or may reference the type of a table column. Depending on the implementation language it may also be allowed to specify pseudotypes such as cstring. If the function is not supposed to return a value, specify `void` as the return type.

When there are OUT or INOUT parameters, the `RETURNS` clause may be omitted. If present, it must agree with the result type implied by the output parameters: `RECORD` if there are multiple output parameters, or the same type as the single output parameter.

The `SETOF` modifier indicates that the function will return a set of items, rather than a single item.

The type of a column is referenced by writing `tablename.columnname%TYPE`.

**langname**

The name of the language that the function is implemented in. May be SQL, C, internal, or the name of a user-defined procedural language. See `CREATE LANGUAGE` for the procedural languages supported in Greenplum Database. For backward compatibility, the name may be enclosed by single quotes.

**IMMUTABLE**

**STABLE**

**VOLATILE**

These attributes inform the query optimizer about the behavior of the function. At most one choice may be specified. If none of these appear, `VOLATILE` is the default assumption. Since Greenplum Database currently has limited use of `VOLATILE` functions, if a function is truly `IMMUTABLE`, you must declare it as so to be able to use it without restrictions.

`IMMUTABLE` indicates that the function cannot modify the database and always returns the same result when given the same argument values. It does not do database lookups or otherwise use information not directly present in its argument list. If this option is given, any call of the function with all-constant arguments can be immediately replaced with the function value.

`STABLE` indicates that the function cannot modify the database, and that within a single table scan it will consistently return the same result for the same argument values, but that its result could change across SQL statements. This is the appropriate selection for functions whose results depend on database lookups, parameter values (such as the current time zone), and so on. Also note that the `current_timestamp` family of functions qualify as stable, since their values do not change within a transaction.

`VOLATILE` indicates that the function value can change even within a single table scan, so no optimizations can be made. Relatively few database functions are volatile in this sense; some examples are `random()`, `timeofday()`. But note that any function that has side-effects must be classified volatile, even if its result is quite predictable, to prevent calls from being optimized away; an example is `setval()`.
CALLED ON NULL INPUT
RETURNS NULL ON NULL INPUT

STRICT

CALLED ON NULL INPUT (the default) indicates that the function will be called normally when some of its arguments are null. It is then the function author’s responsibility to check for null values if necessary and respond appropriately. RETURNS NULL ON NULL INPUT or STRICT indicates that the function always returns null whenever any of its arguments are null. If this parameter is specified, the function is not executed when there are null arguments; instead a null result is assumed automatically.

[EXTERNAL] SECURITY INVOKER
[EXTERNAL] SECURITY DEFINER

SECURITY INVOKER (the default) indicates that the function is to be executed with the privileges of the user that calls it. SECURITY DEFINER specifies that the function is to be executed with the privileges of the user that created it. The key word EXTERNAL is allowed for SQL conformance, but it is optional since, unlike in SQL, this feature applies to all functions not just external ones.

COST execution_cost

A positive number identifying the estimated execution cost for the function, in cpu_operator_cost units. If the function returns a set, execution_cost identifies the cost per returned row. If the cost is not specified, C-language and internal functions default to 1 unit, while functions in other languages default to 100 units. The planner tries to evaluate the function less often when you specify larger execution_cost values.

configuration_parameter

value

The SET clause applies a value to a session configuration parameter when the function is entered. The configuration parameter is restored to its prior value when the function exits. SET FROM CURRENT applies the session’s current value of the parameter when the function is entered.

definition

A string constant defining the function; the meaning depends on the language. It may be an internal function name, the path to an object file, an SQL command, or text in a procedural language.

obj_file, link_symbol

This form of the AS clause is used for dynamically loadable C language functions when the function name in the C language source code is not the same as the name of the SQL function. The string obj_file is the name of the file containing the dynamically loadable object, and link_symbol is the name of the function in the C language source code. If the link symbol is omitted, it is assumed to be the same as the name of the SQL function being defined. It is recommended to locate shared libraries either relative to $libdir (which is located at $GPHOME/lib) or through the dynamic library path (set by the dynamic_library_path server configuration parameter). This simplifies version upgrades if the new installation is at a different location.

describe_function

The name of a callback function to execute when a query that calls this function is parsed. The callback function returns a tuple descriptor that indicates the result type.

Notes

Any compiled code (shared library files) for custom functions must be placed in the same location on every host in your Greenplum Database array (master and all segments). This location must also be in the LD_LIBRARY_PATH so that the server can locate the files. It is recommended to locate shared libraries either relative to $libdir (which is located at $GPHOME/lib) or through the dynamic library path (set
by the `dynamic_library_path` server configuration parameter) on all master segment instances in the Greenplum array.

The full SQL type syntax is allowed for input arguments and return value. However, some details of the type specification (such as the precision field for type `numeric`) are the responsibility of the underlying function implementation and are not recognized or enforced by the `CREATE FUNCTION` command.

Greenplum Database allows function overloading. The same name can be used for several different functions so long as they have distinct argument types. However, the C names of all functions must be different, so you must give overloaded C functions different C names (for example, use the argument types as part of the C names).

Two functions are considered the same if they have the same names and input argument types, ignoring any `OUT` parameters. Thus for example these declarations conflict:

```sql
CREATE FUNCTION foo(int) ...  
CREATE FUNCTION foo(int, out text) ... 
```

Functions that have different argument type lists are not considered to conflict at creation time, but if argument defaults are provided, they might conflict in use. For example, consider:

```sql
CREATE FUNCTION foo(int) ...  
CREATE FUNCTION foo(int, int default 42) ... 
```

The call `foo(10)`, will fail due to the ambiguity about which function should be called.

When repeated `CREATE FUNCTION` calls refer to the same object file, the file is only loaded once. To unload and reload the file, use the `LOAD` command.

You must have the `USAGE` privilege on a language to be able to define a function using that language.

It is often helpful to use dollar quoting to write the function definition string, rather than the normal single quote syntax. Without dollar quoting, any single quotes or backslashes in the function definition must be escaped by doubling them. A dollar-quoted string constant consists of a dollar sign ($), an optional tag of zero or more characters, another dollar sign, an arbitrary sequence of characters that makes up the string content, a dollar sign, the same tag that began this dollar quote, and a dollar sign. Inside the dollar-quoted string, single quotes, backslashes, or any character can be used without escaping. The string content is always written literally. For example, here are two different ways to specify the string "Dianne's horse" using dollar quoting:

```sql
$$Dianne's horse$$  
$SomeTag$Dianne's horse$SomeTag$ 
```

If a `SET` clause is attached to a function, the effects of a `SET LOCAL` command executed inside the function for the same variable are restricted to the function; the configuration parameter's prior value is still restored when the function exits. However, an ordinary `SET` command (without `LOCAL`) overrides the `CREATE FUNCTION SET` clause, much as it would for a previous `SET LOCAL` command. The effects of such a command will persist after the function exits, unless the current transaction is rolled back.

If a function with a `VARIADIC` argument is declared as `STRICT`, the strictness check tests that the variadic array as a whole is non-null. PL/pgSQL will still call the function if the array has null elements.

### Using Functions With Queries on Distributed Data

In some cases, Greenplum Database does not support using functions in a query where the data in a table specified in the `FROM` clause is distributed over Greenplum Database segments. As an example, this SQL query contains the function `func()`:

```sql
SELECT func(a) FROM table1; 
```

The function is not supported for use in the query if all of the following conditions are met:
The data of table `table1` is distributed over Greenplum Database segments.
The function `func()` reads or modifies data from distributed tables.
The function `func()` returns more than one row or takes an argument (a) that comes from `table1`.

If any of the conditions are not met, the function is supported. Specifically, the function is supported if any of the following conditions apply:

- The function `func()` does not access data from distributed tables, or accesses data that is only on the Greenplum Database master.
- The table `table1` is a master only table.
- The function `func()` returns only one row and only takes input arguments that are constant values.
  The function is supported if it can be changed to require no input arguments.

### Examples

A very simple addition function:

```sql
CREATE FUNCTION add(integer, integer) RETURNS integer
    AS 'select $1 + $2;'
    LANGUAGE SQL
    IMMUTABLE
    RETURNS NULL ON NULL INPUT;
```

Increment an integer, making use of an argument name, in PL/pgSQL:

```sql
CREATE OR REPLACE FUNCTION increment(i integer) RETURNS integer
    AS $$
    BEGIN
    RETURN i + 1;
    END;
    $$ LANGUAGE plpgsql;
```

Increase the default segment host memory per query for a PL/pgSQL function:

```sql
CREATE OR REPLACE FUNCTION function_with_query() RETURNS SETOF text
    AS $$
    BEGIN
    RETURN QUERY EXPLAIN ANALYZE SELECT * FROM large_table;
    END;
    $$ LANGUAGE plpgsql
SET statement_mem='256MB';
```

Use polymorphic types to return an `ENUM` array:

```sql
CREATE TYPE rainbow AS
    ENUM('red','orange','yellow','green','blue','indigo','violet');
CREATE FUNCTION return_enum_as_array( anyenum, anyelement, anyelement )
    RETURNS TABLE (ae anyenum, aa anyarray) AS $$
    SELECT $1, array[$2, $3]
    $$ LANGUAGE SQL STABLE;
SELECT * FROM return_enum_as_array('red'::rainbow, 'green'::rainbow, 'blue'::rainbow);
```

Return a record containing multiple output parameters:

```sql
CREATE FUNCTION dup(in int, out f1 int, out f2 text)
    AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
    LANGUAGE SQL;
SELECT * FROM dup(42);
```
You can do the same thing more verbosely with an explicitly named composite type:

```sql
CREATE TYPE dup_result AS (f1 int, f2 text);
CREATE FUNCTION dup(int) RETURNS dup_result
  AS $$ SELECT $1, CAST($1 AS text) || ' is text' $$
  LANGUAGE SQL;
SELECT * FROM dup(42);
```

**Compatibility**

`CREATE FUNCTION` is defined in SQL:1999 and later. The Greenplum Database version is similar but not fully compatible. The attributes are not portable, neither are the different available languages.

For compatibility with some other database systems, `argmode` can be written either before or after `argname`. But only the first way is standard-compliant.

The SQL standard does not specify parameter defaults.

**See Also**

`ALTER FUNCTION`, `DROP FUNCTION`, `LOAD`

---

**CREATE GROUP**

Defines a new database role.

**Synopsis**

```sql
CREATE GROUP name [[WITH] option [ ... ]]
```

where `option` can be:

- `SUPERUSER | NOSUPERUSER`
- `CREATEDB | NOCREATEDB`
- `CREATEROLE | NOCREATEROLE`
- `CREATEUSER | NOCREATEUSER`
- `CREATEEXTABLE | NOCREATEEXTABLE`
- `[ ( attribute='value'[, ...] ) ]` where attributes and value are:
  - `type='readable'|'writable'`
  - `protocol='gpfdist'|'http'`
- `INHERIT | NOINHERIT`
- `LOGIN | NOLOGIN`
- `CONNECTION LIMIT connlimit`
- `[ ENCRYPTED | UNENCRYPTED ] PASSWORD 'password'`
- `VALID UNTIL 'timestamp'`
- `IN ROLE rolename [, ...]`
- `ROLE rolename [, ...]`
- `ADMIN rolename [, ...]`
- `RESOURCE QUEUE queue_name`
- `RESOURCE GROUP group_name`
- `[ DENY deny_point ]`
- `[ DENY BETWEEN deny_point AND deny_point]`

**Description**

`CREATE GROUP` is an alias for `CREATE ROLE`.
Compatibility
There is no CREATE GROUP statement in the SQL standard.

See Also
CREATE ROLE

CREATE INDEX
Defines a new index.

Synopsis
CREATE [UNIQUE] INDEX name ON table
[USING btree|bitmap|gist]
( {column | (expression) } [opclass] [, ... ] )
[ WITH ( FILLFACTOR = value )]
[TABLESPACE tablespace]
[WHERE predicate]

Description
CREATE INDEX constructs an index on the specified table. Indexes are primarily used to enhance
database performance (though inappropriate use can result in slower performance).

The key field(s) for the index are specified as column names, or alternatively as expressions written in
parentheses. Multiple fields can be specified if the index method supports multicolumn indexes.

An index field can be an expression computed from the values of one or more columns of the table row.
This feature can be used to obtain fast access to data based on some transformation of the basic data. For
example, an index computed on upper(col) would allow the clause WHERE upper(col) = 'JIM' to
use an index.

Greenplum Database provides the index methods B-tree, bitmap, and GiST. Users can also define their
own index methods, but that is fairly complicated.

When the WHERE clause is present, a partial index is created. A partial index is an index that contains
entries for only a portion of a table, usually a portion that is more useful for indexing than the rest of
the table. For example, if you have a table that contains both billed and unbilled orders where the
unbilled orders take up a small fraction of the total table and yet is most often selected, you can improve
performance by creating an index on just that portion.

The expression used in the WHERE clause may refer only to columns of the underlying table, but it can use
all columns, not just the ones being indexed. Subqueries and aggregate expressions are also forbidden in
WHERE. The same restrictions apply to index fields that are expressions.

All functions and operators used in an index definition must be immutable. Their results must depend
only on their arguments and never on any outside influence (such as the contents of another table or a
parameter value). This restriction ensures that the behavior of the index is well-defined. To use a user-
defined function in an index expression or WHERE clause, remember to mark the function IMMUTABLE
when you create it.

Parameters
UNIQUE
Checks for duplicate values in the table when the index is created and each time data
is added. Duplicate entries will generate an error. Unique indexes only apply to B-tree
indexes. In Greenplum Database, unique indexes are allowed only if the columns of the
index key are the same as (or a superset of) the Greenplum distribution key. On partitioned
tables, a unique index is only supported within an individual partition - not across all partitions.

name

The name of the index to be created. The index is always created in the same schema as its parent table.

table

The name (optionally schema-qualified) of the table to be indexed.

btree | bitmap | gist

The name of the index method to be used. Choices are btree, bitmap, and gist. The default method is btree.

GPORCA supports only B-tree and bitmap indexes. GPORCA ignores indexes created with unsupported indexing methods.

column

The name of a column of the table on which to create the index. Only the B-tree, bitmap, and GiST index methods support multicolumn indexes.

expression

An expression based on one or more columns of the table. The expression usually must be written with surrounding parentheses, as shown in the syntax. However, the parentheses may be omitted if the expression has the form of a function call.

opclass

The name of an operator class. The operator class identifies the operators to be used by the index for that column. For example, a B-tree index on four-byte integers would use the int4_ops class (this operator class includes comparison functions for four-byte integers). In practice the default operator class for the column's data type is usually sufficient. The main point of having operator classes is that for some data types, there could be more than one meaningful ordering. For example, a complex-number data type could be sorted by either absolute value or by real part. We could do this by defining two operator classes for the data type and then selecting the proper class when making an index.

FILLFACTOR

The fill factor for an index is a percentage that determines how full the index method will try to pack index pages. For B-trees, leaf pages are filled to this percentage during initial index build, and also when extending the index at the right (largest key values). If pages subsequently become completely full, they will be split, leading to gradual degradation in the index's efficiency.

B-trees use a default fill factor of 90, but any value from 10 to 100 can be selected. If the table is static then fill factor 100 is best to minimize the index's physical size, but for heavily updated tables a smaller fill factor is better to minimize the need for page splits. The other index methods use fill factor in different but roughly analogous ways; the default fill factor varies between methods.

tablespace

The tablespace in which to create the index. If not specified, the default tablespace is used.

predicate

The constraint expression for a partial index.
Notes

When an index is created on a partitioned table, the index is propagated to all the child tables created by Greenplum Database. Creating an index on a table that is created by Greenplum Database for use by a partitioned table is not supported.

**UNIQUE** indexes are allowed only if the index columns are the same as (or a superset of) the Greenplum distribution key columns.

**UNIQUE** indexes are not allowed on append-optimized tables.

A **UNIQUE** index can be created on a partitioned table. However, uniqueness is enforced only within a partition; uniqueness is not enforced between partitions. For example, for a partitioned table with partitions that are based on year and a subpartitions that are based on quarter, uniqueness is enforced only on each individual quarter partition. Uniqueness is not enforced between quarter partitions.

Indexes are not used for **IS NULL** clauses by default. The best way to use indexes in such cases is to create a partial index using an **IS NULL** predicate.

**bitmap** indexes perform best for columns that have between 100 and 100,000 distinct values. For a column with more than 100,000 distinct values, the performance and space efficiency of a bitmap index decline. The size of a bitmap index is proportional to the number of rows in the table times the number of distinct values in the indexed column.

Columns with fewer than 100 distinct values usually do not benefit much from any type of index. For example, a gender column with only two distinct values for male and female would not be a good candidate for an index.

Prior releases of Greenplum Database also had an R-tree index method. This method has been removed because it had no significant advantages over the GiST method. If **USING rtree** is specified, **CREATE INDEX** will interpret it as **USING gist**.

For more information on the GiST index type, refer to the [PostgreSQL documentation](https://www.postgresql.org/).

The use of hash and GiN indexes has been disabled in Greenplum Database.

Examples

To create a B-tree index on the column **title** in the table **films**:

```
CREATE UNIQUE INDEX title_idx ON films (title);
```

To create a bitmap index on the column **gender** in the table **employee**:

```
CREATE INDEX gender_bmp_idx ON employee USING bitmap (gender);
```

To create an index on the expression **lower(title)**, allowing efficient case-insensitive searches:

```
CREATE INDEX lower_title_idx ON films ((lower(title)));
```

To create an index with non-default fill factor:

```
CREATE UNIQUE INDEX title_idx ON films (title) WITH (fillfactor = 70);
```

To create an index on the column **code** in the table **films** and have the index reside in the tablespace **indexspace**:

```
CREATE INDEX code_idx ON films(code) TABLESPACE indexspace;
```
Compatibility

CREATE INDEX is a Greenplum Database language extension. There are no provisions for indexes in the SQL standard.

Greenplum Database does not support the concurrent creation of indexes (CONCURRENTLY keyword not supported).

See Also

ALTER INDEX, DROP INDEX, CREATE TABLE, CREATE OPERATOR CLASS

CREATE LANGUAGE

Defines a new procedural language.

Synopsis

CREATE [PROCEDURAL] LANGUAGE name
CREATE [TRUSTED] [PROCEDURAL] LANGUAGE name
    HANDLER call_handler [ INLINE inline_handler ]
    [VALIDATOR valfunction]

Description

CREATE LANGUAGE registers a new procedural language with a Greenplum database. Subsequently, functions and trigger procedures can be defined in this new language.

Superusers can register a new language with a Greenplum database. A database owner can also register within that database any language listed in the pg_pltemplate catalog in which the tmpldbacreate field is true. The default configuration allows only trusted languages to be registered by database owners. The creator of a language becomes its owner and can later drop it, rename it, or assign ownership to a new user.

CREATE LANGUAGE effectively associates the language name with a call handler that is responsible for executing functions written in that language. For a function written in a procedural language (a language other than C or SQL), the database server has no built-in knowledge about how to interpret the function's source code. The task is passed to a special handler that knows the details of the language. The handler could either do all the work of parsing, syntax analysis, execution, and so on or it could serve as a bridge between Greenplum Database and an existing implementation of a programming language. The handler itself is a C language function compiled into a shared object and loaded on demand, just like any other C function. Therese procedural language packages are included in the standard Greenplum Database distribution: PL/pgSQL, PL/Perl, and PL/Python. Language handlers have also been added for PL/Java and PL/R, but those languages are not pre-installed with Greenplum Database. See the topic on Procedural Languages in the PostgreSQL documentation for more information on developing functions using these procedural languages.

The PL/Perl, PL/Java, and PL/R libraries require the correct versions of Perl, Java, and R to be installed, respectively.

On RHEL and SUSE platforms, download the appropriate extensions from Pivotal Network, then install the extensions using the Greenplum Package Manager (gppkg) utility to ensure that all dependencies are installed as well as the extensions. See the Greenplum Database Utility Guide for details about gppkg.

There are two forms of the CREATE LANGUAGE command. In the first form, the user specifies the name of the desired language and the Greenplum Database server uses the pg_pltemplate system catalog to determine the correct parameters. In the second form, the user specifies the language parameters as well as the language name. You can use the second form to create a language that is not defined in pg_pltemplate.
When the server finds an entry in the `pg_pltemplate` catalog for the given language name, it will use the catalog data even if the command includes language parameters. This behavior simplifies loading of old dump files, which are likely to contain out-of-date information about language support functions.

**Parameters**

**TRUSTED**

Ignored if the server has an entry for the specified language name in `pg_pltemplate`. Specifies that the call handler for the language is safe and does not offer an unprivileged user any functionality to bypass access restrictions. If this key word is omitted when registering the language, only users with the superuser privilege can use this language to create new functions.

**PROCEDURAL**

This is a noise word.

**name**

The name of the new procedural language. The language name is case insensitive. The name must be unique among the languages in the database. Built-in support is included for `plpgsql`, `plperl`, `plpythonu`, and `plr`. The languages `plpgsql` (PL/pgSQL) and `plpythonu` (PL/Python) are installed by default in Greenplum Database.

**HANDLER call_handler**

Ignored if the server has an entry for the specified language name in `pg_pltemplate`. The name of a previously registered function that will be called to execute the procedural language functions. The call handler for a procedural language must be written in a compiled language such as C with version 1 call convention and registered with Greenplum Database as a function taking no arguments and returning the `language_handler` type, a placeholder type that is simply used to identify the function as a call handler.

**INLINE inline_handler**

The name of a previously registered function that is called to execute an anonymous code block in this language that is created with the `DO` command. If an `inline_handler` function is not specified, the language does not support anonymous code blocks. The handler function must take one argument of type `internal`, which is the `DO` command internal representation. The function typically returns `void`. The return value of the handler is ignored.

**VALIDATOR valfunction**

Ignored if the server has an entry for the specified language name in `pg_pltemplate`. The name of a previously registered function that will be called to execute the procedural language functions. The call handler for a procedural language must be written in a compiled language such as C with version 1 call convention and registered with Greenplum Database as a function taking no arguments and returning the `language_handler` type, a placeholder type that is simply used to identify the function as a call handler.

**Notes**

The PL/pgSQL language is already registered in all databases by default. The PL/Python language extension is installed but not registered.

The system catalog `pg_language` records information about the currently installed languages.

To create functions in a procedural language, a user must have the `USAGE` privilege for the language. By default, `USAGE` is granted to `PUBLIC` (everyone) for trusted languages. This may be revoked if desired.

Procedural languages are local to individual databases. You create and drop languages for individual databases.
The call handler function and the validator function (if any) must already exist if the server does not have an entry for the language in `pg_pltemplate`. But when there is an entry, the functions need not already exist; they will be automatically defined if not present in the database.

Any shared library that implements a language must be located in the same `LD_LIBRARY_PATH` location on all segment hosts in your Greenplum Database array.

**Examples**
The preferred way of creating any of the standard procedural languages:

```sql
CREATE LANGUAGE plpgsql;
CREATE LANGUAGE plr;
```

For a language not known in the `pg_pltemplate` catalog:

```sql
CREATE FUNCTION plsample_call_handler() RETURNS language_handler
    AS '$libdir/plsample'
    LANGUAGE C;
CREATE LANGUAGE plsample
    HANDLER plsample_call_handler;
```

**Compatibility**
`CREATE LANGUAGE` is a Greenplum Database extension.

**See Also**

`ALTER LANGUAGE`, `CREATE FUNCTION`, `DROP LANGUAGE` DO

---

**CREATE OPERATOR**

Defines a new operator.

**Synopsis**

```sql
CREATE OPERATOR name (  
    PROCEDURE = funcname  
    [, LEFTARG = lefttype] [, RIGHTARG = righttype]  
    [, COMMUTATOR = com_op] [, NEGATOR = neg_op]  
    [, RESTRICT = res_proc] [, JOIN = join_proc]  
    [, HASHES] [, MERGES] )
```

**Description**

`CREATE OPERATOR` defines a new operator. The user who defines an operator becomes its owner.

The operator name is a sequence of up to `NAMEDATALEN-1` (63 by default) characters from the following list: `+ - * / < > = ~ ! @ # % ^ & | ` ?

There are a few restrictions on your choice of name:

- `--` and `/*` cannot appear anywhere in an operator name, since they will be taken as the start of a comment.
- A multicharacter operator name cannot end in `+` or `−`, unless the name also contains at least one of these characters: `~ ! @ # % ^ & | ` ?

For example, `@-` is an allowed operator name, but `*−` is not. This restriction allows Greenplum Database to parse SQL-compliant commands without requiring spaces between tokens.
The operator != is mapped to <> on input, so these two names are always equivalent.

At least one of LEFTARG and RIGHTARG must be defined. For binary operators, both must be defined. For right unary operators, only LEFTARG should be defined, while for left unary operators only RIGHTARG should be defined.

The funcname procedure must have been previously defined using CREATE FUNCTION, must be IMMUTABLE, and must be defined to accept the correct number of arguments (either one or two) of the indicated types.

The other clauses specify optional operator optimization clauses. These clauses should be provided whenever appropriate to speed up queries that use the operator. But if you provide them, you must be sure that they are correct. Incorrect use of an optimization clause can result in server process crashes, subtly wrong output, or other unexpected results. You can always leave out an optimization clause if you are not sure about it.

**Parameters**

*name*

The (optionally schema-qualified) name of the operator to be defined. Two operators in the same schema can have the same name if they operate on different data types.

*funcname*

The function used to implement this operator (must be an IMMUTABLE function).

*lefttype*

The data type of the operator's left operand, if any. This option would be omitted for a left-unary operator.

*righttype*

The data type of the operator's right operand, if any. This option would be omitted for a right-unary operator.

*com_op*

The optional COMMUATOR clause names an operator that is the commutator of the operator being defined. We say that operator A is the commutator of operator B if (x A y) equals (y B x) for all possible input values x, y. Notice that B is also the commutator of A. For example, operators < and > for a particular data type are usually each others commutators, and operator + is usually commutative with itself. But operator − is usually not commutative with anything. The left operand type of a commutable operator is the same as the right operand type of its commutator, and vice versa. So the name of the commutator operator is all that needs to be provided in the COMMUATOR clause.

*neg_op*

The optional NEGATOR clause names an operator that is the negator of the operator being defined. We say that operator A is the negator of operator B if both return Boolean results and (x A y) equals NOT (x B y) for all possible inputs x, y. Notice that B is also the negator of A. For example, < and >= are a negator pair for most data types. An operator's negator must have the same left and/or right operand types as the operator to be defined, so only the operator name need be given in the NEGATOR clause.

*res_proc*

The optional RESTRICT names a restriction selectivity estimation function for the operator. Note that this is a function name, not an operator name. RESTRICT clauses only make sense for binary operators that return boolean. The idea behind a restriction selectivity estimator is to guess what fraction of the rows in a table will satisfy a WHERE-clause condition of the form:

```
column OP constant
```
for the current operator and a particular constant value. This assists the optimizer by giving it some idea of how many rows will be eliminated by WHERE clauses that have this form.

You can usually just use one of the following system standard estimator functions for many of your own operators:

- `eqsel` for `=`
- `neqsel` for `<>`
- `scalarltsel` for `<` or `<=`
- `scalargtsel` for `>` or `>=`

**join_proc**

The optional JOIN clause names a join selectivity estimation function for the operator. Note that this is a function name, not an operator name. JOIN clauses only make sense for binary operators that return boolean. The idea behind a join selectivity estimator is to guess what fraction of the rows in a pair of tables will satisfy a WHERE-clause condition of the form

```
table1.column1 OP table2.column2
```

for the current operator. This helps the optimizer by letting it figure out which of several possible join sequences is likely to take the least work.

You can usually just use one of the following system standard join selectivity estimator functions for many of your own operators:

- `eqjoinsel` for `=`
- `neqjoinsel` for `<>`
- `scalarltjoinsel` for `<` or `<=`
- `scalargtjoinsel` for `>` or `>=`
- `areajoinsel` for 2D area-based comparisons
- `positionjoinsel` for 2D position-based comparisons
- `contjoinsel` for 2D containment-based comparisons

**HASHES**

The optional HASHES clause tells the system that it is permissible to use the hash join method for a join based on this operator. HASHES only makes sense for a binary operator that returns boolean. The hash join operator can only return true for pairs of left and right values that hash to the same hash code. If two values are put in different hash buckets, the join will never compare them, implicitly assuming that the result of the join operator must be false. Because of this, it never makes sense to specify HASHES for operators that do not represent equality.

In most cases, it is only practical to support hashing for operators that take the same data type on both sides. However, you can design compatible hash functions for two or more data types, which are functions that will generate the same hash codes for “equal” values, even if the values are differently represented.

To be marked HASHES, the join operator must appear in a hash index operator class. Attempts to use the operator in hash joins will fail at run time if no such operator class exists. The system needs the operator class to find the data-type-specific hash function for the operator’s input data type. You must also supply a suitable hash function before you can create the operator class. Exercise care when preparing a hash function, as there are machine-dependent ways in which it could fail to function correctly. For example, on machines that meet the IEEE floating-point standard, negative zero and positive zero are
different values (different bit patterns) but are defined to compare as equal. If a float value could contain a negative zero, define it to generate the same hash value as positive zero.

A hash-joinable operator must have a commutator (itself, if the two operand data types are the same, or a related equality operator if they are different) that appears in the same operator family. Otherwise, planner errors can occur when the operator is used. For better optimization, a hash operator family that supports multiple data types should provide equality operators for every combination of the data types.

**Note:** The function underlying a hash-joinable operator must be marked immutable or stable; an operator marked as volatile will not be used. If a hash-joinable operator has an underlying function that is marked strict, the function must also be complete, returning true or false, and not null, for any two non-null inputs.

**MERGES**

The **MERGES** clause, if present, tells the system that it is permissible to use the merge-join method for a join based on this operator. **MERGES** only makes sense for a binary operator that returns **boolean**, and in practice the operator must represent equality for some data type or pair of data types.

Merge join is based on the idea of sorting the left- and right-hand tables into order and then scanning them in parallel. This means both data types must be capable of being fully ordered, and the join operator must be one that can only succeed for pairs of values that fall at equivalent places in the sort order. In practice, this means that the join operator must behave like an equality operator. However, you can merge-join two distinct data types so long as they are logically compatible. For example, the **smallint-versus-integer** equality operator is merge-joinable. Only sorting operators that bring both data types into a logically compatible sequence are needed.

To be marked **MERGES**, the join operator must appear as an equality member of a btree index operator family. This is not enforced when you create the operator, because the referencing operator family does not exist until later. However, the operator will not actually be used for merge joins unless a matching operator family can be found. The **MERGE** flag thus acts as a suggestion to the planner to look for a matching operator family.

A merge-joinable operator must have a commutator that appears in the same operator family. This would be itself, if the two operand data types are the same, or a related equality operator if the data types are different. Without an appropriate commutator, planner errors can occur when the operator is used. Also, although not strictly required, a btree operator family that supports multiple data types should be able to provide equality operators for every combination of the data types; this allows better optimization.

**Note:** **SORT1**, **SORT2**, **LTCMP**, and **GTCMP** were formerly used to specify the names of sort operators associated with a merge-joinable operator. Information about associated operators is now found by looking at B-tree operator families; specifying any of these operators will be ignored, except that it will implicitly set **MERGES** to true.

**Notes**

Any functions used to implement the operator must be defined as **IMMUTABLE**.

**Examples**

Here is an example of creating an operator for adding two complex numbers, assuming we have already created the definition of type **complex**. First define the function that does the work, then define the operator:

```sql
CREATE FUNCTION complex_add(complex, complex)
```
CREATE OPERATOR CLASS

Defines a new operator class.

Synopsis

CREATE OPERATOR CLASS name [DEFAULT] FOR TYPE data_type
  USING index_method AS
  {
    OPERATOR strategy_number op_name [(op_type, op_type)] [RECHECK]
    | FUNCTION support_number funcname (argument_type [, ...] )
    | STORAGE storage_type
  } [, ... ]

Description

CREATE OPERATOR CLASS creates a new operator class. An operator class defines how a particular data type can be used with an index. The operator class specifies that certain operators will fill particular roles or strategies for this data type and this index method. The operator class also specifies the support procedures to be used by the index method when the operator class is selected for an index column. All the operators and functions used by an operator class must be defined before the operator class is created. Any functions used to implement the operator class must be defined as IMMUTABLE. CREATE OPERATOR CLASS does not presently check whether the operator class definition includes all the operators and functions required by the index method, nor whether the operators and functions form a self-consistent set. It is the user’s responsibility to define a valid operator class.

You must be a superuser to create an operator class.

Parameters

name

The (optionally schema-qualified) name of the operator class to be defined. Two operator classes in the same schema can have the same name only if they are for different index methods.

DEFAULT
Makes the operator class the default operator class for its data type. At most one operator class can be the default for a specific data type and index method.

**data_type**

The column data type that this operator class is for.

**index_method**

The name of the index method this operator class is for. Choices are `btree`, `bitmap`, and `gist`.

**strategy_number**

The operators associated with an operator class are identified by strategy numbers, which serve to identify the semantics of each operator within the context of its operator class. For example, B-trees impose a strict ordering on keys, lesser to greater, and so operators like `less than` and `greater than or equal to` are interesting with respect to a B-tree. These strategies can be thought of as generalized operators. Each operator class specifies which actual operator corresponds to each strategy for a particular data type and interpretation of the index semantics. The corresponding strategy numbers for each index method are as follows:

**Table 98: B-tree and Bitmap Strategies**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Strategy Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than</td>
<td>1</td>
</tr>
<tr>
<td>less than or equal</td>
<td>2</td>
</tr>
<tr>
<td>equal</td>
<td>3</td>
</tr>
<tr>
<td>greater than or equal</td>
<td>4</td>
</tr>
<tr>
<td>greater than</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 99: GiST Two-Dimensional Strategies (R-Tree)**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Strategy Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>strictly left of</td>
<td>1</td>
</tr>
<tr>
<td>does not extend to right of</td>
<td>2</td>
</tr>
<tr>
<td>overlaps</td>
<td>3</td>
</tr>
<tr>
<td>does not extend to left of</td>
<td>4</td>
</tr>
<tr>
<td>strictly right of</td>
<td>5</td>
</tr>
<tr>
<td>same</td>
<td>6</td>
</tr>
<tr>
<td>contains</td>
<td>7</td>
</tr>
<tr>
<td>contained by</td>
<td>8</td>
</tr>
<tr>
<td>does not extend above</td>
<td>9</td>
</tr>
<tr>
<td>strictly below</td>
<td>10</td>
</tr>
<tr>
<td>strictly above</td>
<td>11</td>
</tr>
<tr>
<td>does not extend below</td>
<td>12</td>
</tr>
</tbody>
</table>

**operator_name**

The name (optionally schema-qualified) of an operator associated with the operator class.
**op_type**

The operand data type(s) of an operator, or `NONE` to signify a left-unary or right-unary operator. The operand data types may be omitted in the normal case where they are the same as the operator class data type.

**RECHECK**

If present, the index is "lossy" for this operator, and so the rows retrieved using the index must be rechecked to verify that they actually satisfy the qualification clause involving this operator.

**support_number**

Index methods require additional support routines in order to work. These operations are administrative routines used internally by the index methods. As with strategies, the operator class identifies which specific functions should play each of these roles for a given data type and semantic interpretation. The index method defines the set of functions it needs, and the operator class identifies the correct functions to use by assigning them to the *support function numbers* as follows:

**Table 100: B-tree and Bitmap Support Functions**

<table>
<thead>
<tr>
<th>Function</th>
<th>Support Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compare two keys and return an integer less than zero, zero, or greater than zero, indicating whether the first key is less than, equal to, or greater than the second.</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 101: GiST Support Functions**

<table>
<thead>
<tr>
<th>Function</th>
<th>Support Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>consistent - determine whether key satisfies the query qualifier.</td>
<td>1</td>
</tr>
<tr>
<td>union - compute union of a set of keys.</td>
<td>2</td>
</tr>
<tr>
<td>compress - compute a compressed representation of a key or value to be indexed.</td>
<td>3</td>
</tr>
<tr>
<td>decompress - compute a decompressed representation of a compressed key.</td>
<td>4</td>
</tr>
<tr>
<td>penalty - compute penalty for inserting new key into subtree with given subtree's key.</td>
<td>5</td>
</tr>
<tr>
<td>picksplit - determine which entries of a page are to be moved to the new page and compute the union keys for resulting pages.</td>
<td>6</td>
</tr>
<tr>
<td>equal - compare two keys and return true if they are equal.</td>
<td>7</td>
</tr>
</tbody>
</table>

**funcname**

The name (optionally schema-qualified) of a function that is an index method support procedure for the operator class.

**argument_types**

The parameter data type(s) of the function.
**storage_type**

The data type actually stored in the index. Normally this is the same as the column data type, but the GiST index method allows it to be different. The STORAGE clause must be omitted unless the index method allows a different type to be used.

**Notes**

Because the index machinery does not check access permissions on functions before using them, including a function or operator in an operator class is the same as granting public execute permission on it. This is usually not an issue for the sorts of functions that are useful in an operator class.

The operators should not be defined by SQL functions. A SQL function is likely to be inlined into the calling query, which will prevent the optimizer from recognizing that the query matches an index.

Any functions used to implement the operator class must be defined as **IMMUTABLE**.

**Examples**

The following example command defines a GiST index operator class for the data type _int4 (array of int4):

```
CREATE OPERATOR CLASS gist__int_ops
DEFAULT FOR TYPE _int4 USING gist AS
  OPERATOR 3 &&,
  OPERATOR 6 = RECHECK,
  OPERATOR 7 @>,
  OPERATOR 8 <@,
  OPERATOR 20 @@ (_int4, query_int),
  FUNCTION 1 g_intconsistent (internal, _int4, int4),
  FUNCTION 2 g_intunion (bytea, internal),
  FUNCTION 3 g_intcompress (internal),
  FUNCTION 4 g_intdecompress (internal),
  FUNCTION 5 g_intpenalty (internal, internal, internal),
  FUNCTION 6 g_intpicksplit (internal, internal),
  FUNCTION 7 g_intsame (_int4, _int4, internal);
```

**Compatibility**

CREATE OPERATOR CLASS is a Greenplum Database extension. There is no CREATE OPERATOR CLASS statement in the SQL standard.

**See Also**

ALTER OPERATOR CLASS, DROP OPERATOR CLASS, CREATE FUNCTION

**CREATE OPERATOR FAMILY**

Defines a new operator family.

**Synopsis**

```
CREATE OPERATOR FAMILY name USING index_method
```

**Description**

CREATE OPERATOR FAMILY creates a new operator family. An operator family defines a collection of related operator classes, and perhaps some additional operators and support functions that are compatible with these operator classes but not essential for the functioning of any individual index. (Operators and
functions that are essential to indexes should be grouped within the relevant operator class, rather than being "loose" in the operator family. Typically, single-data-type operators are bound to operator classes, while cross-data-type operators can be loose in an operator family containing operator classes for both data types.

The new operator family is initially empty. It should be populated by issuing subsequent CREATE OPERATOR CLASS commands to add contained operator classes, and optionally ALTER OPERATOR FAMILY commands to add "loose" operators and their corresponding support functions.

If a schema name is given then the operator family is created in the specified schema. Otherwise it is created in the current schema. Two operator families in the same schema can have the same name only if they are for different index methods.

The user who defines an operator family becomes its owner. Presently, the creating user must be a superuser. (This restriction is made because an erroneous operator family definition could confuse or even crash the server.)

**Parameters**

- **name**
  The (optionally schema-qualified) name of the operator family to be defined. The name can be schema-qualified.

- **index_method**
  The name of the index method this operator family is for.

**Compatibility**

CREATE OPERATOR FAMILY is a Greenplum Database extension. There is no CREATE OPERATOR FAMILY statement in the SQL standard.

**See Also**

ALTER OPERATOR FAMILY, DROP OPERATOR FAMILY, CREATE FUNCTION, ALTER OPERATOR CLASS, CREATE OPERATOR CLASS, DROP OPERATOR CLASS

**CREATE PROTOCOL**

Registers a custom data access protocol that can be specified when defining a Greenplum Database external table.

**Synopsis**

```
CREATE [TRUSTED] PROTOCOL name (  
    [readfunc='read_call_handler'] [, writefunc='write_call_handler']  
    [, validatorfunc='validate_handler'] )
```

**Description**

CREATE PROTOCOL associates a data access protocol name with call handlers that are responsible for reading from and writing data to an external data source.

The CREATE PROTOCOL must specify either a read call handler or a write call handler. The call handlers specified in the CREATE PROTOCOL command must be defined in the database.

The protocol name can be specified in an CREATE EXTERNAL TABLE command.

For information about creating and enabling a custom data access protocol, see "Example Custom Data Access Protocol" in the Greenplum Database Administrator Guide.
Parameters

**TRUSTED**

A noise word.

**name**

The name of the data access protocol. The protocol name is case sensitive. The name must be unique among the protocols in the database.

**readfunc= 'read_call_handler'**

The name of a previously registered function that Greenplum Database calls to read data from an external data source. The command must specify either a read call handler or a write call handler.

**writefunc= 'write_call_handler'**

The name of a previously registered function that Greenplum Database calls to write data to an external data source. The command must specify either a read call handler or a write call handler.

**validatorfunc= 'validate_handler'**

An optional validator function that validates the URL specified in the `CREATE EXTERNAL TABLE` command.

Notes

Greenplum Database installs the custom protocols `file`, `gpfdist`, `gpfdists`, and `gphdfs` by default. Optionally, the `s3` protocol can be installed.

Any shared library that implements a data access protocol must be located in the same location on all Greenplum Database segment hosts. For example, the shared library can be in a location specified by the operating system environment variable `LD_LIBRARY_PATH` on all hosts. You can also specify the location when you define the handler function. For example, when you define the `s3` protocol in the `CREATE PROTOCOL` command, you specify `$libdir/gps3ext.so` as the location of the shared object, where `$libdir` is located at `$GPHOME/lib`.

Compatibility

`CREATE PROTOCOL` is a Greenplum Database extension.

See Also

`ALTER PROTOCOL`, `CREATE EXTERNAL TABLE`, `DROP PROTOCOL`

---

**CREATE RESOURCE GROUP**

Defines a new resource group.

Synopsis

```
CREATE RESOURCE GROUP name WITH (group_attribute=value [, ... ])
```

where **group_attribute** is:

```
CPU_RATE_LIMIT=integer  
MEMORY_LIMIT=integer  
[ CONCURRENcy=integer ]  
[ MEMORY_SHARED_QUOTA=integer ]  
[ MEMORY_SPILL_RATIO=integer ]  
[ MEMORY_AUDITOR= {vmtracker | cgroup} ]
```
Description

Creates a new resource group for Greenplum Database resource management. You can create resource groups to manage resources for roles or to manage the resources of a Greenplum Database external component such as PL/Container.

A resource group that you create to manage a user role identifies concurrent transaction, memory, and CPU limits for the role when resource groups are enabled. You may assign such resource groups to one or more roles.

A resource group that you create to manage the resources of a Greenplum Database external component such as PL/Container identifies the memory and CPU limits for the component when resource groups are enabled. These resource groups use cgroups to manage both CPU and memory management. Assignment of resource groups to external components is component-specific. For example, you assign a PL/Container resource group when you configure a PL/Container runtime. You cannot assign a resource group that you create for external components to a role, nor can you assign a resource group that you create for roles to an external component.

You must have SUPERUSER privileges to create a resource group. The maximum number of resource groups allowed in your Greenplum Database cluster is 100.

Greenplum Database pre-defines two default resource groups: admin_group and default_group. These group names, as well as the group name none, are reserved.

To set appropriate limits for resource groups, the Greenplum Database administrator must be familiar with the queries typically executed on the system, as well as the users/roles executing those queries and the external components they may be using, such as PL/Containers.

After creating a resource group for a role, assign the group to one or more roles using the ALTER ROLE or CREATE ROLE commands.

After you create a resource group to manage the CPU and memory resources of an external component, configure the external component to use the resource group. For example, configure the PL/Container runtime resource_group_id.

Parameters

name

The name of the resource group.

CONCURRENCY integer

The maximum number of concurrent transactions, including active and idle transactions, that are permitted for this resource group. The CONCURRENCY value must be an integer in the range [0 .. max_connections]. The default CONCURRENCY value for resource groups defined for roles is 20.

You must set CONCURRENCY to zero (0) for resource groups that you create for external components.

Note: You cannot set the CONCURRENCY value for the admin_group to zero (0).

CPU_RATE_LIMIT integer

Required. The percentage of CPU resources to allocate to this resource group. The minimum CPU percentage you can specify for a resource group is 1. The maximum is 100. The sum of the CPU_RATE_LIMIT values specified for all resource groups defined in the Greenplum Database cluster must be less than or equal to 100.

MEMORY_LIMIT integer

Required. The total percentage of Greenplum Database memory resources to allocate to this resource group. The minimum memory percentage you can specify for a resource group is 1. The maximum is 100. The sum of the MEMORY_LIMIT values specified for all
resource groups defined in the Greenplum Database cluster must be less than or equal to 100.

**MEMORY_SHARED_QUOTA integer**

The quota of shared memory in the resource group. Resource groups with a MEMORY_SHARED_QUOTA threshold set aside a percentage of memory allotted to the resource group to share across transactions. This shared memory is allocated on a first-come, first-served basis as available. A transaction may use none, some, or all of this memory. The minimum memory shared quota percentage you can specify for a resource group is 0. The maximum is 100. The default MEMORY_SHARED_QUOTA value is 20.

**MEMORY_SPILL_RATIO integer**

The memory usage threshold for memory-intensive operators in a transaction. When this threshold is reached, a transaction spills to disk. The minimum memory spill ratio percentage you can specify for a resource group is 0. The maximum is 100. The default MEMORY_SPILL_RATIO value is 20.

**MEMORY_AUDITOR {vmtracker | cgroup}**

The memory auditor for the resource group. Greenplum Database employs virtual memory tracking for role resources and cgroup memory tracking for resources used by external components. The default MEMORY_AUDITOR is vmtracker. When you create a resource group with vmtracker memory auditing, Greenplum Database tracks that resource group's memory internally.

When you create a resource group specifying the cgroup MEMORY_AUDITOR, Greenplum Database defers the accounting of memory used by that resource group to cgroups. CONCURRENCY must be zero (0) for a resource group that you create for external components such as PL/Container. You cannot assign a resource group that you create for external components to a Greenplum Database role.

**Notes**

You cannot submit a CREATE RESOURCE GROUP command in an explicit transaction or sub-transaction.

Use the **gp_toolkit.gp_resgroup_config** system view to display the limit settings of all resource groups:

```sql
SELECT * FROM gp_toolkit.gp_resgroup_config;
```

**Examples**

Create a resource group with CPU and memory limit percentages of 35:

```sql
CREATE RESOURCE GROUP rgroup1 WITH (CPU_RATE_LIMIT=35, MEMORY_LIMIT=35);
```

Create a resource group with a concurrent transaction limit of 20, a memory limit of 15, and a CPU limit of 25:

```sql
CREATE RESOURCE GROUP rgroup2 WITH (CONCURRENCY=20, MEMORY_LIMIT=15, CPU_RATE_LIMIT=25);
```

Create a resource group to manage PL/Container resources specifying a memory limit of 10, and a CPU limit of 10:

```sql
CREATE RESOURCE GROUP plc_run1 WITH (MEMORY_LIMIT=10, CPU_RATE_LIMIT=10, CONCURRENCY=0, MEMORY_AUDITOR=cgroup);
```
**Compatibility**

CREATE RESOURCE GROUP is a Greenplum Database extension. There is no provision for resource groups or resource management in the SQL standard.

**See Also**

ALTER ROLE, CREATE ROLE, ALTER RESOURCE GROUP, DROP RESOURCE GROUP

---

**CREATE RESOURCE QUEUE**

Defines a new resource queue.

**Synopsis**

```sql
CREATE RESOURCE QUEUE name WITH (queue_attribute=value [, ... ])
```

where `queue_attribute` is:

```sql
ACTIVE_STATEMENTS=integer
  [ MAX_COST=float [COST_OVERCOMMIT={TRUE|FALSE}] ]
  [ MIN_COST=float ]
  [ PRIORITY={MIN|LOW|MEDIUM|HIGH|MAX} ]
  [ MEMORY_LIMIT='memory_units' ]
```

| MAX_COST=float [COST_OVERCOMMIT={TRUE|FALSE}] |
|-----------------------------------------------|
| [ ACTIVE_STATEMENTS=integer ]
| [ MIN_COST=float ]
| [ PRIORITY={MIN|LOW|MEDIUM|HIGH|MAX} ]
| [ MEMORY_LIMIT='memory_units' ]

**Description**

Creates a new resource queue for Greenplum Database resource management. A resource queue must have either an `ACTIVE_STATEMENTS` or a `MAX_COST` value (or it can have both). Only a superuser can create a resource queue.

Resource queues with an `ACTIVE_STATEMENTS` threshold set a maximum limit on the number of queries that can be executed by roles assigned to that queue. It controls the number of active queries that are allowed to run at the same time. The value for `ACTIVE_STATEMENTS` should be an integer greater than 0.

Resource queues with a `MAX_COST` threshold set a maximum limit on the total cost of queries that can be executed by roles assigned to that queue. Cost is measured in the estimated total cost for the query as determined by the Greenplum Database query planner (as shown in the EXPLAIN output for a query). Therefore, an administrator must be familiar with the queries typically executed on the system in order to set an appropriate cost threshold for a queue. Cost is measured in units of disk page fetches; 1.0 equals one sequential disk page read. The value for `MAX_COST` is specified as a floating point number (for example 100.0) or can also be specified as an exponent (for example 1e+2). If a resource queue is limited based on a cost threshold, then the administrator can allow `COST_OVERCOMMIT=TRUE` (the default). This means that a query that exceeds the allowed cost threshold will be allowed to run but only when the system is idle. If `COST_OVERCOMMIT=FALSE` is specified, queries that exceed the cost limit will always be rejected and never allowed to run. Specifying a value for `MIN_COST` allows the administrator to define a cost for small queries that will be exempt from resource queueing.

**Note:** GPORCA and the legacy Greenplum Database query optimizer utilize different query costing models and may compute different costs for the same query. The Greenplum Database resource queue resource management scheme neither differentiates nor aligns costs between GPORCA and the legacy optimizer; it uses the literal cost value returned from the optimizer to throttle queries.
When resource queue-based resource management is active, use the `MEMORY_LIMIT` and `ACTIVE_STATEMENTS` limits for resource queues rather than configuring cost-based limits. Even when using GPORCA, Greenplum Database may fall back to using the legacy query optimizer for certain queries, so using cost-based limits can lead to unexpected results.

If a value is not defined for `ACTIVE_STATEMENTS` or `MAX_COST`, it is set to -1 by default (meaning no limit). After defining a resource queue, you must assign roles to the queue using the `ALTER ROLE` or `CREATE ROLE` command.

You can optionally assign a `PRIORITY` to a resource queue to control the relative share of available CPU resources used by queries associated with the queue in relation to other resource queues. If a value is not defined for `PRIORITY`, queries associated with the queue have a default priority of `MEDIUM`.

Resource queues with an optional `MEMORY_LIMIT` threshold set a maximum limit on the amount of memory that all queries submitted through a resource queue can consume on a segment host. This determines the total amount of memory that all worker processes of a query can consume on a segment host during query execution. Greenplum recommends that `MEMORY_LIMIT` be used in conjunction with `ACTIVE_STATEMENTS` rather than with `MAX_COST`. The default amount of memory allotted per query on statement-based queues is: `MEMORY_LIMIT / ACTIVE_STATEMENTS`. The default amount of memory allotted per query on cost-based queues is: `MEMORY_LIMIT * (query_cost / MAX_COST)`.

The default memory allotment can be overridden on a per-query basis using the `statement_mem` server configuration parameter, provided that `MEMORY_LIMIT` or `max_statement_mem` is not exceeded. For example, to allocate more memory to a particular query:

```sql
=> SET statement_mem='2GB';
=> SELECT * FROM my_big_table WHERE column='value' ORDER BY id;
=> RESET statement_mem;
```

The `MEMORY_LIMIT` value for all of your resource queues should not exceed the amount of physical memory of a segment host. If workloads are staggered over multiple queues, memory allocations can be oversubscribed. However, queries can be cancelled during execution if the segment host memory limit specified in `gp_vmem_protect_limit` is exceeded.

For information about `statement_mem`, `max_statement`, and `gp_vmem_protect_limit`, see [Server Configuration Parameters](#).

**Parameters**

- **name**
  The name of the resource queue.

- **ACTIVE_STATEMENTS integer**
  Resource queues with an `ACTIVE_STATEMENTS` threshold limit the number of queries that can be executed by roles assigned to that queue. It controls the number of active queries that are allowed to run at the same time. The value for `ACTIVE_STATEMENTS` should be an integer greater than 0.

- **MEMORY_LIMIT ‘memory_units’**
  Sets the total memory quota for all statements submitted from users in this resource queue. Memory units can be specified in kB, MB or GB. The minimum memory quota for a resource queue is 10MB. There is no maximum, however the upper boundary at query execution time is limited by the physical memory of a segment host. The default is no limit (-1).

- **MAX_COST float**
  Resource queues with a `MAX_COST` threshold set a maximum limit on the total cost of queries that can be executed by roles assigned to that queue. Cost is measured in the `estimated total cost` for the query as determined by the Greenplum Database query optimizer (as shown in the `EXPLAIN` output for a query). Therefore, an administrator must
be familiar with the queries typically executed on the system in order to set an appropriate cost threshold for a queue. Cost is measured in units of disk page fetches; 1.0 equals one sequential disk page read. The value for `MAX_COST` is specified as a floating point number (for example 100.0) or can also be specified as an exponent (for example 1e+2).

**COST_OVERCOMMIT boolean**

If a resource queue is limited based on `MAX_COST`, then the administrator can allow `COST_OVERCOMMIT` (the default). This means that a query that exceeds the allowed cost threshold will be allowed to run but only when the system is idle. If `COST_OVERCOMMIT=False` is specified, queries that exceed the cost limit will always be rejected and never allowed to run.

**MIN_COST float**

The minimum query cost limit of what is considered a small query. Queries with a cost under this limit will not be queued and run immediately. Cost is measured in the estimated total cost for the query as determined by the Greenplum Database query planner (as shown in the EXPLAIN output for a query). Therefore, an administrator must be familiar with the queries typically executed on the system in order to set an appropriate cost for what is considered a small query. Cost is measured in units of disk page fetches; 1.0 equals one sequential disk page read. The value for `MIN_COST` is specified as a floating point number (for example 100.0) or can also be specified as an exponent (for example 1e+2).

**PRIORITY={MIN|LOW|MEDIUM|HIGH|MAX}**

Sets the priority of queries associated with a resource queue. Queries or statements in queues with higher priority levels will receive a larger share of available CPU resources in case of contention. Queries in low-priority queues may be delayed while higher priority queries are executed. If no priority is specified, queries associated with the queue have a priority of `MEDIUM`.

**Notes**

Use the `gp_toolkit.gp_resqueue_status` system view to see the limit settings and current status of a resource queue:

```sql
SELECT * from gp_toolkit.gp_resqueue_status WHERE rsqname='queue_name';
```

There is also another system view named `pg_stat_resqueues` which shows statistical metrics for a resource queue over time. To use this view, however, you must enable the `stats_queue_level` server configuration parameter. See "Managing Workload and Resources" in the Greenplum Database Administrator Guide for more information about using resource queues.

**CREATE RESOURCE QUEUE** cannot be run within a transaction.

Also, an SQL statement that is run during the execution of an EXPLAIN ANALYZE command is excluded from resource queues.

**Examples**

Create a resource queue with an active query limit of 20:

```sql
CREATE RESOURCE QUEUE myqueue WITH (ACTIVE_STATEMENTS=20);
```

Create a resource queue with an active query limit of 20 and a total memory limit of 2000MB (each query will be allocated 100MB of segment host memory at execution time):

```sql
CREATE RESOURCE QUEUE myqueue WITH (ACTIVE_STATEMENTS=20,
   MEMORY_LIMIT='2000MB');
```
Create a resource queue with a query cost limit of 3000.0:

```
CREATE RESOURCE QUEUE myqueue WITH (MAX_COST=3000.0);
```

Create a resource queue with a query cost limit of \(3^{10}\) (or 30000000000.0) and do not allow overcommit. Allow small queries with a cost under 500 to run immediately:

```
CREATE RESOURCE QUEUE myqueue WITH (MAX_COST=3e+10,
    COST_OVERCOMMIT=False, MIN_COST=500.0);
```

Create a resource queue with both an active query limit and a query cost limit:

```
CREATE RESOURCE QUEUE myqueue WITH (ACTIVE_STATEMENTS=30,
    MAX_COST=5000.00);
```

Create a resource queue with an active query limit of 5 and a maximum priority setting:

```
CREATE RESOURCE QUEUE myqueue WITH (ACTIVE_STATEMENTS=5,
    PRIORITY=MAX);
```

**Compatibility**

`CREATE RESOURCE QUEUE` is a Greenplum Database extension. There is no provision for resource queues or resource management in the SQL standard.

**See Also**

`ALTER ROLE, CREATE ROLE, ALTER RESOURCE QUEUE, DROP RESOURCE QUEUE`

---

**CREATE ROLE**

Defines a new database role (user or group).

**Synopsis**

```
CREATE ROLE name [[WITH] option [ ... ]]
```

where `option` can be:

```
SUPERUSER | NOSUPERUSER
| CREATEDB | NOCREATEDB
| CREATEROLE | NOCREATEROLE
| CREATEUSER | NOCREATEUSER
| CREATEEXTTABLE | NOCREATEEXTTABLE
  [ ( attribute='value'[, ...] ) ]
  where attributes and value are:
  type='readable'|'writable'
  protocol='gpfdist'|'http'
| INHERIT | NOINHERIT
| LOGIN | NOLOGIN
| CONNECTION LIMIT connlimit
| [ ENCRYPTED | UNENCRYPTED ] PASSWORD 'password'
| VALID UNTIL 'timestamp'
| IN ROLE rolename [, ...]
| ROLE rolename [, ...]
| ADMIN rolename [, ...]
| RESOURCE QUEUE queue_name
| RESOURCE GROUP group_name
| [ DENY deny_point ]
```
Description

CREATE ROLE adds a new role to a Greenplum Database system. A role is an entity that can own
database objects and have database privileges. A role can be considered a user, a group, or both
depending on how it is used. You must have CREATEROLE privilege or be a database superuser to use this
command.

Note that roles are defined at the system-level and are valid for all databases in your Greenplum Database
system.

Parameters

define name

The name of the new role.

SUPERUSER
NOSUPERUSER

If SUPERUSER is specified, the role being defined will be a superuser, who can override all
access restrictions within the database. Superuser status is dangerous and should be used
only when really needed. You must yourself be a superuser to create a new superuser.
NOSUPERUSER is the default.

CREATEDB
NOCREATEDB

If CREATEDB is specified, the role being defined will be allowed to create new databases.
NOCREATEDB (the default) will deny a role the ability to create databases.

CREATEROLE
NOCREATEROLE

If CREATEROLE is specified, the role being defined will be allowed to create new roles, alter
other roles, and drop other roles. NOCREATEROLE (the default) will deny a role the ability to
create roles or modify roles other than their own.

CREATEUSER
NOCREATEUSER

These clauses are obsolete, but still accepted, spellings of SUPERUSER and
NOSUPERUSER. Note that they are not equivalent to the CREATEROLE and NOCREATEROLE
clauses.

CREATEEXTTABLE
NOCREATEEXTTABLE

If CREATEEXTTABLE is specified, the role being defined is allowed to create external
tables. The default type is readable and the default protocol is gpfdist if not
specified. NOCREATEEXTTABLE (the default) denies the role the ability to create external
tables. Note that external tables that use the file or execute protocols can only be
created by superusers.

INHERIT
NOINHERIT

If specified, INHERIT (the default) allows the role to use whatever database privileges
have been granted to all roles it is directly or indirectly a member of. With NOINHERIT,
membership in another role only grants the ability to SET ROLE to that other role.

LOGIN
NOLOGIN
If specified, `LOGIN` allows a role to log in to a database. A role having the `LOGIN` attribute can be thought of as a user. Roles with `NOLOGIN` (the default) are useful for managing database privileges, and can be thought of as groups.

**CONNECTION LIMIT** *connlimit*

The number maximum of concurrent connections this role can make. The default of -1 means there is no limitation.

**PASSWORD** *password*

Sets the user password for roles with the `LOGIN` attribute. If you do not plan to use password authentication you can omit this option. If no password is specified, the password will be set to null and password authentication will always fail for that user. A null password can optionally be written explicitly as `PASSWORD NULL`.

**ENCRYPTED**

**UNENCRIPTED**

These key words control whether the password is stored encrypted in the system catalogs. (If neither is specified, the default behavior is determined by the configuration parameter `password_encryption`.) If the presented password string is already in MD5-encrypted format, then it is stored encrypted as-is, regardless of whether `ENCRYPTED` or `UNENCRIPTED` is specified (since the system cannot decrypt the specified encrypted password string). This allows reloading of encrypted passwords during dump/restore.

Note that older clients may lack support for the MD5 authentication mechanism that is needed to work with passwords that are stored encrypted.

**VALID UNTIL** `'timestamp'`

The `VALID UNTIL` clause sets a date and time after which the role's password is no longer valid. If this clause is omitted the password will never expire.

**IN ROLE** *rolename*

Adds the new role as a member of the named roles. Note that there is no option to add the new role as an administrator; use a separate `GRANT` command to do that.

**ROLE** *rolename*

Adds the named roles as members of this role, making this new role a group.

**ADMIN** *rolename*

The `ADMIN` clause is like `ROLE`, but the named roles are added to the new role with `ADMIN OPTION`, giving them the right to grant membership in this role to others.

**RESOURCE GROUP** *group_name*

The name of the resource group to assign to the the new role. The role will be subject to the concurrent transaction, memory, and CPU limits configured for the resource group. You can assign a single resource group to one or more roles.

If you do not specify a resource group for a new role, the role is automatically assigned the default resource group for the role's capability, `admin_group` for `SUPERUSER` roles, `default_group` for non-admin roles.

You can assign the `admin_group` resource group to any role having the `SUPERUSER` attribute.

You can assign the `default_group` resource group to any role.

You cannot assign a resource group that you create for an external component to a role.

**RESOURCE QUEUE** *queue_name*

The name of the resource queue to which the new user-level role is to be assigned. Only roles with `LOGIN` privilege can be assigned to a resource queue. The special keyword `NONE` means that the role is assigned to the default resource queue. A role can only belong to one resource queue.
Roles with the SUPERUSER attribute are exempt from resource queue limits. For a superuser role, queries always run immediately regardless of limits imposed by an assigned resource queue.

**DENY deny_point**

**DENY BETWEEN deny_point AND deny_point**

The **DENY** and **DENY BETWEEN** keywords set time-based constraints that are enforced at login. **DENY** sets a day or a day and time to deny access. **DENY BETWEEN** sets an interval during which access is denied. Both use the parameter **deny_point** that has the following format:

```sql
DAY day [ TIME 'time' ]
```

The two parts of the **deny_point** parameter use the following formats:

For day:

```sql
{ 'Sunday' | 'Monday' | 'Tuesday' | 'Wednesday' | 'Thursday' | 'Friday' | 'Saturday' | 0-6 }
```

For time:

```sql
{ 00-23 : 00-59 | 01-12 : 00-59 { AM | PM }}
```

The **DENY BETWEEN** clause uses two **deny_point** parameters:

**DENY BETWEEN deny_point AND deny_point**

For more information and examples about time-based constraints, see "Managing Roles and Privileges" in the Greenplum Database Administrator Guide.

**Notes**

The preferred way to add and remove role members (manage groups) is to use **GRANT** and **REVOKE**.

The **VALID UNTIL** clause defines an expiration time for a password only, not for the role. The expiration time is not enforced when logging in using a non-password-based authentication method.

The **INHERIT** attribute governs inheritance of grantable privileges (access privileges for database objects and role memberships). It does not apply to the special role attributes set by **CREATE ROLE** and **ALTER ROLE**. For example, being a member of a role with **CREATEDB** privilege does not immediately grant the ability to create databases, even if **INHERIT** is set. These privileges/attributes are never inherited: **SUPERUSER**, **CREATEDB**, **CREATEROLE**, **CREATEEXTTABLE**, **LOGIN**, **RESOURCE GROUP**, and **RESOURCE QUEUE**. The attributes must be set on each user-level role.

The **INHERIT** attribute is the default for reasons of backwards compatibility. In prior releases of Greenplum Database, users always had access to all privileges of groups they were members of. However, **NOINHERIT** provides a closer match to the semantics specified in the SQL standard.

Be careful with the **CREATEROLE** privilege. There is no concept of inheritance for the privileges of a **CREATEROLE**-role. That means that even if a role does not have a certain privilege but is allowed to create other roles, it can easily create another role with different privileges than its own (except for creating roles with superuser privileges). For example, if a role has the **CREATEROLE** privilege but not the **CREATEDB** privilege, it can create a new role with the **CREATEDB** privilege. Therefore, regard roles that have the **CREATEROLE** privilege as almost-supersuser-roles.

The **CONNECTION LIMIT** option is never enforced for superusers.

Caution must be exercised when specifying an unencrypted password with this command. The password will be transmitted to the server in clear-text, and it might also be logged in the client’s command history or
the server log. The client program `createuser`, however, transmits the password encrypted. Also, `psql` contains a command `\password` that can be used to safely change the password later.

**Examples**

Create a role that can log in, but don’t give it a password:

```
CREATE ROLE jonathan LOGIN;
```

Create a role that belongs to a resource queue:

```
CREATE ROLE jonathan LOGIN RESOURCE QUEUE poweruser;
```

Create a role with a password that is valid until the end of 2016 (`CREATE USER` is the same as `CREATE ROLE` except that it implies `LOGIN`):

```
CREATE USER joelle WITH PASSWORD 'jw8s0F4' VALID UNTIL '2017-01-01';
```

Create a role that can create databases and manage other roles:

```
CREATE ROLE admin WITH CREATEDB CREATEROLE;
```

Create a role that does not allow login access on Sundays:

```
CREATE ROLE user3 DENY DAY 'Sunday';
```

Create a role, assigning a resource group:

```
CREATE ROLE bill RESOURCE GROUP rg_light;
```

**Compatibility**

The SQL standard defines the concepts of users and roles, but it regards them as distinct concepts and leaves all commands defining users to be specified by the database implementation. In Greenplum Database users and roles are unified into a single type of object. Roles therefore have many more optional attributes than they do in the standard.

`CREATE ROLE` is in the SQL standard, but the standard only requires the syntax:

```
CREATE ROLE name [WITH ADMIN rolename]
```

Allowing multiple initial administrators, and all the other options of `CREATE ROLE`, are Greenplum Database extensions.

The behavior specified by the SQL standard is most closely approximated by giving users the `NOINHERIT` attribute, while roles are given the `INHERIT` attribute.

**See Also**

`SET ROLE`, `ALTER ROLE`, `DROP ROLE`, `GRANT`, `REVOKE`, `CREATE RESOURCE QUEUE`, `CREATE RESOURCE GROUP`

**CREATE RULE**

Defines a new rewrite rule.
Synopsis

```sql
CREATE [OR REPLACE] RULE name AS ON event
  TO table [WHERE condition]
  DO [ALSO | INSTEAD] { NOTHING | command | (command; command
  ...} }
```

Description

CREATE RULE defines a new rule applying to a specified table or view. CREATE OR REPLACE RULE will either create a new rule, or replace an existing rule of the same name for the same table.

The Greenplum Database rule system allows one to define an alternate action to be performed on insertions, updates, or deletions in database tables. A rule causes additional or alternate commands to be executed when a given command on a given table is executed. Rules can be used on views as well. It is important to realize that a rule is really a command transformation mechanism, or command macro. The transformation happens before the execution of the commands starts. It does not operate independently for each physical row as does a trigger.

ON SELECT rules must be unconditional INSTEAD rules and must have actions that consist of a single SELECT command. Thus, an ON SELECT rule effectively turns the table into a view, whose visible contents are the rows returned by the rule's SELECT command rather than whatever had been stored in the table (if anything). It is considered better style to write a CREATE VIEW command than to create a real table and define an ON SELECT rule for it.

You can create the illusion of an updatable view by defining ON INSERT, ON UPDATE, and ON DELETE rules to replace update actions on the view with appropriate updates on other tables.

There is a catch if you try to use conditional rules for view updates: there must be an unconditional INSTEAD rule for each action you wish to allow on the view. If the rule is conditional, or is not INSTEAD, then the system will still reject attempts to perform the update action, because it thinks it might end up trying to perform the action on the dummy table of the view in some cases. If you want to handle all the useful cases in conditional rules, add an unconditional DO INSTEAD NOTHING rule to ensure that the system understands it will never be called on to update the dummy table. Then make the conditional rules non-INSTEAD; in the cases where they are applied, they add to the default INSTEAD NOTHING action. (This method does not currently work to support RETURNING queries, however.)

Parameters

- **name**
  The name of a rule to create. This must be distinct from the name of any other rule for the same table. Multiple rules on the same table and same event type are applied in alphabetical name order.

- **event**
  The event is one of SELECT, INSERT, UPDATE, or DELETE.

- **table**
  The name (optionally schema-qualified) of the table or view the rule applies to.

- **condition**
  Any SQL conditional expression (returning boolean). The condition expression may not refer to any tables except NEW and OLD, and may not contain aggregate functions. NEW and OLD refer to values in the referenced table. NEW is valid in ON INSERT and ON UPDATE rules to refer to the new row being inserted or updated. OLD is valid in ON UPDATE and ON DELETE rules to refer to the existing row being updated or deleted.

- **INSTEAD**
  INSTEAD indicates that the commands should be executed instead of the original command.
**Create a rule that inserts rows into the child table b2001 when a user tries to insert into the partitioned parent table rank:**

```sql
CREATE RULE b2001 AS ON INSERT TO rank WHERE gender='M' and year='2001' DO INSTEAD INSERT INTO b2001 VALUES (NEW.id, NEW.rank, NEW.year, NEW.gender, NEW.count);
```

**Compatibility**

`CREATE RULE` is a Greenplum Database language extension, as is the entire query rewrite system.

**See Also**

`DROP RULE`, `CREATE TABLE`, `CREATE VIEW`

---

**Create Schema**

Defines a new schema.

**Synopsis**

```sql
CREATE SCHEMA schema_name [AUTHORIZATION username] [schema_element [ ... ]]
```

**Description**

`CREATE SCHEMA` enters a new schema into the current database. The schema name must be distinct from the name of any existing schema in the current database.

A schema is essentially a namespace: it contains named objects (tables, data types, functions, and operators) whose names may duplicate those of other objects existing in other schemas. Named objects are accessed either by qualifying their names with the schema name as a prefix, or by setting a search path that includes the desired schema(s). A `CREATE` command specifying an unqualified object name creates the object in the current schema (the one at the front of the search path, which can be determined with the function `current_schema`).
Optionally, `CREATE_SCHEMA` can include subcommands to create objects within the new schema. The subcommands are treated essentially the same as separate commands issued after creating the schema, except that if the `AUTHORIZATION` clause is used, all the created objects will be owned by that role.

**Parameters**

- **schema_name**
  The name of a schema to be created. If this is omitted, the user name is used as the schema name. The name cannot begin with `pg_`, as such names are reserved for system catalog schemas.

- **rolename**
  The name of the role who will own the schema. If omitted, defaults to the role executing the command. Only superusers may create schemas owned by roles other than themselves.

- **schema_element**
  An SQL statement defining an object to be created within the schema. Currently, only `CREATE TABLE`, `CREATE VIEW`, `CREATE INDEX`, `CREATE SEQUENCE`, `CREATE TRIGGER` and `GRANT` are accepted as clauses within `CREATE_SCHEMA`. Other kinds of objects may be created in separate commands after the schema is created.

  **Note:** Greenplum Database does not support triggers.

**Notes**

To create a schema, the invoking user must have the `CREATE` privilege for the current database or be a superuser.

**Examples**

Create a schema:

```
CREATE SCHEMA myschema;
```

Create a schema for role `joe` (the schema will also be named `joe`):

```
CREATE SCHEMA AUTHORIZATION joe;
```

**Compatibility**

The SQL standard allows a `DEFAULT CHARACTER SET` clause in `CREATE_SCHEMA`, as well as more subcommand types than are presently accepted by Greenplum Database.

The SQL standard specifies that the subcommands in `CREATE_SCHEMA` may appear in any order. The present Greenplum Database implementation does not handle all cases of forward references in subcommands; it may sometimes be necessary to reorder the subcommands in order to avoid forward references.

According to the SQL standard, the owner of a schema always owns all objects within it. Greenplum Database allows schemas to contain objects owned by users other than the schema owner. This can happen only if the schema owner grants the `CREATE` privilege on the schema to someone else.

**See Also**

`ALTER_SCHEMA`, `DROP_SCHEMA`

**CREATE_SEQUENCE**

Defines a new sequence generator.
**Synopsis**

```sql
CREATE [TEMPORARY | TEMP] SEQUENCE name
    [INCREMENT [BY] value]
    [MINVALUE minvalue | NO MINVALUE]
    [MAXVALUE maxvalue | NO MAXVALUE]
    [START [ WITH ] start]
    [CACHE cache]
    [[NO] CYCLE]
    [OWNED BY { table.column | NONE }]
```

**Description**

`CREATE SEQUENCE` creates a new sequence number generator. This involves creating and initializing a new special single-row table. The generator will be owned by the user issuing the command.

If a schema name is given, then the sequence is created in the specified schema. Otherwise it is created in the current schema. Temporary sequences exist in a special schema, so a schema name may not be given when creating a temporary sequence. The sequence name must be distinct from the name of any other sequence, table, index, or view in the same schema.

After a sequence is created, you use the `nextval()` function to operate on the sequence. For example, to insert a row into a table that gets the next value of a sequence:

```sql
INSERT INTO distributors VALUES (nextval('myserial'), 'acme');
```

You can also use the function `setval()` to operate on a sequence, but only for queries that do not operate on distributed data. For example, the following query is allowed because it resets the sequence counter value for the sequence generator process on the master:

```sql
SELECT setval('myserial', 201);
```

But the following query will be rejected in Greenplum Database because it operates on distributed data:

```sql
INSERT INTO product VALUES (setval('myserial', 201), 'gizmo');
```

In a regular (non-distributed) database, functions that operate on the sequence go to the local sequence table to get values as they are needed. In Greenplum Database, however, keep in mind that each segment is its own distinct database process. Therefore the segments need a single point of truth to go for sequence values so that all segments get incremented correctly and the sequence moves forward in the right order. A sequence server process runs on the master and is the point-of-truth for a sequence in a Greenplum distributed database. Segments get sequence values at runtime from the master.

Because of this distributed sequence design, there are some limitations on the functions that operate on a sequence in Greenplum Database:

- `lastval()` and `currval()` functions are not supported.
- `setval()` can only be used to set the value of the sequence generator on the master, it cannot be used in subqueries to update records on distributed table data.
- `nextval()` sometimes grabs a block of values from the master for a segment to use, depending on the query. So values may sometimes be skipped in the sequence if all of the block turns out not to be needed at the segment level. Note that a regular PostgreSQL database does this too, so this is not something unique to Greenplum Database.

Although you cannot update a sequence directly, you can use a query like:

```sql
SELECT * FROM sequence_name;
```
to examine the parameters and current state of a sequence. In particular, the last_value field of the
sequence shows the last value allocated by any session.

Parameters

TEMPORARY | TEMP
If specified, the sequence object is created only for this session, and is automatically
dropped on session exit. Existing permanent sequences with the same name are not
visible (in this session) while the temporary sequence exists, unless they are referenced
with schema-qualified names.

name
The name (optionally schema-qualified) of the sequence to be created.

increment
Specifies which value is added to the current sequence value to create a new value. A
positive value will make an ascending sequence, a negative one a descending sequence.
The default value is 1.

minvalue
NO MINVALUE
Determines the minimum value a sequence can generate. If this clause is not supplied or
NO MINVALUE is specified, then defaults will be used. The defaults are 1 and -263-1 for
ascending and descending sequences, respectively.

maxvalue
NO MAXVALUE
Determines the maximum value for the sequence. If this clause is not supplied or NO
MAXVALUE is specified, then default values will be used. The defaults are 263-1 and -1 for
ascending and descending sequences, respectively.

start
Allows the sequence to begin anywhere. The default starting value is minvalue for
ascending sequences and maxvalue for descending ones.

cache
Specifies how many sequence numbers are to be preallocated and stored in memory for
faster access. The minimum (and default) value is 1 (no cache).

CYCLE
NO CYCLE
Allows the sequence to wrap around when the maxvalue (for ascending) or minvalue (for
descending) has been reached. If the limit is reached, the next number generated will
be the minvalue (for ascending) or maxvalue (for descending). If NO CYCLE is specified,
any calls to nextval() after the sequence has reached its maximum value will return an
error. If not specified, NO CYCLE is the default.

OWNED BY table.column
OWNED BY NONE
Causes the sequence to be associated with a specific table column, such that if that
column (or its whole table) is dropped, the sequence will be automatically dropped as
well. The specified table must have the same owner and be in the same schema as the
sequence. OWNED BY NONE, the default, specifies that there is no such association.

Notes
Sequences are based on bigint arithmetic, so the range cannot exceed the range of an eight-byte integer
(-922372036854775808 to 9223372036854775807).
Although multiple sessions are guaranteed to allocate distinct sequence values, the values may be generated out of sequence when all the sessions are considered. For example, session A might reserve values 1..10 and return `nextval=1`, then session B might reserve values 11..20 and return `nextval=11` before session A has generated `nextval=2`. Thus, you should only assume that the `nextval()` values are all distinct, not that they are generated purely sequentially. Also, `last_value` will reflect the latest value reserved by any session, whether or not it has yet been returned by `nextval()`.

**Examples**

Create a sequence named `myseq`:

```sql
CREATE SEQUENCE myseq START 101;
```

Insert a row into a table that gets the next value of the sequence named `idseq`:

```sql
INSERT INTO distributors VALUES (nextval('idseq'), 'acme');
```

Reset the sequence counter value on the master:

```sql
SELECT setval('myseq', 201);
```

Illegal use of `setval()` in Greenplum Database (setting sequence values on distributed data):

```sql
INSERT INTO product VALUES (setval('myseq', 201), 'gizmo');
```

**Compatibility**

`CREATE SEQUENCE` conforms to the SQL standard, with the following exceptions:

- The `AS data_type` expression specified in the SQL standard is not supported.
- Obtaining the next value is done using the `nextval()` function instead of the `NEXT VALUE FOR` expression specified in the SQL standard.
- The `OWNED BY` clause is a Greenplum Database extension.

**See Also**

`ALTER SEQUENCE`, `DROP SEQUENCE`
[ TABLESPACE tablespace ]
[ DISTRIBUTED BY (column, [ ... ] ) | DISTRIBUTED RANDOMLY ]
[ PARTITION BY partition_type (column) ]
[ SUBPARTITION BY partition_type (column) ]
[ SUBPARTITION TEMPLATE ( template_spec ) ]
[ partition_spec ]
[ SUBPARTITION BY partition_type (column) ]
[ partition_spec ]
[ ( subpartition_spec ]
[ (...)]
[ ) ]

where column_constraint is:

[CONSTRAINT constraint_name]
NOT NULL | NULL
| UNIQUE [USING INDEX TABLESPACE tablespace]
[WITH ( FILLFACTOR = value )]
| PRIMARY KEY [USING INDEX TABLESPACE tablespace]
[WITH ( FILLFACTOR = value )]
| CHECK ( expression )
| REFERENCES table_name [ ( column_name [, ... ] ) ]
[ key_match_type ]
[ key_action ]

where storage_directive for a column is:

COMPRESSTYPE={ZLIB | QUICKLZ | RLE_TYPE | NONE}
[COMPRESSLEVEL={0-9} ]
[BLOCKSIZE={8192-2097152} ]

where storage_parameter for the table is:

APPENDONLY={TRUE|FALSE}
BLOCKSIZE={8192-2097152}
ORIENTATION={COLUMN|ROW}
CHECKSUM={TRUE|FALSE}
COMPRESSTYPE={ZLIB|QUICKLZ|RLE_TYPE|NONE}
COMPRESSLEVEL={0-9}
FILLFACTOR={10-100}
OIDS[=TRUE|FALSE]

and table_constraint is:

[CONSTRAINT constraint_name]
UNIQUE ( column_name [, ... ] )
[USING INDEX TABLESPACE tablespace]
[WITH ( FILLFACTOR=value )]
| PRIMARY KEY ( column_name [, ... ] )
[USING INDEX TABLESPACE tablespace]
[WITH ( FILLFACTOR=value )]
| CHECK ( expression )
| FOREIGN KEY ( column_name [, ... ] )
 REFERENCES table_name [ ( column_name [, ... ] ) ]
[ key_match_type ]
[ key_action ]
[ key_checking_mode ]
where `key_match_type` is:

- MATCH FULL
- SIMPLE

where `key_action` is:

- ON DELETE
- ON UPDATE
- NO ACTION
- RESTRICT
- CASCADE
- SET NULL
- SET DEFAULT

where `key_checking_mode` is:

- DEFERRABLE
- NOT DEFERRABLE
- INITIALLY DEFERRED
- INITIALLY IMMEDIATE

where `partition_type` is:

- LIST
- RANGE

where `partition_specification` is:

```
partition_element [, ...]
```

and `partition_element` is:

```
DEFAULT PARTITION name
| [PARTITION name] VALUES (list_value [, ...] )
| [PARTITION name]
  START ([datatype] 'start_value') [INCLUSIVE | EXCLUSIVE]
  [ END ([datatype] 'end_value') [INCLUSIVE | EXCLUSIVE] ]
  [ EVERY ([datatype] [number | INTERVAL] 'interval_value') ]
| [PARTITION name]
  END ([datatype] 'end_value') [INCLUSIVE | EXCLUSIVE]
  [ EVERY ([datatype] [number | INTERVAL] 'interval_value') ]
  [ WITH ( partition_storage_parameter=value [, ... ] ) ]
  [ TABLESPACE tablespace ]
```

where `subpartition_spec` or `template_spec` is:

```
subpartition_element [, ...]
```

and `subpartition_element` is:

```
DEFAULT SUBPARTITION name
| [SUBPARTITION name] VALUES (list_value [, ...] )
| [SUBPARTITION name]
  START ([datatype] 'start_value') [INCLUSIVE | EXCLUSIVE]
  [ END ([datatype] 'end_value') [INCLUSIVE | EXCLUSIVE] ]
  [ EVERY ([datatype] [number | INTERVAL] 'interval_value') ]
| [SUBPARTITION name]
  END ([datatype] 'end_value') [INCLUSIVE | EXCLUSIVE]
  [ EVERY ([datatype] [number | INTERVAL] 'interval_value') ]
```
where storage_parameter for a partition is:

- **APPENDONLY**={TRUE|FALSE}
- **BLOCKSIZE**={8192-2097152}
- **ORIENTATION**={COLUMN|ROW}
- **CHECKSUM**={TRUE|FALSE}
- **COMPRESSTYPE**={ZLIB|QUICKLZ|RLE_TYPE|NONE}
- **COMPRESSLEVEL**={1-9}
- **FILLFACTOR**={10-100}
- **OIDS**[=TRUE|FALSE]

### Description

**CREATE TABLE** creates an initially empty table in the current database. The user who issues the command owns the table.

If you specify a schema name, Greenplum creates the table in the specified schema. Otherwise Greenplum creates the table in the current schema. Temporary tables exist in a special schema, so you cannot specify a schema name when creating a temporary table. Table names must be distinct from the name of any other table, external table, sequence, index, or view in the same schema.

The optional constraint clauses specify conditions that new or updated rows must satisfy for an insert or update operation to succeed. A constraint is an SQL object that helps define the set of valid values in the table in various ways. Constraints apply to tables, not to partitions. You cannot add a constraint to a partition or subpartition.

Referential integrity constraints (foreign keys) are accepted but not enforced. The information is kept in the system catalogs but is otherwise ignored.

There are two ways to define constraints: table constraints and column constraints. A column constraint is defined as part of a column definition. A table constraint definition is not tied to a particular column, and it can encompass more than one column. Every column constraint can also be written as a table constraint; a column constraint is only a notational convenience for use when the constraint only affects one column.

When creating a table, there is an additional clause to declare the Greenplum Database distribution policy. If a **DISTRIBUTED BY** or **DISTRIBUTED RANDOMLY** clause is not supplied, then Greenplum assigns a hash distribution policy to the table using either the **PRIMARY KEY** (if the table has one) or the first column of the table as the distribution key. Columns of geometric or user-defined data types are not eligible as Greenplum distribution key columns. If a table does not have a column of an eligible data type, the rows are distributed based on a round-robin or random distribution. To ensure an even distribution of data in your Greenplum Database system, you want to choose a distribution key that is unique for each record, or if that is not possible, then choose **DISTRIBUTED RANDOMLY**.

The **PARTITION BY** clause allows you to divide the table into multiple sub-tables (or parts) that, taken together, make up the parent table and share its schema. Though the sub-tables exist as independent tables, the Greenplum Database restricts their use in important ways. Internally, partitioning is implemented as a special form of inheritance. Each child table partition is created with a distinct **CHECK** constraint which limits the data the table can contain, based on some defining criteria. The **CHECK** constraints are also used by the query optimizer to determine which table partitions to scan in order to satisfy a given query predicate. These partition constraints are managed automatically by the Greenplum Database.

### Parameters

- **GLOBAL | LOCAL**
  
  These keywords are present for SQL standard compatibility, but have no effect in Greenplum Database.
TEMPORARY | TEMP

If specified, the table is created as a temporary table. Temporary tables are automatically dropped at the end of a session, or optionally at the end of the current transaction (see ON COMMIT). Existing permanent tables with the same name are not visible to the current session while the temporary table exists, unless they are referenced with schema-qualified names. Any indexes created on a temporary table are automatically temporary as well.

table_name

The name (optionally schema-qualified) of the table to be created.

column_name

The name of a column to be created in the new table.

data_type

The data type of the column. This may include array specifiers.

For table columns that contain textual data, Specify the data type VARCHAR or TEXT. Specifying the data type CHAR is not recommended. In Greenplum Database, the data types VARCHAR or TEXT handles padding added to the data (space characters added after the last non-space character) as significant characters, the data type CHAR does not. See Notes.

DEFAULT default_expr

The DEFAULT clause assigns a default data value for the column whose column definition it appears within. The value is any variable-free expression (subqueries and cross-references to other columns in the current table are not allowed). The data type of the default expression must match the data type of the column. The default expression will be used in any insert operation that does not specify a value for the column. If there is no default for a column, then the default is null.

ENCODING (storage_directive [, ...] )

For a column, the optional ENCODING clause specifies the type of compression and block size for the column data. See storage_options for COMPRESSTYPE, COMPRESSLEVEL, and BLOCKSIZE values.

The clause is valid only for append-optimized, column-oriented tables.

Column compression settings are inherited from the table level to the partition level to the subpartition level. The lowest-level settings have priority.

INHERITS

The optional INHERITS clause specifies a list of tables from which the new table automatically inherits all columns. Use of INHERITS creates a persistent relationship between the new child table and its parent table(s). Schema modifications to the parent(s) normally propagate to children as well, and by default the data of the child table is included in scans of the parent(s).

In Greenplum Database, the INHERITS clause is not used when creating partitioned tables. Although the concept of inheritance is used in partition hierarchies, the inheritance structure of a partitioned table is created using the PARTITION BY clause.

If the same column name exists in more than one parent table, an error is reported unless the data types of the columns match in each of the parent tables. If there is no conflict, then the duplicate columns are merged to form a single column in the new table. If the column name list of the new table contains a column name that is also inherited, the data type must likewise match the inherited column(s), and the column definitions are merged into one. However, inherited and new column declarations of the same name need not specify identical constraints: all constraints provided from any declaration are merged together and all are applied to the new table. If the new table explicitly specifies a default value for the column, this default overrides any defaults from inherited declarations of the
column. Otherwise, any parents that specify default values for the column must all specify the same default, or an error will be reported.

\textit{LIKE other_table \{\{INCLUDING | EXCLUDING\} \{DEFAULTS | CONSTRAINTS\}\}}

The \textit{LIKE} clause specifies a table from which the new table automatically copies all column names, data types, not-null constraints, and distribution policy. Storage properties like append-optimized or partition structure are not copied. Unlike \textit{INHERITS}, the new table and original table are completely decoupled after creation is complete.

Default expressions for the copied column definitions will only be copied if \textit{INCLUDING DEFAULTS} is specified. The default behavior is to exclude default expressions, resulting in the copied columns in the new table having null defaults.

Not-null constraints are always copied to the new table. \textit{CHECK} constraints will only be copied if \textit{INCLUDING CONSTRAINTS} is specified; other types of constraints will never be copied. Also, no distinction is made between column constraints and table constraints — when constraints are requested, all check constraints are copied.

Note also that unlike \textit{INHERITS}, copied columns and constraints are not merged with similarly named columns and constraints. If the same name is specified explicitly or in another \textit{LIKE} clause an error is signalled.

\textit{CONSTRAINT constraint_name}

An optional name for a column or table constraint. If the constraint is violated, the constraint name is present in error messages, so constraint names like \textit{column must be positive} can be used to communicate helpful constraint information to client applications. (Double-quotes are needed to specify constraint names that contain spaces.) If a constraint name is not specified, the system generates a name.

\textbf{Note:} The specified \textit{constraint_name} is used for the constraint, but a system-generated unique name is used for the index name. In some prior releases, the provided name was used for both the constraint name and the index name.

\textbf{NULL | NOT NULL}

Specifies if the column is or is not allowed to contain null values. \textbf{NULL} is the default.

\textbf{UNIQUE ( column constraint )}
\textbf{UNIQUE ( column_name [ , ... ] ) ( table constraint )}

The \textbf{UNIQUE} constraint specifies that a group of one or more columns of a table may contain only unique values. The behavior of the unique table constraint is the same as that for column constraints, with the additional capability to span multiple columns. For the purpose of a unique constraint, null values are not considered equal. The column(s) that are unique must contain all the columns of the Greenplum distribution key. In addition, the \textit{<key>} must contain all the columns in the partition key if the table is partitioned. Note that a \textit{<key>} constraint in a partitioned table is not the same as a simple \textbf{UNIQUE INDEX}.

For information about unique constraint management and limitations, see \textit{Notes}.

\textbf{PRIMARY KEY ( column constraint )}
\textbf{PRIMARY KEY ( column_name [ , ... ] ) ( table constraint )}

The primary key constraint specifies that a column or columns of a table may contain only unique (non-duplicate), non-null values. Technically, \textbf{PRIMARY KEY} is merely a combination of \textbf{UNIQUE} and \textbf{NOT NULL}, but identifying a set of columns as primary key also provides metadata about the design of the schema, as a primary key implies that other tables may rely on this set of columns as a unique identifier for rows. For a table to have a primary key, it must be hash distributed (not randomly distributed), and the primary key. The column(s) that are unique must contain all the columns of the Greenplum distribution key. In addition, the \textit{<key>} must contain all the columns in the partition key if
the table is partitioned. Note that a `<key>` constraint in a partitioned table is not the same as a simple UNIQUE INDEX.

For information about primary key management and limitations, see Notes.

**CHECK ( expression )**

The CHECK clause specifies an expression producing a Boolean result which new or updated rows must satisfy for an insert or update operation to succeed. Expressions evaluating to TRUE or UNKNOWN succeed. Should any row of an insert or update operation produce a FALSE result an error exception is raised and the insert or update does not alter the database. A check constraint specified as a column constraint should reference that column's value only, while an expression appearing in a table constraint may reference multiple columns. CHECK expressions cannot contain subqueries nor refer to variables other than columns of the current row.

**REFERENCES table_name [ ( column_name [, ... ] ) ]**

**FOREIGN KEY ( column_name [, ... ] )**

REFERENCES table_name [ ( column_name [, ... ] ) ]

[ key_match_type ] [ key_action ]

The REFERENCES and FOREIGN KEY clauses specify referential integrity constraints (foreign key constraints). Greenplum accepts referential integrity constraints as specified in PostgreSQL syntax but does not enforce them. See the PostgreSQL documentation for information about referential integrity constraints.

**WITH ( storage_option=value )**

The WITH clause can be used to set storage options for the table or its indexes. Note that you can also set storage parameters on a particular partition or subpartition by declaring the WITH clause in the partition specification. The lowest-level settings have priority.

The defaults for some of the table storage options can be specified with the server configuration parameter `gp_default_storage_options`. For information about setting default storage options, see Notes.

The following storage options are available:

**APPENDONLY** — Set to TRUE to create the table as an append-optimized table. If FALSE or not declared, the table will be created as a regular heap-storage table.

**BLOCKSIZE** — Set to the size, in bytes for each block in a table. The BLOCKSIZE must be between 8192 and 2097152 bytes, and be a multiple of 8192. The default is 32768.

**ORIENTATION** — Set to column for column-oriented storage, or row (the default) for row-oriented storage. This option is only valid if APPENDONLY=TRUE. Heap-storage tables can only be row-oriented.

**CHECKSUM** — This option is valid only for append-optimized tables (APPENDONLY=TRUE). The value TRUE is the default and enables CRC checksum validation for append-optimized tables. The checksum is calculated during block creation and is stored on disk. Checksum validation is performed during block reads. If the checksum calculated during the read does not match the stored checksum, the transaction is aborted. If you set the value to FALSE to disable checksum validation, checking the table data for on-disk corruption will not be performed.

**COMPRESSION** — Set to ZLIB (the default), RLE-TYPE, or QUICKLZ\(^1\) to specify the type of compression used. The value NONE disables compression. QuickLZ uses less CPU power and compresses data faster at a lower compression ratio than zlib. Conversely, zlib provides more compact compression ratios at lower speeds. This option is only valid if APPENDONLY=TRUE.

Note:\(^1\)QuickLZ compression is available only in the commercial release of Pivotal Greenplum Database.
The value RLE_TYPE is supported only if ORIENTATION = column is specified. Greenplum Database uses the run-length encoding (RLE) compression algorithm. RLE compresses data better than the zlib or QuickLZ compression algorithm when the same data value occurs in many consecutive rows.

For columns of type BIGINT, INTEGER, DATE, TIME, or TIMESTAMP, delta compression is also applied if the COMPRESSTYPE option is set to RLE-TYPE compression. The delta compression algorithm is based on the delta between column values in consecutive rows and is designed to improve compression when data is loaded in sorted order or the compression is applied to column data that is in sorted order.

For information about using table compression, see "Choosing the Table Storage Model" in the Greenplum Database Administrator Guide.

**COMPRESSLEVEL** — For zlib compression of append-optimized tables, set to an integer value between 1 (fastest compression) to 9 (highest compression ratio). QuickLZ compression level can only be set to 1. If not declared, the default is 1. For RLE_TYPE, the compression level can be set an integer value between 1 (fastest compression) to 4 (highest compression ratio).

This option is valid only if APPENDONLY=True.

**FILLFACTOR** — See CREATE_INDEX for more information about this index storage parameter.

**OIDS** — Set to OIDS=FALSE (the default) so that rows do not have object identifiers assigned to them. Greenplum strongly recommends that you do not enable OIDS when creating a table. On large tables, such as those in a typical Greenplum Database system, using OIDs for table rows can cause wrap-around of the 32-bit OID counter. Once the counter wraps around, OIDs can no longer be assumed to be unique, which not only makes them useless to user applications, but can also cause problems in the Greenplum Database system catalog tables. In addition, excluding OIDs from a table reduces the space required to store the table on disk by 4 bytes per row, slightly improving performance. OIDs are not allowed on partitioned tables or append-optimized column-oriented tables.

**ON COMMIT**

The behavior of temporary tables at the end of a transaction block can be controlled using ON COMMIT. The three options are:

**PRESEVER ROWS** - No special action is taken at the ends of transactions for temporary tables. This is the default behavior.

**DELETE ROWS** - All rows in the temporary table will be deleted at the end of each transaction block. Essentially, an automatic TRUNCATE is done at each commit.

**DROP** - The temporary table will be dropped at the end of the current transaction block.

**TABLESPACE tablespace**

The name of the tablespace in which the new table is to be created. If not specified, the database’s default tablespace is used.

**USING INDEX TABLESPACE tablespace**

This clause allows selection of the tablespace in which the index associated with a UNIQUE or PRIMARY KEY constraint will be created. If not specified, the database’s default tablespace is used.

**DISTRIBUTED BY (column, [ ... ] )**

**DISTRIBUTED RANDOMLY**

Used to declare the Greenplum Database distribution policy for the table. DISTRIBUTED BY uses hash distribution with one or more columns declared as the distribution key. For the most even data distribution, the distribution key should be the primary key of the
table or a unique column (or set of columns). If that is not possible, then you may choose DISTRIBUTED RANDOMLY, which will send the data round-robin to the segment instances.

The Greenplum Database server configuration parameter gp_create_table_random_default_distribution controls the default table distribution policy if the DISTRIBUTED BY clause is not specified when you create a table. Greenplum Database follows these rules to create a table if a distribution policy is not specified.

If the value of the parameter is off (the default), Greenplum Database chooses the table distribution key based on the command. If the LIKE or INHERITS clause is specified in table creation command, the created table uses the same distribution key as the source or parent table.

If the value of the parameter is set to on, Greenplum Database follows these rules:

- If PRIMARY KEY or UNIQUE columns are not specified, the distribution of the table is random (DISTRIBUTED RANDOMLY). Table distribution is random even if the table creation command contains the LIKE or INHERITS clause.
- If PRIMARY KEY or UNIQUE columns are specified, a DISTRIBUTED BY clause must also be specified. If a DISTRIBUTED BY clause is not specified as part of the table creation command, the command fails.

For information about the parameter, see "Server Configuration Parameters."

PARTITION BY
Declares one or more columns by which to partition the table.

When creating a partitioned table, Greenplum Database creates the root partitioned table (the root partition) with the specified table name. Greenplum Database also creates a hierarchy of tables, child tables, that are the subpartitions based on the partitioning options that you specify. The Greenplum Database pg_partition* system views contain information about the subpartition tables.

For each partition level (each hierarchy level of tables), a partitioned table can have a maximum of 32,767 partitions.

Note: Greenplum Database stores partitioned table data in the leaf child tables, the lowest-level tables in the hierarchy of child tables for use by the partitioned table.

partition_type
Declares partition type: LIST (list of values) or RANGE (a numeric or date range).

partition_specification
Declares the individual partitions to create. Each partition can be defined individually or, for range partitions, you can use the EVERY clause (with a START and optional END clause) to define an increment pattern to use to create the individual partitions.

DEFAULT PARTITION name — Declares a default partition. When data does not match to an existing partition, it is inserted into the default partition. Partition designs that do not have a default partition will reject incoming rows that do not match to an existing partition.

PARTITION name — Declares a name to use for the partition. Partitions are created using the following naming convention: parentname_level#_prt_givenname.

VALUES — For list partitions, defines the value(s) that the partition will contain.

START — For range partitions, defines the starting range value for the partition. By default, start values are INCLUSIVE. For example, if you declared a start date of '2016-01-01', then the partition would contain all dates greater than or equal to '2016-01-01'. Typically the data type of the START expression is the same type as the partition key column. If that is not the case, then you must explicitly cast to the intended data type.
**END** — For range partitions, defines the ending range value for the partition. By default, end values are **EXCLUSIVE**. For example, if you declared an end date of '2016-02-01', then the partition would contain all dates less than but not equal to '2016-02-01'. Typically the data type of the **END** expression is the same type as the partition key column. If that is not the case, then you must explicitly cast to the intended data type.

**EVERY** — For range partitions, defines how to increment the values from **START** to **END** to create individual partitions. Typically the data type of the **EVERY** expression is the same type as the partition key column. If that is not the case, then you must explicitly cast to the intended data type.

**WITH** — Sets the table storage options for a partition. For example, you may want older partitions to be append-optimized tables and newer partitions to be regular heap tables.

**TABLESPACE** — The name of the tablespace in which the partition is to be created.

**SUBPARTITION BY**

Declares one or more columns by which to subpartition the first-level partitions of the table. The format of the subpartition specification is similar to that of a partition specification described above.

**SUBPARTITION TEMPLATE**

Instead of declaring each subpartition definition individually for each partition, you can optionally declare a subpartition template to be used to create the subpartitions (lower level child tables). This subpartition specification would then apply to all parent partitions.

**Notes**

- In Greenplum Database (a Postgres-based system) the data types **VARCHAR** or **TEXT** handles padding added to the textual data (space characters added after the last non-space character) as significant characters, the data type **CHAR** does not.

  In Greenplum Database, values of type **CHAR(n)** are padded with trailing spaces to the specified width n. The values are stored and displayed with the spaces. However, the padding spaces are treated as semantically insignificant. When the values are distributed, the trailing spaces are disregarded. The trailing spaces are also treated as semantically insignificant when comparing two values of data type **CHAR**, and the trailing spaces are removed when converting a character value to one of the other string types.

- Using OIDs in new applications is not recommended: where possible, using a **SERIAL** or other sequence generator as the table’s primary key is preferred. However, if your application does make use of OIDs to identify specific rows of a table, it is recommended to create a unique constraint on the OID column of that table, to ensure that OIDs in the table will indeed uniquely identify rows even after counter wrap-around. Avoid assuming that OIDs are unique across tables; if you need a database-wide unique identifier, use the combination of table OID and row OID for the purpose.

- Greenplum Database has some special conditions for primary key and unique constraints with regards to columns that are the distribution key in a Greenplum table. For a unique constraint to be enforced in Greenplum Database, the table must be hash-distributed (not **DISTRIBUTED RANDOMLY**), and the constraint columns must be the same as (or a superset of) the table’s distribution key columns. Also, the distribution key must be a left-subset of the constraint columns with the columns in the correct order. For example, if the primary key is (a,b,c), the distribution key can be only one of the following: (a), (a,b), or (a,b,c).

  A primary key constraint is simply a combination of a unique constraint and a not-null constraint.

  Greenplum Database automatically creates a **UNIQUE** index for each **UNIQUE** or **PRIMARY KEY** constraint to enforce uniqueness. Thus, it is not necessary to create an index explicitly for primary key columns. **UNIQUE** and **PRIMARY KEY** constraints are not allowed on append-optimized tables because the **UNIQUE** indexes that are created by the constraints are not allowed on append-optimized tables.

  Foreign key constraints are not supported in Greenplum Database.
For inherited tables, unique constraints, primary key constraints, indexes and table privileges are not inherited in the current implementation.

- For append-optimized tables, UPDATE and DELETE are not allowed in a serializable transaction and will cause the transaction to abort. CLUSTER, DECLARE...FORUPDATE, and triggers are not supported with append-optimized tables.

- To insert data into a partitioned table, you specify the root partitioned table, the table created with the CREATE TABLE command. You also can specify a leaf child table of the partitioned table in an INSERT command. An error is returned if the data is not valid for the specified leaf child table. Specifying a child table that is not a leaf child table in the INSERT command is not supported. Execution of other DML commands such as UPDATE and DELETE on any child table of a partitioned table is not supported. These commands must be executed on the root partitioned table, the table created with the CREATE TABLE command.

- The default values for these table storage options can be specified with the server configuration parameter gp_default_storage_option.
  - APPENDONLY
  - BLOCKSIZE
  - CHECKSUM
  - COMPRESSTYPE
  - COMPRESSLEVEL
  - ORIENTATION

The defaults can be set for the system, a database, or a user. For information about setting storage options, see the server configuration parameter gp_default_storage_options.

Important: The current Greenplum Database legacy optimizer allows list partitions with multi-column (composite) partition keys. GPORCA does not support composite keys, so using composite partition keys is not recommended.

Examples

Create a table named rank in the schema named baby and distribute the data using the columns rank, gender, and year:

```sql
CREATE TABLE baby.rank (id int, rank int, year smallint, gender char(1), count int ) DISTRIBUTED BY (rank, gender, year);
```

Create table films and table distributors (the primary key will be used as the Greenplum distribution key by default):

```sql
CREATE TABLE films (code char(5) CONSTRAINT firstkey PRIMARY KEY, title varchar(40) NOT NULL, did integer NOT NULL, date_prod date, kind varchar(10), len interval hour to minute );
CREATE TABLE distributors (did integer PRIMARY KEY DEFAULT nextval('serial'), name varchar(40) NOT NULL CHECK (name <> '') );
```

Create a gzip-compressed, append-optimized table:

```sql
CREATE TABLE sales (txn_id int, qty int, date date)
```
WITH (appendonly=true, compresslevel=5)
DISTRIBUTED BY (txn_id);

Create a three level partitioned table using subpartition templates and default partitions at each level:

CREATE TABLE sales (id int, year int, month int, day int, region text)
DISTRIBUTED BY (id)
PARTITION BY RANGE (year)
    SUBPARTITION BY RANGE (month)
        SUBPARTITION TEMPLATE (
            START (1) END (13) EVERY (1),
            DEFAULT SUBPARTITION other_months )
    SUBPARTITION BY LIST (region)
        SUBPARTITION TEMPLATE (  
            SUBPARTITION usa VALUES ('usa'),
            SUBPARTITION europe VALUES ('europe'),
            SUBPARTITION asia VALUES ('asia'),
            DEFAULT SUBPARTITION other_regions )
    ( START (2008) END (2016) EVERY (1),
    DEFAULT PARTITION outlying_years);

Compatibility

CREATE TABLE command conforms to the SQL standard, with the following exceptions:

- **Temporary Tables** — In the SQL standard, temporary tables are defined just once and automatically exist (starting with empty contents) in every session that needs them. Greenplum Database instead requires each session to issue its own CREATE TEMPORARY TABLE command for each temporary table to be used. This allows different sessions to use the same temporary table name for different purposes, whereas the standard's approach constrains all instances of a given temporary table name to have the same table structure.

  The standard's distinction between global and local temporary tables is not in Greenplum Database. Greenplum Database will accept the GLOBAL and LOCAL keywords in a temporary table declaration, but they have no effect.

  If the ON COMMIT clause is omitted, the SQL standard specifies that the default behavior as ON COMMIT DELETE ROWS. However, the default behavior in Greenplum Database is ON COMMIT PRESERVE ROWS. The ON COMMIT DROP option does not exist in the SQL standard.

- **Column Check Constraints** — The SQL standard says that CHECK column constraints may only refer to the column they apply to; only CHECK table constraints may refer to multiple columns. Greenplum Database does not enforce this restriction; it treats column and table check constraints alike.

- **NULL Constraint** — The NULL constraint is a Greenplum Database extension to the SQL standard that is included for compatibility with some other database systems (and for symmetry with the NOT NULL constraint). Since it is the default for any column, its presence is not required.

- **Inheritance** — Multiple inheritance via the INHERITS clause is a Greenplum Database language extension. SQL:1999 and later define single inheritance using a different syntax and different semantics. SQL:1999-style inheritance is not yet supported by Greenplum Database.

- **Partitioning** — Table partitioning via the PARTITION BY clause is a Greenplum Database language extension.

- **Zero-column tables** — Greenplum Database allows a table of no columns to be created (for example, CREATE TABLE foo();). This is an extension from the SQL standard, which does not allow zero-column tables. Zero-column tables are not in themselves very useful, but disallowing them creates odd special cases for ALTER TABLE DROP COLUMN, so Greenplum decided to ignore this spec restriction.
• **WITH clause** — The `WITH` clause is a Greenplum Database extension; neither storage parameters nor OIDs are in the standard.

• **Tablespaces** — The Greenplum Database concept of tablespaces is not part of the SQL standard. The clauses `TABLESPACE` and `USING INDEX TABLESPACE` are extensions.

• **Data Distribution** — The Greenplum Database concept of a parallel or distributed database is not part of the SQL standard. The `DISTRIBUTED` clauses are extensions.

**See Also**

`ALTER TABLE`, `DROP TABLE`, `CREATE EXTERNAL TABLE`, `CREATE TABLE AS`

### CREATE TABLE AS

Defines a new table from the results of a query.

#### Synopsis

```sql
CREATE [ [GLOBAL | LOCAL] [TEMPORARY | TEMP] ] TABLE table_name
  [((column_name [, ...] ))]
  [ WITH (storage_parameter=value [, ... ] ) ]
  [ON COMMIT {PRESERVE ROWS | DELETE ROWS | DROP}]
  [TABLESPACE tablespace]
  AS query
  [DISTRIBUTED BY (column, [ ... ] ) | DISTRIBUTED RANDOMLY]
```

where `storage_parameter` is:

- `APPENDONLY={TRUE|FALSE}`
- `BLOCKSIZE={8192-2097152}`
- `ORIENTATION={COLUMN|ROW}`
- `COMPRESSTYPE={ZLIB|QUICKLZ}`
- `COMPRESSLEVEL={1-9 | 1}`
- `FILLFACTOR={10-100}`
- `OID[S]={[TRUE|FALSE]}

#### Description

`CREATE TABLE AS` creates a table and fills it with data computed by a `SELECT` command. The table columns have the names and data types associated with the output columns of the `SELECT`, however you can override the column names by giving an explicit list of new column names.

`CREATE TABLE AS` creates a new table and evaluates the query just once to fill the new table initially. The new table will not track subsequent changes to the source tables of the query.

#### Parameters

- **GLOBAL | LOCAL**

  These keywords are present for SQL standard compatibility, but have no effect in Greenplum Database.

- **TEMPORARY | TEMP**

  If specified, the new table is created as a temporary table. Temporary tables are automatically dropped at the end of a session, or optionally at the end of the current transaction (see `ON COMMIT`). Existing permanent tables with the same name are not visible to the current session while the temporary table exists, unless they are referenced with schema-qualified names. Any indexes created on a temporary table are automatically temporary as well.

- **table_name**
The name (optionally schema-qualified) of the new table to be created.

\textit{column\_name}

The name of a column in the new table. If column names are not provided, they are taken from the output column names of the query. If the table is created from an \texttt{EXECUTE} command, a column name list cannot be specified.

\textbf{WITH (} \textit{storage\_parameter=value} )

The \texttt{WITH} clause can be used to set storage options for the table or its indexes. Note that you can also set different storage parameters on a particular partition or subpartition by declaring the \texttt{WITH} clause in the partition specification. The following storage options are available:

\begin{itemize}
  \item \texttt{APPENDONLY} — Set to \texttt{TRUE} to create the table as an append-optimized table. If \texttt{FALSE} or not declared, the table will be created as a regular heap-storage table.
  \item \texttt{BLOCKSIZE} — Set to the size, in bytes for each block in a table. The \texttt{BLOCKSIZE} must be between 8192 and 2097152 bytes, and be a multiple of 8192. The default is 32768.
  \item \texttt{ORIENTATION} — Set to \texttt{column} for column-oriented storage, or \texttt{row} (the default) for row-oriented storage. This option is only valid if \texttt{APPENDONLY=TRUE}. Heap-storage tables can only be row-oriented.
  \item \texttt{COMPRESSTYPE} — Set to \texttt{ZLIB} (the default) or \texttt{QUICKLZ} \(^1\) to specify the type of compression used. QuickLZ uses less CPU power and compresses data faster at a lower compression ratio than zlib. Conversely, zlib provides more compact compression ratios at lower speeds. This option is only valid if \texttt{APPENDONLY=TRUE}.
\end{itemize}

\textbf{Note:} \(^1\)QuickLZ compression is available only in the commercial release of Pivotal Greenplum Database.

\texttt{COMPRESSLEVEL} — For zlib compression of append-optimized tables, set to a value between 1 (fastest compression) to 9 (highest compression ratio). QuickLZ compression level can only be set to 1. If not declared, the default is 1. This option is only valid if \texttt{APPENDONLY=TRUE}.

\texttt{FILLFACTOR} — See \texttt{CREATE INDEX} for more information about this index storage parameter.

\texttt{OIDS} — Set to \texttt{OIDS=FALSE} (the default) so that rows do not have object identifiers assigned to them. Greenplum strongly recommends that you do not enable OIDS when creating a table. On large tables, such as those in a typical Greenplum Database system, using OIDs for table rows can cause wrap-around of the 32-bit OID counter. Once the counter wraps around, OIDs can no longer be assumed to be unique, which not only makes them useless to user applications, but can also cause problems in the Greenplum Database system catalog tables. In addition, excluding OIDs from a table reduces the space required to store the table on disk by 4 bytes per row, slightly improving performance. OIDs are not allowed on column-oriented tables.

\textbf{ON COMMIT}

The behavior of temporary tables at the end of a transaction block can be controlled using \texttt{ON COMMIT}. The three options are:

\begin{itemize}
  \item \texttt{PRESERVE ROWS} — No special action is taken at the ends of transactions for temporary tables. This is the default behavior.
  \item \texttt{DELETE ROWS} — All rows in the temporary table will be deleted at the end of each transaction block. Essentially, an automatic \texttt{TRUNCATE} is done at each commit.
  \item \texttt{DROP} — The temporary table will be dropped at the end of the current transaction block.
\end{itemize}

\textbf{TABLESPACE} \textit{tablespace}

The tablespace is the name of the tablespace in which the new table is to be created. If not specified, the database's default tablespace is used.
AS query

A SELECT or VALUES command, or an EXECUTE command that runs a prepared SELECT or VALUES query.

DISTRIBUTED BY (column, [ ... ] )

DISTRIBUTED RANDOMLY

Used to declare the Greenplum Database distribution policy for the table. DISTRIBUTED BY uses hash distribution with one or more columns declared as the distribution key. For the most even data distribution, the distribution key should be the primary key of the table or a unique column (or set of columns). If that is not possible, then you may choose DISTRIBUTED RANDOMLY, which will send the data round-robin to the segment instances.

The Greenplum Database server configuration parameter gp_create_table_random_default_distribution controls the default table distribution policy if the DISTRIBUTED BY clause is not specified when you create a table. Greenplum Database follows these rules to create a table if a distribution policy is not specified.

• If the legacy query optimizer creates the table, and the value of the parameter is off, the table distribution policy is determined based on the command.
• If the legacy query optimizer creates the table, and the value of the parameter is on, the table distribution policy is random.
• If GPORCA creates the table, the table distribution policy is random. The parameter value has no affect.

For information about the parameter, see "Server Configuration Parameters." For information about the legacy query optimizer and GPORCA, see "Querying Data" in the Greenplum Database Administrator Guide.

Notes

This command is functionally similar to SELECT INTO, but it is preferred since it is less likely to be confused with other uses of the SELECT INTO syntax. Furthermore, CREATE TABLE AS offers a superset of the functionality offered by SELECT INTO.

CREATE TABLE AS can be used for fast data loading from external table data sources. See CREATE EXTERNAL TABLE.

Examples

Create a new table films_recent consisting of only recent entries from the table films:

```
CREATE TABLE films_recent AS SELECT * FROM films WHERE date_prod >= '2007-01-01';
```

Create a new temporary table films_recent, consisting of only recent entries from the table films, using a prepared statement. The new table has OIDs and will be dropped at commit:

```
PREPARE recentfilms(date) AS SELECT * FROM films WHERE date_prod > $1;
CREATE TEMP TABLE films_recent WITH (OIDS) ON COMMIT DROP AS EXECUTE recentfilms('2007-01-01');
```

Compatibility

CREATE TABLE AS conforms to the SQL standard, with the following exceptions:

• The standard requires parentheses around the subquery clause; in Greenplum Database, these parentheses are optional.
The standard defines a WITH [NO] DATA clause; this is not currently implemented by Greenplum Database. The behavior provided by Greenplum Database is equivalent to the standard's WITH DATA case. WITH NO DATA can be simulated by appending LIMIT 0 to the query.

Greenplum Database handles temporary tables differently from the standard; see CREATE TABLE for details.

The WITH clause is a Greenplum Database extension; neither storage parameters nor OIDs are in the standard.

The Greenplum Database concept of tablespaces is not part of the standard. The TABLESPACE clause is an extension.

### See Also

CREATE EXTERNAL TABLE, CREATE EXTERNAL TABLE, EXECUTE, SELECT, SELECT INTO, VALUES

### CREATE TABLESPACE

Defines a new tablespace.

#### Synopsis

```
CREATE TABLESPACE tablespace_name [OWNER username] FILESPACE filename
```

#### Description

CREATE TABLESPACE registers a new tablespace for your Greenplum Database system. The tablespace name must be distinct from the name of any existing tablespace in the system.

A tablespace allows superusers to define an alternative location on the file system where the data files containing database objects (such as tables and indexes) may reside.

A user with appropriate privileges can pass a tablespace name to CREATE DATABASE, CREATE TABLE, or CREATE INDEX to have the data files for these objects stored within the specified tablespace.

In Greenplum Database, there must be a file system location defined for the master, each primary segment, and each mirror segment in order for the tablespace to have a location to store its objects across an entire Greenplum system. This collection of file system locations is defined in a filespace object. A filespace must be defined before you can create a tablespace. See gpfilespace in the Greenplum Database Utility Guide for more information.

#### Parameters

- **tablespacename**
  
  The name of a tablespace to be created. The name cannot begin with `pg_` or `gp_`, as such names are reserved for system tablespaces.

- **OWNER username**
  
  The name of the user who will own the tablespace. If omitted, defaults to the user executing the command. Only superusers may create tablespaces, but they can assign ownership of tablespaces to non-superusers.

- **FILESPACE**
  
  The name of a Greenplum Database filespace that was defined using the gpfilespace management utility.
Notes
You must first create a filespace to be used by the tablespace. See gpfilespace in the Greenplum Database Utility Guide for more information.

Tablespaces are only supported on systems that support symbolic links.

CREATE TABLESPACE cannot be executed inside a transaction block.

Examples
Create a new tablespace by specifying the corresponding filespace to use:

```
CREATE TABLESPACE mytblspace FILESPACE myfilespace;
```

Compatibility
CREATE TABLESPACE is a Greenplum Database extension.

See Also
CREATE DATABASE, CREATE TABLE, CREATE INDEX, DROP TABLESPACE, ALTER TABLESPACE, gpfilespace in the Greenplum Database Utility Guide

CREATE TYPE
Defines a new data type.

Synopsis
```
CREATE TYPE name AS ( attribute_name data_type [, ... ] )
CREATE TYPE name AS ENUM ( 'label' [, ... ] )
CREATE TYPE name ( INPUT = input_function,
  OUTPUT = output_function
  [, RECEIVE = receive_function]
  [, SEND = send_function]
  [, TYPMOD_IN = 'type modifier input_function ']
  [, TYPMOD_OUT = 'type modifier output_function ']
  [, INTERNALLENGTH = {internallength | VARIABLE}]
  [, PASSEDBYVALUE]
  [, ALIGNMENT = alignment]
  [, STORAGE = storage]
  [, DEFAULT = default]
  [, ELEMENT = element]
  [, DELIMITER = delimiter ]
)
```

Description
CREATE TYPE registers a new data type for use in the current database. The user who defines a type becomes its owner.

If a schema name is given then the type is created in the specified schema. Otherwise it is created in the current schema. The type name must be distinct from the name of any existing type or domain in the same schema. The type name must also be distinct from the name of any existing table in the same schema.

Composite Types
The first form of `CREATE  TYPE` creates a composite type. The composite type is specified by a list of attribute names and data types. This is essentially the same as the row type of a table, but using `CREATE  TYPE` avoids the need to create an actual table when all that is wanted is to define a type. A stand-alone composite type is useful as the argument or return type of a function.

**Enumerated Types**

The second form of `CREATE  TYPE` creates an enumerated (`ENUM`) type, as described in *Enumerated Types* in the PostgreSQL documentation. Enum types take a list of one or more quoted labels, each of which must be less than `NAMEDATALEN` bytes long (64 in a standard build).

**Base Types**

The third form of `CREATE  TYPE` creates a new base type (scalar type). The parameters may appear in any order, not only that shown in the syntax, and most are optional. You must register two or more functions (using `CREATE  FUNCTION`) before defining the type. The support functions `input_function` and `output_function` are required, while the functions `receive_function`, `send_function`, `type_modifier_input_function`, `type_modifier_output_function`, and `analyze_function` are optional. Generally these functions have to be coded in C or another low-level language. In Greenplum Database, any function used to implement a data type must be defined as `IMMUTABLE`.

The `input_function` converts the type's external textual representation to the internal representation used by the operators and functions defined for the type. `output_function` performs the reverse transformation. The input function may be declared as taking one argument of type `cstring`, or as taking three arguments of types `cstring`, `oid`, `integer`. The first argument is the input text as a C string, the second argument is the type's own OID (except for array types, which instead receive their element type's OID), and the third is the `typtypmod` of the destination column, if known (-1 will be passed if not). The input function must return a value of the data type itself. Usually, an input function should be declared `STRICT`; if it is not, it will be called with a `NULL` first parameter when reading a `NULL` input value. The function must still return `NULL` in this case, unless it raises an error. (This case is mainly meant to support domain input functions, which may need to reject `NULL` inputs.) The output function must be declared as taking one argument of the new data type. The output function must return type `cstring`. Output functions are not invoked for `NULL` values.

The optional `receive_function` converts the type's external binary representation to the internal representation. If this function is not supplied, the type cannot participate in binary input. The binary representation should be chosen to be cheap to convert to internal form, while being reasonably portable. (For example, the standard integer data types use network byte order as the external binary representation, while the internal representation is in the machine's native byte order.) The receive function should perform adequate checking to ensure that the value is valid. The receive function may be declared as taking one argument of type `internal`, or as taking three arguments of types `internal`, `oid`, `integer`. The first argument is a pointer to a `StringInfo` buffer holding the received byte string; the optional arguments are the same as for the text input function. The receive function must return a value of the data type itself. Usually, a receive function should be declared `STRICT`; if it is not, it will be called with a `NULL` first parameter when reading a `NULL` input value. The function must still return `NULL` in this case, unless it raises an error. (This case is mainly meant to support domain receive functions, which may need to reject `NULL` inputs.) Similarly, the optional `send_function` converts from the internal representation to the external binary representation. If this function is not supplied, the type cannot participate in binary output. The send function must be declared as taking one argument of the new data type. The send function must return type `bytea`. Send functions are not invoked for `NULL` values.

The optional `type_modifier_input_function` and `type_modifier_output_function` are required if the type supports modifiers. Modifiers are optional constraints attached to a type declaration, such as `char(5)` or `numeric(30,2)`. While Greenplum Database allows user-defined types to take one or more simple constants or identifiers as modifiers, this information must fit into a single non-negative integer value for storage in the system catalogs. Greenplum Database passes the declared modifier(s) to the `type_modifier_input_function` in the form of a `cstring` array. The modifier input function must check the values for validity, throwing an error if they are incorrect. If the values are correct, the modifier input function returns a single non-negative integer value that Greenplum Database stores as the column `typtypmod`. Type modifiers are rejected if the type was not defined with a `type_modifier_input_function`. The
**type_modifier_output_function** converts the internal integer *typmod* value back to the correct form for user display. The modifier output function must return a *cstring* value that is the exact string to append to the type name. For example, *numeric*’s function might return `(30,2)`. The **type_modifier_output_function** is optional. When not specified, the default display format is the stored *typmod* integer value enclosed in parentheses.

You should at this point be wondering how the input and output functions can be declared to have results or arguments of the new type, when they have to be created before the new type can be created. The answer is that the type should first be defined as a shell type, which is a placeholder type that has no properties except a name and an owner. This is done by issuing the command `CREATE TYPE name`, with no additional parameters. Then the I/O functions can be defined referencing the shell type. Finally, `CREATE TYPE` with a full definition replaces the shell entry with a complete, valid type definition, after which the new type can be used normally.

While the details of the new type’s internal representation are only known to the I/O functions and other functions you create to work with the type, there are several properties of the internal representation that must be declared to Greenplum Database. Foremost of these is `internallength`. Base data types can be fixed-length, in which case `internallength` is a positive integer, or variable length, indicated by setting `internallength` to `VARIABLE`. (Internally, this is represented by setting `typlen` to `-1`.) The internal representation of all variable-length types must start with a 4-byte integer giving the total length of this value of the type.

The optional flag `PASSEDBYVALUE` indicates that values of this data type are passed by value, rather than by reference. You may not pass by value types whose internal representation is larger than the size of the Datum type (4 bytes on most machines, 8 bytes on a few).

The `alignment` parameter specifies the storage alignment required for the data type. The allowed values equate to alignment on 1, 2, 4, or 8 byte boundaries. Note that variable-length types must have an alignment of at least 4, since they necessarily contain an `int4` as their first component.

The `storage` parameter allows selection of storage strategies for variable-length data types. (Only `plain` is allowed for fixed-length types.) `plain` specifies that data of the type will always be stored in-line and not compressed. `extended` specifies that the system will first try to compress a long data value, and will move the value out of the main table row if it’s still too long. `external` allows the value to be moved out of the main table, but the system will not try to compress it. `main` allows compression, but discourages moving the value out of the main table. (Data items with this storage strategy may still be moved out of the main table if there is no other way to make a row fit, but they will be kept in the main table preferentially over `extended` and `external` items.)

A default value may be specified, in case a user wants columns of the data type to default to something other than the null value. Specify the default with the `DEFAULT` key word. (Such a default may be overridden by an explicit `DEFAULT` clause attached to a particular column.)

To indicate that a type is an array, specify the type of the array elements using the `ELEMENT` key word. For example, to define an array of 4-byte integers (int4), specify `ELEMENT = int4`. More details about array types appear below.

To indicate the delimiter to be used between values in the external representation of arrays of this type, `delimiter` can be set to a specific character. The default delimiter is the comma (,). Note that the delimiter is associated with the array element type, not the array type itself.

**Array Types**

Whenever a user-defined base data type is created, Greenplum Database automatically creates an associated array type, whose name consists of the base type’s name prepended with an underscore. The parser understands this naming convention, and translates requests for columns of type `foo[]` into requests for type `_foo`. The implicitly-created array type is variable length and uses the built-in input and output functions `array_in` and `array_out`.

You might reasonably ask why there is an `ELEMENT` option, if the system makes the correct array type automatically. The only case where it’s useful to use `ELEMENT` is when you are making a fixed-length type that happens to be internally an array of a number of identical things, and you want to allow these things
to be accessed directly by subscripting, in addition to whatever operations you plan to provide for the type as a whole. For example, type name allows its constituent char elements to be accessed this way. A 2-D point type could allow its two component numbers to be accessed like point[0] and point[1]. Note that this facility only works for fixed-length types whose internal form is exactly a sequence of identical fixed-length fields. A subscriptable variable-length type must have the generalized internal representation used by array_in and array_out. For historical reasons, subscripting of fixed-length array types starts from zero, rather than from one as for variable-length arrays.

Parameters

**name**

The name (optionally schema-qualified) of a type to be created.

**attribute_name**

The name of an attribute (column) for the composite type.

**data_type**

The name of an existing data type to become a column of the composite type.

**label**

A string literal representing the textual label associated with one value of an enum type.

**input_function**

The name of a function that converts data from the type's external textual form to its internal form.

**output_function**

The name of a function that converts data from the type's internal form to its external textual form.

**receive_function**

The name of a function that converts data from the type's external binary form to its internal form.

**send_function**

The name of a function that converts data from the type's internal form to its external binary form.

**type_modifier_input_function**

The name of a function that converts an array of modifier(s) for the type to internal form.

**type_modifier_output_function**

The name of a function that converts the internal form of the type's modifier(s) to external textual form.

**internallength**

A numeric constant that specifies the length in bytes of the new type's internal representation. The default assumption is that it is variable-length.

**alignment**

The storage alignment requirement of the data type. Must be one of char, int2, int4, or double. The default is int4.

**storage**

The storage strategy for the data type. Must be one of plain, external, extended, or main. The default is plain.

**default**

The default value for the data type. If this is omitted, the default is null.

**element**
The type being created is an array; this specifies the type of the array elements.

**delimiter**

The delimiter character to be used between values in arrays made of this type.

**Notes**

User-defined type names cannot begin with the underscore character (_) and can only be 62 characters long (or in general NAMEDATALEN - 2, rather than the NAMEDATALEN - 1 characters allowed for other names). Type names beginning with underscore are reserved for internally-created array type names.

Because there are no restrictions on use of a data type once it's been created, creating a base type is tantamount to granting public execute permission on the functions mentioned in the type definition. (The creator of the type is therefore required to own these functions.) This is usually not an issue for the sorts of functions that are useful in a type definition. But you might want to think twice before designing a type in a way that would require 'secret' information to be used while converting it to or from external form.

Before Greenplum Database version 2.4, the syntax `CREATE TYPE name` did not exist. The way to create a new base type was to create its input function first. In this approach, Greenplum Database will first see the name of the new data type as the return type of the input function. The shell type is implicitly created in this situation, and then it can be referenced in the definitions of the remaining I/O functions. This approach still works, but is deprecated and may be disallowed in some future release. Also, to avoid accidentally cluttering the catalogs with shell types as a result of simple typos in function definitions, a shell type will only be made this way when the input function is written in C.

**Examples**

This example creates a composite type and uses it in a function definition:

```
CREATE TYPE compfoo AS (f1 int, f2 text);
CREATE FUNCTION getfoo() RETURNS SETOF compfoo AS $$
  SELECT fooid, fooname FROM foo
$$ LANGUAGE SQL;
```

This example creates the enumerated type `mood` and uses it in a table definition.

```
CREATE TYPE mood AS ENUM ('sad', 'ok', 'happy');
CREATE TABLE person (  
  name text,  
  current_mood mood
);
INSERT INTO person VALUES ('Moe', 'happy');
SELECT * FROM person WHERE current_mood = 'happy';
```

This example creates the base data type `box` and then uses the type in a table definition:

```
CREATE TYPE box;
CREATE FUNCTION my_box_in_function(cstring) RETURNS box AS ...
CREATE FUNCTION my_box_out_function(box) RETURNS cstring AS ...
CREATE TYPE box (  
  INTERNALLENGTH = 16,
```
If the internal structure of `box` were an array of four `float4` elements, we might instead use:

```
CREATE TYPE box (  
  INTERNALLENGTH = 16,  
  INPUT = my_box_in_function,  
  OUTPUT = my_box_out_function,  
  ELEMENT = float4  
);
```

which would allow a box value’s component numbers to be accessed by subscripting. Otherwise the type behaves the same as before.

This example creates a large object type and uses it in a table definition:

```
CREATE TYPE bigobj (  
  INPUT = lo_filein, OUTPUT = lo_fileout,  
  INTERNALLENGTH = VARIABLE  
);

CREATE TABLE big_objs (  
  id integer,  
  obj bigobj  
);
```

**Compatibility**

This `CREATE TYPE` command is a Greenplum Database extension. There is a `CREATE TYPE` statement in the SQL standard that is rather different in detail.

**See Also**

`CREATE FUNCTION`, `ALTER TYPE`, `DROP TYPE`, `CREATE DOMAIN`

**CREATE USER**

Defines a new database role with the `LOGIN` privilege by default.

**Synopsis**

```
CREATE USER name [[WITH] option [ ... ]]  
```

where `option` can be:

```
  | SUPERUSER | NOSUPERUSER  
  | CREATEDB | NOCREATEDB  
  | CREATEROLE | NOCREATEROLE  
  | CREATEUSER | NOCREATEUSER  
  | CREATEEXTTABLE | NOCREATEEXTTABLE  
  | [ ( attribute='value'[, ... ] ) ]  
  where attributes and value are:  
  type='readable'|'writable'
```
Description

CREATE USER is an alias for CREATE ROLE.

The only difference between CREATE ROLE and CREATE USER is that LOGIN is assumed by default with CREATE USER, whereas NOLOGIN is assumed by default with CREATE ROLE.

Compatibility

There is no CREATE USER statement in the SQL standard.

See Also

CREATE ROLE

CREATE VIEW

Defines a new view.

Synopsis

```sql
CREATE [OR REPLACE] [TEMP | TEMPORARY] VIEW name
  [ ( column_name [, ...] ) ]
AS query
```

Description

CREATE VIEW defines a view of a query. The view is not physically materialized. Instead, the query is run every time the view is referenced in a query.

CREATE OR REPLACE VIEW is similar, but if a view of the same name already exists, it is replaced. You can only replace a view with a new query that generates the identical set of columns (same column names and data types).

If a schema name is given then the view is created in the specified schema. Otherwise it is created in the current schema. Temporary views exist in a special schema, so a schema name may not be given when creating a temporary view. The name of the view must be distinct from the name of any other view, table, sequence, or index in the same schema.

Parameters

- **TEMPORARY | TEMP**

  If specified, the view is created as a temporary view. Temporary views are automatically dropped at the end of the current session. Existing permanent relations with the same name are not visible to the current session while the temporary view exists, unless they are referenced with schema-qualified names. If any of the tables referenced by the view are
temporary, the view is created as a temporary view (whether TEMPORARY is specified or not).

name

The name (optionally schema-qualified) of a view to be created.

column_name

An optional list of names to be used for columns of the view. If not given, the column names are deduced from the query.

query

A SELECT or VALUES command which will provide the columns and rows of the view.

Notes

Views in Greenplum Database are read only. The system will not allow an insert, update, or delete on a view. You can get the effect of an updatable view by creating rewrite rules on the view into appropriate actions on other tables. For more information see CREATE RULE.

Be careful that the names and data types of the view's columns will be assigned the way you want. For example:

CREATE VIEW vista AS SELECT 'Hello World';

is bad form in two ways: the column name defaults to column?, and the column data type defaults to unknown. If you want a string literal in a view's result, use something like:

CREATE VIEW vista AS SELECT text 'Hello World' AS hello;

Access to tables referenced in the view is determined by permissions of the view owner not the current user (even if the current user is a superuser). This can be confusing in the case of superusers, since superusers typically have access to all objects. In the case of a view, even superusers must be explicitly granted access to tables referenced in the view if they are not the owner of the view.

However, functions called in the view are treated the same as if they had been called directly from the query using the view. Therefore the user of a view must have permissions to call any functions used by the view.

If you create a view with an ORDER BY clause, the ORDER BY clause is ignored when you do a SELECT from the view.

Examples

Create a view consisting of all comedy films:

CREATE VIEW comedies AS SELECT * FROM films WHERE kind = 'comedy';

Create a view that gets the top ten ranked baby names:

CREATE VIEW topten AS SELECT name, rank, gender, year FROM names, rank WHERE rank < '11' AND names.id=rank.id;

Compatibility

The SQL standard specifies some additional capabilities for the CREATE VIEW statement that are not in Greenplum Database. The optional clauses for the full SQL command in the standard are:
• **CHECK OPTION** — This option has to do with updatable views. All `INSERT` and `UPDATE` commands on the view will be checked to ensure data satisfy the view-defining condition (that is, the new data would be visible through the view). If they do not, the update will be rejected.

• **LOCAL** — Check for integrity on this view.

• **CASCADED** — Check for integrity on this view and on any dependent view. `CASCADED` is assumed if neither `CASCADED` nor `LOCAL` is specified.

`CREATE OR REPLACE VIEW` is a Greenplum Database language extension. So is the concept of a temporary view.

**See Also**

`SELECT, DROP VIEW`

---

**DEALLOCATE**

Deallocates a prepared statement.

**Synopsis**

```
DEALLOCATE [PREPARE] name
```

**Description**

`DEALLOCATE` is used to deallocate a previously prepared SQL statement. If you do not explicitly deallocate a prepared statement, it is deallocated when the session ends.

For more information on prepared statements, see `PREPARE`.

**Parameters**

`PREPARE`

Optional key word which is ignored.

`name`

The name of the prepared statement to deallocate.

**Examples**

Deallocated the previously prepared statement named `insert_names`:

```
DEALLOCATE insert_names;
```

**Compatibility**

The SQL standard includes a `DEALLOCATE` statement, but it is only for use in embedded SQL.

**See Also**

`EXECUTE, PREPARE`

---

**DECLARE**

Defines a cursor.

**Synopsis**

```
DECLARE name [BINARY] [INSENSITIVE] [NO SCROLL] CURSOR
```
Explanation

**DECLARE** allows a user to create cursors, which can be used to retrieve a small number of rows at a time out of a larger query. Cursors can return data either in text or in binary format using **FETCH**.

Normal cursors return data in text format, the same as a **SELECT** would produce. Since data is stored natively in binary format, the system must do a conversion to produce the text format. Once the information comes back in text form, the client application may need to convert it to a binary format to manipulate it. In addition, data in the text format is often larger in size than in the binary format. Binary cursors return the data in a binary representation that may be more easily manipulated. Nevertheless, if you intend to display the data as text anyway, retrieving it in text form will save you some effort on the client side.

As an example, if a query returns a value of one from an integer column, you would get a string of 1 with a default cursor whereas with a binary cursor you would get a 4-byte field containing the internal representation of the value (in big-endian byte order).

Binary cursors should be used carefully. Many applications, including psql, are not prepared to handle binary cursors and expect data to come back in the text format.

**Note:**

When the client application uses the 'extended query' protocol to issue a **FETCH** command, the Bind protocol message specifies whether data is to be retrieved in text or binary format. This choice overrides the way that the cursor is defined. The concept of a binary cursor as such is thus obsolete when using extended query protocol — any cursor can be treated as either text or binary.

A cursor can be specified in the **WHERE CURRENT OF** clause of the **UPDATE** or **DELETE** statement to update or delete table data. The **UPDATE** or **DELETE** statement can only be executed on the server, for example in an interactive psql session or a script. Language extensions such as PL/pgSQL do not have support for updatable cursors.

**Parameters**

**name**

The name of the cursor to be created.

**BINARY**

Causes the cursor to return data in binary rather than in text format.

**INSENSITIVE**

Indicates that data retrieved from the cursor should be unaffected by updates to the tables underlying the cursor while the cursor exists. In Greenplum Database, all cursors are insensitive. This key word currently has no effect and is present for compatibility with the SQL standard.

**NO SCROLL**

A cursor cannot be used to retrieve rows in a nonsequential fashion. This is the default behavior in Greenplum Database, since scrollable cursors (**SCROLL**) are not supported.

**WITH HOLD**

**WITHOUT HOLD**

**WITH HOLD** specifies that the cursor may continue to be used after the transaction that created it successfully commits. **WITHOUT HOLD** specifies that the cursor cannot be used outside of the transaction that created it. **WITHOUT HOLD** is the default.

**WITH HOLD** cannot not be specified when the **query** includes a **FOR UPDATE** or **FOR SHARE** clause.
A `SELECT` or `VALUES` command which will provide the rows to be returned by the cursor.

If the cursor is used in the `WHERE CURRENT OF` clause of the `UPDATE` or `DELETE` command, the `SELECT` command must satisfy the following conditions:

- Cannot reference a view or external table.
- References only one table.

The table must be updatable. For example, the following are not updatable: table functions, set-returning functions, append-only tables, columnar tables.

- Cannot contain any of the following:
  - A grouping clause
  - A set operation such as `UNION ALL` or `UNION DISTINCT`
  - A sorting clause
  - A windowing clause
  - A join or a self-join

Specifying the `FOR UPDATE` clause in the `SELECT` command prevents other sessions from changing the rows between the time they are fetched and the time they are updated. Without the `FOR UPDATE` clause, a subsequent use of the `UPDATE` or `DELETE` command with the `WHERE CURRENT OF` clause has no effect if the row was changed since the cursor was created.

**Note:** Specifying the `FOR UPDATE` clause in the `SELECT` command locks the entire table, not just the selected rows.

**FOR READ ONLY**

`FOR READ ONLY` indicates that the cursor is used in a read-only mode.

**Notes**

Unless `WITH HOLD` is specified, the cursor created by this command can only be used within the current transaction. Thus, `DECLARE` without `WITH HOLD` is useless outside a transaction block: the cursor would survive only to the completion of the statement. Therefore Greenplum Database reports an error if this command is used outside a transaction block. Use `BEGIN`, `COMMIT` and `ROLLBACK` to define a transaction block.

If `WITH HOLD` is specified and the transaction that created the cursor successfully commits, the cursor can continue to be accessed by subsequent transactions in the same session. (But if the creating transaction is aborted, the cursor is removed.) A cursor created with `WITH HOLD` is closed when an explicit `CLOSE` command is issued on it, or the session ends. In the current implementation, the rows represented by a held cursor are copied into a temporary file or memory area so that they remain available for subsequent transactions.

If you create a cursor with the `DECLARE` command in a transaction, you cannot use the `SET` command in the transaction until you close the cursor with the `CLOSE` command.

Scrollable cursors are not currently supported in Greenplum Database. You can only use `FETCH` to move the cursor position forward, not backwards.

`DECLARE...FOR UPDATE` is not supported with append-optimized tables.

You can see all available cursors by querying the `pg_cursors` system view.

**Examples**

Declare a cursor:

```sql
DECLARE mycursor CURSOR FOR SELECT * FROM mytable;
```
Compatibility
SQL standard allows cursors only in embedded SQL and in modules. Greenplum Database permits cursors to be used interactively.

Greenplum Database does not implement an `OPEN` statement for cursors. A cursor is considered to be open when it is declared.

The SQL standard allows cursors to move both forward and backward. All Greenplum Database cursors are forward moving only (not scrollable).

Binary cursors are a Greenplum Database extension.

See Also
`CLOSE`, `DELETE`, `FETCH`, `MOVE`, `SELECT`, `UPDATE`

DELETE
Deletes rows from a table.

Synopsis
```
DELETE FROM [ONLY] table [[AS] alias]
    [USING usinglist]
    [WHERE condition | WHERE CURRENT OF cursor_name ]
```

Description
`DELETE` deletes rows that satisfy the `WHERE` clause from the specified table. If the `WHERE` clause is absent, the effect is to delete all rows in the table. The result is a valid, but empty table.

By default, `DELETE` will delete rows in the specified table and all its child tables. If you wish to delete only from the specific table mentioned, you must use the `ONLY` clause.

There are two ways to delete rows in a table using information contained in other tables in the database: using sub-selects, or specifying additional tables in the `USING` clause. Which technique is more appropriate depends on the specific circumstances.

If the `WHERE CURRENT OF` clause is specified, the row that is deleted is the one most recently fetched from the specified cursor.

You must have the `DELETE` privilege on the table to delete from it.

Outputs
On successful completion, a `DELETE` command returns a command tag of the form
```
DELETE count
```

The count is the number of rows deleted. If count is 0, no rows matched the condition (this is not considered an error).

Parameters
`ONLY`
If specified, delete rows from the named table only. When not specified, any tables inheriting from the named table are also processed.

`table`
The name (optionally schema-qualified) of an existing table.

`alias`
A substitute name for the target table. When an alias is provided, it completely hides the actual name of the table. For example, given `DELETE FROM foo AS f`, the remainder of the `DELETE` statement must refer to this table as `f` not `foo`.

**usinglist**

A list of table expressions, allowing columns from other tables to appear in the `WHERE` condition. This is similar to the list of tables that can be specified in the `FROM` Clause of a `SELECT` statement; for example, an alias for the table name can be specified. Do not repeat the target table in the `usinglist`, unless you wish to set up a self-join.

**condition**

An expression returning a value of type `boolean`, which determines the rows that are to be deleted.

**cursor_name**

The name of the cursor to use in a `WHERE CURRENT OF` condition. The row to be deleted is the one most recently fetched from this cursor. The cursor must be a simple (non-join, non-aggregate) query on the `DELETE` target table.

`WHERE CURRENT OF` cannot be specified together with a Boolean condition.

The `DELETE...WHERE CURRENT OF` cursor statement can only be executed on the server, for example in an interactive `psql` session or a script. Language extensions such as PL/pgSQL do not have support for updatable cursors.

See `DECLARE` for more information about creating cursors.

**Notes**

Greenplum Database lets you reference columns of other tables in the `WHERE` condition by specifying the other tables in the `USING` clause. For example, to the name `Hannah` from the `rank` table, one might do:

```sql
DELETE FROM rank USING names WHERE names.id = rank.id AND name = 'Hannah';
```

What is essentially happening here is a join between `rank` and `names`, with all successfully joined rows being marked for deletion. This syntax is not standard. However, this join style is usually easier to write and faster to execute than a more standard sub-select style, such as:

```sql
DELETE FROM rank WHERE id IN (SELECT id FROM names WHERE name = 'Hannah');
```

When using `DELETE` to remove all the rows of a table (for example: `DELETE * FROM table;`), Greenplum Database adds an implicit `TRUNCATE` command (when user permissions allow). The added `TRUNCATE` command frees the disk space occupied by the deleted rows without requiring a `VACUUM` of the table. This improves scan performance of subsequent queries, and benefits ELT workloads that frequently insert and delete from temporary tables.

Execution of `UPDATE` and `DELETE` commands directly on a specific partition (child table) of a partitioned table is not supported. Instead, these commands must be executed on the root partitioned table, the table created with the `CREATE TABLE` command.

**Examples**

Delete all films but musicals:

```sql
DELETE FROM films WHERE kind <> 'Musical';
```
Clear the table films:

```sql
DELETE FROM films;
```

Delete using a join:

```sql
DELETE FROM rank USING names WHERE names.id = rank.id AND name = 'Hannah';
```

**Compatibility**

This command conforms to the SQL standard, except that the `USING` clause is a Greenplum Database extension.

**See Also**

`DECLARE`, `TRUNCATE`

---

**DISCARD**

Discards the session state.

**Synopsis**

```
DISCARD { ALL | PLANS | TEMPORARY | TEMP }
```

**Description**

`DISCARD` releases internal resources associated with a database session. These resources are normally released at the end of the session. `DISCARD TEMP` drops all temporary tables created in the current session. `DISCARD PLANS` releases all internally cached query plans. `DISCARD ALL` resets a session to its original state, discarding temporary resources and resetting session-local configuration changes.

**Parameters**

- `TEMPORARY`, `TEMP`
  - Drops all temporary tables created in the current session.
- `PLANS`
  - Releases all cached query plans.
- `ALL`
  - Releases all temporary resources associated with the current session and resets the session to its initial state. Currently, this has the same effect as executing the following sequence of statements:

  ```sql
  SET SESSION AUTHORIZATION DEFAULT;
  RESET ALL;
  DEALLOCATE ALL;
  CLOSE ALL;
  UNLISTEN *;
  SELECT pg_advisory_unlock_all();
  DISCARD PLANS;
  DISCARD TEMP;
  ```

**Notes**

`DISCARD ALL` cannot be executed inside a transaction block.
Compatibility

DISCARD is a Greenplum Database extension.

**DO**

Executes an anonymous code block as a transient anonymous function.

**Synopsis**

```
DO [ LANGUAGE lang_name ] code
```

**Description**

DO executes an anonymous code block, or in other words a transient anonymous function in a procedural language.

The code block is treated as though it were the body of a function with no parameters, returning void. It is parsed and executed a single time.

The optional LANGUAGE clause can appear either before or after the code block.

Anonymous blocks are procedural language structures that provide the capability to create and execute procedural code on the fly without persistently storing the code as database objects in the system catalogs. The concept of anonymous blocks is similar to UNIX shell scripts, which enable several manually entered commands to be grouped and executed as one step. As the name implies, anonymous blocks do not have a name, and for this reason they cannot be referenced from other objects. Although built dynamically, anonymous blocks can be easily stored as scripts in the operating system files for repetitive execution.

Anonymous blocks are standard procedural language blocks. They carry the syntax and obey the rules that apply to the procedural language, including declaration and scope of variables, execution, exception handling, and language usage.

The compilation and execution of anonymous blocks are combined in one step, while a user-defined function needs to be re-defined before use each time its definition changes.

**Parameters**

- **code**
  
  The procedural language code to be executed. This must be specified as a string literal, just as with the `CREATE FUNCTION` command. Use of a dollar-quoted literal is recommended. Optional keywords have no effect. These procedural languages are supported: PL/pgSQL (plpgsql), PL/Python (plpythonu), and PL/Perl (plperl and plperlu).

- **lang_name**
  
  The name of the procedural language that the code is written in. The default is plpgsql. The language must be installed on the Greenplum Database system and registered in the database.

**Notes**

The PL/pgSQL language is installed on the Greenplum Database system and is registered in a user created database. The PL/Python language is installed by default, but not registered. Other languages are not installed or registered. The system catalog `pg_language` contains information about the registered languages in a database.

The user must have **USAGE** privilege for the procedural language, or must be a superuser if the language is untrusted. This is the same privilege requirement as for creating a function in the language.
Examples

This PL/pgSQL example grants all privileges on all views in schema `public` to role `webuser`:

```sql
DO $$
DECLARE r record;
BEGIN
  FOR r IN SELECT table_schema, table_name FROM information_schema.tables
    WHERE table_type = 'VIEW' AND table_schema = 'public'
  LOOP
    EXECUTE 'GRANT ALL ON ' || quote_ident(r.table_schema) || '.' ||
    quote_ident(r.table_name) || ' TO webuser';
  END LOOP;
END$$;
```

This PL/pgSQL example determines if a Greenplum Database user is a superuser. In the example, the anonymous block retrieves the input value from a temporary table.

```sql
CREATE TEMP TABLE list AS VALUES ('gpadmin') DISTRIBUTED RANDOMLY;
DO $$
DECLARE
  name TEXT := 'gpadmin' ;
  superuser TEXT := '' ;
  t1_row   pg_authid%ROWTYPE;
BEGIN
  SELECT * INTO t1_row FROM pg_authid, list
    WHERE pg_authid.rolname = name ;
  IF t1_row.rolsuper = 'f' THEN
    superuser := 'not ';
  END IF ;
  RAISE NOTICE 'user % is %a superuser', t1_row.rolname, superuser ;
END $$ LANGUAGE plpgsql ;
```

Note: The example PL/pgSQL uses `SELECT` with the `INTO` clause. It is different from the SQL command `SELECT INTO`.

Compatibility

There is no `DO` statement in the SQL standard.

See Also

CREATE LANGUAGE Greenplum PL/pgSQL Procedural Language

**DROP AGGREGATE**

Removes an aggregate function.

**Synopsis**

```
DROP AGGREGATE [IF EXISTS] name ( type [, ...] ) [CASCADE | RESTRICT]
```

**Description**

`DROP AGGREGATE` will delete an existing aggregate function. To execute this command the current user must be the owner of the aggregate function.

**Parameters**

IF EXISTS
Do not throw an error if the aggregate does not exist. A notice is issued in this case.

**name**

The name (optionally schema-qualified) of an existing aggregate function.

**type**

An input data type on which the aggregate function operates. To reference a zero-argument aggregate function, write `*` in place of the list of input data types.

**CASCADE**

Automatically drop objects that depend on the aggregate function.

**RESTRICT**

Refuse to drop the aggregate function if any objects depend on it. This is the default.

**Examples**

To remove the aggregate function `myavg` for type `integer`:

```
DROP AGGREGATE myavg(integer);
```

**Compatibility**

There is no `DROP AGGREGATE` statement in the SQL standard.

**See Also**

`ALTER AGGREGATE`, `CREATE AGGREGATE`

---

**DROP CAST**

Removes a cast.

**Synopsis**

```
DROP CAST [IF EXISTS] (sourcetype AS targettype) [CASCADE | RESTRICT]
```

**Description**

`DROP CAST` will delete a previously defined cast. To be able to drop a cast, you must own the source or the target data type. These are the same privileges that are required to create a cast.

**Parameters**

**IF EXISTS**

Do not throw an error if the cast does not exist. A notice is issued in this case.

**sourcetype**

The name of the source data type of the cast.

**targettype**

The name of the target data type of the cast.

**CASCADE**

**RESTRICT**

These keywords have no effect since there are no dependencies on casts.
Examples
To drop the cast from type `text` to type `int`:

```sql
DROP CAST (text AS int);
```

Compatibility
There `DROP CAST` command conforms to the SQL standard.

See Also
`CREATE CAST`

**DROP CONVERSION**

Removes a conversion.

**Synopsis**

```sql
DROP CONVERSION [IF EXISTS] name [CASCADE | RESTRICT]
```

**Description**

`DROP CONVERSION` removes a previously defined conversion. To be able to drop a conversion, you must own the conversion.

**Parameters**

**IF EXISTS**

Do not throw an error if the conversion does not exist. A notice is issued in this case.

**name**

The name of the conversion. The conversion name may be schema-qualified.

**CASCADE**

**RESTRICT**

These keywords have no effect since there are no dependencies on conversions.

**Examples**

Drop the conversion named `myname`:

```sql
DROP CONVERSION myname;
```

Compatibility

There is no `DROP CONVERSION` statement in the SQL standard.

See Also

`ALTER CONVERSION, CREATE CONVERSION`

**DROP DATABASE**

Removes a database.
Synopsis

```
DROP DATABASE [IF EXISTS] name
```

Description

DROP DATABASE drops a database. It removes the catalog entries for the database and deletes the directory containing the data. It can only be executed by the database owner. Also, it cannot be executed while you or anyone else are connected to the target database. (Connect to `postgres` or any other database to issue this command.)

Warning: DROP DATABASE cannot be undone. Use it with care!

Parameters

**IF EXISTS**

Do not throw an error if the database does not exist. A notice is issued in this case.

**name**

The name of the database to remove.

Notes

DROP DATABASE cannot be executed inside a transaction block.

This command cannot be executed while connected to the target database. Thus, it might be more convenient to use the program `dropdb` instead, which is a wrapper around this command.

Examples

Drop the database named `testdb`:

```
DROP DATABASE testdb;
```

Compatibility

There is no DROP DATABASE statement in the SQL standard.

See Also

*ALTER DATABASE*, *CREATE DATABASE*

**DROP DOMAIN**

Removes a domain.

Synopsis

```
DROP DOMAIN [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

Description

DROP DOMAIN removes a previously defined domain. You must be the owner of a domain to drop it.

Parameters

**IF EXISTS**

Do not throw an error if the domain does not exist. A notice is issued in this case.
name

The name (optionally schema-qualified) of an existing domain.

CASCADE

Automatically drop objects that depend on the domain (such as table columns).

RESTRICT

Refuse to drop the domain if any objects depend on it. This is the default.

Examples

Drop the domain named zipcode:

DROP DOMAIN zipcode;

Compatibility

This command conforms to the SQL standard, except for the IF EXISTS option, which is a Greenplum Database extension.

See Also

ALTER DOMAIN, CREATE DOMAIN

DROP EXTENSION

Removes an extension from a Greenplum database.

Synopsis

DROP EXTENSION [ IF EXISTS ] name [, ...] [ CASCADE | RESTRICT ]

Description

DROP EXTENSION removes extensions from the database. Dropping an extension causes its component objects to be dropped as well.

Note: The required supporting extension files what were installed to create the extension are not deleted. The files must be manually removed from the Greenplum Database hosts.

You must own the extension to use DROP EXTENSION.

This command fails if any of the extension objects are in use in the database. For example, if a table is defined with columns of the extension type. Add the CASCADE option to forcibly remove those dependent objects.

Important: Before issuing a DROP EXTENSION with the CASCADE keyword, you should be aware of all object that depend on the extension to avoid unintended consequences.

Parameters

IF EXISTS

Do not throw an error if the extension does not exist. A notice is issued.

name

The name of an installed extension.

CASCADE
Automatically drop objects that depend on the extension, and in turn all objects that depend on those objects. See the PostgreSQL information about *Dependency Tracking*.

**RESTRICT**

Refuse to drop an extension if any objects depend on it, other than the extension member objects. This is the default.

**Compatibility**

DROP EXTENSION is a Greenplum Database extension.

**See Also**

CREATE EXTENSION, ALTER EXTENSION

## DROP EXTERNAL TABLE

Removes an external table definition.

### Synopsis

```sql
DROP EXTERNAL [WEB] TABLE [IF EXISTS] name [CASCADE | RESTRICT]
```

### Description

DROP EXTERNAL TABLE drops an existing external table definition from the database system. The external data sources or files are not deleted. To execute this command you must be the owner of the external table.

### Parameters

**WEB**

Optional keyword for dropping external web tables.

**IF EXISTS**

Do not throw an error if the external table does not exist. A notice is issued in this case.

**name**

The name (optionally schema-qualified) of an existing external table.

**CASCADE**

Automatically drop objects that depend on the external table (such as views).

**RESTRICT**

Refuse to drop the external table if any objects depend on it. This is the default.

### Examples

Remove the external table named `staging` if it exists:

```sql
DROP EXTERNAL TABLE IF EXISTS staging;
```

### Compatibility

There is no DROP EXTERNAL TABLE statement in the SQL standard.
See Also
CREATE EXTERNAL TABLE

**DROP FILESPACE**

Removes a filespace.

### Synopsis

```
DROP FILESPACE [IF EXISTS] filespacename
```

### Description

DROP FILESPACE removes a filespace definition and its system-generated data directories from the system.

A filespace can only be dropped by its owner or a superuser. The filespace must be empty of all tablespace objects before it can be dropped. It is possible that tablespaces in other databases may still be using a filespace even if no tablespaces in the current database are using the filespace.

### Parameters

**IF EXISTS**

Do not throw an error if the filespace does not exist. A notice is issued in this case.

**filespacename**

The name of the filespace to remove.

### Examples

Remove the tablespace `myfs`:

```
DROP FILESPACE myfs;
```

### Compatibility

There is no DROP FILESPACE statement in the SQL standard or in PostgreSQL.

### See Also

ALTER FILESPACE, DROP TABLESPACE, gpfilespace in the Greenplum Database Utility Guide

**DROP FUNCTION**

Removes a function.

### Synopsis

```
DROP FUNCTION [IF EXISTS] name ( [ [argmode] argname] argtype [, ...] ) [CASCADE | RESTRICT]
```

### Description

DROP FUNCTION removes the definition of an existing function. To execute this command the user must be the owner of the function. The argument types to the function must be specified, since several different functions may exist with the same name and different argument lists.
Parameters

IF EXISTS
Do not throw an error if the function does not exist. A notice is issued in this case.

name
The name (optionally schema-qualified) of an existing function.

argmode
The mode of an argument: either IN, OUT, INOUT, or VARIADIC. If omitted, the default is IN. Note that DROP FUNCTION does not actually pay any attention to OUT arguments, since only the input arguments are needed to determine the function's identity. So it is sufficient to list the IN, INOUT, and VARIADIC arguments.

argname
The name of an argument. Note that DROP FUNCTION does not actually pay any attention to argument names, since only the argument data types are needed to determine the function's identity.

argtype
The data type(s) of the function's arguments (optionally schema-qualified), if any.

CASCADE
Automatically drop objects that depend on the function such as operators.

RESTRICT
Refuse to drop the function if any objects depend on it. This is the default.

Examples
Drop the square root function:

DROP FUNCTION sqrt(integer);

Compatibility
A DROP FUNCTION statement is defined in the SQL standard, but it is not compatible with this command.

See Also
CREATE FUNCTION, ALTER FUNCTION

DROP GROUP
Removes a database role.

Synopsis

DROP GROUP [IF EXISTS] name [, ...]

Description
DROP GROUP is an alias for DROP ROLE. See DROP ROLE for more information.

Compatibility
There is no DROP GROUP statement in the SQL standard.
**DROP INDEX**

Removes an index.

**Synopsis**

```sql
DROP INDEX [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

**Description**

`DROP INDEX` drops an existing index from the database system. To execute this command you must be the owner of the index.

**Parameters**

- **IF EXISTS**
  
  Do not throw an error if the index does not exist. A notice is issued in this case.

- **name**
  
  The name (optionally schema-qualified) of an existing index.

- **CASCADE**
  
  Automatically drop objects that depend on the index.

- **RESTRICT**
  
  Refuse to drop the index if any objects depend on it. This is the default.

**Examples**

Remove the index `title_idx`:

```
DROP INDEX title_idx;
```

**Compatibility**

`DROP INDEX` is a Greenplum Database language extension. There are no provisions for indexes in the SQL standard.

**See Also**

`ALTER INDEX`, `CREATE INDEX`, `REINDEX`
Description

DROP LANGUAGE will remove the definition of the previously registered procedural language. You must be a superuser or owner of the language to drop a language.

Parameters

PROCEDURAL
Optional keyword - has no effect.

IF EXISTS
Do not throw an error if the language does not exist. A notice is issued in this case.

name
The name of an existing procedural language. For backward compatibility, the name may be enclosed by single quotes.

CASCADE
Automatically drop objects that depend on the language (such as functions written in that language).

RESTRICT
Refuse to drop the language if any objects depend on it. This is the default.

Examples

Remove the procedural language plsample:

```
DROP LANGUAGE plsample;
```

Compatibility

There is no DROP LANGUAGE statement in the SQL standard.

See Also

ALTER LANGUAGE, CREATE LANGUAGE

DROP OPERATOR

Removes an operator.

Synopsis

```
DROP OPERATOR [IF EXISTS] name ( {lefttype | NONE} , {righttype | NONE} ) [CASCADE | RESTRICT]
```

Description

DROP OPERATOR drops an existing operator from the database system. To execute this command you must be the owner of the operator.

Parameters

IF EXISTS
Do not throw an error if the operator does not exist. A notice is issued in this case.

name
The name (optionally schema-qualified) of an existing operator.
lefttype
The data type of the operator's left operand; write NONE if the operator has no left operand.
	righttype
The data type of the operator's right operand; write NONE if the operator has no right operand.

CASCADE
Automatically drop objects that depend on the operator.

RESTRICT
Refuse to drop the operator if any objects depend on it. This is the default.

Examples
Remove the power operator \(a^b\) for type integer:

\[
\text{DROP OPERATOR} ^ \text{ (integer, integer)};
\]

Remove the left unary bitwise complement operator \(~b\) for type bit:

\[
\text{DROP OPERATOR} ~ \text{ (none, bit)};
\]

Remove the right unary factorial operator \(x!\) for type bigint:

\[
\text{DROP OPERATOR} ! \text{ (bigint, none)};
\]

Compatibility
There is no DROP OPERATOR statement in the SQL standard.

See Also
ALTER OPERATOR, CREATE OPERATOR

DROP OPERATOR CLASS
Removes an operator class.

Synopsis

\[
\text{DROP OPERATOR CLASS} [\text{IF EXISTS}] \ name \ \text{USING} \ index\_method \ [\text{CASCADE} \ | \ \text{RESTRICT}]
\]

Description

DROP OPERATOR drops an existing operator class. To execute this command you must be the owner of the operator class.

Parameters

\text{IF EXISTS}
Do not throw an error if the operator class does not exist. A notice is issued in this case.

\text{name}
The name (optionally schema-qualified) of an existing operator class.

\text{index\_method}
The name of the index access method the operator class is for.
CASCADE
Automatically drop objects that depend on the operator class.

RESTRICT
Refuse to drop the operator class if any objects depend on it. This is the default.

Examples
Remove the B-tree operator class widget_ops:

```
DROP OPERATOR CLASS widget_ops USING btree;
```

This command will not succeed if there are any existing indexes that use the operator class. Add CASCADE to drop such indexes along with the operator class.

Compatibility
There is no DROP OPERATOR CLASS statement in the SQL standard.

See Also
ALTER OPERATOR CLASS, CREATE OPERATOR CLASS

DROP OPERATOR FAMILY
Removes an operator family.

Synopsis

```
DROP OPERATOR FAMILY [IF EXISTS] name USING index_method [CASCADE | RESTRICT]
```

Description
DROP OPERATOR FAMILY drops an existing operator family. To execute this command you must be the owner of the operator family.

DROP OPERATOR FAMILY includes dropping any operator classes contained in the family, but it does not drop any of the operators or functions referenced by the family. If there are any indexes depending on operator classes within the family, you will need to specify CASCADE for the drop to complete.

Parameters

**IF EXISTS**
Do not throw an error if the operator family does not exist. A notice is issued in this case.

**name**
The name (optionally schema-qualified) of an existing operator family.

**index_method**
The name of the index access method the operator family is for.

**CASCADE**
Automatically drop objects that depend on the operator family.

**RESTRICT**
Refuse to drop the operator family if any objects depend on it. This is the default.
Examples
Remove the B-tree operator family float_ops:

```
DROP OPERATOR FAMILY float_ops USING btree;
```

This command will not succeed if there are any existing indexes that use the operator family. Add
CASCADE to drop such indexes along with the operator family.

Compatibility

There is no DROP OPERATOR FAMILY statement in the SQL standard.

See Also

ALTER OPERATOR FAMILY, CREATE OPERATOR FAMILY, ALTER OPERATOR CLASS, CREATE
OPERATOR CLASS, DROP OPERATOR CLASS

**DROP OWNED**

Removes database objects owned by a database role.

Synopsis

```
DROP OWNED BY name [, ...] [CASCADE | RESTRICT]
```

Description

**DROP OWNED** drops all the objects in the current database that are owned by one of the specified roles.
Any privileges granted to the given roles on objects in the current database will also be revoked.

Parameters

- **name**
  
  The name of a role whose objects will be dropped, and whose privileges will be revoked.

  - **CASCADE**
    
    Automatically drop objects that depend on the affected objects.

  - **RESTRICT**
    
    Refuse to drop the objects owned by a role if any other database objects depend on one of
    the affected objects. This is the default.

Notes

**DROP OWNED** is often used to prepare for the removal of one or more roles. Because **DROP OWNED** only
affects the objects in the current database, it is usually necessary to execute this command in each
database that contains objects owned by a role that is to be removed.

Using the **CASCADE** option may make the command recurse to objects owned by other users.

The **REASSIGN OWNED** command is an alternative that reassigns the ownership of all the database objects
owned by one or more roles.

Examples

Remove any database objects owned by the role named sally:

```
DROP OWNED BY sally;
```
**DROP PROTOCOL**

Removes a external table data access protocol from a database.

**Synopsis**

```
DROP PROTOCOL [IF EXISTS] name
```

**Description**

`DROP PROTOCOL` removes the specified protocol from a database. A protocol name can be specified in the `CREATE EXTERNAL TABLE` command to read data from or write data to an external data source.

**Warning:** If you drop a data access protocol, external tables that have been defined with the protocol will no longer be able to access the external data source.

**Parameters**

- **IF EXISTS**
  - Do not throw an error if the protocol does not exist. A notice is issued in this case.

- **name**
  - The name of an existing data access protocol.

**Notes**

If you drop a data access protocol, the call handlers that defined in the database that are associated with the protocol are not dropped. You must drop the functions manually.

Shared libraries that were used by the protocol should also be removed from the Greenplum Database hosts.

**Compatibility**

`DROP PROTOCOL` is a Greenplum Database extension.

**See Also**

`CREATE EXTERNAL TABLE`, `CREATE PROTOCOL`

**DROP RESOURCE GROUP**

Removes a resource group.

**Synopsis**

```
DROP RESOURCE GROUP group_name
```
Description
This command removes a resource group from Greenplum Database. Only a superuser can drop a resource group.

To drop a role resource group, the group cannot be assigned to any roles, nor can it have any statements pending or running in the group. If you drop a resource group that you created for an external component, the behavior is determined by the external component. For example, dropping a resource group that you assigned to a PL/Container runtime kills running containers in the group.

You cannot drop the pre-defined admin_group and default_group resource groups.

Parameters

**group_name**
The name of the resource group to remove.

Notes
You cannot submit a DROP RESOURCE GROUP command in an explicit transaction or sub-transaction.

Use ALTER ROLE to remove a resource group assigned to a specific user/role.

Perform the following query to view all of the currently active queries for all resource groups:

```sql
SELECT usename, current_query, waiting, procpid, rsgid, rsgname, rsgqueueduration
FROM pg_stat_activity;
```

To view the resource group assignments, perform the following query on the pg_roles and pg_resgroup system catalog tables:

```sql
SELECT rolname, rsgname
FROM pg_roles, pg_resgroup
WHERE pg_roles.rolresgroup=pg_resgroup.oid;
```

Examples

Remove the resource group assigned to a role. This operation then assigns the default resource group default_group to the role:

```sql
ALTER ROLE bob RESOURCE GROUP NONE;
```

Remove the resource group named adhoc:

```sql
DROP RESOURCE GROUP adhoc;
```

Compatibility
The DROP RESOURCE GROUP statement is a Greenplum Database extension.

See Also
ALTER RESOURCE GROUP, CREATE RESOURCE GROUP, ALTER ROLE

**DROP RESOURCE QUEUE**

Removes a resource queue.
Synopsis

```
DROP RESOURCE QUEUE queue_name
```

Description

This command removes a resource queue from Greenplum Database. To drop a resource queue, the queue cannot have any roles assigned to it, nor can it have any statements waiting in the queue. Only a superuser can drop a resource queue.

Parameters

```
queue_name
```

The name of a resource queue to remove.

Notes

Use `ALTER ROLE` to remove a user from a resource queue.

To see all the currently active queries for all resource queues, perform the following query of the `pg_locks` table joined with the `pg_roles` and `pg_resqueue` tables:

```
SELECT rolname, rsqname, locktype, objid, pid,
mode, granted FROM pg_roles, pg_resqueue, pg_locks WHERE
pg_roles.rolresqueue=pg_locks.objid AND
pg_locks.objid=pg_resqueue.oid;
```

To see the roles assigned to a resource queue, perform the following query of the `pg_roles` and `pg_resqueue` system catalog tables:

```
SELECT rolname, rsqname FROM pg_roles, pg_resqueue WHERE
pg_roles.rolresqueue=pg_resqueue.oid;
```

Examples

Remove a role from a resource queue (and move the role to the default resource queue, `pg_default`):

```
ALTER ROLE bob RESOURCE QUEUE NONE;
```

Remove the resource queue named `adhoc`:

```
DROP RESOURCE QUEUE adhoc;
```

Compatibility

The `DROP RESOURCE QUEUE` statement is a Greenplum Database extension.

See Also

`ALTER RESOURCE QUEUE`, `CREATE RESOURCE QUEUE`, `ALTER ROLE`

**DROP ROLE**

Removes a database role.
**Synopsis**

`DROP ROLE [IF EXISTS] name [, ...]`

**Description**

`DROP ROLE` removes the specified role(s). To drop a superuser role, you must be a superuser yourself. To drop non-superuser roles, you must have `CREATEROLE` privilege.

A role cannot be removed if it is still referenced in any database; an error will be raised if so. Before dropping the role, you must drop all the objects it owns (or reassign their ownership) and revoke any privileges the role has been granted. The `REASSIGN OWNED` and `DROP OWNED` commands can be useful for this purpose.

However, it is not necessary to remove role memberships involving the role; `DROP ROLE` automatically revokes any memberships of the target role in other roles, and of other roles in the target role. The other roles are not dropped nor otherwise affected.

**Parameters**

- **IF EXISTS**
  Do not throw an error if the role does not exist. A notice is issued in this case.

- **name**
  The name of the role to remove.

**Examples**

Remove the roles named `sally` and `bob`:

```
DROP ROLE sally, bob;
```

**Compatibility**

The SQL standard defines `DROP ROLE`, but it allows only one role to be dropped at a time, and it specifies different privilege requirements than Greenplum Database uses.

**See Also**

`REASSIGN OWNED`, `DROP OWNED`, `CREATE ROLE`, `ALTER ROLE`, `SET ROLE`

**DROP RULE**

Removes a rewrite rule.

**Synopsis**

`DROP RULE [IF EXISTS] name ON relation [CASCADE | RESTRICT]`

**Description**

`DROP RULE` drops a rewrite rule from a table or view.

**Parameters**

- **IF EXISTS**
  Do not throw an error if the rule does not exist. A notice is issued in this case.

- **name**
The name of the rule to remove.

relation

The name (optionally schema-qualified) of the table or view that the rule applies to.

CASCADE

Automatically drop objects that depend on the rule.

RESTRICT

Refuse to drop the rule if any objects depend on it. This is the default.

Examples

Remove the rewrite rule sales_2006 on the table sales:

```
DROP RULE sales_2006 ON sales;
```

Compatibility

There is no DROP RULE statement in the SQL standard.

See Also

CREATE RULE

DROP SCHEMA

Removes a schema.

Synopsis

```
DROP SCHEMA [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

Description

DROP SCHEMA removes schemas from the database. A schema can only be dropped by its owner or a superuser. Note that the owner can drop the schema (and thereby all contained objects) even if he does not own some of the objects within the schema.

Parameters

IF EXISTS

Do not throw an error if the schema does not exist. A notice is issued in this case.

name

The name of the schema to remove.

CASCADE

Automatically drops any objects contained in the schema (tables, functions, etc.).

RESTRICT

Refuse to drop the schema if it contains any objects. This is the default.

Examples

Remove the schema mystuff from the database, along with everything it contains:

```
DROP SCHEMA mystuff CASCADE;
```
Compatibility

DROP SCHEMA is fully conforming with the SQL standard, except that the standard only allows one schema to be dropped per command. Also, the IF EXISTS option is a Greenplum Database extension.

See Also

CREATE SCHEMA, ALTER SCHEMA

DROP SEQUENCE

Removes a sequence.

Synopsis

\[
\text{DROP SEQUENCE [IF EXISTS] name [, ...] [CASCADE \mid RESTRICT]}
\]

Description

DROP SEQUENCE removes a sequence generator table. You must own the sequence to drop it (or be a superuser).

Parameters

IF EXISTS

Do not throw an error if the sequence does not exist. A notice is issued in this case.

name

The name (optionally schema-qualified) of the sequence to remove.

CASCADE

Automatically drop objects that depend on the sequence.

RESTRICT

Refuse to drop the sequence if any objects depend on it. This is the default.

Examples

Remove the sequence myserial:

\[
\text{DROP SEQUENCE myserial;}
\]

Compatibility

DROP SEQUENCE is fully conforming with the SQL standard, except that the standard only allows one sequence to be dropped per command. Also, the IF EXISTS option is a Greenplum Database extension.

See Also

ALTER SEQUENCE, CREATE SEQUENCE

DROP TABLE

Removes a table.
Synopsis

```sql
DROP TABLE [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

Description

**DROP TABLE** removes tables from the database. Only its owner may drop a table. To empty a table of rows without removing the table definition, use `DELETE` or `TRUNCATE`.

**DROP TABLE** always removes any indexes, rules, triggers, and constraints that exist for the target table. However, to drop a table that is referenced by a view, **CASCADE** must be specified. **CASCADE** will remove a dependent view entirely.

Parameters

**IF EXISTS**

Do not throw an error if the table does not exist. A notice is issued in this case.

**name**

The name (optionally schema-qualified) of the table to remove.

**CASCADE**

Automatically drop objects that depend on the table (such as views).

**RESTRICT**

Refuse to drop the table if any objects depend on it. This is the default.

Examples

Remove the table `mytable`:

```sql
DROP TABLE mytable;
```

Compatibility

**DROP TABLE** is fully conforming with the SQL standard, except that the standard only allows one table to be dropped per command. Also, the **IF EXISTS** option is a Greenplum Database extension.

See Also

`CREATE TABLE`, `ALTER TABLE`, `TRUNCATE`

**DROP TABLESPACE**

Removes a tablespace.

Synopsis

```sql
DROP TABLESPACE [IF EXISTS] tablespacename
```

Description

**DROP TABLESPACE** removes a tablespace from the system.

A tablespace can only be dropped by its owner or a superuser. The tablespace must be empty of all database objects before it can be dropped. It is possible that objects in other databases may still reside in the tablespace even if no objects in the current database are using the tablespace.
Parameters

**IF EXISTS**

Do not throw an error if the tablespace does not exist. A notice is issued in this case.

**tablespacename**

The name of the tablespace to remove.

Examples

Remove the tablespace *mystuff*:

```sql
DROP TABLESPACE mystuff;
```

Compatibility

**DROP TABLESPACE** is a Greenplum Database extension.

See Also

*CREATE TABLESPACE, ALTER TABLESPACE*

**DROP TYPE**

Removes a data type.

Synopsis

```sql
DROP TYPE [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

Description

**DROP TYPE** will remove a user-defined data type. Only the owner of a type can remove it.

Parameters

**IF EXISTS**

Do not throw an error if the type does not exist. A notice is issued in this case.

**name**

The name (optionally schema-qualified) of the data type to remove.

**CASCADE**

Automatically drop objects that depend on the type (such as table columns, functions, operators).

**RESTRICT**

Refuse to drop the type if any objects depend on it. This is the default.

Examples

Remove the data type *box*:

```sql
DROP TYPE box;
```
Compatibility

This command is similar to the corresponding command in the SQL standard, apart from the IF EXISTS option, which is a Greenplum Database extension. But note that the CREATE TYPE command and the data type extension mechanisms in Greenplum Database differ from the SQL standard.

See Also

ALTER TYPE, CREATE TYPE

DROP USER

Removes a database role.

Synopsis

```
DROP USER [IF EXISTS] name [, ...]
```

Description

DROP USER is an alias for DROP ROLE. See DROP ROLE for more information.

Compatibility

There is no DROP USER statement in the SQL standard. The SQL standard leaves the definition of users to the implementation.

See Also

DROP ROLE

DROP VIEW

Removes a view.

Synopsis

```
DROP VIEW [IF EXISTS] name [, ...] [CASCADE | RESTRICT]
```

Description

DROP VIEW will remove an existing view. Only the owner of a view can remove it.

Parameters

- **IF EXISTS**
  
  Do not throw an error if the view does not exist. A notice is issued in this case.

- **name**
  
  The name (optionally schema-qualified) of the view to remove.

- **CASCADE**
  
  Automatically drop objects that depend on the view (such as other views).

- **RESTRICT**
  
  Refuse to drop the view if any objects depend on it. This is the default.
Examples
Remove the view topten;

DROP VIEW topten;

Compatibility
DROP VIEW is fully conforming with the SQL standard, except that the standard only allows one view to be dropped per command. Also, the IF EXISTS option is a Greenplum Database extension.

See Also
CREATE VIEW

END
Commits the current transaction.

Synopsis
END [WORK | TRANSACTION]

Description
END commits the current transaction. All changes made by the transaction become visible to others and are guaranteed to be durable if a crash occurs. This command is a Greenplum Database extension that is equivalent to COMMIT.

Parameters
WORK
TRANSACTION
Optional keywords. They have no effect.

Examples
Commit the current transaction:

END;

Compatibility
END is a Greenplum Database extension that provides functionality equivalent to COMMIT, which is specified in the SQL standard.

See Also
BEGIN, ROLLBACK, COMMIT

EXECUTE
Executes a prepared SQL statement.
Synopsis

EXECUTE name [ (parameter [, ...] ) ]

Description

EXECUTE is used to execute a previously prepared statement. Since prepared statements only exist for the duration of a session, the prepared statement must have been created by a PREPARE statement executed earlier in the current session.

If the PREPARE statement that created the statement specified some parameters, a compatible set of parameters must be passed to the EXECUTE statement, or else an error is raised. Note that (unlike functions) prepared statements are not overloaded based on the type or number of their parameters; the name of a prepared statement must be unique within a database session.

For more information on the creation and usage of prepared statements, see PREPARE.

Parameters

name

The name of the prepared statement to execute.

parameter

The actual value of a parameter to the prepared statement. This must be an expression yielding a value that is compatible with the data type of this parameter, as was determined when the prepared statement was created.

Examples

Create a prepared statement for an INSERT statement, and then execute it:

```
PREPARE fooplan (int, text, bool, numeric) AS INSERT INTO foo VALUES($1, $2, $3, $4);
EXECUTE fooplan(1, 'Hunter Valley', 't', 200.00);
```

Compatibility

The SQL standard includes an EXECUTE statement, but it is only for use in embedded SQL. This version of the EXECUTE statement also uses a somewhat different syntax.

See Also

DEALLOCATE, PREPARE

**EXPLAIN**

Shows the query plan of a statement.

Synopsis

EXPLAIN [ANALYZE] [VERBOSE] statement

Description

EXPLAIN displays the query plan that the Greenplum planner generates for the supplied statement. Query plans are a tree plan of nodes. Each node in the plan represents a single operation, such as table scan, join, aggregation or a sort.
Plans should be read from the bottom up as each node feeds rows into the node directly above it. The bottom nodes of a plan are usually table scan operations (sequential, index or bitmap index scans). If the query requires joins, aggregations, or sorts (or other operations on the raw rows) then there will be additional nodes above the scan nodes to perform these operations. The topmost plan nodes are usually the Greenplum Database motion nodes (redistribute, explicit redistribute, broadcast, or gather motions). These are the operations responsible for moving rows between the segment instances during query processing.

The output of `EXPLAIN` has one line for each node in the plan tree, showing the basic node type plus the following cost estimates that the planner made for the execution of that plan node:

- **cost** — measured in units of disk page fetches; that is, 1.0 equals one sequential disk page read. The first estimate is the start-up cost (cost of getting to the first row) and the second is the total cost (cost of getting all rows). Note that the total cost assumes that all rows will be retrieved, which may not always be the case (if using `LIMIT` for example).
- **rows** — the total number of rows output by this plan node. This is usually less than the actual number of rows processed or scanned by the plan node, reflecting the estimated selectivity of any `WHERE` clause conditions. Ideally the top-level nodes estimate will approximate the number of rows actually returned, updated, or deleted by the query.
- **width** — total bytes of all the rows output by this plan node.

It is important to note that the cost of an upper-level node includes the cost of all its child nodes. The topmost node of the plan has the estimated total execution cost for the plan. This is this number that the planner seeks to minimize. It is also important to realize that the cost only reflects things that the query optimizer cares about. In particular, the cost does not consider the time spent transmitting result rows to the client.

`EXPLAIN ANALYZE` causes the statement to be actually executed, not only planned. The `EXPLAIN ANALYZE` plan shows the actual results along with the planner's estimates. This is useful for seeing whether the planner's estimates are close to reality. In addition to the information shown in the `EXPLAIN` plan, `EXPLAIN ANALYZE` will show the following additional information:

- The total elapsed time (in milliseconds) that it took to run the query.
- The number of `workers` (segments) involved in a plan node operation. Only segments that return rows are counted.
- The maximum number of rows returned by the segment that produced the most rows for an operation. If multiple segments produce an equal number of rows, the one with the longest `time to end` is the one chosen.
- The segment id number of the segment that produced the most rows for an operation.
- For relevant operations, the `work_mem` used by the operation. If `work_mem` was not sufficient to perform the operation in memory, the plan will show how much data was spilled to disk and how many passes over the data were required for the lowest performing segment. For example:

```
Work_mem used: 64K bytes avg, 64K bytes max (seg0).
Work_mem wanted: 90K bytes avg, 90K bytes max (seg0) to abate workfile
I/O affecting 2 workers.
[seg0] pass 0: 488 groups made from 488 rows; 263 rows written to
workfile
[seg0] pass 1: 263 groups made from 263 rows
```
- The time (in milliseconds) it took to retrieve the first row from the segment that produced the most rows, and the total time taken to retrieve all rows from that segment. The `<time> to first row` may be omitted if it is the same as the `<time> to end`.

**Important:** Keep in mind that the statement is actually executed when `EXPLAIN ANALYZE` is used. Although `EXPLAIN ANALYZE` will discard any output that a `SELECT` would return, other side
effects of the statement will happen as usual. If you wish to use `EXPLAIN ANALYZE` on a DML statement without letting the command affect your data, use this approach:

```
BEGIN;
EXPLAIN ANALYZE ...;
ROLLBACK;
```

### Parameters

**name**

The name of the prepared statement to execute.

**parameter**

The actual value of a parameter to the prepared statement. This must be an expression yielding a value that is compatible with the data type of this parameter, as was determined when the prepared statement was created.

### Notes

In order to allow the query optimizer to make reasonably informed decisions when optimizing queries, the `ANALYZE` statement should be run to record statistics about the distribution of data within the table. If you have not done this (or if the statistical distribution of the data in the table has changed significantly since the last time `ANALYZE` was run), the estimated costs are unlikely to conform to the real properties of the query, and consequently an inferior query plan may be chosen.

An SQL statement that is run during the execution of an `EXPLAIN ANALYZE` command is excluded from Greenplum Database resource queues.

For more information about query profiling, see "Query Profiling" in the *Greenplum Database Administrator Guide*. For more information about resource queues, see "Resource Management with Resource Queues" in the *Greenplum Database Administrator Guide*.

### Examples

To illustrate how to read an `EXPLAIN` query plan, consider the following example for a very simple query:

```
EXPLAIN SELECT * FROM names WHERE name = 'Joelle';
```

```
QUERY PLAN

Gather Motion 2:1 (slice1) (cost=0.00..20.88 rows=1 width=13)
  -> Seq Scan on 'names' (cost=0.00..20.88 rows=1 width=13)
      Filter: name::text ~~ 'Joelle '::text
```

If we read the plan from the bottom up, the query optimizer starts by doing a sequential scan of the `names` table. Notice that the `WHERE` clause is being applied as a `filter` condition. This means that the scan operation checks the condition for each row it scans, and outputs only the ones that pass the condition.

The results of the scan operation are passed up to a `gather motion` operation. In Greenplum Database, a gather motion is when segments send rows up to the master. In this case we have 2 segment instances sending to 1 master instance (2:1). This operation is working on `slice1` of the parallel query execution plan. In Greenplum Database a query plan is divided into `slices` so that portions of the query plan can be worked on in parallel by the segments.

The estimated startup cost for this plan is 00.00 (no cost) and a total cost of 20.88 disk page fetches. The planner is estimating that this query will return one row.

### Compatibility

There is no `EXPLAIN` statement defined in the SQL standard.
See Also

ANALYZE

**FETCH**

Retrieves rows from a query using a cursor.

**Synopsis**

```sql
FETCH [ forward_direction { FROM | IN } ] cursorname
```

where `forward_direction` can be empty or one of:

- NEXT
- FIRST
- LAST
- ABSOLUTE `count`
- RELATIVE `count`
- `count`
- ALL
- FORWARD
- FORWARD `count`
- FORWARD ALL

**Description**

`FETCH` retrieves rows using a previously-created cursor.

A cursor has an associated position, which is used by `FETCH`. The cursor position can be before the first row of the query result, on any particular row of the result, or after the last row of the result. When created, a cursor is positioned before the first row. After fetching some rows, the cursor is positioned on the row most recently retrieved. If `FETCH` runs off the end of the available rows then the cursor is left positioned after the last row. `FETCH ALL` will always leave the cursor positioned after the last row.

The forms `NEXT`, `FIRST`, `LAST`, `ABSOLUTE`, `RELATIVE` fetch a single row after moving the cursor appropriately. If there is no such row, an empty result is returned, and the cursor is left positioned before the first row or after the last row as appropriate.

The forms using `FORWARD` retrieve the indicated number of rows moving in the forward direction, leaving the cursor positioned on the last-returned row (or after all rows, if the count exceeds the number of rows available). Note that it is not possible to move a cursor position backwards in Greenplum Database, since scrollable cursors are not supported. You can only move a cursor forward in position using `FETCH`.

`RELATIVE 0` and `FORWARD 0` request fetching the current row without moving the cursor, that is, re-fetching the most recently fetched row. This will succeed unless the cursor is positioned before the first row or after the last row, in which case no row is returned.

**Outputs**

On successful completion, a `FETCH` command returns a command tag of the form

```sql
FETCH count
```

The count is the number of rows fetched (possibly zero). Note that in `psql`, the command tag will not actually be displayed, since `psql` displays the fetched rows instead.

**Parameters**

`forward_direction`
Defines the fetch direction and number of rows to fetch. Only forward fetches are allowed in Greenplum Database. It can be one of the following:

**NEXT**
Fetch the next row. This is the default if direction is omitted.

**FIRST**
Fetch the first row of the query (same as `ABSOLUTE 1`). Only allowed if it is the first FETCH operation using this cursor.

**LAST**
Fetch the last row of the query (same as `ABSOLUTE -1`).

**ABSOLUTE count**
Fetch the specified row of the query. Position after last row if count is out of range. Only allowed if the row specified by `count` moves the cursor position forward.

**RELATIVE count**
Fetch the specified row of the query `count` rows ahead of the current cursor position. `RELATIVE 0` re-fetches the current row, if any. Only allowed if `count` moves the cursor position forward.

`count`
Fetch the next `count` number of rows (same as `FORWARD count`).

**ALL**
Fetch all remaining rows (same as `FORWARD ALL`).

**FORWARD**
Fetch the next row (same as `NEXT`).

**FORWARD count**
Fetch the next `count` number of rows. `FORWARD 0` re-fetches the current row.

**FORWARD ALL**
Fetch all remaining rows.

`cursorname`
The name of an open cursor.

**Notes**
Greenplum Database does not support scrollable cursors, so you can only use FETCH to move the cursor position forward.

`ABSOLUTE` fetches are not any faster than navigating to the desired row with a relative move: the underlying implementation must traverse all the intermediate rows anyway.

`DECLARE` is used to define a cursor. Use `MOVE` to change cursor position without retrieving data.

**Examples**
-- Start the transaction:

```sql
BEGIN;
```

-- Set up a cursor:

```sql
DECLARE mycursor CURSOR FOR SELECT * FROM films;
```
-- Fetch the first 5 rows in the cursor `mycursor`:

```
FETCH FORWARD 5 FROM mycursor;
```

<table>
<thead>
<tr>
<th>code</th>
<th>title</th>
<th>did</th>
<th>date_prod</th>
<th>kind</th>
<th>len</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL101</td>
<td>The Third Man</td>
<td>101</td>
<td>1949-12-23</td>
<td>Drama</td>
<td>01:44</td>
</tr>
<tr>
<td>BL102</td>
<td>The African Queen</td>
<td>101</td>
<td>1951-08-11</td>
<td>Romantic</td>
<td>01:43</td>
</tr>
<tr>
<td>JL201</td>
<td>Une Femme est une Femme</td>
<td>102</td>
<td>1961-03-12</td>
<td>Romantic</td>
<td>01:25</td>
</tr>
<tr>
<td>P_301</td>
<td>Vertigo</td>
<td>103</td>
<td>1958-11-14</td>
<td>Action</td>
<td>02:08</td>
</tr>
<tr>
<td>P_302</td>
<td>Becket</td>
<td>103</td>
<td>1964-02-03</td>
<td>Drama</td>
<td>02:28</td>
</tr>
</tbody>
</table>

-- Close the cursor and end the transaction:

```
CLOSE mycursor;
COMMIT;
```

Change the `kind` column of the table `films` in the row at the `c_films` cursor's current position:

```
UPDATE films SET kind = 'Dramatic' WHERE CURRENT OF c_films;
```

**Compatibility**

SQL standard allows cursors only in embedded SQL and in modules. Greenplum Database permits cursors to be used interactively.

The variant of `FETCH` described here returns the data as if it were a `SELECT` result rather than placing it in host variables. Other than this point, `FETCH` is fully upward-compatible with the SQL standard.

The `FETCH` forms involving `FORWARD`, as well as the forms `FETCH count` and `FETCHALL`, in which `FORWARD` is implicit, are Greenplum Database extensions. `BACKWARD` is not supported.

The SQL standard allows only `FROM` preceding the cursor name; the option to use `IN` is an extension.

**See Also**

`DECLARE`, `CLOSE`, `MOVE`

**GRANT**

Defines access privileges.

**Synopsis**

```
GRANT { {SELECT | INSERT | UPDATE | DELETE | REFERENCES | TRIGGER | TRUNCATE } [, ...] | ALL [PRIVILEGES] } 
ON [TABLE] tablename [, ...] 
TO { rolename | PUBLIC} [, ...] [WITH GRANT OPTION]

GRANT { {USAGE | SELECT | UPDATE} [, ...] | ALL [PRIVILEGES] } 
ON SEQUENCE sequencename [, ...] 
TO { rolename | PUBLIC} [, ...] [WITH GRANT OPTION]

GRANT { {CREATE | CONNECT | TEMPORARY | TEMP} [, ...] | ALL [PRIVILEGES] } 
ON DATABASE dbname [, ...] 
TO { rolename | PUBLIC} [, ...] [WITH GRANT OPTION]

GRANT { EXECUTE | ALL [PRIVILEGES] } 
ON FUNCTION funcname { [ [argmode] [argname] argtype [, ...] ] } [, ...] 
TO { rolename | PUBLIC} [, ...] [WITH GRANT OPTION]
```
GRANT { USAGE | ALL [PRIVILEGES] } 
  ON LANGUAGE langname [, ...] 
  TO { rolename | PUBLIC } [, ...] [WITH GRANT OPTION]

GRANT { {CREATE | USAGE} [, ...] | ALL [PRIVILEGES] } 
  ON SCHEMA schemaname [, ...] 
  TO { rolename | PUBLIC } [, ...] [WITH GRANT OPTION]

GRANT { CREATE | ALL [PRIVILEGES] } 
  ON TABLESPACE tablespacename [, ...] 
  TO { rolename | PUBLIC } [, ...] [WITH GRANT OPTION]

GRANT parent_role [, ...] 
  TO member_role [, ...] [WITH ADMIN OPTION]

GRANT { SELECT | INSERT | ALL [PRIVILEGES] } 
  ON PROTOCOL protocolname 
  TO username

Description

The GRANT command has two basic variants: one that grants privileges on a database object (table, view, sequence, database, function, procedural language, schema, or tablespace), and one that grants membership in a role.

GRANT on Database Objects

This variant of the GRANT command gives specific privileges on a database object to one or more roles. These privileges are added to those already granted, if any.

The key word PUBLIC indicates that the privileges are to be granted to all roles, including those that may be created later. PUBLIC may be thought of as an implicitly defined group-level role that always includes all roles. Any particular role will have the sum of privileges granted directly to it, privileges granted to any role it is presently a member of, and privileges granted to PUBLIC.

If WITH GRANT OPTION is specified, the recipient of the privilege may in turn grant it to others. Without a grant option, the recipient cannot do that. Grant options cannot be granted to PUBLIC.

There is no need to grant privileges to the owner of an object (usually the role that created it), as the owner has all privileges by default. The right to drop an object, or to alter its definition in any way is not described by a grantable privilege; it is inherent in the owner, and cannot be granted or revoked. The owner implicitly has all grant options for the object, too.

Depending on the type of object, the initial default privileges may include granting some privileges to PUBLIC. The default is no public access for tables, schemas, and tablespaces; CONNECT privilege and TEMP table creation privilege for databases; EXECUTE privilege for functions; and USAGE privilege for languages. The object owner may of course revoke these privileges.

GRANT on Roles

This variant of the GRANT command grants membership in a role to one or more other roles. Membership in a role is significant because it conveys the privileges granted to a role to each of its members.

If WITH ADMIN OPTION is specified, the member may in turn grant membership in the role to others, and revoke membership in the role as well. Database superusers can grant or revoke membership in any role to anyone. Roles having CREATEROLE privilege can grant or revoke membership in any role that is not a superuser.

Unlike the case with privileges, membership in a role cannot be granted to PUBLIC.

GRANT on Protocols
After creating a custom protocol, specify `CREATE TRUSTED PROTOCOL` to be able to allowing any user besides the owner to access it. If the protocol is not trusted, you cannot give any other user permission to use it to read or write data. After a **TRUSTED** protocol is created, you can specify which other users can access it with the `GRANT` command.

- To allow a user to create a readable external table with a trusted protocol
  
  ```sql
  GRANT SELECT ON PROTOCOL protocolname TO username
  ```

- To allow a user to create a writable external table with a trusted protocol
  
  ```sql
  GRANT INSERT ON PROTOCOL protocolname TO username
  ```

- To allow a user to create both readable and writable external table with a trusted protocol
  
  ```sql
  GRANT ALL ON PROTOCOL protocolname TO username
  ```

### Parameters

#### SELECT

Allows `SELECT` from any column of the specified table, view, or sequence. Also allows the use of `COPY TO`.

#### INSERT

Allows `INSERT` of a new row into the specified table. Also allows `COPY FROM`.

#### UPDATE

Allows `UPDATE` of any column of the specified table. `SELECT ... FOR UPDATE` and `SELECT ... FOR SHARE` also require this privilege (as well as the `SELECT` privilege). For sequences, this privilege allows the use of the `nextval()` and `setval()` functions.

#### DELETE

Allows `DELETE` of a row from the specified table.

#### REFERENCES

This keyword is accepted, although foreign key constraints are currently not supported in Greenplum Database. To create a foreign key constraint, it is necessary to have this privilege on both the referencing and referenced tables.

#### TRIGGER

Allows the creation of a trigger on the specified table.  

**Note:** Greenplum Database does not support triggers.

#### TRUNCATE

Allows `TRUNCATE` of all rows from the specified table.

#### CREATE

For databases, allows new schemas to be created within the database.

For schemas, allows new objects to be created within the schema. To rename an existing object, you must own the object and have this privilege for the containing schema.

For tablespaces, allows tables and indexes to be created within the tablespace, and allows databases to be created that have the tablespace as their default tablespace. (Note that revoking this privilege will not alter the placement of existing objects.)

#### CONNECT

Allows the user to connect to the specified database. This privilege is checked at connection startup (in addition to checking any restrictions imposed by `pg_hba.conf`).

#### TEMPORARY
TEMP

Allows temporary tables to be created while using the database.

EXECUTE

Allows the use of the specified function and the use of any operators that are implemented on top of the function. This is the only type of privilege that is applicable to functions. (This syntax works for aggregate functions, as well.)

USAGE

For procedural languages, allows the use of the specified language for the creation of functions in that language. This is the only type of privilege that is applicable to procedural languages.

For schemas, allows access to objects contained in the specified schema (assuming that the objects' own privilege requirements are also met). Essentially this allows the grantee to look up objects within the schema.

For sequences, this privilege allows the use of the nextval() function.

ALL PRIVILEGES

Grant all of the available privileges at once. The PRIVILEGES keyword is optional in Greenplum Database, though it is required by strict SQL.

PUBLIC

A special group-level role that denotes that the privileges are to be granted to all roles, including those that may be created later.

WITH GRANT OPTION

The recipient of the privilege may in turn grant it to others.

WITH ADMIN OPTION

The member of a role may in turn grant membership in the role to others.

Notes

Database superusers can access all objects regardless of object privilege settings. One exception to this rule is view objects. Access to tables referenced in the view is determined by permissions of the view owner not the current user (even if the current user is a superuser).

If a superuser chooses to issue a GRANT or REVOKE command, the command is performed as though it were issued by the owner of the affected object. In particular, privileges granted via such a command will appear to have been granted by the object owner. For role membership, the membership appears to have been granted by the containing role itself.

GRANT and REVOKE can also be done by a role that is not the owner of the affected object, but is a member of the role that owns the object, or is a member of a role that holds privileges WITH GRANT OPTION on the object. In this case the privileges will be recorded as having been granted by the role that actually owns the object or holds the privileges WITH GRANT OPTION.

Granting permission on a table does not automatically extend permissions to any sequences used by the table, including sequences tied to SERIAL columns. Permissions on a sequence must be set separately.

Greenplum Database does not support granting or revoking privileges for individual columns of a table. One possible workaround is to create a view having just the desired columns and then grant privileges to that view.

Use psql's \z meta-command to obtain information about existing privileges for an object.
Examples
Grant insert privilege to all roles on table mytable:

    GRANT INSERT ON mytable TO PUBLIC;

Grant all available privileges to role sally on the view topten. Note that while the above will indeed grant all privileges if executed by a superuser or the owner of topten, when executed by someone else it will only grant those permissions for which the granting role has grant options.

    GRANT ALL PRIVILEGES ON topten TO sally;

Grant membership in role admins to user joe:

    GRANT admins TO joe;

Compatibility
The PRIVILEGES key word in is required in the SQL standard, but optional in Greenplum Database. The SQL standard does not support setting the privileges on more than one object per command.

Greenplum Database allows an object owner to revoke his own ordinary privileges: for example, a table owner can make the table read-only to himself by revoking his own INSERT, UPDATE, DELETE, and TRUNCATE privileges. This is not possible according to the SQL standard. Greenplum Database treats the owner's privileges as having been granted by the owner to himself; therefore he can revoke them too. In the SQL standard, the owner's privileges are granted by an assumed system entity.

The SQL standard allows setting privileges for individual columns within a table.

The SQL standard provides for a USAGE privilege on other kinds of objects: character sets, collations, translations, domains.

Privileges on databases, tablespaces, schemas, and languages are Greenplum Database extensions.

See Also
REVOKE

INSERT

Creates new rows in a table.

Synopsis

    INSERT INTO table [( column [, ...] )]
    {DEFAULT VALUES | VALUES ( {expression | DEFAULT} [, ...] )
    [, ...] | query}

Description

INSERT inserts new rows into a table. One can insert one or more rows specified by value expressions, or zero or more rows resulting from a query.

The target column names may be listed in any order. If no list of column names is given at all, the default is the columns of the table in their declared order. The values supplied by the VALUES clause or query are associated with the explicit or implicit column list left-to-right.

Each column not present in the explicit or implicit column list will be filled with a default value, either its declared default value or null if there is no default.
If the expression for any column is not of the correct data type, automatic type conversion will be attempted.

You must have INSERT privilege on a table in order to insert into it.

**Outputs**

On successful completion, an INSERT command returns a command tag of the form:

```
INSERT  oid  count
```

The *count* is the number of rows inserted. If `count` is exactly one, and the target table has OIDs, then *oid* is the OID assigned to the inserted row. Otherwise *oid* is zero.

**Parameters**

- **table**
  The name (optionally schema-qualified) of an existing table.

- **column**
  The name of a column in table. The column name can be qualified with a subfield name or array subscript, if needed. (Inserting into only some fields of a composite column leaves the other fields null.)

- **DEFAULT VALUES**
  All columns will be filled with their default values.

- **expression**
  An expression or value to assign to the corresponding column.

- **DEFAULT**
  The corresponding column will be filled with its default value.

- **query**
  A query (SELECT statement) that supplies the rows to be inserted. Refer to the SELECT statement for a description of the syntax.

**Notes**

To insert data into a partitioned table, you specify the root partitioned table, the table created with the CREATE TABLE command. You also can specify a leaf child table of the partitioned table in an INSERT command. An error is returned if the data is not valid for the specified leaf child table. Specifying a child table that is not a leaf child table in the INSERT command is not supported. Execution of other DML commands such as UPDATE and DELETE on any child table of a partitioned table is not supported. These commands must be executed on the root partitioned table, the table created with the CREATE TABLE command.

For append-optimized tables, Greenplum Database supports a maximum of 127 concurrent INSERT transactions into a single append-optimized table.

For writable S3 external tables, the INSERT operation uploads to one or more files in the configured S3 bucket, as described in s3:// Protocol. Pressing Ctrl-c cancels the INSERT and stops uploading to S3.

**Examples**

Insert a single row into table `films`:

```
INSERT INTO films VALUES ('UA502', 'Bananas', 105, '1971-07-13', 'Comedy', '82 minutes');
```
In this example, the `length` column is omitted and therefore it will have the default value:

```sql
INSERT INTO films (code, title, did, date_prod, kind) VALUES ('T_601', 'Yojimbo', 106, '1961-06-16', 'Drama');
```

This example uses the `DEFAULT` clause for the `date_prod` column rather than specifying a value:

```sql
INSERT INTO films VALUES ('UA502', 'Bananas', 105, DEFAULT, 'Comedy', '82 minutes');
```

To insert a row consisting entirely of default values:

```sql
INSERT INTO films DEFAULT VALUES;
```

To insert multiple rows using the multirow `VALUES` syntax:

```sql
INSERT INTO films (code, title, did, date_prod, kind) VALUES ('B6717', 'Tampopo', 110, '1985-02-10', 'Comedy'), ('HG120', 'The Dinner Game', 140, DEFAULT, 'Comedy');
```

This example inserts some rows into table `films` from a table `tmp_films` with the same column layout as `films`:

```sql
INSERT INTO films SELECT * FROM tmp_films WHERE date_prod < '2004-05-07';
```

**Compatibility**

`INSERT` conforms to the SQL standard. The case in which a column name list is omitted, but not all the columns are filled from the `VALUES` clause or query, is disallowed by the standard.

Possible limitations of the `query` clause are documented under `SELECT`.

**See Also**

`COPY`, `SELECT`, `CREATE EXTERNAL TABLE`, `s3:// Protocol`

---

**LOAD**

Loads or reloads a shared library file.

**Synopsis**

```
LOAD 'filename'
```

**Description**

This command loads a shared library file into the Greenplum Database server address space. If the file had been loaded previously, it is first unloaded. This command is primarily useful to unload and reload a shared library file that has been changed since the server first loaded it. To make use of the shared library, function(s) in it need to be declared using the `CREATE FUNCTION` command.

The file name is specified in the same way as for shared library names in `CREATE FUNCTION`; in particular, one may rely on a search path and automatic addition of the system's standard shared library file name extension.

Note that in Greenplum Database the shared library file (`.so` file) must reside in the same path location on every host in the Greenplum Database array (masters, segments, and mirrors).
Only database superusers can load shared library files.

**Parameters**

`filename`

The path and file name of a shared library file. This file must exist in the same location on all hosts in your Greenplum Database array.

**Examples**

Load a shared library file:

```sql
LOAD '/usr/local/greenplum-db/lib/myfuncs.so';
```

**Compatibility**

LOAD is a Greenplum Database extension.

**See Also**

`CREATE FUNCTION`

---

**LOCK**

Locks a table.

**Synopsis**

```sql
LOCK [TABLE] name [, ...] [IN lockmode MODE] [NOWAIT]
```

where `lockmode` is one of:

- `ACCESS SHARE` | `ROW SHARE` | `ROW EXCLUSIVE` | `SHARE UPDATE EXCLUSIVE`
- `SHARE` | `SHARE ROW EXCLUSIVE` | `EXCLUSIVE` | `ACCESS EXCLUSIVE`

**Description**

`LOCK TABLE` obtains a table-level lock, waiting if necessary for any conflicting locks to be released. If `NOWAIT` is specified, `LOCK TABLE` does not wait to acquire the desired lock; if it cannot be acquired immediately, the command is aborted and an error is emitted. Once obtained, the lock is held for the remainder of the current transaction. There is no `UNLOCK TABLE` command; locks are always released at transaction end.

When acquiring locks automatically for commands that reference tables, Greenplum Database always uses the least restrictive lock mode possible. `LOCK TABLE` provides for cases when you might need more restrictive locking. For example, suppose an application runs a transaction at the Read Committed isolation level and needs to ensure that data in a table remains stable for the duration of the transaction. To achieve this you could obtain `SHARE` lock mode over the table before querying. This will prevent concurrent data changes and ensure subsequent reads of the table see a stable view of committed data, because `SHARE` lock mode conflicts with the `ROW EXCLUSIVE` lock acquired by writers, and your `LOCK TABLE name IN SHARE MODE` statement will wait until any concurrent holders of `ROW EXCLUSIVE` mode locks commit or roll back. Thus, once you obtain the lock, there are no uncommitted writes outstanding; furthermore none can begin until you release the lock.

To achieve a similar effect when running a transaction at the Serializable isolation level, you have to execute the `LOCK TABLE` statement before executing any `SELECT` or data modification statement. A serializable transaction's view of data will be frozen when its first `SELECT` or data modification statement...
begins. A `LOCK TABLE` later in the transaction will still prevent concurrent writes — but it won't ensure that what the transaction reads corresponds to the latest committed values.

If a transaction of this sort is going to change the data in the table, then it should use `SHARE ROW EXCLUSIVE` lock mode instead of `SHARE` mode. This ensures that only one transaction of this type runs at a time. Without this, a deadlock is possible: two transactions might both acquire `SHARE` mode, and then be unable to also acquire `ROW EXCLUSIVE` mode to actually perform their updates. Note that a transaction's own locks never conflict, so a transaction can acquire `ROW EXCLUSIVE` mode when it holds `SHARE` mode — but not if anyone else holds `SHARE` mode. To avoid deadlocks, make sure all transactions acquire locks on the same objects in the same order, and if multiple lock modes are involved for a single object, then transactions should always acquire the most restrictive mode first.

**Parameters**

**name**

The name (optionally schema-qualified) of an existing table to lock.

If multiple tables are given, tables are locked one-by-one in the order specified in the `LOCK TABLE` command.

**lockmode**

The lock mode specifies which locks this lock conflicts with. If no lock mode is specified, then `ACCESS EXCLUSIVE`, the most restrictive mode, is used. Lock modes are as follows:

- **ACCESS SHARE** — Conflicts with the `ACCESS EXCLUSIVE` lock mode only. The commands `SELECT` and `ANALYZE` automatically acquire a lock of this mode on referenced tables. In general, any query that only reads a table and does not modify it will acquire this lock mode.
- **ROW SHARE** — Conflicts with the `EXCLUSIVE` and `ACCESS EXCLUSIVE` lock modes. The `SELECT FOR SHARE` command automatically acquires a lock of this mode on the target table(s) (in addition to `ACCESS SHARE` locks on any other tables that are referenced but not selected `FOR SHARE`).
- **ROW EXCLUSIVE** — Conflicts with the `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes. The commands `INSERT` and `COPY` automatically acquire this lock mode on the target table (in addition to `ACCESS SHARE` locks on any other referenced tables).
- **SHARE UPDATE EXCLUSIVE** — Conflicts with the `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes. This mode protects a table against concurrent schema changes and `VACUUM` runs. Acquired automatically by `VACUUM` (without `FULL`) on heap tables.
- **SHARE** — Conflicts with the `ROW EXCLUSIVE`, `SHARE UPDATE EXCLUSIVE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes. This mode protects a table against concurrent data changes. Acquired automatically by `CREATE INDEX`.
- **SHARE ROW EXCLUSIVE** — Conflicts with the `ROW EXCLUSIVE`, `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes. This lock mode is not automatically acquired by any Greenplum Database command.
- **EXCLUSIVE** — Conflicts with the `ROW SHARE`, `ROW EXCLUSIVE`, `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE` lock modes. This mode allows only concurrent `ACCESS SHARE` locks, i.e., only reads from the table can proceed in parallel with a transaction holding this lock mode. This lock mode is automatically acquired for `UPDATE`, `SELECT FOR UPDATE`, and `DELETE` in Greenplum Database (which is more restrictive locking than in regular PostgreSQL).
- **ACCESS EXCLUSIVE** — Conflicts with locks of all modes (`ACCESS SHARE`, `ROW SHARE`, `ROW EXCLUSIVE`, `SHARE UPDATE EXCLUSIVE`, `SHARE`, `SHARE ROW EXCLUSIVE`, `EXCLUSIVE`, and `ACCESS EXCLUSIVE`). This mode guarantees that the
holder is the only transaction accessing the table in any way. Acquired automatically by the ALTER TABLE, DROP TABLE, TRUNCATE, REINDEX, CLUSTER, and VACUUM FULL commands. This is the default lock mode for LOCK TABLE statements that do not specify a mode explicitly. This lock is also briefly acquired by VACUUM (without FULL) on append-optimized tables during processing.

NOWAIT

Specifies that LOCK TABLE should not wait for any conflicting locks to be released: if the specified lock(s) cannot be acquired immediately without waiting, the transaction is aborted.

Notes

LOCK TABLE ... IN ACCESS SHARE MODE requires SELECT privileges on the target table. All other forms of LOCK require UPDATE and/or DELETE privileges.

LOCK TABLE is useful only inside a transaction block (BEGIN/COMMIT pair), since the lock is dropped as soon as the transaction ends. A LOCK TABLE command appearing outside any transaction block forms a self-contained transaction, so the lock will be dropped as soon as it is obtained.

LOCK TABLE only deals with table-level locks, and so the mode names involving ROW are all misnomers. These mode names should generally be read as indicating the intention of the user to acquire row-level locks within the locked table. Also, ROW EXCLUSIVE mode is a sharable table lock. Keep in mind that all the lock modes have identical semantics so far as LOCK TABLE is concerned, differing only in the rules about which modes conflict with which. For information on how to acquire an actual row-level lock, see the FOR UPDATE/FOR SHARE clause in the SELECT reference documentation.

Examples

Obtain a SHARE lock on the films table when going to perform inserts into the films_user_comments table:

```
BEGIN WORK;
LOCK TABLE films IN SHARE MODE;
SELECT id FROM films
    WHERE name = 'Star Wars: Episode I - The Phantom Menace';
-- Do ROLLBACK if record was not returned
INSERT INTO films_user_comments VALUES
    (id, 'GREAT! I was waiting for it for so long!');
COMMIT WORK;
```

Take a SHARE ROW EXCLUSIVE lock on a table when performing a delete operation:

```
BEGIN WORK;
LOCK TABLE films IN SHARE ROW EXCLUSIVE MODE;
DELETE FROM films_user_comments WHERE id IN
    (SELECT id FROM films WHERE rating < 5);
DELETE FROM films WHERE rating < 5;
COMMIT WORK;
```

Compatibility

There is no LOCK TABLE in the SQL standard, which instead uses SET TRANSACTION to specify concurrency levels on transactions. Greenplum Database supports that too.

Except for ACCESS SHARE, ACCESS EXCLUSIVE, and SHARE UPDATE EXCLUSIVE lock modes, the Greenplum Database lock modes and the LOCK TABLE syntax are compatible with those present in Oracle.
MOVE

Positions a cursor.

Synopsis

MOVE [ forward_direction {FROM | IN} ] cursorname

where forward_direction can be empty or one of:

NEXT
FIRST
LAST
ABSOLUTE count
RELATIVE count
count
ALL
FORWARD
FORWARD count
FORWARD ALL

Description

MOVE repositions a cursor without retrieving any data. MOVE works exactly like the FETCH command, except it only positions the cursor and does not return rows.

Note that it is not possible to move a cursor position backwards in Greenplum Database, since scrollable cursors are not supported. You can only move a cursor forward in position using MOVE.

Outputs

On successful completion, a MOVE command returns a command tag of the form

MOVE count

The count is the number of rows that a FETCH command with the same parameters would have returned (possibly zero).

Parameters

forward_direction

See FETCH for more information.

cursorname

The name of an open cursor.

Examples

-- Start the transaction:

BEGIN;

-- Set up a cursor:

DECLARE mycursor CURSOR FOR SELECT * FROM films;
-- Move forward 5 rows in the cursor mycursor:

MOVE FORWARD 5 IN mycursor;
MOVE 5

-- Fetch the next row after that (row 6):

FETCH 1 FROM mycursor;

<table>
<thead>
<tr>
<th>code</th>
<th>title</th>
<th>did</th>
<th>date_prod</th>
<th>kind</th>
<th>len</th>
</tr>
</thead>
<tbody>
<tr>
<td>P_303</td>
<td>48 Hrs</td>
<td>103</td>
<td>1982-10-22</td>
<td>Action</td>
<td>01:37</td>
</tr>
</tbody>
</table>

(1 row)

-- Close the cursor and end the transaction:

CLOSE mycursor;
COMMIT;

Compatibility

There is no MOVE statement in the SQL standard.

See Also

DECLARE, FETCH, CLOSE

**PREPARE**

Prepare a statement for execution.

**Synopsis**

PREPARE name [ (datatype [, ...] ) ] AS statement

**Description**

PREPARE creates a prepared statement, possibly with unbound parameters. A prepared statement is a server-side object that can be used to optimize performance. A prepared statement may be subsequently executed with a binding for its parameters. Greenplum Database may choose to replan the query for different executions of the same prepared statement.

Prepared statements can take parameters: values that are substituted into the statement when it is executed. When creating the prepared statement, refer to parameters by position, using $1, $2, etc. A corresponding list of parameter data types can optionally be specified. When a parameter's data type is not specified or is declared as unknown, the type is inferred from the context in which the parameter is used (if possible). When executing the statement, specify the actual values for these parameters in the EXECUTE statement.

Prepared statements only last for the duration of the current database session. When the session ends, the prepared statement is forgotten, so it must be recreated before being used again. This also means that a single prepared statement cannot be used by multiple simultaneous database clients; however, each client can create their own prepared statement to use. The prepared statement can be manually cleaned up using the DEALLOCATE command.

Prepared statements have the largest performance advantage when a single session is being used to execute a large number of similar statements. The performance difference will be particularly significant if the statements are complex to plan or rewrite, for example, if the query involves a join of many tables.
or requires the application of several rules. If the statement is relatively simple to plan and rewrite but relatively expensive to execute, the performance advantage of prepared statements will be less noticeable.

**Parameters**

*name*

An arbitrary name given to this particular prepared statement. It must be unique within a single session and is subsequently used to execute or deallocate a previously prepared statement.

*datatype*

The data type of a parameter to the prepared statement. If the data type of a particular parameter is unspecified or is specified as unknown, it will be inferred from the context in which the parameter is used. To refer to the parameters in the prepared statement itself, use $1, $2, etc.

*statement*

Any SELECT, INSERT, UPDATE, DELETE, or VALUES statement.

**Notes**

In some situations, the query plan produced for a prepared statement will be inferior to the query plan that would have been chosen if the statement had been submitted and executed normally. This is because when the statement is planned and the planner attempts to determine the optimal query plan, the actual values of any parameters specified in the statement are unavailable. Greenplum Database collects statistics on the distribution of data in the table, and can use constant values in a statement to make guesses about the likely result of executing the statement. Since this data is unavailable when planning prepared statements with parameters, the chosen plan may be suboptimal. To examine the query plan Greenplum Database has chosen for a prepared statement, use EXPLAIN.

For more information on query planning and the statistics collected by Greenplum Database for that purpose, see the ANALYZE documentation.

You can see all available prepared statements of a session by querying the `pg_prepared_statements` system view.

**Examples**

Create a prepared statement for an INSERT statement, and then execute it:

```sql
PREPARE fooplan (int, text, bool, numeric) AS INSERT INTO foo VALUES($1, $2, $3, $4);
EXECUTE fooplan(1, 'Hunter Valley', 't', 200.00);
```

Create a prepared statement for a SELECT statement, and then execute it. Note that the data type of the second parameter is not specified, so it is inferred from the context in which $2 is used:

```sql
PREPARE usrrptplan (int) AS SELECT * FROM users u, logs l WHERE u.usrid=$1 AND u.usrid=l.usrid AND l.date = $2;
EXECUTE usrrptplan(1, current_date);
```

**Compatibility**

The SQL standard includes a PREPARE statement, but it is only for use in embedded SQL. This version of the PREPARE statement also uses a somewhat different syntax.

**See Also**

EXECUTE, DEALLOCATE
**REASSIGN OWNED**

Changes the ownership of database objects owned by a database role.

**Synopsis**

```
REASSIGN OWNED BY old_role [, ...] TO new_role
```

**Description**

The `REASSIGN OWNED` command reassigns all the objects in the current database that are owned by `old_role` to `new_role`. Note that it does not change the ownership of the database itself.

**Parameters**

- **old_role**: The name of a role. The ownership of all the objects in the current database owned by this role will be reassigned to `new_role`.
- **new_role**: The name of the role that will be made the new owner of the affected objects.

**Notes**

- `REASSIGN OWNED` is often used to prepare for the removal of one or more roles. Because `REASSIGN OWNED` only affects the objects in the current database, it is usually necessary to execute this command in each database that contains objects owned by a role that is to be removed.
- The `DROP OWNED` command is an alternative that drops all the database objects owned by one or more roles.
- The `REASSIGN OWNED` command does not affect the privileges granted to the old roles in objects that are not owned by them. Use `DROP OWNED` to revoke those privileges.

**Examples**

Reassign any database objects owned by the role named `sally` and `bob` to `admin`;

```
REASSIGN OWNED BY sally, bob TO admin;
```

**Compatibility**

- The `REASSIGN OWNED` statement is a Greenplum Database extension.

**See Also**

- `DROP OWNED`, `DROP ROLE`

---

**REINDEX**

Rebuilds indexes.

**Synopsis**

```
REINDEX {INDEX | TABLE | DATABASE | SYSTEM} name
```
Description

`REINDEX` rebuilds an index using the data stored in the index's table, replacing the old copy of the index. There are several scenarios in which to use `REINDEX`:

- An index has become bloated, that it is contains many empty or nearly-empty pages. This can occur with B-tree indexes in Greenplum Database under certain uncommon access patterns. `REINDEX` provides a way to reduce the space consumption of the index by writing a new version of the index without the dead pages.
- You have altered the fillfactor storage parameter for an index, and wish to ensure that the change has taken full effect.

Parameters

`INDEX`  
Recreate the specified index.

`TABLE`  
Recreate all indexes of the specified table. If the table has a secondary TOAST table, that is reindexed as well.

`DATABASE`  
Recreate all indexes within the current database. Indexes on shared system catalogs are skipped. This form of `REINDEX` cannot be executed inside a transaction block.

`SYSTEM`  
Recreate all indexes on system catalogs within the current database. Indexes on user tables are not processed. Also, indexes on shared (global) system catalogs are skipped. This form of `REINDEX` cannot be executed inside a transaction block.

`name`  
The name of the specific index, table, or database to be reindexed. Index and table names may be schema-qualified. Presently, `REINDEX DATABASE` and `REINDEX SYSTEM` can only reindex the current database, so their parameter must match the current database's name.

Notes

`REINDEX` is similar to a drop and recreate of the index in that the index contents are rebuilt from scratch. However, the locking considerations are rather different. `REINDEX` locks out writes but not reads of the index's parent table. It also takes an exclusive lock on the specific index being processed, which will block reads that attempt to use that index. In contrast, `DROP INDEX` momentarily takes exclusive lock on the parent table, blocking both writes and reads. The subsequent `CREATE INDEX` locks out writes but not reads; since the index is not there, no read will attempt to use it, meaning that there will be no blocking but reads may be forced into expensive sequential scans.

Reindexing a single index or table requires being the owner of that index or table. Reindexing a database requires being the owner of the database (note that the owner can therefore rebuild indexes of tables owned by other users). Of course, superusers can always reindex anything.

If you suspect that shared global system catalog indexes are corrupted, they can only be reindexed in Greenplum utility mode. The typical symptom of a corrupt shared index is "index is not a btree" errors, or else the server crashes immediately at startup due to reliance on the corrupted indexes. Contact Greenplum Customer Support for assistance in this situation.

Examples

Rebuild a single index:

```
REINDEX INDEX my_index;
```
Rebuild all the indexes on the table `my_table`:

```sql
REINDEX TABLE my_table;
```

**Compatibility**
There is no `REINDEX` command in the SQL standard.

**See Also**
- `CREATE INDEX`
- `DROP INDEX`
- `VACUUM`

---

**RELEASE SAVEPOINT**

Destroys a previously defined savepoint.

**Synopsis**

```sql
RELEASE [SAVEPOINT] savepoint_name
```

**Description**

`RELEASE SAVEPOINT` destroys a savepoint previously defined in the current transaction.

Destroying a savepoint makes it unavailable as a rollback point, but it has no other user visible behavior. It does not undo the effects of commands executed after the savepoint was established. (To do that, see `ROLLBACK TO SAVEPOINT`.) Destroying a savepoint when it is no longer needed may allow the system to reclaim some resources earlier than transaction end.

`RELEASE SAVEPOINT` also destroys all savepoints that were established *after* the named savepoint was established.

**Parameters**

`savepoint_name`

The name of the savepoint to destroy.

**Examples**

To establish and later destroy a savepoint:

```sql
BEGIN;
    INSERT INTO table1 VALUES (3);
    SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES (4);
    RELEASE SAVEPOINT my_savepoint;
    COMMIT;
```

The above transaction will insert both 3 and 4.

**Compatibility**

This command conforms to the SQL standard. The standard specifies that the keyword `SAVEPOINT` is mandatory, but Greenplum Database allows it to be omitted.

**See Also**

- `BEGIN`
- `SAVEPOINT`
- `ROLLBACK TO SAVEPOINT`
- `COMMIT`
RESET

Restores the value of a system configuration parameter to the default value.

Synopsis

RESET configuration_parameter

RESET ALL

Description

RESET restores system configuration parameters to their default values. RESET is an alternative spelling for SET configuration_parameter TO DEFAULT.

The default value is defined as the value that the parameter would have had, had no SET ever been issued for it in the current session. The actual source of this value might be a compiled-in default, the master postgresql.conf configuration file, command-line options, or per-database or per-user default settings. See Server Configuration Parameters for more information.

Parameters

configuration_parameter

The name of a system configuration parameter. See Server Configuration Parameters for details.

ALL

 Resets all settable configuration parameters to their default values.

Examples

Set the statement_mem configuration parameter to its default value:

RESET statement_mem;

Compatibility

RESET is a Greenplum Database extension.

See Also

SET

REVOKE

Removes access privileges.

Synopsis

REVOKE [GRANT OPTION FOR] { {SELECT | INSERT | UPDATE | DELETE
| REFERENCES | TRIGGER | TRUNCATE } [, ...] | ALL [PRIVILEGES] }
ON [TABLE] tablename [, ...]
FROM {rolename | PUBLIC} [, ...]
[CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] { {USAGE | SELECT | UPDATE} [, ...]
| ALL [PRIVILEGES] }
ON SEQUENCE sequencename [, ...]
FROM { rolename | PUBLIC } [, ...]
[CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] { {CREATE | CONNECT
| TEMPORARY | TEMP} [, ...] | ALL [PRIVILEGES] }
ON DATABASE dbname [, ...]
FROM { rolename | PUBLIC } [, ...]
[CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] { EXECUTE | ALL [PRIVILEGES] }
ON FUNCTION funcname ( [[argmode] [argname] argtype
[, ...]] ) [, ...]
FROM { rolename | PUBLIC } [, ...]
[CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] { USAGE | ALL [PRIVILEGES] }
ON LANGUAGE langname [, ...]
FROM { rolename | PUBLIC } [, ...]
[CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] { {CREATE | USAGE} [, ...]
| ALL [PRIVILEGES] }
ON SCHEMA schemaname [, ...]
FROM { rolename | PUBLIC } [, ...]
[CASCADE | RESTRICT]

REVOKE [GRANT OPTION FOR] { CREATE | ALL [PRIVILEGES] }
ON TABLESPACE tablespacename [, ...]
FROM { rolename | PUBLIC } [, ...]
[CASCADE | RESTRICT]

REVOKE [ADMIN OPTION FOR] parent_role [, ...]
FROM member_role [, ...] --
[CASCADE | RESTRICT]

Description

REVOKE command revokes previously granted privileges from one or more roles. The key word PUBLIC refers to the implicitly defined group of all roles.

See the description of the GRANT command for the meaning of the privilege types.

Note that any particular role will have the sum of privileges granted directly to it, privileges granted to any role it is presently a member of, and privileges granted to PUBLIC. Thus, for example, revoking SELECT privilege from PUBLIC does not necessarily mean that all roles have lost SELECT privilege on the object: those who have it granted directly or via another role will still have it. Similarly, revoking SELECT from a user might not prevent that user from using SELECT if PUBLIC or another membership role still has SELECT rights.

If GRANT OPTION FOR is specified, only the grant option for the privilege is revoked, not the privilege itself. Otherwise, both the privilege and the grant option are revoked.

If a role holds a privilege with grant option and has granted it to other roles then the privileges held by those other roles are called dependent privileges. If the privilege or the grant option held by the first role is being revoked and dependent privileges exist, those dependent privileges are also revoked if CASCADE is specified, else the revoke action will fail. This recursive revocation only affects privileges that were granted through a chain of roles that is traceable to the role that is the subject of this REVOKE command. Thus, the affected roles may effectively keep the privilege if it was also granted through other roles.

When revoking membership in a role, GRANT OPTION is instead called ADMIN OPTION, but the behavior is similar.
Parameters
See `GRANT`.

Examples
Revoke insert privilege for the public on table `films`:

```
REVOKE INSERT ON films FROM PUBLIC;
```

Revoke all privileges from role `sally` on view `topten`. Note that this actually means revoke all privileges that the current role granted (if not a superuser).

```
REVOKE ALL PRIVILEGES ON topten FROM sally;
```

Revoke membership in role `admins` from user `joe`:

```
REVOKE admins FROM joe;
```

Compatibility
The compatibility notes of the `GRANT` command also apply to `REVOKE`.

Either `RESTRICT` or `CASCADE` is required according to the standard, but Greenplum Database assumes `RESTRICT` by default.

See Also
`GRANT`

**ROLLBACK**
Aborts the current transaction.

Synopsis

```
ROLLBACK [WORK | TRANSACTION]
```

Description

`ROLLBACK` rolls back the current transaction and causes all the updates made by the transaction to be discarded.

Parameters

```
ROLLBACK [WORK | TRANSACTION]
```

Optional key words. They have no effect.

Notes
Use `COMMIT` to successfully end the current transaction.

Issuing `ROLLBACK` when not inside a transaction does no harm, but it will provoke a warning message.
Examples
To discard all changes made in the current transaction:

```
ROLLBACK;
```

Compatibility
The SQL standard only specifies the two forms `ROLLBACK` and `ROLLBACK WORK`. Otherwise, this command is fully conforming.

See Also
`BEGIN`, `COMMIT`, `SAVEPOINT`, `ROLLBACK TO SAVEPOINT`

**ROLLBACK TO SAVEPOINT**
Rolls back the current transaction to a savepoint.

**Synopsis**

```
ROLLBACK [WORK | TRANSACTION] TO [SAVEPOINT] savepoint_name
```

**Description**
This command will roll back all commands that were executed after the savepoint was established. The savepoint remains valid and can be rolled back to again later, if needed.

`ROLLBACK TO SAVEPOINT` implicitly destroys all savepoints that were established after the named savepoint.

**Parameters**

- `WORK`
  - `TRANSACTION`
    - Optional key words. They have no effect.

- `savepoint_name`
  - The name of a savepoint to roll back to.

**Notes**
Use `RELEASE SAVEPOINT` to destroy a savepoint without discarding the effects of commands executed after it was established.

Specifying a savepoint name that has not been established is an error.

Cursors have somewhat non-transactional behavior with respect to savepoints. Any cursor that is opened inside a savepoint will be closed when the savepoint is rolled back. If a previously opened cursor is affected by a `FETCH` command inside a savepoint that is later rolled back, the cursor position remains at the position that `FETCH` left it pointing to (that is, `FETCH` is not rolled back). Closing a cursor is not undone by rolling back, either. A cursor whose execution causes a transaction to abort is put in a can't-execute state, so while the transaction can be restored using `ROLLBACK TO SAVEPOINT`, the cursor can no longer be used.
Examples

To undo the effects of the commands executed after `my_savepoint` was established:

```
ROLLBACK TO SAVEPOINT my_savepoint;
```

Cursor positions are not affected by a savepoint rollback:

```
BEGIN;
DECLARE foo CURSOR FOR SELECT 1 UNION SELECT 2;
SAVEPOINT foo;
FETCH 1 FROM foo;
column
---------
1
ROLLBACK TO SAVEPOINT foo;
FETCH 1 FROM foo;
column
---------
2
COMMIT;
```

Compatibility

The SQL standard specifies that the key word `SAVEPOINT` is mandatory, but Greenplum Database (and Oracle) allow it to be omitted. SQL allows only `WORK`, not `TRANSACTION`, as a noise word after `ROLLBACK`. Also, SQL has an optional clause `AND [NO] CHAIN` which is not currently supported by Greenplum Database. Otherwise, this command conforms to the SQL standard.

See Also

`BEGIN`, `COMMIT`, `SAVEPOINT`, `RELEASE SAVEPOINT`, `ROLLBACK`

```
SAVEPOINT
```

Defines a new savepoint within the current transaction.

Synopsis

```
SAVEPOINT savepoint_name
```

Description

`SAVEPOINT` establishes a new savepoint within the current transaction.

A savepoint is a special mark inside a transaction that allows all commands that are executed after it was established to be rolled back, restoring the transaction state to what it was at the time of the savepoint.

Parameters

```
savepoint_name
```

The name of the new savepoint.

Notes

Use `ROLLBACK TO SAVEPOINT` to rollback to a savepoint. Use `RELEASE SAVEPOINT` to destroy a savepoint, keeping the effects of commands executed after it was established.
Savepoints can only be established when inside a transaction block. There can be multiple savepoints defined within a transaction.

**Examples**

To establish a savepoint and later undo the effects of all commands executed after it was established:

```
BEGIN;
    INSERT INTO table1 VALUES (1);
    SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES (2);
    ROLLBACK TO SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES (3);
COMMIT;
```

The above transaction will insert the values 1 and 3, but not 2.

To establish and later destroy a savepoint:

```
BEGIN;
    INSERT INTO table1 VALUES (3);
    SAVEPOINT my_savepoint;
    INSERT INTO table1 VALUES (4);
    RELEASE SAVEPOINT my_savepoint;
COMMIT;
```

The above transaction will insert both 3 and 4.

**Compatibility**

SQL requires a savepoint to be destroyed automatically when another savepoint with the same name is established. In Greenplum Database, the old savepoint is kept, though only the more recent one will be used when rolling back or releasing. (Releasing the newer savepoint will cause the older one to again become accessible to `ROLLBACK TO SAVEPOINT` and `RELEASE SAVEPOINT`.) Otherwise, `SAVEPOINT` is fully SQL conforming.

**See Also**

`BEGIN`, `COMMIT`, `ROLLBACK`, `RELEASE SAVEPOINT`, `ROLLBACK TO SAVEPOINT`

**SELECT**

Retrieves rows from a table or view.

**Synopsis**

```
[ WITH [ RECURSIVE^ ] with_query [, ...] ]
SELECT [ ALL | DISTINCT [ ON (expression [, ...]) ]]
  * | expression [[AS] output_name] [, ...]
  [ FROM from_item [, ...] ]
  [ WHERE condition ]
  [ GROUP BY grouping_element [, ...] ]
  [ HAVING condition [, ...] ]
  [ WINDOW window_name AS (window specification) ]
  [ [ UNION | INTERSECT | EXCEPT ] [ ALL ] ]
  [ ORDER BY expression [ ASC | DESC | USING operator ] [ NULLS { FIRST | LAST } ]
    [, ... ] ]
  [ LIMIT { count | ALL } ]
  [ OFFSET start ]
  [ FOR { UPDATE | SHARE } OF table_name [, ...] ] [ NOWAIT ] [, ... ]
```
where *with_query*: is:

```plaintext
with_query_name [( column_name [, ...] )] AS ( select )
```

where *grouping_element* can be one of:

```plaintext
() expression
ROLLUP (expression [, ...])
CUBE (expression [, ...])
GROUPING SETS ((grouping_element [, ...]))
```

where *window_specification* can be:

```plaintext
[window_name]
[PARTITION BY expression [, ...]]
[ORDER BY expression [ASC | DESC | USING operator] [NULLS {FIRST | LAST}] [, ...]
  [[RANGE | ROWS]
   | UNBOUNDED PRECEDING
   | expression PRECEDING
   | CURRENT ROW
   | BETWEEN window_frame_bound AND window_frame_bound ]]]
```

where *window_frame_bound* can be one of:

- UNBOUNDED PRECEDING
- expression PRECEDING
- CURRENT ROW
- expression FOLLOWING
- UNBOUNDED FOLLOWING

where *from_item* can be one of:

```plaintext
[ONLY] table_name [[AS] alias [( column_alias [, ...] )]]
(select) [AS] alias [( column_alias [, ...] )]
with_query_name [( AS] alias [( column_alias [, ...] )]]
function_name ( [AS] alias [( column_alias [, ...] )] [AS] alias
  [( column_alias [, ...] ]
  [ column_definition [, ...] )
) AS
function_name ( [argument [, ...] ] AS
  column_definition [, ...] ) AS
from_item [NATURAL] join_type from_item
[ON join_condition | USING ( join_column [, ...] )]
```

**Note:** The **RECURSIVE** keyword is an experimental feature and is not recommended for production use.

**Description**

**SELECT** retrieves rows from zero or more tables. The general processing of **SELECT** is as follows:

1. All queries in the **WITH** clause are computed. These effectively serve as temporary tables that can be referenced in the **FROM** list.
2. All elements in the **FROM** list are computed. (Each element in the **FROM** list is a real or virtual table.) If more than one element is specified in the **FROM** list, they are cross-joined together.
3. If the **WHERE** clause is specified, all rows that do not satisfy the condition are eliminated from the output.
4. If the **GROUP BY** clause is specified, the output is divided into groups of rows that match on one or more of the defined grouping elements. If the **HAVING** clause is present, it eliminates groups that do not satisfy the given condition.
5. If a window expression is specified (and optional **WINDOW** clause), the output is organized according to the positional (row) or value-based (range) window frame.
6. **DISTINCT** eliminates duplicate rows from the result. **DISTINCT ON** eliminates rows that match on all the specified expressions. **ALL** (the default) will return all candidate rows, including duplicates.

7. The actual output rows are computed using the **SELECT** output expressions for each selected row.

8. Using the operators **UNION**, **INTERSECT**, and **EXCEPT**, the output of more than one **SELECT** statement can be combined to form a single result set. The **UNION** operator returns all rows that are in one or both of the result sets. The **INTERSECT** operator returns all rows that are strictly in both result sets. The **EXCEPT** operator returns the rows that are in the first result set but not in the second. In all three cases, duplicate rows are eliminated unless **ALL** is specified.

9. If the **ORDER BY** clause is specified, the returned rows are sorted in the specified order. If **ORDER BY** is not given, the rows are returned in whatever order the system finds fastest to produce.

10. If the **LIMIT** or **OFFSET** clause is specified, the **SELECT** statement only returns a subset of the result rows.

11. If **FOR UPDATE** or **FOR SHARE** is specified, the **SELECT** statement locks the entire table against concurrent updates.

You must have **SELECT** privilege on a table to read its values. The use of **FOR UPDATE** or **FOR SHARE** requires **UPDATE** privilege as well.

### Parameters

#### The WITH Clause

The optional **WITH** clause allows you to specify one or more subqueries that can be referenced by name in the primary query. The subqueries effectively act as temporary tables or views for the duration of the primary query. Each subquery can be a **SELECT**, or **VALUES** command.

A **with_query_name** without schema qualification must be specified for each query in the **WITH** clause. Optionally, a list of column names can be specified; if the list of column names is omitted, the names are inferred from the subquery. The primary query and the **WITH** queries are all (notionally) executed at the same time.

The **RECURSIVE** keyword can be enabled by setting the server configuration parameter **gp_recursive_cte_prototype** to **true**. For information about the parameter, see [Server Configuration Parameters](#).

**Warning:** The **RECURSIVE** keyword is an experimental feature and is not intended for use in a production environment. Experimental features are subject to change without notice in future releases.

If **RECURSIVE** is specified, it allows a subquery to reference itself by name. Such a subquery, the **select** portion of the **with_query**, must have the form

```
non_recursive_term UNION [ALL] recursive_term
```

The recursive self-reference must appear on the right-hand side of the **UNION** [**ALL**]. Only one recursive self-reference is permitted per query.

If the **RECURSIVE** keyword is specified, the **WITH** queries need not be ordered: a query can reference another query that is later in the list. However, circular references, or mutual recursion, are not supported.

Without the **RECURSIVE** keyword, **WITH** queries can only reference sibling **WITH** queries that are earlier in the **WITH** list.

**WITH** **RECURSIVE** limitations. These items are not supported,

- A recursive **WITH** clause that contains the following in the **recursive_term**.
  - Subqueries with a self-reference
  - **DISTINCT** clause
  - **GROUP BY** clause
  - A window function
• A recursive WITH clause where the WITH_query_name is a part of a set operation.

An example the set operation limitation. This query returns an error because the set operation UNION contains a reference to the table foo.

```sql
WITH RECURSIVE foo(i) AS (
    SELECT 1
    UNION ALL
    SELECT i+1 FROM (SELECT * FROM foo UNION SELECT 0) bar
)
SELECT * FROM foo LIMIT 5;
```

This recursive CTE is allowed because the set operation UNION does not have a reference to the CTE foo.

```sql
WITH RECURSIVE foo(i) AS (
    SELECT 1
    UNION ALL
    SELECT i+1 FROM (SELECT * FROM bar UNION SELECT 0) bar, foo
    WHERE foo.i = bar.a
)
SELECT * FROM foo LIMIT 5;
```

See WITH Queries (Common Table Expressions) in the Greenplum Database Administrator Guide for additional information.

**The SELECT List**

The SELECT list (between the key words SELECT and FROM) specifies expressions that form the output rows of the SELECT statement. The expressions can (and usually do) refer to columns computed in the FROM clause.

Using the clause [AS] output_name, another name can be specified for an output column. This name is primarily used to label the column for display. It can also be used to refer to the column's value in ORDER BY and GROUP BY clauses, but not in the WHERE or HAVING clauses; there you must write out the expression instead. The AS keyword is optional in most cases (such as when declaring an alias for column names, constants, function calls, and simple unary operator expressions). In cases where the declared alias is a reserved SQL keyword, the output_name must be enclosed in double quotes to avoid ambiguity.

An expression in the SELECT list can be a constant value, a column reference, an operator invocation, a function call, an aggregate expression, a window expression, a scalar subquery, and so on. A number of constructs can be classified as an expression but do not follow any general syntax rules. These generally have the semantics of a function or operator. For information about SQL value expressions and function calls, see "Querying Data" in the Greenplum Database Administrator Guide.

Instead of an expression, * can be written in the output list as a shorthand for all the columns of the selected rows. Also, you can write table_name.* as a shorthand for the columns coming from just that table.

**The FROM Clause**

The FROM clause specifies one or more source tables for the SELECT. If multiple sources are specified, the result is the Cartesian product (cross join) of all the sources. But usually qualification conditions are added to restrict the returned rows to a small subset of the Cartesian product. The FROM clause can contain the following elements:

- `table_name`
  The name (optionally schema-qualified) of an existing table or view. If ONLY is specified, only that table is scanned. If ONLY is not specified, the table and all its descendant tables (if any) are scanned.

- `alias`
A substitute name for the FROM item containing the alias. An alias is used for brevity or to eliminate ambiguity for self-joins (where the same table is scanned multiple times). When an alias is provided, it completely hides the actual name of the table or function; for example given FROM foo AS f, the remainder of the SELECT must refer to this FROM item as f not foo. If an alias is written, a column alias list can also be written to provide substitute names for one or more columns of the table.

**select**

A sub-SELECT can appear in the FROM clause. This acts as though its output were created as a temporary table for the duration of this single SELECT command. Note that the sub-SELECT must be surrounded by parentheses, and an alias must be provided for it. A VALUES command can also be used here. See "Non-standard Clauses" in the Compatibility section for limitations of using correlated sub-selects in Greenplum Database.

**with_query_name**

A with_query is referenced in the FROM clause by specifying its with_query_name, just as though the name were a table name. The with_query_name cannot contain a schema qualifier. An alias can be provided in the same way as for a table.

The with_query hides a table of the same name for the purposes of the primary query. If necessary, you can refer to a table of the same name by qualifying the table name with the schema.

**function_name**

Function calls can appear in the FROM clause. (This is especially useful for functions that return result sets, but any function can be used.) This acts as though its output were created as a temporary table for the duration of this single SELECT command. An alias may also be used. If an alias is written, a column alias list can also be written to provide substitute names for one or more attributes of the function's composite return type. If the function has been defined as returning the record data type, then an alias or the key word AS must be present, followed by a column definition list in the form ( column_name data_type [, ... ] ). The column definition list must match the actual number and types of columns returned by the function.

**join_type**

One of:

- [INNER] JOIN
- LEFT [OUTER] JOIN
- RIGHT [OUTER] JOIN
- FULL [OUTER] JOIN
- CROSS JOIN

For the INNER and OUTER join types, a join condition must be specified, namely exactly one of NATURAL, ON join_condition, or USING ( join_column [, ...]). See below for the meaning. For CROSS JOIN, none of these clauses may appear.

A JOIN clause combines two FROM items. Use parentheses if necessary to determine the order of nesting. In the absence of parentheses, JOINS nest left-to-right. In any case JOIN binds more tightly than the commas separating FROM items.

CROSS JOIN and INNER JOIN produce a simple Cartesian product, the same result as you get from listing the two items at the top level of FROM, but restricted by the join condition (if any). CROSS JOIN is equivalent to INNER JOIN ON(TRUE), that is, no rows are removed by qualification. These join types are just a notational convenience, since they do nothing you could not do with plain FROM and WHERE.

LEFT OUTER JOIN returns all rows in the qualified Cartesian product (i.e., all combined rows that pass its join condition), plus one copy of each row in the left-hand table for which
there was no right-hand row that passed the join condition. This left-hand row is extended to the full width of the joined table by inserting null values for the right-hand columns. Note that only the JOIN clause's own condition is considered while deciding which rows have matches. Outer conditions are applied afterwards.

Conversely, RIGHT OUTER JOIN returns all the joined rows, plus one row for each unmatched right-hand row (extended with nulls on the left). This is just a notational convenience, since you could convert it to a LEFT OUTER JOIN by switching the left and right inputs.

FULL OUTER JOIN returns all the joined rows, plus one row for each unmatched left-hand row (extended with nulls on the right), plus one row for each unmatched right-hand row (extended with nulls on the left).

**ON**  

**join_condition** is an expression resulting in a value of type boolean (similar to a WHERE clause) that specifies which rows in a join are considered to match.

**USING**  

A clause of the form USING ( a, b, ... ) is shorthand for ON left_table.a = right_table.a AND left_table.b = right_table.b .... Also, USING implies that only one of each pair of equivalent columns will be included in the join output, not both.

**NATURAL**  

NATURAL is shorthand for a USING list that mentions all columns in the two tables that have the same names.

The WHERE Clause

The optional WHERE clause has the general form:

```
WHERE condition
```

where **condition** is any expression that evaluates to a result of type boolean. Any row that does not satisfy this condition will be eliminated from the output. A row satisfies the condition if it returns true when the actual row values are substituted for any variable references.

The GROUP BY Clause

The optional GROUP BY clause has the general form:

```
GROUP BY grouping_element [, ...]
```

where **grouping_element** can be one of:

- ()
- expression
- ROLLUP (expression [,...])
- CUBE (expression [,...])
- GROUPING SETS ((grouping_element [, ...]))

**GROUP BY** will condense into a single row all selected rows that share the same values for the grouped expressions. **expression** can be an input column name, or the name or ordinal number of an output column (SELECT list item), or an arbitrary expression formed from input-column values. In case of ambiguity, a GROUP BY name will be interpreted as an input-column name rather than an output column name.

Aggregate functions, if any are used, are computed across all rows making up each group, producing a separate value for each group (whereas without **GROUP BY**, an aggregate produces a single value computed across all the selected rows). When **GROUP BY** is present, it is not valid for the SELECT list expressions to refer to ungrouped columns except within aggregate functions, since there would be more than one possible value to return for an ungrouped column.
Greenplum Database has the following additional OLAP grouping extensions (often referred to as *supergroups*):

**ROLLUP**

A **ROLLUP** grouping is an extension to the **GROUP BY** clause that creates aggregate subtotals that roll up from the most detailed level to a grand total, following a list of grouping columns (or expressions). **ROLLUP** takes an ordered list of grouping columns, calculates the standard aggregate values specified in the **GROUP BY** clause, then creates progressively higher-level subtotals, moving from right to left through the list. Finally, it creates a grand total. A **ROLLUP** grouping can be thought of as a series of grouping sets. For example:

```
GROUP BY ROLLUP (a,b,c)
```

is equivalent to:

```
GROUP BY GROUPING SETS( (a,b,c), (a,b), (a), () )
```

Notice that the $n$ elements of a **ROLLUP** translate to $n+1$ grouping sets. Also, the order in which the grouping expressions are specified is significant in a **ROLLUP**.

**CUBE**

A **CUBE** grouping is an extension to the **GROUP BY** clause that creates subtotals for all of the possible combinations of the given list of grouping columns (or expressions). In terms of multidimensional analysis, **CUBE** generates all the subtotals that could be calculated for a data cube with the specified dimensions. For example:

```
GROUP BY CUBE (a,b,c)
```

is equivalent to:

```
GROUP BY GROUPING SETS( (a,b,c), (a,b), (a,c), (b,c), (a),
(b), (c), () )
```

Notice that $n$ elements of a **CUBE** translate to $2n$ grouping sets. Consider using CUBE in any situation requiring cross-tabular reports. **CUBE** is typically most suitable in queries that use columns from multiple dimensions rather than columns representing different levels of a single dimension. For instance, a commonly requested cross-tabulation might need subtotals for all the combinations of month, state, and product.

**GROUPING SETS**

You can selectively specify the set of groups that you want to create using a **GROUPING SETS** expression within a **GROUP BY** clause. This allows precise specification across multiple dimensions without computing a whole **ROLLUP** or **CUBE**. For example:

```
GROUP BY GROUPING SETS( (a,c), (a,b) )
```

If using the grouping extension clauses **ROLLUP**, **CUBE**, or **GROUPING SETS**, two challenges arise. First, how do you determine which result rows are subtotals, and then the exact level of aggregation for a given subtotal. Or, how do you differentiate between result rows that contain both stored **NULL** values and "NULL" values created by the **ROLLUP** or **CUBE**. Secondly, when duplicate grouping sets are specified in the **GROUP BY** clause, how do you determine which result rows are duplicates? There are two additional grouping functions you can use in the **SELECT** list to help with this:

- **grouping(column [, ...])** — The grouping function can be applied to one or more grouping attributes to distinguish super-aggregated rows from regular grouped rows. This can be helpful in distinguishing a "NULL" representing the set of all values in...
a super-aggregated row from a NULL value in a regular row. Each argument in this function produces a bit — either 1 or 0, where 1 means the result row is super-aggregated, and 0 means the result row is from a regular grouping. The grouping function returns an integer by treating these bits as a binary number and then converting it to a base-10 integer.

- **group_id()** — For grouping extension queries that contain duplicate grouping sets, the group_id function is used to identify duplicate rows in the output. All unique grouping set output rows will have a group_id value of 0. For each duplicate grouping set detected, the group_id function assigns a group_id number greater than 0. All output rows in a particular duplicate grouping set are identified by the same group_id number.

### The WINDOW Clause

The WINDOW clause is used to define a window that can be used in the OVER() expression of a window function such as rank or avg. For example:

```sql
SELECT vendor, rank() OVER (mywindow) FROM sale
GROUP BY vendor
WINDOW mywindow AS (ORDER BY sum(prc*qty));
```

A WINDOW clause has this general form:

```
WINDOW window_name AS (window_specification)
```

where **window_specification** can be:

- `[window_name]`
- `[PARTITION BY expression [, ...]]`
- `[ORDER BY expression [ASC | DESC | USING operator] [NULLS {FIRST | LAST}] [, ...]]`
- `[[{RANGE | ROWS}]
  | expression PRECEDING
  | CURRENT ROW
  | BETWEEN window_frame_bound AND window_frame_bound ]]

where **window_frame_bound** can be one of:
- UNBOUNDED PRECEDING
- expression PRECEDING
- CURRENT ROW
- expression FOLLOWING
- UNBOUNDED FOLLOWING

**window_name**  
Gives a name to the window specification.

**PARTITION BY**  
The PARTITION BY clause organizes the result set into logical groups based on the unique values of the specified expression. When used with window functions, the functions are applied to each partition independently. For example, if you follow PARTITION BY with a column name, the result set is partitioned by the distinct values of that column. If omitted, the entire result set is considered one partition.

**ORDER BY**  
The ORDER BY clause defines how to sort the rows in each partition of the result set. If omitted, rows are returned in whatever order is most efficient and may vary. Note: Columns of data types that lack a coherent ordering, such as time, are not good candidates for use in the ORDER BY clause of a window specification. Time, with or without time zone, lacks a coherent ordering because addition and subtraction do not have the
expected effects. For example, the following is not generally true:

\[
x::\text{time} < x::\text{time} + '2 hour'::\text{interval}
\]

**ROWS | RANGE**

Use either a **ROWS** or **RANGE** clause to express the bounds of the window. The window bound can be one, many, or all rows of a partition. You can express the bound of the window either in terms of a range of data values offset from the value in the current row (**RANGE**), or in terms of the number of rows offset from the current row (**ROWS**). When using the **RANGE** clause, you must also use an **ORDER BY** clause. This is because the calculation performed to produce the window requires that the values be sorted. Additionally, the **ORDER BY** clause cannot contain more than one expression, and the expression must result in either a date or a numeric value. When using the **ROWS** or **RANGE** clauses, if you specify only a starting row, the current row is used as the last row in the window.

**PRECEDING** — The **PRECEDING** clause defines the first row of the window using the current row as a reference point. The starting row is expressed in terms of the number of rows preceding the current row. For example, in the case of **ROWS** framing, 5 **PRECEDING** sets the window to start with the fifth row preceding the current row. In the case of **RANGE** framing, it sets the window to start with the first row whose ordering column value precedes that of the current row by 5 in the given order. If the specified order is ascending by date, this will be the first row within 5 days before the current row. **UNBOUNDED PRECEDING** sets the first row in the window to be the first row in the partition.

**BETWEEN** — The **BETWEEN** clause defines the first and last row of the window, using the current row as a reference point. First and last rows are expressed in terms of the number of rows preceding and following the current row, respectively. For example, **BETWEEN 3 PRECEDING AND 5 FOLLOWING** sets the window to start with the third row preceding the current row, and end with the fifth row following the current row. Use **BETWEEN UNBOUNDED PRECEDING AND UNBOUNDED FOLLOWING** to set the first and last rows in the window to be the first and last row in the partition, respectively. This is equivalent to the default behavior if no **ROW** or **RANGE** clause is specified.

**FOLLOWING** — The **FOLLOWING** clause defines the last row of the window using the current row as a reference point. The last row is expressed in terms of the number of rows following the current row. For example, in the case of **ROWS** framing, 5 **FOLLOWING** sets the window to end with the fifth row following the current row. In the case of **RANGE** framing, it sets the window to end with the last row whose ordering column value follows that of the current row by 5 in the given order. If the specified order is ascending by date, this will be the last row within 5 days after the current row. Use **UNBOUNDED FOLLOWING** to set the last row in the window to be the last row in the partition.

If you do not specify a **ROW** or a **RANGE** clause, the window bound starts with the first row in the partition (**UNBOUNDED PRECEDING**) and ends with the current row (**CURRENT ROW**) if **ORDER BY** is used. If an **ORDER BY** is not specified, the window starts with the first row in the partition (**UNBOUNDED PRECEDING**) and ends with last row in the partition (**UNBOUNDED FOLLOWING**).

**The HAVING Clause**

The optional **HAVING** clause has the general form:

```
HAVING condition
```

where **condition** is the same as specified for the **WHERE** clause. **HAVING** eliminates group rows that do not satisfy the condition. **HAVING** is different from **WHERE**: **WHERE** filters individual rows before the application of **GROUP BY**, while **HAVING** filters group rows created by **GROUP BY**. Each column referenced in **condition** must unambiguously reference a grouping column, unless the reference appears within an aggregate function.
The presence of HAVING turns a query into a grouped query even if there is no GROUP BY clause. This is the same as what happens when the query contains aggregate functions but no GROUP BY clause. All the selected rows are considered to form a single group, and the SELECT list and HAVING clause can only reference table columns from within aggregate functions. Such a query will emit a single row if the HAVING condition is true, zero rows if it is not true.

The UNION Clause

The UNION clause has this general form:

```
select_statement UNION [ALL] select_statement
```

where `select_statement` is any SELECT statement without an ORDER BY, LIMIT, FOR UPDATE, or FOR SHARE clause. (ORDER BY and LIMIT can be attached to a subquery expression if it is enclosed in parentheses. Without parentheses, these clauses will be taken to apply to the result of the UNION, not to its right-hand input expression.)

The UNION operator computes the set union of the rows returned by the involved SELECT statements. A row is in the set union of two result sets if it appears in at least one of the result sets. The two SELECT statements that represent the direct operands of the UNION must produce the same number of columns, and corresponding columns must be of compatible data types.

The result of UNION does not contain any duplicate rows unless the ALL option is specified. ALL prevents elimination of duplicates. (Therefore, UNION ALL is usually significantly quicker than UNION; use ALL when you can.)

Multiple UNION operators in the same SELECT statement are evaluated left to right, unless otherwise indicated by parentheses.

Currently, FOR UPDATE and FOR SHARE may not be specified either for a UNION result or for any input of a UNION.

The INTERSECT Clause

The INTERSECT clause has this general form:

```
select_statement INTERSECT [ALL] select_statement
```

where `select_statement` is any SELECT statement without an ORDER BY, LIMIT, FOR UPDATE, or FOR SHARE clause.

The INTERSECT operator computes the set intersection of the rows returned by the involved SELECT statements. A row is in the intersection of two result sets if it appears in both result sets.

The result of INTERSECT does not contain any duplicate rows unless the ALL option is specified. With ALL, a row that has \( m \) duplicates in the left table and \( n \) duplicates in the right table will appear \( \min(m, n) \) times in the result set.

Multiple INTERSECT operators in the same SELECT statement are evaluated left to right, unless parentheses dictate otherwise. INTERSECT binds more tightly than UNION. That is, \( \text{A UNION B INTERSECT C} \) will be read as \( \text{A UNION (B INTERSECT C)} \).

Currently, FOR UPDATE and FOR SHARE may not be specified either for an INTERSECT result or for any input of an INTERSECT.

The EXCEPT Clause

The EXCEPT clause has this general form:

```
select_statement EXCEPT [ALL] select_statement
```

where `select_statement` is any SELECT statement without an ORDER BY, LIMIT, FOR UPDATE, or FOR SHARE clause.
The **EXCEPT** operator computes the set of rows that are in the result of the left **SELECT** statement but not in the result of the right one.

The result of **EXCEPT** does not contain any duplicate rows unless the **ALL** option is specified. With **ALL**, a row that has \( m \) duplicates in the left table and \( n \) duplicates in the right table will appear \( \max(m-n,0) \) times in the result set.

Multiple **EXCEPT** operators in the same **SELECT** statement are evaluated left to right, unless parentheses dictate otherwise. **EXCEPT** binds at the same level as **UNION**.

Currently, **FOR UPDATE** and **FOR SHARE** may not be specified either for an **EXCEPT** result or for any input of an **EXCEPT**.

**The ORDER BY Clause**

The optional **ORDER BY** clause has this general form:

```
ORDER BY expression [ASC | DESC | USING operator] [NULLS { FIRST | LAST}] [, ...]
```

where **expression** can be the name or ordinal number of an output column (**SELECT** list item), or it can be an arbitrary expression formed from input-column values.

The **ORDER BY** clause causes the result rows to be sorted according to the specified expressions. If two rows are equal according to the left-most expression, they are compared according to the next expression and so on. If they are equal according to all specified expressions, they are returned in an implementation-dependent order.

The ordinal number refers to the ordinal (left-to-right) position of the result column. This feature makes it possible to define an ordering on the basis of a column that does not have a unique name. This is never absolutely necessary because it is always possible to assign a name to a result column using the **AS** clause.

It is also possible to use arbitrary expressions in the **ORDER BY** clause, including columns that do not appear in the **SELECT** result list. Thus the following statement is valid:

```
SELECT name FROM distributors ORDER BY code;
```

A limitation of this feature is that an **ORDER BY** clause applying to the result of a **UNION**, **INTERSECT**, or **EXCEPT** clause may only specify an output column name or number, not an expression.

If an **ORDER BY** expression is a simple name that matches both a result column name and an input column name, **ORDER BY** will interpret it as the result column name. This is the opposite of the choice that **GROUP BY** will make in the same situation. This inconsistency is made to be compatible with the SQL standard.

Optionally one may add the key word **ASC** (ascending) or **DESC** (descending) after any expression in the **ORDER BY** clause. If not specified, **ASC** is assumed by default. Alternatively, a specific ordering operator name may be specified in the **USING** clause. **ASC** is usually equivalent to **USING <** and **DESC** is usually equivalent to **USING >**. (But the creator of a user-defined data type can define exactly what the default sort ordering is, and it might correspond to operators with other names.)

If **NULLS LAST** is specified, null values sort after all non-null values; if **NULLS FIRST** is specified, null values sort before all non-null values. If neither is specified, the default behavior is **NULLS LAST** when **ASC** is specified or implied, and **NULLS FIRST** when **DESC** is specified (thus, the default is to act as though nulls are larger than non-nulls). When **USING** is specified, the default nulls ordering depends upon whether the operator is a less-than or greater-than operator.

Note that ordering options apply only to the expression they follow; for example **ORDER BY x, y DESC** does not mean the same thing as **ORDER BY x DESC, y DESC**.

Character-string data is sorted according to the locale-specific collation order that was established when the Greenplum Database system was initialized.
The DISTINCT Clause

If **DISTINCT** is specified, all duplicate rows are removed from the result set (one row is kept from each group of duplicates). **ALL** specifies the opposite: all rows are kept. **ALL** is the default.

**DISTINCT ON** (`expression [, ...]`) keeps only the first row of each set of rows where the given expressions evaluate to equal. The **DISTINCT ON** expressions are interpreted using the same rules as for **ORDER BY**. Note that the 'first row' of each set is unpredictable unless **ORDER BY** is used to ensure that the desired row appears first. For example:

```sql
SELECT DISTINCT ON (location) location, time, report FROM weather_reports ORDER BY location, time DESC;
```

retrieves the most recent weather report for each location. But if we had not used **ORDER BY** to force descending order of time values for each location, we would have gotten a report from an unpredictable time for each location.

The **DISTINCT ON** expression(s) must match the left-most **ORDER BY** expression(s). The **ORDER BY** clause will normally contain additional expression(s) that determine the desired precedence of rows within each **DISTINCT ON** group.

When Greenplum Database processes queries that contain the **DISTINCT** clause, the queries are transformed into **GROUP BY** queries. In many cases, the transformation provides significant performance gains. However, when the number of distinct values is close to the total number of rows, the transformation might result in the generation of a multi-level grouping plan. In this case, there is an expected performance degradation because of the overhead introduced by the lower aggregation level.

The LIMIT Clause

The **LIMIT** clause consists of two independent sub-clauses:

```sql
LIMIT {count | ALL}
OFFSET start
```

where **count** specifies the maximum number of rows to return, while **start** specifies the number of rows to skip before starting to return rows. When both are specified, start rows are skipped before starting to count the count rows to be returned.

When using **LIMIT**, it is a good idea to use an **ORDER BY** clause that constrains the result rows into a unique order. Otherwise you will get an unpredictable subset of the query’s rows — you may be asking for the tenth through twentieth rows, but tenth through twentieth in what ordering? You don’t know what ordering unless you specify **ORDER BY**.

The query optimizer takes **LIMIT** into account when generating a query plan, so you are very likely to get different plans (yielding different row orders) depending on what you use for **LIMIT** and **OFFSET**. Thus, using different **LIMIT/OFFSET** values to select different subsets of a query result will give inconsistent results unless you enforce a predictable result ordering with **ORDER BY**. This is not a defect; it is an inherent consequence of the fact that SQL does not promise to deliver the results of a query in any particular order unless **ORDER BY** is used to constrain the order.

The FOR UPDATE/FOR SHARE Clause

The **FOR UPDATE** clause has this form:

```sql
FOR UPDATE [OF table_name [, ...]] [NOWAIT]
```

The closely related **FOR SHARE** clause has this form:

```sql
FOR SHARE [OF table_name [, ...]] [NOWAIT]
```

**FOR UPDATE** causes the tables accessed by the **SELECT** statement to be locked as though for update. This prevents the table from being modified or deleted by other transactions until the current transaction
ends. That is, other transactions that attempt UPDATE, DELETE, or SELECT FOR UPDATE of this table will be blocked until the current transaction ends. Also, if an UPDATE, DELETE, or SELECT FOR UPDATE from another transaction has already locked a selected table, SELECT FOR UPDATE will wait for the other transaction to complete, and will then lock and return the updated table.

To prevent the operation waiting for other transactions to commit, use the NOWAIT option. SELECT FOR UPDATE NOWAIT reports an error, rather than waiting, if a selected row cannot be locked immediately. Note that NOWAIT applies only to the row-level lock(s) — the required ROW SHARE table-level lock is still taken in the ordinary way. You can use the NOWAIT option of LOCK if you need to acquire the table-level lock without waiting (see LOCK).

FOR SHARE behaves similarly, except that it acquires a shared rather than exclusive lock on the table. A shared lock blocks other transactions from performing UPDATE, DELETE, or SELECT FOR UPDATE on the table, but it does not prevent them from performing SELECT FOR SHARE.

If specific tables are named in FOR UPDATE or FOR SHARE, then only those tables are locked; any other tables used in the SELECT are simply read as usual. A FOR UPDATE or FOR SHARE clause without a table list affects all tables used in the command. If FOR UPDATE or FOR SHARE is applied to a view or subquery, it affects all tables used in the view or subquery.

FOR UPDATE or FOR SHARE do not apply to a with_query referenced by the primary query. If you want row locking to occur within a with_query, specify FOR UPDATE or FOR SHARE within the with_query.

Multiple FOR UPDATE and FOR SHARE clauses can be written if it is necessary to specify different locking behavior for different tables. If the same table is mentioned (or implicitly affected) by both FOR UPDATE and FOR SHARE clauses, then it is processed as FOR UPDATE. Similarly, a table is processed as NOWAIT if that is specified in any of the clauses affecting it.

### Examples

To join the table films with the table distributors:

```
SELECT f.title, f.did, d.name, f.date_prod, f.kind FROM distributors d, films f WHERE f.did = d.did
```

To sum the column length of all films and group the results by kind:

```
SELECT kind, sum(length) AS total FROM films GROUP BY kind;
```

To sum the column length of all films, group the results by kind and show those group totals that are less than 5 hours:

```
SELECT kind, sum(length) AS total FROM films GROUP BY kind HAVING sum(length) < interval '5 hours';
```

Calculate the subtotals and grand totals of all sales for movie kind and distributor.

```
SELECT kind, distributor, sum(prc*qty) FROM sales GROUP BY ROLLUP(kind, distributor) ORDER BY 1,2,3;
```

Calculate the rank of movie distributors based on total sales:

```
SELECT distributor, sum(prc*qty),
    rank() OVER (ORDER BY sum(prc*qty) DESC)
FROM sale
GROUP BY distributor ORDER BY 2 DESC;
```
The following two examples are identical ways of sorting the individual results according to the contents of the second column (name):

```sql
SELECT * FROM distributors ORDER BY name;
SELECT * FROM distributors ORDER BY 2;
```

The next example shows how to obtain the union of the tables `distributors` and `actors`, restricting the results to those that begin with the letter 'W' in each table. Only distinct rows are wanted, so the key word `ALL` is omitted:

```sql
SELECT distributors.name FROM distributors WHERE distributors.name LIKE 'W%' UNION SELECT actors.name FROM actors WHERE actors.name LIKE 'W%';
```

This example shows how to use a function in the `FROM` clause, both with and without a column definition list:

```sql
CREATE FUNCTION distributors(int) RETURNS SETOF distributors
AS $$ SELECT * FROM distributors WHERE did = $1; $$ LANGUAGE SQL;
SELECT * FROM distributors(111);

CREATE FUNCTION distributors_2(int) RETURNS SETOF record AS
$$ SELECT * FROM distributors WHERE did = $1; $$ LANGUAGE SQL;
SELECT * FROM distributors_2(111) AS (dist_id int, dist_name text);
```

This example uses a simple `WITH` clause:

```sql
WITH test AS (  
    SELECT random() as x FROM generate_series(1, 3)  
)  
SELECT * FROM test  
UNION ALL  
SELECT * FROM test;
```

This example uses the `WITH` clause to display per-product sales totals in only the top sales regions.

```sql
WITH regional_sales AS  
    SELECT region, SUM(amount) AS total_sales  
    FROM orders  
    GROUP BY region  
), top_regions AS (  
    SELECT region  
    FROM regional_sales  
    WHERE total_sales > (SELECT SUM(total_sales) FROM regional_sales)  
)
SELECT region, product, SUM(quantity) AS product_units,  
    SUM(amount) AS product_sales  
FROM orders  
WHERE region IN (SELECT region FROM top_regions)  
GROUP BY region, product;
```

The example could have been written without the `WITH` clause but would have required two levels of nested `sub-SELECT` statements.
This example uses the `WITH RECURSIVE` clause to find all subordinates (direct or indirect) of the employee Mary, and their level of indirectness, from a table that shows only direct subordinates:

```sql
WITH RECURSIVE employee_recursive(distance, employee_name, manager_name) AS
(  
    SELECT 1, employee_name, manager_name
    FROM employee
    WHERE manager_name = 'Mary'
  UNION ALL
    SELECT er.distance + 1, e.employee_name, e.manager_name
    FROM employee_recursive er, employee e
    WHERE er.employee_name = e.manager_name
)

SELECT distance, employee_name FROM employee_recursive;
```

The typical form of recursive queries: an initial condition, followed by `UNION [ALL]`, followed by the recursive part of the query. Be sure that the recursive part of the query will eventually return no tuples, or else the query will loop indefinitely. See `WITH Queries (Common Table Expressions)` in the Greenplum Database Administrator Guide for more examples.

### Compatibility

The `SELECT` statement is compatible with the SQL standard, but there are some extensions and some missing features.

#### Omitted FROM Clauses

Greenplum Database allows one to omit the `FROM` clause. It has a straightforward use to compute the results of simple expressions. For example:

```sql
SELECT 2+2;
```

Some other SQL databases cannot do this except by introducing a dummy one-row table from which to do the `SELECT`.

Note that if a `FROM` clause is not specified, the query cannot reference any database tables. For compatibility with applications that rely on this behavior the `add_missing_from` configuration variable can be enabled.

#### The AS Key Word

In the SQL standard, the optional key word `AS` is just noise and can be omitted without affecting the meaning. The Greenplum Database parser requires this key word when renaming output columns because the type extensibility features lead to parsing ambiguities without it. `AS` is optional in `FROM` items, however.

#### Namespace Available to GROUP BY and ORDER BY

In the SQL-92 standard, an `ORDER BY` clause may only use result column names or numbers, while a `GROUP BY` clause may only use expressions based on input column names. Greenplum Database extends each of these clauses to allow the other choice as well (but it uses the standard's interpretation if there is ambiguity). Greenplum Database also allows both clauses to specify arbitrary expressions. Note that names appearing in an expression are always taken as input-column names, not as result-column names.

SQL:1999 and later use a slightly different definition which is not entirely upward compatible with SQL-92. In most cases, however, Greenplum Database interprets an `ORDER BY` or `GROUP BY` expression the same way SQL:1999 does.

#### Nonstandard Clauses

The clauses `DISTINCT ON`, `LIMIT`, and `OFFSET` are not defined in the SQL standard.

#### Limited Use of STABLE and VOLATILE Functions
To prevent data from becoming out-of-sync across the segments in Greenplum Database, any function classified as \texttt{STABLE} or \texttt{VOLATILE} cannot be executed at the segment database level if it contains SQL or modifies the database in any way. See \texttt{CREATE FUNCTION} for more information.

\textbf{See Also}

\texttt{EXPLAIN}

\section*{SELECT INTO}

Defines a new table from the results of a query.

\textbf{Synopsis}

\begin{verbatim}
[ WITH [ RECURSIVE\textsuperscript{1} ] with_query [, ...] ]
SELECT [ALL | DISTINCT [ON ( expression [, ...] )]]
  * | expression [AS output_name] [, ...]
  INTO [TEMPORARY | TEMP] [TABLE] new_table
  [FROM from_item [, ...]]
  [WHERE condition]
  [GROUP BY expression [, ...]]
  [HAVING condition [, ...]]
  [(UNION | INTERSECT | EXCEPT) [ALL] select]
  [ORDER BY expression [ASC | DESC | USING operator] [NULLS {FIRST | LAST}] [, ...]]
  [LIMIT {count | ALL}]
  [OFFSET start]
  [FOR {UPDATE | SHARE} [OF table_name [, ...]] [NOWAIT]
  [...]]
\end{verbatim}

\textbf{Note:} \textsuperscript{1}The \texttt{RECURSIVE} keyword is an experimental feature and is not recommended for production use.

\section*{Description}

\texttt{SELECT INTO} creates a new table and fills it with data computed by a query. The data is not returned to the client, as it is with a normal \texttt{SELECT}. The new table's columns have the names and data types associated with the output columns of the \texttt{SELECT}.

The \texttt{RECURSIVE} keyword can be enabled by setting the server configuration parameter \texttt{gp_recursive_cte_prototype} to \texttt{true}.

\textbf{Warning:} The \texttt{RECURSIVE} keyword is an experimental feature and is not intended for use in a production environment. Experimental features are subject to change without notice in future releases.

\section*{Parameters}

The majority of parameters for \texttt{SELECT INTO} are the same as \texttt{SELECT}.

\textbf{TEMPORARY} \textbf{TEMP}

If specified, the table is created as a temporary table.

\textbf{new_table}

The name (optionally schema-qualified) of the table to be created.
**Examples**

Create a new table `films_recent` consisting of only recent entries from the table `films`:

```
SELECT * INTO films_recent FROM films WHERE date_prod >= '2016-01-01';
```

**Compatibility**

The SQL standard uses `SELECT INTO` to represent selecting values into scalar variables of a host program, rather than creating a new table. The Greenplum Database usage of `SELECT INTO` to represent table creation is historical. It is best to use `CREATE TABLE AS` for this purpose in new applications.

**See Also**

`SELECT, CREATE TABLE AS`

**SET**

Changes the value of a Greenplum Database configuration parameter.

**Synopsis**

```
SET [SESSION | LOCAL] configuration_parameter {TO | =} value |
    'value' | DEFAULT}
SET [SESSION | LOCAL] TIME_ZONE {timezone | LOCAL | DEFAULT}
```

**Description**

The `SET` command changes server configuration parameters. Any configuration parameter classified as a `session` parameter can be changed on-the-fly with `SET`. `SET` affects only the value used by the current session.

If `SET` or `SET SESSION` is issued within a transaction that is later aborted, the effects of the `SET` command disappear when the transaction is rolled back. Once the surrounding transaction is committed, the effects will persist until the end of the session, unless overridden by another `SET`.

The effects of `SET LOCAL` last only till the end of the current transaction, whether committed or not. A special case is `SET` followed by `SET LOCAL` within a single transaction: the `SET LOCAL` value will be seen until the end of the transaction, but afterwards (if the transaction is committed) the `SET` value will take effect.

If `SET LOCAL` is used within a function that includes a `SET` option for the same configuration parameter (see `CREATE FUNCTION`), the effects of the `SET LOCAL` command disappear at function exit; the value in effect when the function was called is restored anyway. This allows `SET LOCAL` to be used for dynamic or repeated changes of a parameter within a function, while retaining the convenience of using the `SET` option to save and restore the caller's value. Note that a regular `SET` command overrides any surrounding function's `SET` option; its effects persist unless rolled back.

If you create a cursor with the `DECLARE` command in a transaction, you cannot use the `SET` command in the transaction until you close the cursor with the `CLOSE` command.

See `Server Configuration Parameters` for information about server parameters.

**Parameters**

**SESSION**

Specifies that the command takes effect for the current session. This is the default.
**LOCAL**

Specifies that the command takes effect for only the current transaction. After **COMMIT** or **ROLLBACK**, the session-level setting takes effect again. Note that **SET LOCAL** will appear to have no effect if it is executed outside of a transaction.

**configuration_parameter**

The name of a Greenplum Database configuration parameter. Only parameters classified as **session** can be changed with **SET**. See **Server Configuration Parameters** for details.

**value**

New value of parameter. Values can be specified as string constants, identifiers, numbers, or comma-separated lists of these. **DEFAULT** can be used to specify resetting the parameter to its default value. If specifying memory sizing or time units, enclose the value in single quotes.

**TIME ZONE**

**SET TIME ZONE** value is an alias for **SET timezone TO** value. The syntax **SET TIME ZONE** allows special syntax for the time zone specification. Here are examples of valid values:

- `'PST8PDT'`
- `'Europe/Rome'`
- `-7` (time zone 7 hours west from UTC)
- `INTERVAL '-08:00' HOUR TO MINUTE` (time zone 8 hours west from UTC).

**LOCAL**

**DEFAULT**

Set the time zone to your local time zone (the one that the server's operating system defaults to). See the **Time zone section of the PostgreSQL documentation** for more information about time zones in Greenplum Database.

**Examples**

Set the schema search path:

```
SET search_path TO my_schema, public;
```

Increase the segment host memory per query to 200 MB:

```
SET statement_mem TO '200MB';
```

Set the style of date to traditional **POSTGRES** with "day before month" input convention:

```
SET datestyle TO postgres, dmy;
```

Set the time zone for San Mateo, California (Pacific Time):

```
SET TIME ZONE 'PST8PDT';
```

Set the time zone for Italy:

```
SET TIME ZONE 'Europe/Rome';
```
Compatibility

SET TIME ZONE extends syntax defined in the SQL standard. The standard allows only numeric time zone offsets while Greenplum Database allows more flexible time-zone specifications. All other SET features are Greenplum Database extensions.

See Also

RESET, SHOW

**SET ROLE**

Sets the current role identifier of the current session.

**Synopsis**

```
SET [SESSION | LOCAL] ROLE rolename
SET [SESSION | LOCAL] ROLE NONE
RESET ROLE
```

**Description**

This command sets the current role identifier of the current SQL-session context to be *rolename*. The role name may be written as either an identifier or a string literal. After SET ROLE, permissions checking for SQL commands is carried out as though the named role were the one that had logged in originally.

The specified *rolename* must be a role that the current session user is a member of. If the session user is a superuser, any role can be selected.

The NONE and RESET forms reset the current role identifier to be the current session role identifier. These forms may be executed by any user.

**Parameters**

**SESSION**

Specifies that the command takes effect for the current session. This is the default.

**LOCAL**

Specifies that the command takes effect for only the current transaction. After COMMIT or ROLLBACK, the session-level setting takes effect again. Note that SET LOCAL will appear to have no effect if it is executed outside of a transaction.

**rolename**

The name of a role to use for permissions checking in this session.

**NONE**

Reset the current role identifier to be the current session role identifier (that of the role used to log in).

**Notes**

Using this command, it is possible to either add privileges or restrict privileges. If the session user role has the INHERITS attribute, then it automatically has all the privileges of every role that it could SET ROLE to; in this case SET ROLE effectively drops all the privileges assigned directly to the session user and to the other roles it is a member of, leaving only the privileges available to the named role. On the other hand, if the session user role has the NOINHERITS attribute, SET ROLE drops the privileges assigned directly to the session user and instead acquires the privileges available to the named role.
In particular, when a superuser chooses to `SET ROLE` to a non-superuser role, she loses her superuser privileges.

`SET ROLE` has effects comparable to `SET SESSION AUTHORIZATION`, but the privilege checks involved are quite different. Also, `SET SESSION AUTHORIZATION` determines which roles are allowable for later `SET ROLE` commands, whereas changing roles with `SET ROLE` does not change the set of roles allowed to a later `SET ROLE`.

**Examples**

```sql
SELECT SESSION_USER, CURRENT_USER;
```

<table>
<thead>
<tr>
<th>session_user</th>
<th>current_user</th>
</tr>
</thead>
<tbody>
<tr>
<td>peter</td>
<td>peter</td>
</tr>
</tbody>
</table>

```sql
SET ROLE 'paul';
```

```sql
SELECT SESSION_USER, CURRENT_USER;
```

<table>
<thead>
<tr>
<th>session_user</th>
<th>current_user</th>
</tr>
</thead>
<tbody>
<tr>
<td>peter</td>
<td>paul</td>
</tr>
</tbody>
</table>
```

**Compatibility**

Greenplum Database allows identifier syntax (rolename), while the SQL standard requires the role name to be written as a string literal. SQL does not allow this command during a transaction; Greenplum Database does not make this restriction. The `SESSION` and `LOCAL` modifiers are a Greenplum Database extension, as is the `RESET` syntax.

**See Also**

`SET SESSION AUTHORIZATION`

**SET SESSION AUTHORIZATION**

Sets the session role identifier and the current role identifier of the current session.

**Synopsis**

```sql
SET [SESSION | LOCAL] SESSION AUTHORIZATION rolename
```

```sql
SET [SESSION | LOCAL] SESSION AUTHORIZATION DEFAULT
```

```sql
RESET SESSION AUTHORIZATION
```

**Description**

This command sets the session role identifier and the current role identifier of the current SQL-session context to be rolename. The role name may be written as either an identifier or a string literal. Using this command, it is possible, for example, to temporarily become an unprivileged user and later switch back to being a superuser.

The session role identifier is initially set to be the (possibly authenticated) role name provided by the client. The current role identifier is normally equal to the session user identifier, but may change temporarily in the context of `setuid` functions and similar mechanisms; it can also be changed by `SET ROLE`. The current user identifier is relevant for permission checking.

The session user identifier may be changed only if the initial session user (the authenticated user) had the superuser privilege. Otherwise, the command is accepted only if it specifies the authenticated user name.
The `DEFAULT` and `RESET` forms reset the session and current user identifiers to be the originally authenticated user name. These forms may be executed by any user.

**Parameters**

- **SESSION**
  - Specifies that the command takes effect for the current session. This is the default.

- **LOCAL**
  - Specifies that the command takes effect for only the current transaction. After `COMMIT` or `ROLLBACK`, the session-level setting takes effect again. Note that `SET LOCAL` will appear to have no effect if it is executed outside of a transaction.

- **rolename**
  - The name of the role to assume.

- **NONE**
  - Reset the session and current role identifiers to be that of the role used to log in.

**Examples**

```sql
SELECT SESSION_USER, CURRENT_USER;
```

<table>
<thead>
<tr>
<th>session_user</th>
<th>current_user</th>
</tr>
</thead>
<tbody>
<tr>
<td>peter</td>
<td>peter</td>
</tr>
</tbody>
</table>

```sql
SET SESSION AUTHORIZATION 'paul';
```

```sql
SELECT SESSION_USER, CURRENT_USER;
```

<table>
<thead>
<tr>
<th>session_user</th>
<th>current_user</th>
</tr>
</thead>
<tbody>
<tr>
<td>paul</td>
<td>paul</td>
</tr>
</tbody>
</table>

**Compatibility**

The SQL standard allows some other expressions to appear in place of the literal `rolename`, but these options are not important in practice. Greenplum Database allows identifier syntax (`rolename`), which SQL does not. SQL does not allow this command during a transaction; Greenplum Database does not make this restriction. The `SESSION` and `LOCAL` modifiers are a Greenplum Database extension, as is the `RESET` syntax.

**See Also**

- `SET ROLE`

**SET TRANSACTION**

Sets the characteristics of the current transaction.

**Synopsis**

```sql
SET TRANSACTION [transaction_mode] [READ ONLY | READ WRITE]

SET SESSION CHARACTERISTICS AS TRANSACTION transaction_mode
[READ ONLY | READ WRITE]
```
where transaction_mode is one of:

<table>
<thead>
<tr>
<th>ISOLATION LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>{SERIALIZABLE</td>
</tr>
</tbody>
</table>

**Description**

The `SET TRANSACTION` command sets the characteristics of the current transaction. It has no effect on any subsequent transactions.

The available transaction characteristics are the transaction isolation level and the transaction access mode (read/write or read-only).

The isolation level of a transaction determines what data the transaction can see when other transactions are running concurrently.

- **READ COMMITTED** — A statement can only see rows committed before it began. This is the default.
- **SERIALIZABLE** — All statements of the current transaction can only see rows committed before the first query or data-modification statement was executed in this transaction.

The SQL standard defines two additional levels, `READ UNCOMMITTED` and `REPEATABLE READ`. In Greenplum Database, `READ UNCOMMITTED` is treated as `READ COMMITTED`. `REPEATABLE READ` is not supported; use `SERIALIZABLE` if `REPEATABLE READ` behavior is required.

The transaction isolation level cannot be changed after the first query or data-modification statement (SELECT, INSERT, DELETE, UPDATE, FETCH, or COPY) of a transaction has been executed.

The transaction access mode determines whether the transaction is read/write or read-only. Read/write is the default. When a transaction is read-only, the following SQL commands are disallowed: INSERT, UPDATE, DELETE, and COPY FROM if the table they would write to is not a temporary table; all CREATE, ALTER, and DROP commands; GRANT, REVOKE, TRUNCATE; and `EXPLAIN ANALYZE` and `EXECUTE` if the command they would execute is among those listed. This is a high-level notion of read-only that does not prevent all writes to disk.

**Parameters**

**SESSION CHARACTERISTICS**

- **SERIALIZABLE**
- **READ COMMITTED**
- **READ UNCOMMITTED**

Sets the default transaction characteristics for subsequent transactions of a session.

The SQL standard defines four transaction isolation levels: `READ COMMITTED`, `READ UNCOMMITTED`, `SERIALIZABLE`, and `REPEATABLE READ`. The default behavior is that a statement can only see rows committed before it began (`READ COMMITTED`). In Greenplum Database, `READ UNCOMMITTED` is treated the same as `READ COMMITTED`. `REPEATABLE READ` is not supported; use `SERIALIZABLE` instead. `SERIALIZABLE` is the strictest transaction isolation. This level emulates serial transaction execution, as if transactions had been executed one after another, serially, rather than concurrently. Applications using this level must be prepared to retry transactions due to serialization failures.

- **READ WRITE**
- **READ ONLY**

Determines whether the transaction is read/write or read-only. Read/write is the default. When a transaction is read-only, the following SQL commands are disallowed: INSERT, UPDATE, DELETE, and COPY FROM if the table they would write to is not a temporary table; all CREATE, ALTER, and DROP commands; GRANT, REVOKE, TRUNCATE; and `EXPLAIN ANALYZE` and `EXECUTE` if the command they would execute is among those listed.
Notes
If `SET TRANSACTION` is executed without a prior `START TRANSACTION` or `BEGIN`, it will appear to have no effect.

It is possible to dispense with `SET TRANSACTION` by instead specifying the desired `transaction_modes` in `BEGIN` or `START TRANSACTION`.

The session default transaction modes can also be set by setting the configuration parameters `default_transaction_isolation` and `default_transaction_read_only`.

Examples
Set the transaction isolation level for the current transaction:

```sql
BEGIN;
SET TRANSACTION ISOLATION LEVEL SERIALIZABLE;
```

Compatibility
Both commands are defined in the SQL standard. `SERIALIZABLE` is the default transaction isolation level in the standard. In Greenplum Database the default is `READ COMMITTED`. Because of lack of predicate locking, the `SERIALIZABLE` level is not truly serializable. Essentially, a predicate-locking system prevents phantom reads by restricting what is written, whereas a multi-version concurrency control model (MVCC) as used in Greenplum Database prevents them by restricting what is read.

In the SQL standard, there is one other transaction characteristic that can be set with these commands: the size of the diagnostics area. This concept is specific to embedded SQL, and therefore is not implemented in the Greenplum Database server.

The SQL standard requires commas between successive `transaction_modes`, but for historical reasons Greenplum Database allows the commas to be omitted.

See Also
`BEGIN`, `LOCK`

SHOW
Shows the value of a system configuration parameter.

Synopsis
```
SHOW configuration_parameter
SHOW ALL
```

Description
`SHOW` displays the current settings of Greenplum Database system configuration parameters. You can set these parameters with the `SET` statement, or by editing the `postgresql.conf` configuration file of the Greenplum Database master. Note that some parameters viewable by `SHOW` are read-only — their values can be viewed but not set. See the Greenplum Database Reference Guide for details.

Parameters

- `configuration_parameter`:
  The name of a system configuration parameter.

- `ALL`
SHOW SHOWS the current value of all configuration parameters.

Examples

Show the current setting of the parameter search_path:

```
SHOW search_path;
```

Show the current setting of all parameters:

```
SHOW ALL;
```

Compatibility

SHOW is a Greenplum Database extension.

See Also

SET, RESET

START TRANSACTION

Starts a transaction block.

Synopsis

```
START TRANSACTION [SERIALIZABLE | READ COMMITTED | READ UNCOMMITTED]
[READ WRITE | READ ONLY]
```

Description

START TRANSACTION begins a new transaction block. If the isolation level or read/write mode is specified, the new transaction has those characteristics, as if SET TRANSACTION was executed. This is the same as the BEGIN command.

Parameters

SERIALIZABLE
READ COMMITTED
READ UNCOMMITTED

The SQL standard defines four transaction isolation levels: READ COMMITTED, READ UNCOMMITTED, SERIALIZABLE, and REPEATABLE READ. The default behavior is that a statement can only see rows committed before it began (READ COMMITTED). In Greenplum Database READ UNCOMMITTED is treated the same as READ COMMITTED. REPEATABLE READ is not supported; use SERIALIZABLE if this behavior is required. SERIALIZABLE, wherein all statements of the current transaction can only see rows committed before the first statement was executed in the transaction, is the strictest transaction isolation. This level emulates serial transaction execution, as if transactions had been executed one after another, serially, rather than concurrently. Applications using this level must be prepared to retry transactions due to serialization failures.

READ WRITE
READ ONLY

Determines whether the transaction is read/write or read-only. Read/write is the default. When a transaction is read-only, the following SQL commands are disallowed: INSERT, UPDATE, DELETE, and COPY FROM if the table they would write to is not a temporary table;
all CREATE, ALTER, and DROP commands; GRANT, REVOKE, TRUNCATE; and EXPLAIN ANALYZE and EXECUTE if the command they would execute is among those listed.

Examples
To begin a transaction block:

```
START TRANSACTION;
```

Compatibility
In the standard, it is not necessary to issue `START TRANSACTION` to start a transaction block: any SQL command implicitly begins a block. Greenplum Database behavior can be seen as implicitly issuing a COMMIT after each command that does not follow `START TRANSACTION` (or `BEGIN`), and it is therefore often called 'autocommit'. Other relational database systems may offer an autocommit feature as a convenience.

The SQL standard requires commas between successive `transaction_modes`, but for historical reasons Greenplum Database allows the commas to be omitted.

See also the compatibility section of `SET TRANSACTION`.

See Also
`BEGIN`, `SET TRANSACTION`

TRUNCATE

Empties a table of all rows.

Synopsis

```
TRUNCATE [TABLE] name [, ...] [CASCADE | RESTRICT]
```

Description

TRUNCATE quickly removes all rows from a table or set of tables. It has the same effect as an unqualified `DELETE` on each table, but since it does not actually scan the tables it is faster. This is most useful on large tables.

You must have the TRUNCATE privilege on the table to truncate table rows.

Parameters

`name`

The name (optionally schema-qualified) of a table to be truncated.

CASCADE

Since this key word applies to foreign key references (which are not supported in Greenplum Database) it has no effect.

RESTRICT

Since this key word applies to foreign key references (which are not supported in Greenplum Database) it has no effect.

Notes

TRUNCATE will not run any user-defined ON DELETE triggers that might exist for the tables.
**TRUNCATE** will not truncate any tables that inherit from the named table. Only the named table is truncated, not its child tables.

**TRUNCATE** will not truncate any sub-tables of a partitioned table. If you specify a sub-table of a partitioned table, **TRUNCATE** will not remove rows from the sub-table and its child tables.

### Examples

Empty the table **films**:

```
TRUNCATE films;
```

### Compatibility

There is no **TRUNCATE** command in the SQL standard.

### See Also

DELETE, DROP TABLE

---

**UPDATE**

Updates rows of a table.

### Synopsis

```
UPDATE [ONLY] table [[AS] alias]
    SET {column = {expression | DEFAULT} | (column [, ...]) = ({expression | DEFAULT} [, ...])} [, ...]
    [FROM fromlist]
    [WHERE condition | WHERE CURRENT OF cursor_name ]
```

### Description

**UPDATE** changes the values of the specified columns in all rows that satisfy the condition. Only the columns to be modified need be mentioned in the **SET** clause; columns not explicitly modified retain their previous values.

By default, **UPDATE** will update rows in the specified table and all its subtables. If you wish to only update the specific table mentioned, you must use the **ONLY** clause.

There are two ways to modify a table using information contained in other tables in the database: using sub-selects, or specifying additional tables in the **FROM** clause. Which technique is more appropriate depends on the specific circumstances.

If the **WHERE CURRENT OF** clause is specified, the row that is updated is the one most recently fetched from the specified cursor.

You must have the **UPDATE** privilege on the table to update it, as well as the **SELECT** privilege to any table whose values are read in the expressions or condition.

### Outputs

On successful completion, an **UPDATE** command returns a command tag of the form:

```
UPDATE count
```

where **count** is the number of rows updated. If **count** is 0, no rows matched the condition (this is not considered an error).
**Parameters**

**ONLY**
If specified, update rows from the named table only. When not specified, any tables inheriting from the named table are also processed.

**table**
The name (optionally schema-qualified) of an existing table.

**alias**
A substitute name for the target table. When an alias is provided, it completely hides the actual name of the table. For example, given `UPDATE foo AS f`, the remainder of the `UPDATE` statement must refer to this table as `f` not `foo`.

**column**
The name of a column in table. The column name can be qualified with a subfield name or array subscript, if needed. Do not include the table's name in the specification of a target column.

**expression**
An expression to assign to the column. The expression may use the old values of this and other columns in the table.

**DEFAULT**
Set the column to its default value (which will be NULL if no specific default expression has been assigned to it).

**fromlist**
A list of table expressions, allowing columns from other tables to appear in the **WHERE** condition and the update expressions. This is similar to the list of tables that can be specified in the **FROM** clause of a **SELECT** statement. Note that the target table must not appear in the **fromlist**, unless you intend a self-join (in which case it must appear with an **alias** in the **fromlist**).

**condition**
An expression that returns a value of type boolean. Only rows for which this expression returns true will be updated.

**cursor_name**
The name of the cursor to use in a **WHERE CURRENT OF** condition. The row to be updated is the one most recently fetched from the cursor. The cursor must be a simple (non-join, non-aggregate) query on the **UPDATE** command target table. See **DECLARE** for more information about creating cursors.

**WHERE CURRENT OF** cannot be specified together with a Boolean condition.

The **UPDATE...WHERE CURRENT OF** statement can only be executed on the server, for example in an interactive psql session or a script. Language extensions such as PL/pgSQL do not have support for updatable cursors.

See **DECLARE** for more information about creating cursors.

**output_expression**
An expression to be computed and returned by the **UPDATE** command after each row is updated. The expression may use any column names of the table or table(s) listed in **FROM**. Write `*` to return all columns.

**output_name**
A name to use for a returned column.
Notes

**SET** is not allowed on the Greenplum distribution key columns of a table.

When a **FROM** clause is present, what essentially happens is that the target table is joined to the tables mentioned in the from list, and each output row of the join represents an update operation for the target table. When using **FROM** you should ensure that the join produces at most one output row for each row to be modified. In other words, a target row should not join to more than one row from the other table(s). If it does, then only one of the join rows will be used to update the target row, but which one will be used is not readily predictable.

Because of this indeterminacy, referencing other tables only within sub-selects is safer, though often harder to read and slower than using a join.

Executing **UPDATE** and **DELETE** commands directly on a specific partition (child table) of a partitioned table is not supported. Instead, execute these commands on the root partitioned table, the table created with the **CREATE TABLE** command.

Examples

Change the word **Drama** to **Dramatic** in the column **kind** of the table **films**:

```sql
UPDATE films SET kind = 'Dramatic' WHERE kind = 'Drama';
```

Adjust temperature entries and reset precipitation to its default value in one row of the table **weather**:

```sql
UPDATE weather SET temp_lo = temp_lo+1, temp_hi = temp_lo+15, prcp = DEFAULT
WHERE city = 'San Francisco' AND date = '2016-07-03';
```

Use the alternative column-list syntax to do the same update:

```sql
UPDATE weather SET (temp_lo, temp_hi, prcp) = (temp_lo+1, temp_lo+15, DEFAULT)
WHERE city = 'San Francisco' AND date = '2016-07-03';
```

Increment the sales count of the salesperson who manages the account for Acme Corporation, using the **FROM** clause syntax (assuming both tables being joined are distributed in Greenplum Database on the **id** column):

```sql
UPDATE employees SET sales_count = sales_count + 1 FROM accounts
WHERE accounts.name = 'Acme Corporation'
AND employees.id = accounts.id;
```

Perform the same operation, using a sub-select in the **WHERE** clause:

```sql
UPDATE employees SET sales_count = sales_count + 1 WHERE id =
(SELECT id FROM accounts WHERE name = 'Acme Corporation');
```

Attempt to insert a new stock item along with the quantity of stock. If the item already exists, instead update the stock count of the existing item. To do this without failing the entire transaction, use savepoints.

```sql
BEGIN;
-- other operations
SAVEPOINT sp1;
INSERT INTO wines VALUES('Chateau Lafite 2003', '24');
-- Assume the above fails because of a unique key violation,
-- so now we issue these commands:
ROLLBACK TO sp1;
UPDATE wines SET stock = stock + 24 WHERE winename = 'Chateau
Lafite 2003';
-- continue with other operations, and eventually
COMMIT;

Compatibility
This command conforms to the SQL standard, except that the FROM clause is a Greenplum Database extension.
According to the standard, the column-list syntax should allow a list of columns to be assigned from a single row-valued expression, such as a sub-select:

```sql
UPDATE accounts SET (contact_last_name, contact_first_name) =
    (SELECT last_name, first_name FROM salesmen
     WHERE salesmen.id = accounts.sales_id);
```

This is not currently implemented — the source must be a list of independent expressions.

Some other database systems offer a FROM option in which the target table is supposed to be listed again within FROM. That is not how Greenplum Database interprets FROM. Be careful when porting applications that use this extension.

See Also
DECLARE, DELETE, SELECT, INSERT

VACUUM
Garbage-collects and optionally analyzes a database.

Synopsis

```
VACUUM [FULL] [FREEZE] [VERBOSE] [table]
VACUUM [FULL] [FREEZE] [VERBOSE] ANALYZE
    [table [(column [, ...] )]]
```

Description

VACUUM reclaims storage occupied by deleted tuples. In normal Greenplum Database operation, tuples that are deleted or obsoleted by an update are not physically removed from their table; they remain present on disk until a VACUUM is done. Therefore it is necessary to do VACUUM periodically, especially on frequently-updated tables.

With no parameter, VACUUM processes every table in the current database. With a parameter, VACUUM processes only that table.

VACUUM ANALYZE performs a VACUUM and then an ANALYZE for each selected table. This is a handy combination form for routine maintenance scripts. See ANALYZE for more details about its processing.

VACUUM (without FULL) marks deleted and obsoleted data in tables and indexes for future reuse and reclaims space for re-use only if the space is at the end of the table and an exclusive table lock can be easily obtained. Unused space at the start or middle of a table remains as is. With heap tables, this form of the command can operate in parallel with normal reading and writing of the table, as an exclusive lock is not obtained.

With append-optimized tables, VACUUM compacts a table by first vacuuming the indexes, then compacting each segment file in turn, and finally vacuuming auxiliary relations and updating statistics. On each segment, visible rows are copied from the current segment file to a new segment file, and then the current segment file is scheduled to be dropped and the new segment file is made available. Plain VACUUM of
An append-optimized table allows scans, inserts, deletes, and updates of the table while a segment file is compacted. However, an Access Exclusive lock is taken briefly to drop the current segment file and activate the new segment file.

**VACUUM FULL** does more extensive processing, including moving of tuples across blocks to try to compact the table to the minimum number of disk blocks. This form is much slower and requires an Access Exclusive lock on each table while it is being processed. The Access Exclusive lock guarantees that the holder is the only transaction accessing the table in any way.

**Important:** For information on the use of **VACUUM**, **VACUUM FULL**, and **VACUUM ANALYZE**, see **Notes**

### Outputs

When **VERBOSE** is specified, **VACUUM** emits progress messages to indicate which table is currently being processed. Various statistics about the tables are printed as well.

### Parameters

**FULL**

Selects a full vacuum, which may reclaim more space, but takes much longer and exclusively locks the table.

**FREEZE**

Specifying **FREEZE** is equivalent to performing **VACUUM** with the **vacuum_freeze_min_age** server configuration parameter set to zero. See **Server Configuration Parameters** for information about **vacuum_freeze_min_age**.

**VERBOSE**

Prints a detailed vacuum activity report for each table.

**ANALYZE**

Updates statistics used by the planner to determine the most efficient way to execute a query.

**table**

The name (optionally schema-qualified) of a specific table to vacuum. Defaults to all tables in the current database.

**column**

The name of a specific column to analyze. Defaults to all columns.

### Notes

**VACUUM** cannot be executed inside a transaction block.

Vacuum active databases frequently (at least nightly), in order to remove expired rows. After adding or deleting a large number of rows, running the **VACUUM ANALYZE** command for the affected table might be useful. This updates the system catalogs with the results of all recent changes, and allows the Greenplum Database query optimizer to make better choices in planning queries.

**Important:** PostgreSQL has a separate optional server process called the **autovacuum daemon**, whose purpose is to automate the execution of **VACUUM** and **ANALYZE** commands. Greenplum Database enables the autovacuum daemon to perform **VACUUM** operations only on the Greenplum Database template database **template0**. Autovacuum is enabled for **template0** because connections are not allowed to **template0**. The autovacuum daemon performs **VACUUM** operations on **template0** to manage transaction IDs (XIDs) and help avoid transaction ID wraparound issues in **template0**.

Manual **VACUUM** operations must be performed in user-defined databases to manage transaction IDs (XIDs) in those databases.
VACUUM causes a substantial increase in I/O traffic, which can cause poor performance for other active sessions. Therefore, it is advisable to vacuum the database at low usage times.

For heap tables, expired rows are held in what is called the free space map. The free space map must be sized large enough to cover the dead rows of all heap tables in your database. If not sized large enough, space occupied by dead rows that overflow the free space map cannot be reclaimed by a regular VACUUM command.

VACUUM commands skip external tables.

VACUUM FULL reclaims all expired row space, however it requires an exclusive lock on each table being processed, is a very expensive operation, and might take a long time to complete on large, distributed Greenplum Database tables. Perform VACUUM FULL operations during database maintenance periods.

As an alternative to VACUUM FULL, you can re-create the table with a CREATE TABLE AS statement and drop the old table.

Size the free space map appropriately. You configure the free space map using the following server configuration parameters:

- max_fsm_pages
- max_fsm_relations

For append-optimized tables, VACUUM requires enough available disk space to accommodate the new segment file during the VACUUM process. If the ratio of hidden rows to total rows in a segment file is less than a threshold value (10, by default), the segment file is not compacted. The threshold value can be configured with the gp_appendonly_compaction_threshold server configuration parameter. VACUUM FULL ignores the threshold and rewrites the segment file regardless of the ratio. VACUUM can be disabled for append-optimized tables using the gp_appendonly_compaction server configuration parameter. See Server Configuration Parameters for information about the server configuration parameters.

If a concurrent serializable transaction is detected when an append-optimized table is being vacuumed, the current and subsequent segment files are not compacted. If a segment file has been compacted but a concurrent serializable transaction is detected in the transaction that drops the original segment file, the drop is skipped. This could leave one or two segment files in an "awaiting drop" state after the vacuum has completed.

For more information about concurrency control in Greenplum Database, see "Routine System Maintenance Tasks" in Greenplum Database Administrator Guide.

Examples

Vacuum all tables in the current database:

```
VACUUM;
```

Vacuum a specific table only:

```
VACUUM mytable;
```

Vacuum all tables in the current database and collect statistics for the query optimizer:

```
VACUUM ANALYZE;
```

Compatibility

There is no VACUUM statement in the SQL standard.

See Also

ANALYZE
VALUES

Computes a set of rows.

Synopsis

VALUES ( expression [, ...] ) [, ...]
    [ORDER BY sort_expression [ASC | DESC | USING operator] [, ...]]
    [LIMIT {count | ALL}] [OFFSET start]

Description

VALUES computes a row value or set of row values specified by value expressions. It is most commonly used to generate a "constant table" within a larger command, but it can be used on its own.

When more than one row is specified, all the rows must have the same number of elements. The data types of the resulting table's columns are determined by combining the explicit or inferred types of the expressions appearing in that column, using the same rules as for UNION.

Within larger commands, VALUES is syntactically allowed anywhere that SELECT is. Because it is treated like a SELECT by the grammar, it is possible to use the ORDERBY, LIMIT, and OFFSET clauses with a VALUES command.

Parameters

expression

A constant or expression to compute and insert at the indicated place in the resulting table (set of rows). In a VALUES list appearing at the top level of an INSERT, an expression can be replaced by DEFAULT to indicate that the destination column's default value should be inserted. DEFAULT cannot be used when VALUES appears in other contexts.

sort_expression

An expression or integer constant indicating how to sort the result rows. This expression may refer to the columns of the VALUES result as column1, column2, etc. For more details, see "The ORDER BY Clause" in the parameters for SELECT.

operator

A sorting operator. For more details, see "The ORDER BY Clause" in the parameters for SELECT.

LIMIT count

OFFSET start

The maximum number of rows to return. For more details, see "The LIMIT Clause" in the parameters for SELECT.

Notes

VALUES lists with very large numbers of rows should be avoided, as you may encounter out-of-memory failures or poor performance. VALUES appearing within INSERT is a special case (because the desired column types are known from the INSERT's target table, and need not be inferred by scanning the VALUES list), so it can handle larger lists than are practical in other contexts.

Examples

A bare VALUES command:

VALUES (1, 'one'), (2, 'two'), (3, 'three');
This will return a table of two columns and three rows. It is effectively equivalent to:

```sql
SELECT 1 AS column1, 'one' AS column2
UNION ALL
SELECT 2, 'two'
UNION ALL
SELECT 3, 'three';
```

More usually, `VALUES` is used within a larger SQL command. The most common use is in `INSERT`:

```sql
INSERT INTO films (code, title, did, date_prod, kind)
VALUES ('T_601', 'Yojimbo', 106, '1961-06-16', 'Drama');
```

In the context of `INSERT`, entries of a `VALUES` list can be `DEFAULT` to indicate that the column default should be used here instead of specifying a value:

```sql
INSERT INTO films VALUES
('UA502', 'Bananas', 105, DEFAULT, 'Comedy', '82 minutes'),
('T_601', 'Yojimbo', 106, DEFAULT, 'Drama', DEFAULT);
```

`VALUES` can also be used where a sub-`SELECT` might be written, for example in a `FROM` clause:

```sql
SELECT f.* FROM films f, (VALUES('MGM', 'Horror'), ('UA', 'Sci-Fi')) AS t (studio, kind) WHERE f.studio = t.studio AND f.kind = t.kind;
```

```sql
UPDATE employees SET salary = salary * v.increase FROM
VALUES(1, 200000, 1.2), (2, 400000, 1.4)) AS v (depno, target, increase) WHERE employees.depno = v.depno AND employees.sales >= v.target;
```

Note that an `AS` clause is required when `VALUES` is used in a `FROM` clause, just as is true for `SELECT`. It is not required that the `AS` clause specify names for all the columns, but it is good practice to do so. The default column names for `VALUES` are `column1`, `column2`, etc. in Greenplum Database, but these names might be different in other database systems.

When `VALUES` is used in `INSERT`, the values are all automatically coerced to the data type of the corresponding destination column. When it is used in other contexts, it may be necessary to specify the correct data type. If the entries are all quoted literal constants, coercing the first is sufficient to determine the assumed type for all:

```sql
SELECT * FROM machines WHERE ip_address IN
VALUES('192.168.0.1::inet), ('192.168.0.10'), ('192.0.2.43'));
```

**Note:** For simple `IN` tests, it is better to rely on the list-of-scalars form of `IN` than to write a `VALUES` query as shown above. The list of scalars method requires less writing and is often more efficient.

### Compatibility

`VALUES` conforms to the SQL standard, except that `LIMIT` and `OFFSET` are Greenplum Database extensions.

### See Also

`INSERT`, `SELECT`
### SQL 2008 Optional Feature Compliance

The following table lists the features described in the 2008 SQL standard. Features that are supported in Greenplum Database are marked as YES in the 'Supported' column, features that are not implemented are marked as NO.

For information about Greenplum features and SQL compliance, see the *Greenplum Database Administrator Guide*.

**Table 102: SQL 2008 Optional Feature Compliance Details**

<table>
<thead>
<tr>
<th>ID</th>
<th>Feature</th>
<th>Supported</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>B011</td>
<td>Embedded Ada</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>B012</td>
<td>Embedded C</td>
<td>NO</td>
<td>Due to issues with PostgreSQL ecpg</td>
</tr>
<tr>
<td>B013</td>
<td>Embedded COBOL</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>B014</td>
<td>Embedded Fortran</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>B015</td>
<td>Embedded MUMPS</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>B016</td>
<td>Embedded Pascal</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>B017</td>
<td>Embedded PL/I</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>B021</td>
<td>Direct SQL</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>B031</td>
<td>Basic dynamic SQL</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>B032</td>
<td>Extended dynamic SQL</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>B033</td>
<td>Untyped SQL-invoked function arguments</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>B034</td>
<td>Dynamic specification of cursor attributes</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>B035</td>
<td>Non-extended descriptor names</td>
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<td></td>
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<td>B041</td>
<td>Extensions to embedded SQL exception declarations</td>
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<td>B051</td>
<td>Enhanced execution rights</td>
<td>NO</td>
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<td>B111</td>
<td>Module language Ada</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>B112</td>
<td>Module language C</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>B113</td>
<td>Module language COBOL</td>
<td>NO</td>
<td></td>
</tr>
<tr>
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<td>Module language Fortran</td>
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<td>INTEGER and SMALLINT data types</td>
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<td>Arithmetic operators</td>
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<td>SUBSTRING function</td>
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<td>Character concatenation</td>
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<td>UPPER and LOWER functions</td>
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<td>Identifiers</td>
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<td>Delimited identifiers</td>
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<td>Lower case identifiers</td>
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<td>Trailing underscore</td>
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<td>SELECT DISTINCT</td>
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<td>GROUP BY clause</td>
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<td>GROUP BY can contain columns not in SELECT list</td>
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<td>SELECT list items can be renamed</td>
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<td>HAVING clause</td>
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<td>Qualified * in SELECT list</td>
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<td>Correlation names in the FROM clause</td>
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<td>Rename columns in the FROM clause</td>
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<td>Comparison predicate</td>
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<td>EXCEPT DISTINCT table operator</td>
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<td>INSERT privilege at the table level</td>
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<td>DECLARE CURSOR</td>
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<td>ORDER BY columns need not be in select list</td>
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<td>WITH HOLD cursors</td>
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<td>NOT NULL constraints</td>
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<td>Basic FOREIGN KEY constraint with the NO ACTION default for both referential delete action and referential update action</td>
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<td>Foreign keys can be declared but are not enforced in Greenplum</td>
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<td>Column defaults</td>
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<td>NOT NULL inferred on PRIMARY KEY</td>
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<td>Names in a foreign key can be specified in any order</td>
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<td>COMMIT statement</td>
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<td>ROLLBACK statement</td>
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<td>Basic SET TRANSACTION statement</td>
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<td>ISOLATION LEVEL SERIALIZABLE clause</td>
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<td>READ ONLY and READ WRITE clauses</td>
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<td>Updatable queries with subqueries</td>
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<td>COLUMNS view</td>
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<td>TABLES view</td>
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<td>VIEWS view</td>
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<td>CREATE TABLE statement to create persistent base tables</td>
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<td>CREATE VIEW statement</td>
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<td>ALTER TABLE statement: ADD COLUMN clause</td>
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<td>DROP TABLE statement: RESTRICT clause</td>
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<td>DROP VIEW statement: RESTRICT clause</td>
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<td>CASCADE drop behavior</td>
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<td>REVOKE statement performed by other than the owner of a schema object</td>
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<td>REVOKE statement to revoke a privilege that the grantee has WITH GRANT OPTION</td>
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<td>Basic joined table</td>
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<td>Inner join (but not necessarily the INNER keyword)</td>
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<td>INNER keyword</td>
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<td>LEFT OUTER JOIN</td>
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<td>RIGHT OUTER JOIN</td>
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<td>Outer joins can be nested</td>
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<td>The inner table in a left or right outer join can also be used in an inner join</td>
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<td>F041-08</td>
<td>All comparison operators are supported (rather than just =)</td>
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<td>Basic date and time</td>
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<td>DATE data type (including support of DATE literal)</td>
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<td>TIME data type (including support of TIME literal) with fractional seconds precision of at least 0</td>
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<td>TIMESTAMP data type (including support of TIMESTAMP literal) with fractional seconds precision of at least 0 and 6</td>
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<td>Comparison predicate on DATE, TIME, and TIMESTAMP data types</td>
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<td>Explicit CAST between datetime types and character string types</td>
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<td>CURRENT_DATE</td>
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<td>Intervals and datetime arithmetic</td>
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<td>OVERLAPS predicate</td>
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<td>Isolation levels other than SERIALIZABLE</td>
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<td>READ UNCOMMITTED isolation level</td>
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<td>REPEATABLE READ isolation level</td>
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<td>All diagnostics</td>
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<td>Grouped operations</td>
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<td>WHERE, GROUP BY, and HAVING clauses supported in queries with grouped</td>
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<td>Nested RESULT OFFSET clause in query expression</td>
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<td>SELECT array_agg(x) FROM ...</td>
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<td>SELECT array_agg (x order by y) FROM ...</td>
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<td>Not supported: Using array_agg as an aggregate derived window function;</td>
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<td>SELECT array_agg(x) over (ORDER BY y) FROM ...</td>
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<td>SELECT array_agg (x order by y) over (PARTITION BY z) FROM ...</td>
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<td>FOR EACH ROW triggers</td>
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<td>Ability to specify a search condition that must be true before the trigger is invoked</td>
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<td>Support for runtime rules for the interaction of triggers and constraints</td>
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<td>Multiple triggers for the same event are executed in the order in which they were created in the catalog</td>
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</tr>
<tr>
<td>X211</td>
<td>XML 1.1 support</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X221</td>
<td>XML passing mechanism BY VALUE</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X222</td>
<td>XML passing mechanism BY REF</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X231</td>
<td>XML( CONTENT (UNTYPED)) type</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X232</td>
<td>XML( CONTENT (ANY)) type</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X241</td>
<td>RETURNING CONTENT in XML publishing</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X242</td>
<td>RETURNING SEQUENCE in XML publishing</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X251</td>
<td>Persistent XML values of XML(DOCUMENT (UNTYPED)) type</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X252</td>
<td>Persistent XML values of XML(DOCUMENT (ANY)) type</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X253</td>
<td>Persistent XML values of XML(CONTENT (UNTYPED)) type</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X254</td>
<td>Persistent XML values of XML(CONTENT (ANY)) type</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X255</td>
<td>Persistent XML values of XML(SEQUENCE) type</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X256</td>
<td>Persistent XML values of XML(DOCUMENT (XMLSCHEMA)) type</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X257</td>
<td>Persistent XML values of XML(CONTENT (XMLSCHEMA)) type</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X260</td>
<td>XML type: ELEMENT clause</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Feature</td>
<td>Supported</td>
<td>Comments</td>
</tr>
<tr>
<td>------</td>
<td>----------------------------------------------</td>
<td>-----------</td>
<td>----------</td>
</tr>
<tr>
<td>X261</td>
<td>XML type: NAMESPACE without ELEMENT clause</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X263</td>
<td>XML type: NO NAMESPACE with ELEMENT clause</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X264</td>
<td>XML type: schema location</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X271</td>
<td>XMLValidate: data-driven case</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X272</td>
<td>XMLValidate: ACCORDING TO clause</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X273</td>
<td>XMLValidate: ELEMENT clause</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X274</td>
<td>XMLValidate: schema location</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X281</td>
<td>XMLValidate: with DOCUMENT option</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X282</td>
<td>XMLValidate with CONTENT option</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X283</td>
<td>XMLValidate with SEQUENCE option</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X284</td>
<td>XMLValidate NAMESPACE without ELEMENT clause</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X286</td>
<td>XMLValidate: NO NAMESPACE with ELEMENT clause</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X300</td>
<td>XMLTable</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X301</td>
<td>XMLTable: derived column list option</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X302</td>
<td>XMLTable: ordinality column option</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X303</td>
<td>XMLTable: column default option</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X304</td>
<td>XMLTable: passing a context item</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X305</td>
<td>XMLTable: initializing an XQuery variable</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>X400</td>
<td>Name and identifier mapping</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>
Greenplum Environment Variables

This reference lists and describes the environment variables to set for Greenplum Database. Set these in your user’s startup shell profile (such as `~/.bashrc` or `~/.bash_profile`), or in `/etc/profile` if you want to set them for all users.

- Required Environment Variables
- Optional Environment Variables

### Required Environment Variables

Note: `GPHOME`, `PATH` and `LD_LIBRARY_PATH` can be set by sourcing the `greenplum_path.sh` file from your Greenplum Database installation directory.

**GPHOME**

This is the installed location of your Greenplum Database software. For example:

```
GPHOME=/usr/local/greenplum-db-<version>
export GPHOME
```

**PATH**

Your `PATH` environment variable should point to the location of the Greenplum Database `bin` directory. For example:

```
PATH=$GPHOME/bin:$PATH
export PATH
```

**LD_LIBRARY_PATH**

The `LD_LIBRARY_PATH` environment variable should point to the location of the Greenplum Database/PostgreSQL library files. For example:

```
LD_LIBRARY_PATH=$GPHOME/lib
export LD_LIBRARY_PATH
```

**MASTER_DATA_DIRECTORY**

This should point to the directory created by the `gpinitsystem` utility in the master data directory location. For example:

```
MASTER_DATA_DIRECTORY=/data/master/gpseg-1
export MASTER_DATA_DIRECTORY
```

### Optional Environment Variables

The following are standard PostgreSQL environment variables, which are also recognized in Greenplum Database. You may want to add the connection-related environment variables to your profile for convenience, so you do not have to type so many options on the command line for client connections. Note that these environment variables should be set on the Greenplum Database master host only.
**PGAPPNAME**

The name of the application that is usually set by an application when it connects to the server. This name is displayed in the activity view and in log entries. The `PGAPPNAME` environmental variable behaves the same as the `application_name` connection parameter. The default value for `application_name` is `psql`. The name cannot be longer than 63 characters.

**PGDATABASE**

The name of the default database to use when connecting.

**PGHOST**

The Greenplum Database master host name.

**PGHOSTADDR**

The numeric IP address of the master host. This can be set instead of or in addition to `PGHOST` to avoid DNS lookup overhead.

**PGPASSWORD**

The password used if the server demands password authentication. Use of this environment variable is not recommended for security reasons (some operating systems allow non-root users to see process environment variables via `ps`). Instead consider using the `~/.pgpass` file.

**PGPASSFILE**

The name of the password file to use for lookups. If not set, it defaults to `~/.pgpass`. See the topic about *The Password File* in the PostgreSQL documentation for more information.

**PGOPTIONS**

Sets additional configuration parameters for the Greenplum Database master server.

**PGPORT**

The port number of the Greenplum Database server on the master host. The default port is 5432.

**PGUSER**

The Greenplum Database user name used to connect.

**PGDATESTYLE**

Sets the default style of date/time representation for a session. (Equivalent to `SET datestyle TO...`)

**PGTZ**

Sets the default time zone for a session. (Equivalent to `SET timezone TO...`)

**PGCLIENTENCODING**

Sets the default client character set encoding for a session. (Equivalent to `SET client_encoding TO...`)
System Catalog Reference

This reference describes the Greenplum Database system catalog tables and views. System tables prefixed with `gp_` relate to the parallel features of Greenplum Database. Tables prefixed with `pg_` are either standard PostgreSQL system catalog tables supported in Greenplum Database, or are related to features Greenplum that provides to enhance PostgreSQL for data warehousing workloads. Note that the global system catalog for Greenplum Database resides on the master instance.

**Warning:** Changes to Pivotal Greenplum Database system catalog tables or views are not supported. If a catalog table or view is changed by the customer, the Pivotal Greenplum Database cluster is not supported. The cluster must be reinitialized and restored by the customer.

- **System Tables**
- **System Views**
- **System Catalogs Definitions**

### System Tables

- `gp_configuration` (Deprecated. See `gp_segment_configuration`.)
- `gp_configuration_history`
- `gp_db_interfaces` (Deprecated. Not used.)
- `gp_distribution_policy`
- `gp_fastsequence`
- `gp_fault_strategy`
- `gp_global_sequence`
- `gp_id`
- `gp_interfaces` (Deprecated. Not used.)
- `gp_master_mirroring` (Deprecated. See `pg_stat_replication`.)
- `gp_persistent_database_node`
- `gp_persistent_filespace_node`
- `gp_persistent_relation_node`
- `gp_persistent_tablespace_node`
- `gp_relation_node`
- `gp_segment_configuration`
- `gp_version_at_initdb`
- `gpeXpand.status`
- `gpeXpand.status_detail`
- `pg_aggregate`
- `pg_am`
- `pg_amop`
- `pg_amproc`
- `pg_appendonly`
- `pg_appendonly_alter_column` (not supported)
- `pg_attrdef`
- `pg_attribute`
- `pg_auth_members`
- `pg_authid`
- `pg_autovacuum` (not supported)
- `pg_cast`
- `pg_class`
- pg_constraint
- pg_conversion
- pg_database
- pg_depend
- pg_description
- pg_exttable
- pg_filespace
- pg_filespace_entry
- pg_foreign_data_wrapper (not supported)
- pg_foreign_server (not supported)
- pg_foreign_table (not supported)
- pg_index
- pg_inherits
- pg_language
- pg_largeobject
- pg_listener
- pg_namespace
- pg_opclass
- pg_operator
- pg_partition
- pg_partition_rule
- pg_pltemplate
- pg_proc
- pg_resgroup
- pg_resgroupcapability
- pg_resourcetype
- pg_resqueue
- pg_resqueuecapability
- pg_rewrite
- pg_shdepend
- pg_shdescription
- pg_stat_last_operation
- pg_stat_last_shoperation
- pg_statistic
- pg_tablespace
- pg_trigger
- pg_type
- pg_user_mapping (not supported)
- pg_window

**System Views**

Greenplum Database provides the following system views not available in PostgreSQL.

- gp_distributed_log
- gp_distributed_xacts
- gp_pgdatabase
- gp_resgroup_config
- gp_resgroup_status
- gp_resqueue_status
- gp_transaction_log
• gpexpand.expansion_progress
• pg_max_external_files
• pg_partition_columns
• pg_partition_templates
• pg_partitions
• pg_resqueue_attributes
• pg_resqueue_status (Deprecated. Use gp_toolkit gp_resqueue_status.)
• pg_stat_activity
• pg_stat_replication
• pg_stat_resqueues
• session_level_memory_consumption (See "Viewing Session Memory Usage Information" in the Greenplum Database Administrator Guide.)

For more information about the standard system views supported in PostgreSQL and Greenplum Database, see the following sections of the PostgreSQL documentation:

• System Views
• Statistics Collector Views
• The Information Schema

System Catalogs Definitions
System catalog table and view definitions in alphabetical order.

gp_configuration_history
The gp_configuration_history table contains information about system changes related to fault detection and recovery operations. The fts_probe process logs data to this table, as do certain related management utilities such as gpcheck, gprecoverseg, and gpinitsystem. For example, when you add a new segment and mirror segment to the system, records for these events are logged to gp_configuration_history.

The event descriptions stored in this table may be helpful for troubleshooting serious system issues in collaboration with Pivotal Support technicians.

This table is populated only on the master. This table is defined in the pg_global tablespace, meaning it is globally shared across all databases in the system.

Table 103: pg_catalog gp_configuration_history

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>timestamp with time zone</td>
<td></td>
<td>Timestamp for the event recorded.</td>
</tr>
<tr>
<td>dbid</td>
<td>smallint</td>
<td>gp_segment_configuration.dbid</td>
<td>System-assigned ID. The unique identifier of a segment (or master) instance.</td>
</tr>
<tr>
<td>desc</td>
<td>text</td>
<td></td>
<td>Text description of the event.</td>
</tr>
</tbody>
</table>

For information about gpcheck, gprecoverseg, and gpinitsystem, see the Greenplum Database Utility Guide.
**gp_distributed_log**

The **gp_distributed_log** view contains status information about distributed transactions and their associated local transactions. A distributed transaction is a transaction that involves modifying data on the segment instances. Greenplum’s distributed transaction manager ensures that the segments stay in synch. This view allows you to see the status of distributed transactions.

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>segment_id</td>
<td>smallint</td>
<td>gp_segment_configuration.content</td>
<td>The content id if the segment. The master is always -1 (no content).</td>
</tr>
<tr>
<td>dbid</td>
<td>small_int</td>
<td>gp_segment_configuration.dbid</td>
<td>The unique id of the segment instance.</td>
</tr>
<tr>
<td>distributed_xid</td>
<td>xid</td>
<td></td>
<td>The global transaction id.</td>
</tr>
<tr>
<td>distributed_id</td>
<td>text</td>
<td></td>
<td>A system assigned ID for a distributed transaction.</td>
</tr>
<tr>
<td>status</td>
<td>text</td>
<td></td>
<td>The status of the distributed transaction (Committed or Aborted).</td>
</tr>
<tr>
<td>local_transaction</td>
<td>xid</td>
<td></td>
<td>The local transaction ID.</td>
</tr>
</tbody>
</table>

**gp_distributed_xacts**

The **gp_distributed_xacts** view contains information about Greenplum Database distributed transactions. A distributed transaction is a transaction that involves modifying data on the segment instances. Greenplum’s distributed transaction manager ensures that the segments stay in synch. This view allows you to see the currently active sessions and their associated distributed transactions.

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>distributed_xid</td>
<td>xid</td>
<td></td>
<td>The transaction ID used by the distributed transaction across the Greenplum Database array.</td>
</tr>
<tr>
<td>distributed_id</td>
<td>text</td>
<td></td>
<td>The distributed transaction identifier. It has 2 parts — a unique timestamp and the distributed transaction number.</td>
</tr>
<tr>
<td>state</td>
<td>text</td>
<td></td>
<td>The current state of this session with regards to distributed transactions.</td>
</tr>
</tbody>
</table>
### gp_session_id

**Description:**
The ID number of the Greenplum Database session associated with this transaction.

**Xmin_distributed_snapshot**

**Description:**
The minimum distributed transaction number found among all open transactions when this transaction was started. It is used for MVCC distributed snapshot purposes.

---

### gp_distribution_policy

The `gp_distribution_policy` table contains information about Greenplum Database tables and their policy for distributing table data across the segments. This table is populated only on the master. This table is not globally shared, meaning each database has its own copy of this table.

**Table 106: pg_catalog.gp_distribution_policy**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>localoid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The table object identifier (OID).</td>
</tr>
<tr>
<td>attrnums</td>
<td>smallint[]</td>
<td>pg_attribute.attnum</td>
<td>The column number(s) of the distribution column(s).</td>
</tr>
</tbody>
</table>

---

### gpexpansion.expansion_progress

The `gpexpansion.expansion_progress` view contains information about the status of a system expansion operation. The view provides calculations of the estimated rate of table redistribution and estimated time to completion.

Status for specific tables involved in the expansion is stored in `gpexpansion.status_detail`.

**Table 107: gpexpansion.expansion_progress**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>text</td>
<td></td>
<td>Name for the data field provided. Includes: Bytes Left, Bytes Done, Estimated Expansion Rate, Estimated Time to Completion, Tables Expanded, Tables Left</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>----------</td>
<td>----------------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>value</td>
<td>text</td>
<td></td>
<td>The value for the progress data. For example:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Estimated Expansion Rate - 9.75667095996092 MB/s</td>
</tr>
</tbody>
</table>

**gpexpand.status**

The `gpexpand.status` table contains information about the status of a system expansion operation. Status for specific tables involved in the expansion is stored in `gpexpand.status_detail`.

In a normal expansion operation it is not necessary to modify the data stored in this table.

**Table 108: gpexpand.status**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>status</td>
<td>text</td>
<td></td>
<td>Tracks the status of an expansion operation. Valid values are:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SETUP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SETUP DONE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>EXPANSION STARTED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>EXPANSION STOPPED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>COMPLETED</td>
</tr>
<tr>
<td>updated</td>
<td>timestamp with time zone</td>
<td></td>
<td>Timestamp of the last change in status.</td>
</tr>
</tbody>
</table>

**gpexpand.status_detail**

The `gpexpand.status_detail` table contains information about the status of tables involved in a system expansion operation. You can query this table to determine the status of tables being expanded, or to view the start and end time for completed tables.

This table also stores related information about the table such as the oid, disk size, and normal distribution policy and key. Overall status information for the expansion is stored in `gpexpand.status`.

In a normal expansion operation it is not necessary to modify the data stored in this table.

**Table 109: gpexpand.status_detail**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>dbname</td>
<td>text</td>
<td></td>
<td>Name of the database to which the table belongs.</td>
</tr>
<tr>
<td>fq_name</td>
<td>text</td>
<td></td>
<td>Fully qualified name of the table.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>schema_oid</td>
<td>oid</td>
<td></td>
<td>OID for the schema of the database to which the table belongs.</td>
</tr>
<tr>
<td>table_oid</td>
<td>oid</td>
<td></td>
<td>OID of the table.</td>
</tr>
<tr>
<td>distribution_policy</td>
<td>smallint()</td>
<td></td>
<td>Array of column IDs for the distribution key of the table.</td>
</tr>
<tr>
<td>distribution_policy_names</td>
<td>text</td>
<td></td>
<td>Column names for the hash distribution key.</td>
</tr>
<tr>
<td>distribution_policy_coloIds</td>
<td>text</td>
<td></td>
<td>Column IDs for the distribution keys of the table.</td>
</tr>
<tr>
<td>storage_options</td>
<td>text</td>
<td></td>
<td>Not enabled in this release. Do not update this field.</td>
</tr>
<tr>
<td>rank</td>
<td>int</td>
<td></td>
<td>Rank determines the order in which tables are expanded. The expansion utility will sort on rank and expand the lowest-ranking tables first.</td>
</tr>
<tr>
<td>status</td>
<td>text</td>
<td></td>
<td>Status of expansion for this table. Valid values are:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NOT STARTED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IN PROGRESS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FINISHED</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NO LONGER EXISTS</td>
</tr>
<tr>
<td>last updated</td>
<td>timestamp with time zone</td>
<td></td>
<td>Timestamp of the last change in status for this table.</td>
</tr>
<tr>
<td>expansion started</td>
<td>timestamp with time zone</td>
<td></td>
<td>Timestamp for the start of the expansion of this table. This field is only populated after a table is successfully expanded.</td>
</tr>
<tr>
<td>expansion finished</td>
<td>timestamp with time zone</td>
<td></td>
<td>Timestamp for the completion of expansion of this table.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>---------------</td>
<td>------------</td>
<td>------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>source bytes</td>
<td></td>
<td></td>
<td>The size of disk space associated with the source table. Due to table bloat in heap tables and differing numbers of segments after expansion, it is not expected that the final number of bytes will equal the source number. This information is tracked to help provide progress measurement to aid in duration estimation for the end-to-end expansion operation.</td>
</tr>
</tbody>
</table>

### gp_fastsequence

The `gp_fastsequence` table contains information about append-optimized and column-oriented tables. The `last_sequence` value indicates maximum row number currently used by the table.

**Table 110: pg_catalog.gp_fastsequence**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>objid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>Object id of the pg_aoseg.pg_aocsseg_* table used to track append-optimized file segments.</td>
</tr>
<tr>
<td>objmod</td>
<td>bigint</td>
<td></td>
<td>Object modifier.</td>
</tr>
<tr>
<td>last_sequence</td>
<td>bigint</td>
<td></td>
<td>The last sequence number used by the object.</td>
</tr>
</tbody>
</table>

### gp_fault_strategy

The `gp_fault_strategy` table specifies the fault action.

**Table 111: pg_catalog.gp_fault_strategy**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>fault_strategy</td>
<td>char</td>
<td></td>
<td>The mirror failover action to take when a segment failure occurs: n = nothing, f = file-based failover</td>
</tr>
</tbody>
</table>
gp_global_sequence

The `gp_global_sequence` table contains the log sequence number position in the transaction log, which is used by the file replication process to determine the file blocks to replicate from a primary to a mirror segment.

Table 112: `pg_catalog.gp_global_sequence`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sequence_num</td>
<td>bigint</td>
<td></td>
<td>Log sequence number position in the transaction log</td>
</tr>
</tbody>
</table>

gp_id

The `gp_id` system catalog table identifies the Greenplum Database system name and number of segments for the system. It also has local values for the particular database instance (segment or master) on which the table resides. This table is defined in the `pg_global` tablespace, meaning it is globally shared across all databases in the system.

Table 113: `pg_catalog.gp_id`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>gpname</td>
<td>name</td>
<td></td>
<td>The name of this Greenplum Database system.</td>
</tr>
<tr>
<td>numsegments</td>
<td>integer</td>
<td></td>
<td>The number of segments in the Greenplum Database system.</td>
</tr>
<tr>
<td>dbid</td>
<td>integer</td>
<td></td>
<td>The unique identifier of this segment (or master) instance.</td>
</tr>
<tr>
<td>content</td>
<td>integer</td>
<td></td>
<td>The ID for the portion of data on this segment instance. A primary and its mirror will have the same content ID. For a segment the value is from 0-(N-1), where (N) is the number of segments in Greenplum Database. For the master, the value is -1.</td>
</tr>
</tbody>
</table>

gp_persistent_database_node

The `gp_persistent_database_node` table keeps track of the status of file system objects in relation to the transaction status of database objects. This information is used to make sure the state of the system catalogs and the file system files persisted to disk are synchronized. This information is used by the primary to mirror file replication process.
Table 114: `pg_catalog.gp_persistent_database_node`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>tablespace_oid</code></td>
<td>oid</td>
<td><code>pg_tablespace.oid</code></td>
<td>Table space object id.</td>
</tr>
<tr>
<td><code>database_oid</code></td>
<td>oid</td>
<td><code>pg_database.oid</code></td>
<td>Database object id.</td>
</tr>
<tr>
<td><code>persistent_state</code></td>
<td>smallint</td>
<td></td>
<td>0 - free&lt;br&gt;1 - create pending&lt;br&gt;2 - created&lt;br&gt;3 - drop pending&lt;br&gt;4 - aborting create&lt;br&gt;5 - &quot;Just in Time&quot; create pending&lt;br&gt;6 - bulk load create pending</td>
</tr>
<tr>
<td><code>mirror_existence_state</code></td>
<td>smallint</td>
<td></td>
<td>0 - none&lt;br&gt;1 - not mirrored&lt;br&gt;2 - mirror create pending&lt;br&gt;3 - mirrorcreated&lt;br&gt;4 - mirror down before create&lt;br&gt;5 - mirror down during create&lt;br&gt;6 - mirror drop pending&lt;br&gt;7 - only mirror drop remains</td>
</tr>
<tr>
<td><code>parent_xid</code></td>
<td>integer</td>
<td></td>
<td>Global transaction id.</td>
</tr>
<tr>
<td><code>persistent_serial_num</code></td>
<td>bigint</td>
<td></td>
<td>Log sequence number position in the transaction log for a file block.</td>
</tr>
<tr>
<td><code>previous_free_tid</code></td>
<td>tid</td>
<td></td>
<td>Used by Greenplum Database to internally manage persistent representations of file system objects.</td>
</tr>
</tbody>
</table>

**gp_persistent_filespace_node**

The `gp_persistent_filespace_node` table keeps track of the status of file system objects in relation to the transaction status of filespace objects. This information is used to make sure the state of the system catalogs and the file system files persisted to disk are synchronized. This information is used by the primary to mirror file replication process.
Table 115: pg_catalog.gp_persistent_filespace_node

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(filespace_oid)</td>
<td>oid</td>
<td>pg_filespace.oid</td>
<td>object id of the filespace</td>
</tr>
<tr>
<td>db_id_1</td>
<td>smallint</td>
<td></td>
<td>primary segment id</td>
</tr>
<tr>
<td>location_1</td>
<td>text</td>
<td></td>
<td>primary filesystem location</td>
</tr>
<tr>
<td>db_id_2</td>
<td>smallint</td>
<td></td>
<td>mirror segment id</td>
</tr>
<tr>
<td>location_2</td>
<td>text</td>
<td></td>
<td>mirror filesystem location</td>
</tr>
<tr>
<td>persistent_state</td>
<td>smallint</td>
<td></td>
<td>0 - free</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - create pending</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 - created</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - drop pending</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4 - aborting create</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - &quot;Just in Time&quot; create pending</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6 - bulk load create</td>
</tr>
<tr>
<td>mirror_existence_</td>
<td>smallint</td>
<td></td>
<td>0 - none</td>
</tr>
<tr>
<td>state</td>
<td></td>
<td></td>
<td>1 - not mirrored</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 - mirror create pending</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - mirrorcreated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4 - mirror down before create</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - mirror down during create</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6 - mirror drop pending</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7 - only mirror drop remains</td>
</tr>
<tr>
<td>parent_xid</td>
<td>integer</td>
<td></td>
<td>Global transaction id</td>
</tr>
<tr>
<td>persistent_serial_</td>
<td>bigint</td>
<td></td>
<td>Log sequence number position in the transaction log for a file block.</td>
</tr>
<tr>
<td>num</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>previous_free_tid</td>
<td>tid</td>
<td></td>
<td>Used by Greenplum Database to internally manage persistent representations of filesystem objects.</td>
</tr>
</tbody>
</table>
gp_persistent_relation_node

The gp_persistent_relation_node table keeps track of the status of file system objects in relation to the transaction status of relation objects (tables, view, indexes, and so on). This information is used to make sure the state of the system catalogs and the file system files persisted to disk are synchronized. This information is used by the primary to mirror file replication process.

Table 116: pg_catalog.gp_persistent_relation_node

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tablespace_oid</td>
<td>oid</td>
<td>pg_tablespace.oid</td>
<td>Tablespace object id</td>
</tr>
<tr>
<td>database_oid</td>
<td>oid</td>
<td>pg_database.oid</td>
<td>Database object id</td>
</tr>
<tr>
<td>relfilenode_oid</td>
<td>oid</td>
<td>pg_class.relfilenode</td>
<td>The object id of the relation file node.</td>
</tr>
<tr>
<td>segment_file_num</td>
<td>integer</td>
<td></td>
<td>For append-optimized tables, the append-optimized segment file number.</td>
</tr>
<tr>
<td>relation_storage_manager</td>
<td>smallint</td>
<td></td>
<td>Whether the relation is heap storage or append-optimized storage.</td>
</tr>
</tbody>
</table>
| persistent_state     | smallint   |                     | 0 - free
|                      |            |                     | 1 - create pending
|                      |            |                     | 2 - created
|                      |            |                     | 3 - drop pending
|                      |            |                     | 4 - aborting create
|                      |            |                     | 5 - "Just in Time" create pending
|                      |            |                     | 6 - bulk load create pending                                               |
| mirror_existence_state | smallint |                     | 0 - none
|                      |            |                     | 1 - not mirrored
|                      |            |                     | 2 - mirror create pending
|                      |            |                     | 3 - mirrorcreated
|                      |            |                     | 4 - mirror down before create
|                      |            |                     | 5 - mirror down during create
|                      |            |                     | 6 - mirror drop pending
<p>|                      |            |                     | 7 - only mirror drop remains                                              |
| parent_xid           | integer    |                     | Global transaction id.                                                     |</p>
<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>persistent_serial_num</td>
<td>bigint</td>
<td></td>
<td>Log sequence number position in the transaction log for a file block.</td>
</tr>
<tr>
<td>previous_free_tid</td>
<td>tid</td>
<td></td>
<td>Used by Greenplum Database to internally manage persistent representations of file system objects.</td>
</tr>
</tbody>
</table>

**gp_persistent_tablespace_node**

The `gp_persistent_tablespace_node` table keeps track of the status of file system objects in relation to the transaction status of tablespace objects. This information is used to make sure the state of the system catalogs and the file system files persisted to disk are synchronized. This information is used by the primary to mirror file replication process.

Table 117: `pg_catalog.gp_persistent_tablespace_node`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>filesystem_oid</td>
<td>oid</td>
<td><code>pg_filespace.oid</code></td>
<td>Filespace object id</td>
</tr>
<tr>
<td>tablespace_oid</td>
<td>oid</td>
<td><code>pg_tablespace.oid</code></td>
<td>Tablespace object id</td>
</tr>
<tr>
<td>persistent_state</td>
<td>smallint</td>
<td></td>
<td>0 - free</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - create pending</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 - created</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - drop pending</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4 - aborting create</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - &quot;Just In Time&quot; create pending</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6 - bulk load create pending</td>
</tr>
<tr>
<td>mirror_existence_state</td>
<td>smallint</td>
<td></td>
<td>0 - none</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - not mirrored</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 - mirror create pending</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - mirrorcreated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4 - mirror down before create</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - mirror down during create</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6 - mirror drop pending</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7 - only mirror drop remains</td>
</tr>
<tr>
<td>parent_xid</td>
<td>integer</td>
<td></td>
<td>Global transaction id.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------</td>
<td>---------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>persistent_serial_num</td>
<td>bigint</td>
<td></td>
<td>Log sequence number position in the transaction log for a file block.</td>
</tr>
<tr>
<td>previous_free_tid</td>
<td>tid</td>
<td></td>
<td>Used by Greenplum Database to internally manage persistent representations of file system objects.</td>
</tr>
</tbody>
</table>

### gp_pgdatabase

The `gp_pgdatabase` view shows status information about the Greenplum segment instances and whether they are acting as the mirror or the primary. This view is used internally by the Greenplum fault detection and recovery utilities to determine failed segments.

**Table 118: pg_catalog.gp_pgdatabase**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>dbid</td>
<td>smallint</td>
<td>gp_segment_configuration.dbid</td>
<td>System-assigned ID. The unique identifier of a segment (or master) instance.</td>
</tr>
<tr>
<td>isprimary</td>
<td>boolean</td>
<td>gp_segment_configuration.role</td>
<td>Whether or not this instance is active. Is it currently acting as the primary segment (as opposed to the mirror).</td>
</tr>
<tr>
<td>content</td>
<td>smallint</td>
<td>gp_segment_configuration.content</td>
<td>The ID for the portion of data on an instance. A primary segment instance and its mirror will have the same content ID. For a segment the value is from 0-N-1, where N is the number of segments in Greenplum Database. For the master, the value is -1.</td>
</tr>
<tr>
<td>definedprimary</td>
<td>boolean</td>
<td>gp_segment_configuration.preferred_role</td>
<td>Whether or not this instance was defined as the primary (as opposed to the mirror) at the time the system was initialized.</td>
</tr>
</tbody>
</table>
**gp_relation_node**

The `gp_relation_node` table contains information about the file system objects for a relation (table, view, index, and so on).

Table 119: `pg_catalog.gp_relation_node`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>relfilenode_oid</td>
<td>oid</td>
<td>pg_class.relfilenode</td>
<td>The object id of the relation file node.</td>
</tr>
<tr>
<td>segment_file_num</td>
<td>integer</td>
<td></td>
<td>For append-optimized tables, the append-optimized segment file number.</td>
</tr>
<tr>
<td>persistent_tid</td>
<td>tid</td>
<td></td>
<td>Used by Greenplum Database to internally manage persistent representations of file system objects.</td>
</tr>
<tr>
<td>persistent_serial_num</td>
<td>bigint</td>
<td></td>
<td>Log sequence number position in the transaction log for a file block.</td>
</tr>
</tbody>
</table>

**gp_resgroup_config**

The `gp_toolkit.gp_resgroup_config` view allows administrators to see the current CPU, memory, and concurrency limits for a resource group. The view also displays proposed limit settings. A proposed limit will differ from a current limit when the limit has been altered, but the new value could not be immediately applied.

Note: The `gp_resgroup_config` view is valid only when resource group-based resource management is active.

Table 120: `gp_toolkit.gp_resgroup_config`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>groupid</td>
<td>oid</td>
<td>pg_resgroup.oid</td>
<td>The ID of the resource group.</td>
</tr>
<tr>
<td>groupname</td>
<td>name</td>
<td>pg_resgroup.rsgname</td>
<td>The name of the resource group.</td>
</tr>
<tr>
<td>concurrency</td>
<td>text</td>
<td>pg_resgroupcapability.value for pg_resgroupcapability.</td>
<td>The concurrency (CONCURRENCY) value specified for the resource group.</td>
</tr>
<tr>
<td>proposed_concurrency</td>
<td>text</td>
<td>pg_resgroupcapability.proposed for pg_resgroupcapability. reslimittyype = 1</td>
<td>The pending concurrency value for the resource group.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>cpu_rate_limit</td>
<td>text</td>
<td>pg_resgroupcapability.reslimittype = 2</td>
<td>The CPU limit (CPU_RATE_LIMIT) value specified for the resource group.</td>
</tr>
<tr>
<td>memory_limit</td>
<td>text</td>
<td>pg_resgroupcapability.reslimittype = 3</td>
<td>The memory limit (MEMORY_LIMIT) value specified for the resource group.</td>
</tr>
<tr>
<td>proposed_memory_limit</td>
<td>text</td>
<td>pg_resgroupcapability.reslimittype = 3</td>
<td>The pending memory limit value for the resource group.</td>
</tr>
<tr>
<td>memory_shared_quota</td>
<td>text</td>
<td>pg_resgroupcapability.reslimittype = 4</td>
<td>The shared memory quota (MEMORY_SHARED_QUOTA) value specified for the resource group.</td>
</tr>
<tr>
<td>proposed_memory_shared_quota</td>
<td>text</td>
<td>pg_resgroupcapability.reslimittype = 4</td>
<td>The pending shared memory quota value for the resource group.</td>
</tr>
<tr>
<td>memory_spill_ratio</td>
<td>text</td>
<td>pg_resgroupcapability.reslimittype = 5</td>
<td>The memory spill ratio (MEMORY_SPILL_RATIO) value specified for the resource group.</td>
</tr>
<tr>
<td>proposed_memory_spill_ratio</td>
<td>text</td>
<td>pg_resgroupcapability.reslimittype &gt; 5</td>
<td>The pending memory spill ratio value for the resource group.</td>
</tr>
</tbody>
</table>

**gp_resgroup_status**

The `gp_toolkit.gp_resgroup_status` view allows administrators to see status and activity for a resource group. It shows how many queries are waiting to run and how many queries are currently active in the system for each resource group. The view also displays current memory and CPU usage for the resource group.

*Note:* The `gp_resgroup_status` view is valid only when resource group-based resource management is active.

**Table 121: gp_toolkit.gp_resgroup_status**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rsgname</td>
<td>name</td>
<td>pg_resgroup.rsgname</td>
<td>The name of the resource group.</td>
</tr>
<tr>
<td>groupid</td>
<td>oid</td>
<td>pg_resgroup.oid</td>
<td>The ID of the resource group.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>---------------</td>
<td>------------</td>
<td>------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>num_running</td>
<td>integer</td>
<td></td>
<td>The number of transactions currently executing in the resource group.</td>
</tr>
<tr>
<td>num_queueing</td>
<td>integer</td>
<td></td>
<td>The number of currently queued transactions for the resource group.</td>
</tr>
<tr>
<td>num_queued</td>
<td>integer</td>
<td></td>
<td>The total number of queued transactions for the resource group since the Greenplum Database cluster was last started, excluding the num_queueing.</td>
</tr>
<tr>
<td>num_executed</td>
<td>integer</td>
<td></td>
<td>The total number of executed transactions in the resource group since the Greenplum Database cluster was last started, excluding the num_running.</td>
</tr>
<tr>
<td>total_queue_duration</td>
<td>interval</td>
<td></td>
<td>The total time any transaction was queued since the Greenplum Database cluster was last started.</td>
</tr>
<tr>
<td>cpu_usage</td>
<td>json</td>
<td></td>
<td>The real-time CPU usage of the resource group on each Greenplum Database segment's host.</td>
</tr>
<tr>
<td>memory_usage</td>
<td>json</td>
<td></td>
<td>The real-time memory usage of the resource group on each Greenplum Database segment's host.</td>
</tr>
</tbody>
</table>

The `cpu_usage` field is a JSON-formatted, key:value string that identifies, for each resource group, the per-segment CPU usage percentage. The key is segment id, the value is the percentage of CPU usage by the resource group on the segment host. The total CPU usage of all segments running on a segment host should not exceed the `gp_resource_group_cpu_limit`. Example `cpu_usage` column output:

```
{"-1":0.01, "0":0.31, "1":0.31}
```

The `memory_usage` field is also a JSON-formatted, key:value string. The string contents differ depending upon the type of resource group. For each resource group that you assign to a role (default memory auditor `vmtracker`), this string identifies the used, available, granted, and proposed fixed and shared memory quota allocations on each segment. The key is segment id. The values are memory values.
displayed in MB units. The following example shows memory_usage column output for a single segment for a resource group that you assign to a role:

```
"0":{"used":0, "available":76, "quota_used":1, "quota_available":60, "quota_granted":60, "quota_proposed":60, "shared_used":0, "shared_available":16, "shared_granted":16, "shared_proposed":16}
```

For each resource group that you assign to an external component, the memory_usage JSON-formatted string identifies the memory used and the memory limit on each segment. The following example shows memory_usage column output for an external component resource group for a single segment:

```
"1":{"used":11, "limit_granted":15}
```

### gp_resqueue_status

The `gp_toolkit.gp_resqueue_status` view allows administrators to see status and activity for a resource queue. It shows how many queries are waiting to run and how many queries are currently active in the system from a particular resource queue.

**Note:** The `gp_resqueue_status` view is valid only when resource queue-based resource management is active.

**Table 122: gp_toolkit.gp_resqueue_status**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>queueid</td>
<td>oid</td>
<td><code>gp_toolkit.gp_resqueue_queueid</code></td>
<td>The ID of the resource queue.</td>
</tr>
<tr>
<td>rsqname</td>
<td>name</td>
<td><code>gp_toolkit.gp_resqueue_rsqname</code></td>
<td>The name of the resource queue.</td>
</tr>
<tr>
<td>rsqcountlimit</td>
<td>real</td>
<td><code>gp_toolkit.gp_resqueue_rsqcountlimit</code></td>
<td>The active query threshold of the resource queue. A value of -1 means no limit.</td>
</tr>
<tr>
<td>rsqcountvalue</td>
<td>real</td>
<td><code>gp_toolkit.gp_resqueue_rsqcountvalue</code></td>
<td>The number of active query slots currently being used in the resource queue.</td>
</tr>
<tr>
<td>rsqcotstoplimit</td>
<td>real</td>
<td><code>gp_toolkit.gp_resqueue_rsqcotstoplimit</code></td>
<td>The query cost threshold of the resource queue. A value of -1 means no limit.</td>
</tr>
<tr>
<td>rsqcostvalue</td>
<td>real</td>
<td><code>gp_toolkit.gp_resqueue_rsqcostvalue</code></td>
<td>The total cost of all statements currently in the resource queue.</td>
</tr>
<tr>
<td>rsqmemorylimit</td>
<td>real</td>
<td><code>gp_toolkit.gp_resqueue_rsqmemorylimit</code></td>
<td>The memory limit for the resource queue.</td>
</tr>
<tr>
<td>rsqmemoryvalue</td>
<td>real</td>
<td><code>gp_toolkit.gp_resqueue_rsqmemoryvalue</code></td>
<td>The total memory used by all statements currently in the resource queue.</td>
</tr>
</tbody>
</table>
### rsqwaiters
- **Type**: integer
- **References**: `gp_toolkit.gp_resqueue_rsqwaiter`
- **Description**: The number of statements currently waiting in the resource queue.

### rsqholders
- **Type**: integer
- **References**: `gp_toolkit.gp_resqueue_rsqholders`
- **Description**: The number of statements currently running on the system from this resource queue.

### gp_segment_configuration

The `gp_segment_configuration` table contains information about mirroring and segment configuration.

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>dbid</td>
<td>smallint</td>
<td></td>
<td>The unique identifier of a segment (or master) instance.</td>
</tr>
<tr>
<td>content</td>
<td>smallint</td>
<td></td>
<td>The content identifier for a segment instance. A primary segment instance and its corresponding mirror will always have the same content identifier. For a segment the value is from 0-N-1, where N is the number of primary segments in the system. For the master, the value is always -1.</td>
</tr>
<tr>
<td>role</td>
<td>char</td>
<td></td>
<td>The role that a segment is currently running as. Values are <code>p</code> (primary) or <code>m</code> (mirror).</td>
</tr>
<tr>
<td>preferred_role</td>
<td>char</td>
<td></td>
<td>The role that a segment was originally assigned at initialization time. Values are <code>p</code> (primary) or <code>m</code> (mirror).</td>
</tr>
<tr>
<td>mode</td>
<td>char</td>
<td></td>
<td>The synchronization status of a segment with its mirror copy. Values are <code>s</code> (synchronized), <code>c</code> (change logging), or <code>r</code> (resyncing).</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
<td>------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>status</td>
<td>char</td>
<td></td>
<td>The fault status of a segment. Values are u (up) or d (down).</td>
</tr>
<tr>
<td>port</td>
<td>integer</td>
<td></td>
<td>The TCP port the database server listener process is using.</td>
</tr>
<tr>
<td>hostname</td>
<td>text</td>
<td></td>
<td>The hostname of a segment host.</td>
</tr>
<tr>
<td>address</td>
<td>text</td>
<td></td>
<td>The hostname used to access a particular segment on a segment host. This value may be the same as hostname in systems upgraded from 3.x or on systems that do not have per-interface hostnames configured.</td>
</tr>
<tr>
<td>replication_port</td>
<td>integer</td>
<td></td>
<td>The TCP port the file block replication process is using to keep primary and mirror segments synchronized.</td>
</tr>
</tbody>
</table>

**gp_transaction_log**

The `gp_transaction_log` view contains status information about transactions local to a particular segment. This view allows you to see the status of local transactions.

**Table 124: pg_catalog.gp_transaction_log**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>segment_id</td>
<td>smallint</td>
<td>gp_segment_configuration.content</td>
<td>The content id if the segment. The master is always -1 (no content).</td>
</tr>
<tr>
<td>dbid</td>
<td>smallint</td>
<td>gp_segment_configuration.dbid</td>
<td>The unique id of the segment instance.</td>
</tr>
<tr>
<td>transaction</td>
<td>xid</td>
<td></td>
<td>The local transaction ID.</td>
</tr>
<tr>
<td>status</td>
<td>text</td>
<td></td>
<td>The status of the local transaction (Committed or Aborted).</td>
</tr>
</tbody>
</table>

**gp_version_at_initdb**

The `gp_version_at_initdb` table is populated on the master and each segment in the Greenplum Database system. It identifies the version of Greenplum Database used when the system was first initialized. This table is defined in the `pg_global` tablespace, meaning it is globally shared across all databases in the system.
Table 125: pg_catalog.gp_version

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>schemaversion</td>
<td>integer</td>
<td></td>
<td>Schema version number.</td>
</tr>
<tr>
<td>productversion</td>
<td>text</td>
<td></td>
<td>Product version number.</td>
</tr>
</tbody>
</table>

**pg_aggregate**

The `pg_aggregate` table stores information about aggregate functions. An aggregate function is a function that operates on a set of values (typically one column from each row that matches a query condition) and returns a single value computed from all these values. Typical aggregate functions are `sum`, `count`, and `max`. Each entry in `pg_aggregate` is an extension of an entry in `pg_proc`. The `pg_proc` entry carries the aggregate's name, input and output data types, and other information that is similar to ordinary functions.

Table 126: pg_catalog.pg_aggregate

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>aggfnoioid</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Aggregate function OID</td>
</tr>
<tr>
<td>aggtransfn</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Transition function OID</td>
</tr>
<tr>
<td>aggprelimfn</td>
<td>regproc</td>
<td></td>
<td>Preliminary function OID (zero if none)</td>
</tr>
<tr>
<td>aggfinalfn</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Final function OID (zero if none)</td>
</tr>
<tr>
<td>agginitval</td>
<td>text</td>
<td></td>
<td>The initial value of the transition state. This is a text field containing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>the initial value in its external string representation. If this field is</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NULL, the transition state value starts out NULL.</td>
</tr>
<tr>
<td>agginvtransfn</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>The OID in <code>pg_proc</code> of the inverse function of <code>aggtransfn</code></td>
</tr>
<tr>
<td>agginvpelimfn</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>The OID in <code>pg_proc</code> of the inverse function of <code>aggprelimfn</code></td>
</tr>
<tr>
<td>aggordered</td>
<td>Boolean</td>
<td></td>
<td>If true, the aggregate is defined as <code>ORDERED</code>.</td>
</tr>
<tr>
<td>aggsortop</td>
<td>oid</td>
<td>pg_operator.oid</td>
<td>Associated sort operator OID (zero if none)</td>
</tr>
<tr>
<td>aggtranstype</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>Data type of the aggregate function's internal transition (state) data</td>
</tr>
</tbody>
</table>
**pg_am**

The *pg_am* table stores information about index access methods. There is one row for each index access method supported by the system.

**Table 127: pg_catalog.pg_am**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>amname</td>
<td>name</td>
<td></td>
<td>Name of the access method</td>
</tr>
<tr>
<td>amstrategies</td>
<td>int2</td>
<td></td>
<td>Number of operator strategies for this access method</td>
</tr>
<tr>
<td>amsupport</td>
<td>int2</td>
<td></td>
<td>Number of support routines for this access method</td>
</tr>
<tr>
<td>amorderstrategy</td>
<td>int2</td>
<td></td>
<td>Zero if the index offers no sort order, otherwise the strategy number of the strategy operator that describes the sort order</td>
</tr>
<tr>
<td>amcanunique</td>
<td>boolean</td>
<td></td>
<td>Does the access method support unique indexes?</td>
</tr>
<tr>
<td>amcanmulticol</td>
<td>boolean</td>
<td></td>
<td>Does the access method support multicolumn indexes?</td>
</tr>
<tr>
<td>amoptionalkey</td>
<td>boolean</td>
<td></td>
<td>Does the access method support a scan without any constraint for the first index column?</td>
</tr>
<tr>
<td>amindexnulls</td>
<td>boolean</td>
<td></td>
<td>Does the access method support null index entries?</td>
</tr>
<tr>
<td>amstorage</td>
<td>boolean</td>
<td></td>
<td>Can index storage data type differ from column data type?</td>
</tr>
<tr>
<td>amclusterable</td>
<td>boolean</td>
<td></td>
<td>Can an index of this type be clustered on?</td>
</tr>
<tr>
<td>aminsert</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>&quot;Insert this tuple&quot; function</td>
</tr>
<tr>
<td>ambeginscan</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>&quot;Start new scan&quot; function</td>
</tr>
<tr>
<td>amgettupl e</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>&quot;Next valid tuple&quot; function</td>
</tr>
<tr>
<td>amgetmulti</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>&quot;Fetch multiple tuples&quot; function</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
<td>--------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>amrescan</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>&quot;Restart this scan&quot; function</td>
</tr>
<tr>
<td>amendscan</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>&quot;End this scan&quot; function</td>
</tr>
<tr>
<td>ammarkpos</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>&quot;Mark current scan position&quot; function</td>
</tr>
<tr>
<td>amrestrpos</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>&quot;Restore marked scan position&quot; function</td>
</tr>
<tr>
<td>amsbuild</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>&quot;Build new index&quot; function</td>
</tr>
<tr>
<td>ambulkdelete</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Bulk-delete function</td>
</tr>
<tr>
<td>amvacuumcleanup</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Post-VACUUM cleanup function</td>
</tr>
<tr>
<td>amcostestimate</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Function to estimate cost of an index scan</td>
</tr>
<tr>
<td>amoptions</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Function to parse and validate reloptions for an index</td>
</tr>
</tbody>
</table>

**pg_amop**

The `pg_amop` table stores information about operators associated with index access method operator classes. There is one row for each operator that is a member of an operator class.

Table 128: `pg_catalog.pg_amop`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>amopclaid</td>
<td>oid</td>
<td>pg_opclass.oid</td>
<td>The index operator class this entry is for</td>
</tr>
<tr>
<td>amopsubtype</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>Subtype to distinguish multiple entries for one strategy; zero for default</td>
</tr>
<tr>
<td>amopstrategy</td>
<td>int2</td>
<td></td>
<td>Operator strategy number</td>
</tr>
<tr>
<td>amopreqcheck</td>
<td>boolean</td>
<td></td>
<td>Index hit must be rechecked</td>
</tr>
<tr>
<td>amopopr</td>
<td>oid</td>
<td>pg_operator.oid</td>
<td>OID of the operator</td>
</tr>
</tbody>
</table>

**pg_amproc**

The `pg_amproc` table stores information about support procedures associated with index access method operator classes. There is one row for each support procedure belonging to an operator class.
### Table 129: pg_catalog.pg_amproc

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>amopclaid</td>
<td>oid</td>
<td>pg_opclass.oid</td>
<td>The index operator class this entry is for</td>
</tr>
<tr>
<td>amprocsubtype</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>Subtype, if cross-type routine, else zero</td>
</tr>
<tr>
<td>amprocnum</td>
<td>int2</td>
<td></td>
<td>Support procedure number</td>
</tr>
<tr>
<td>amproc</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>OID of the procedure</td>
</tr>
</tbody>
</table>

### pg_appendonly

The `pg_appendonly` table contains information about the storage options and other characteristics of append-optimized tables.

### Table 130: pg_catalog.pg_appendonly

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>relid</td>
<td>oid</td>
<td></td>
<td>The table object identifier (OID) of the compressed table.</td>
</tr>
<tr>
<td>blocksize</td>
<td>integer</td>
<td></td>
<td>Block size used for compression of append-optimized tables. Valid values are 8K - 2M. Default is 32K.</td>
</tr>
<tr>
<td>safefswritesize</td>
<td>integer</td>
<td></td>
<td>Minimum size for safe write operations to append-optimized tables in a non-mature file system. Commonly set to a multiple of the extent size of the file system; for example, Linux ext3 is 4096 bytes, so a value of 32768 is commonly used.</td>
</tr>
<tr>
<td>compresslevel</td>
<td>smallint</td>
<td></td>
<td>The compression level, with compression ratio increasing from 1 to 9. When quicklz is specified for compresstype, valid values are 1 or 3. With zlib specified, valid values are 1-9.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>-------------</td>
<td>------------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>majorversion</td>
<td>smallint</td>
<td></td>
<td>The major version number of the pg_appendonly table.</td>
</tr>
<tr>
<td>minorversion</td>
<td>smallint</td>
<td></td>
<td>The minor version number of the pg_appendonly table.</td>
</tr>
<tr>
<td>checksum</td>
<td>boolean</td>
<td></td>
<td>A checksum value that is stored to compare the state of a block of data at compression time and at scan time to ensure data integrity.</td>
</tr>
<tr>
<td>compressstype</td>
<td>text</td>
<td></td>
<td>Type of compression used to compress append-optimized tables. Valid values are:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• zlib (gzip compression)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• quicklz¹</td>
</tr>
<tr>
<td>columnstore</td>
<td>boolean</td>
<td></td>
<td>1 for column-oriented storage, 0 for row-oriented storage.</td>
</tr>
<tr>
<td>segrelid</td>
<td>oid</td>
<td></td>
<td>Table on-disk segment file id.</td>
</tr>
<tr>
<td>segidxid</td>
<td>oid</td>
<td></td>
<td>Index on-disk segment file id.</td>
</tr>
<tr>
<td>blkdirrelid</td>
<td>oid</td>
<td></td>
<td>Block used for on-disk column-oriented table file.</td>
</tr>
<tr>
<td>blkdiridxid</td>
<td>oid</td>
<td></td>
<td>Block used for on-disk column-oriented index file.</td>
</tr>
<tr>
<td>visimaprelid</td>
<td>oid</td>
<td></td>
<td>Visibility map for the table.</td>
</tr>
<tr>
<td>visimapidxid</td>
<td>oid</td>
<td></td>
<td>B-tree index on the visibility map.</td>
</tr>
</tbody>
</table>

**Note:** ¹QuickLZ compression is available only in the commercial release of Pivotal Greenplum Database.

**pg_attrdef**

The pg_attrdef table stores column default values. The main information about columns is stored in pg_attribute. Only columns that explicitly specify a default value (when the table is created or the column is added) will have an entry here.
Table 131: pg_catalog.pg_attrdef

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>adrelid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The table this column belongs to</td>
</tr>
<tr>
<td>adnum</td>
<td>int2</td>
<td>pg_attribute.attnum</td>
<td>The number of the column</td>
</tr>
<tr>
<td>adbin</td>
<td>text</td>
<td></td>
<td>The internal representation of the column default value</td>
</tr>
<tr>
<td>adsrc</td>
<td>text</td>
<td></td>
<td>A human-readable representation of the default value. This field is historical, and is best not used.</td>
</tr>
</tbody>
</table>

pg_attribute

The pg_attribute table stores information about table columns. There will be exactly one pg_attribute row for every column in every table in the database. (There will also be attribute entries for indexes, and all objects that have pg_class entries.) The term attribute is equivalent to column.

Table 132: pg_catalog.pg_attribute

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>attrelid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The table this column belongs to</td>
</tr>
<tr>
<td>attname</td>
<td>name</td>
<td></td>
<td>The column name</td>
</tr>
<tr>
<td>atttypid</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>The data type of this column</td>
</tr>
<tr>
<td>attstattrtarget</td>
<td>int4</td>
<td></td>
<td>Controls the level of detail of statistics accumulated for this column by ANALYZE. A zero value indicates that no statistics should be collected. A negative value says to use the system default statistics target. The exact meaning of positive values is data type-dependent. For scalar data types, it is both the target number of &quot;most common values&quot; to collect, and the target number of histogram bins to create.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>-----------</td>
<td>----------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>attlen</td>
<td>int2</td>
<td></td>
<td>A copy of pg_type.typlen of this column's type.</td>
</tr>
<tr>
<td>attnum</td>
<td>int2</td>
<td></td>
<td>The number of the column. Ordinary columns are numbered from 1 up. System columns, such as oid, have (arbitrary) negative numbers.</td>
</tr>
<tr>
<td>attndims</td>
<td>int4</td>
<td></td>
<td>Number of dimensions, if the column is an array type; otherwise 0. (Presently, the number of dimensions of an array is not enforced, so any nonzero value effectively means it is an array)</td>
</tr>
<tr>
<td>attcacheoff</td>
<td>int4</td>
<td></td>
<td>Always -1 in storage, but when loaded into a row descriptor in memory this may be updated to cache the offset of the attribute within the row</td>
</tr>
<tr>
<td>atttypmod</td>
<td>int4</td>
<td></td>
<td>Records type-specific data supplied at table creation time (for example, the maximum length of a varchar column). It is passed to type-specific input functions and length coercion functions. The value will generally be -1 for types that do not need it.</td>
</tr>
<tr>
<td>attbyval</td>
<td>boolean</td>
<td></td>
<td>A copy of pg_type.typbyval of this column's type.</td>
</tr>
<tr>
<td>attstorage</td>
<td>char</td>
<td></td>
<td>Normally a copy of pg_type.typstorage of this column's type. For TOAST-able data types, this can be altered after column creation to control storage policy.</td>
</tr>
<tr>
<td>attalign</td>
<td>char</td>
<td></td>
<td>A copy of pg_type.typalign of this column's type.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>------------</td>
<td>---------------</td>
<td>------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>attnotnull</td>
<td>boolean</td>
<td></td>
<td>This represents a not-null constraint. It is possible to change this column to enable or disable the constraint.</td>
</tr>
<tr>
<td>atthasdef</td>
<td>boolean</td>
<td></td>
<td>This column has a default value, in which case there will be a corresponding entry in the pg_attddef catalog that actually defines the value</td>
</tr>
<tr>
<td>attisdropped</td>
<td>boolean</td>
<td></td>
<td>This column has been dropped and is no longer valid. A dropped column is still physically present in the table, but is ignored by the parser and so cannot be accessed via SQL</td>
</tr>
<tr>
<td>attislocal</td>
<td>boolean</td>
<td></td>
<td>This column is defined locally in the relation. Note that a column may be locally defined and inherited simultaneously</td>
</tr>
<tr>
<td>attinhcount</td>
<td>int4</td>
<td></td>
<td>The number of direct ancestors this column has. A column with a nonzero number of ancestors cannot be dropped nor renamed</td>
</tr>
</tbody>
</table>

**pg_attribute_encoding**

The `pg_attribute_encoding` system catalog table contains column storage information.

**Table 133: pg_catalog.pg_attribute_encoding**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>modifiers</th>
<th>storage</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>attrelid</td>
<td>oid</td>
<td>not null</td>
<td>plain</td>
<td>Foreign key to pg_attribute.attrelid</td>
</tr>
<tr>
<td>attnum</td>
<td>smallint</td>
<td>not null</td>
<td>plain</td>
<td>Foreign key to pg_attribute.attnum</td>
</tr>
<tr>
<td>attoptions</td>
<td>text [ ]</td>
<td></td>
<td>extended</td>
<td>The options</td>
</tr>
</tbody>
</table>
pg_auth_members

The pg_auth_members system catalog table shows the membership relations between roles. Any non-circular set of relationships is allowed. Because roles are system-wide, pg_auth_members is shared across all databases of a Greenplum Database system.

Table 134: pg_catalog.pg_auth_members

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>roleid</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>ID of the parent-level (group) role</td>
</tr>
<tr>
<td>member</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>ID of a member role</td>
</tr>
<tr>
<td>grantor</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>ID of the role that granted this membership</td>
</tr>
<tr>
<td>admin_option</td>
<td>boolean</td>
<td></td>
<td>True if role member may grant membership to others</td>
</tr>
</tbody>
</table>

pg_authid

The pg_authid table contains information about database authorization identifiers (roles). A role subsumes the concepts of users and groups. A user is a role with the rolcanlogin flag set. Any role (with or without rolcanlogin) may have other roles as members. See pg_auth_members.

Since this catalog contains passwords, it must not be publicly readable. pg_roles is a publicly readable view on pg_authid that blanks out the password field.

Because user identities are system-wide, pg_authid is shared across all databases in a Greenplum Database system: there is only one copy of pg_authid per system, not one per database.

Table 135: pg_catalog.pg_authid

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rolname</td>
<td>name</td>
<td></td>
<td>Role name</td>
</tr>
<tr>
<td>rolsuper</td>
<td>boolean</td>
<td></td>
<td>Role has superuser privileges</td>
</tr>
<tr>
<td>rolinherit</td>
<td>boolean</td>
<td></td>
<td>Role automatically inherits privileges of roles it is a member of</td>
</tr>
<tr>
<td>rolcreaterole</td>
<td>boolean</td>
<td></td>
<td>Role may create more roles</td>
</tr>
<tr>
<td>rolcreatedb</td>
<td>boolean</td>
<td></td>
<td>Role may create databases</td>
</tr>
<tr>
<td>rolcateupdate</td>
<td>boolean</td>
<td></td>
<td>Role may update system catalogs directly. (Even a superuser may not do this unless this column is true)</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>rolcanlogin</td>
<td>boolean</td>
<td></td>
<td>Role may log in. That is, this role can be given as the initial session authorization identifier</td>
</tr>
<tr>
<td>rolconnlimit</td>
<td>int4</td>
<td></td>
<td>For roles that can log in, this sets maximum number of concurrent connections this role can make. -1 means no limit</td>
</tr>
<tr>
<td>rolpassword</td>
<td>text</td>
<td></td>
<td>Password (possibly encrypted); NULL if none</td>
</tr>
<tr>
<td>rovaliduntil</td>
<td>timestamptz</td>
<td></td>
<td>Password expiry time (only used for password authentication); NULL if no expiration</td>
</tr>
<tr>
<td>rolconfig</td>
<td>text[]</td>
<td></td>
<td>Session defaults for server configuration parameters</td>
</tr>
<tr>
<td>rolresqueue</td>
<td>oid</td>
<td></td>
<td>Object ID of the associated resource queue ID in <code>pg_resqueue</code></td>
</tr>
<tr>
<td>rolcreaterextgpfd</td>
<td>boolean</td>
<td></td>
<td>Privilege to create read external tables with the gpfdist or gpfdists protocol</td>
</tr>
<tr>
<td>rolcreaterexhttp</td>
<td>boolean</td>
<td></td>
<td>Privilege to create read external tables with the http protocol</td>
</tr>
<tr>
<td>rolcreatewextgpfd</td>
<td>boolean</td>
<td></td>
<td>Privilege to create write external tables with the gpfdist or gpfdists protocol</td>
</tr>
<tr>
<td>rolcreaterexthdfs</td>
<td>boolean</td>
<td></td>
<td>Privilege to create read external tables with the gphdfs protocol</td>
</tr>
<tr>
<td>rolcreatewexthdfs</td>
<td>boolean</td>
<td></td>
<td>Privilege to create write external tables with the gphdfs protocol</td>
</tr>
<tr>
<td>rolresgroup</td>
<td>oid</td>
<td></td>
<td>Object ID of the associated resource group ID in <code>pg_resgroup</code></td>
</tr>
</tbody>
</table>

**pg_available_extension_versions**

The `pg_available_extension_versions` view lists the specific extension versions that are available for installation. The `pg_extension` system catalog table shows the extensions currently installed.
The view is read only.

**Table 136: pg_catalog.pg_available_extension_versions**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>name</td>
<td>Extension name.</td>
</tr>
<tr>
<td>version</td>
<td>text</td>
<td>Version name.</td>
</tr>
<tr>
<td>installed</td>
<td>boolean</td>
<td>True if this version of this extension is currently installed, False otherwise.</td>
</tr>
<tr>
<td>superuser</td>
<td>boolean</td>
<td>True if only superusers are allowed to install the extension, False otherwise.</td>
</tr>
<tr>
<td>relocatable</td>
<td>boolean</td>
<td>True if extension can be relocated to another schema, False otherwise.</td>
</tr>
<tr>
<td>schema</td>
<td>name</td>
<td>Name of the schema that the extension must be installed into, or NULL if partially or fully relocatable.</td>
</tr>
<tr>
<td>requires</td>
<td>name[]</td>
<td>Names of prerequisite extensions, or NULL if none</td>
</tr>
<tr>
<td>comment</td>
<td>text</td>
<td>Comment string from the extension control file.</td>
</tr>
</tbody>
</table>

**pg_available_extensions**

The `pg_available_extensions` view lists the extensions that are available for installation. The `pg_extension` system catalog table shows the extensions currently installed.

The view is read only.

**Table 137: pg_catalog.pg_available_extensions**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>name</td>
<td>Extension name.</td>
</tr>
<tr>
<td>default_version</td>
<td>text</td>
<td>Name of default version, or NULL if none is specified.</td>
</tr>
<tr>
<td>installed_version</td>
<td>text</td>
<td>Currently installed version of the extension, or NULL if not installed.</td>
</tr>
<tr>
<td>comment</td>
<td>text</td>
<td>Comment string from the extension control file.</td>
</tr>
</tbody>
</table>

**pg_cast**

The `pg_cast` table stores data type conversion paths, both built-in paths and those defined with `CREATE CAST`. The cast functions listed in `pg_cast` must always take the cast source type as their first argument type, and return the cast destination type as their result type. A cast function can have up to three arguments. The second argument, if present, must be type `integer`; it receives the type modifier
associated with the destination type, or -1 if there is none. The third argument, if present, must be type boolean; it receives true if the cast is an explicit cast, false otherwise.

It is legitimate to create a `pg_cast` entry in which the source and target types are the same, if the associated function takes more than one argument. Such entries represent 'length coercion functions' that coerce values of the type to be legal for a particular type modifier value. Note however that at present there is no support for associating non-default type modifiers with user-created data types, and so this facility is only of use for the small number of built-in types that have type modifier syntax built into the grammar.

When a `pg_cast` entry has different source and target types and a function that takes more than one argument, it represents converting from one type to another and applying a length coercion in a single step. When no such entry is available, coercion to a type that uses a type modifier involves two steps, one to convert between data types and a second to apply the modifier.

### Table 138: `pg_catalog.pg_cast`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>castsource</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>OID of the source data type.</td>
</tr>
<tr>
<td>casttarget</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>OID of the target data type.</td>
</tr>
<tr>
<td>castfunc</td>
<td>oid</td>
<td>pg_proc.oid</td>
<td>The OID of the function to use to perform this cast. Zero is stored if the data types are binary compatible (that is, no run-time operation is needed to perform the cast).</td>
</tr>
<tr>
<td>castcontext</td>
<td>char</td>
<td></td>
<td>Indicates what contexts the cast may be invoked in. e means only as an explicit cast (using <code>CAST</code> or <code>::</code> syntax). a means implicitly in assignment to a target column, as well as explicitly. i means implicitly in expressions, as well as the other cases.</td>
</tr>
</tbody>
</table>

### pg_class

The system catalog table `pg_class` catalogs tables and most everything else that has columns or is otherwise similar to a table (also known as `relations`). This includes indexes (see also `pg_index`), sequences, views, composite types, and TOAST tables. Not all columns are meaningful for all relation types.

### Table 139: `pg_catalog.pg_class`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>relname</td>
<td>name</td>
<td></td>
<td>Name of the table, index, view, etc.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>---------------</td>
<td>-------</td>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>relnamespace</td>
<td>oid</td>
<td>pg_namespace.oid</td>
<td>The OID of the namespace (schema) that contains this relation</td>
</tr>
<tr>
<td>reltype</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>The OID of the data type that corresponds to this table's row type, if any</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(zero for indexes, which have no pg_type entry)</td>
</tr>
<tr>
<td>relowner</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>Owner of the relation</td>
</tr>
<tr>
<td>relam</td>
<td>oid</td>
<td>pg_am.oid</td>
<td>If this is an index, the access method used (B-tree, Bitmap, hash, etc.)</td>
</tr>
<tr>
<td>relfilenode</td>
<td>oid</td>
<td></td>
<td>Name of the on-disk file of this relation; 0 if none.</td>
</tr>
<tr>
<td>reltablespace</td>
<td>oid</td>
<td>pg_tablespace.oid</td>
<td>The tablespace in which this relation is stored.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>If zero, the database’s default tablespace is implied. (Not meaningful if</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>the relation has no on-disk file.)</td>
</tr>
<tr>
<td>relpages</td>
<td>int4</td>
<td></td>
<td>Size of the on-disk representation of this table in pages (of 32K each).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>This is only an estimate used by the planner. It is updated by VACUUM,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ANALYZE, and a few DDL commands.</td>
</tr>
<tr>
<td>reltuples</td>
<td>float4</td>
<td></td>
<td>Number of rows in the table. This is only an estimate used by the planner.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>It is updated by VACUUM, ANALYZE, and a few DDL commands.</td>
</tr>
<tr>
<td>reltoastrelid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>OID of the TOAST table associated with this table, 0 if none. The TOAST</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>table stores large attributes &quot;out of line&quot; in a secondary table.</td>
</tr>
<tr>
<td>reltoastidxid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>For a TOAST table, the OID of its index. 0 if not a TOAST table.</td>
</tr>
<tr>
<td>relaosegidxid</td>
<td>oid</td>
<td></td>
<td>Deprecated in Greenplum Database 3. 4.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>----------------</td>
<td>--------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>relaosegrelid</td>
<td>oid</td>
<td></td>
<td>Deprecated in Greenplum Database 3.4.</td>
</tr>
<tr>
<td>relhasindex</td>
<td>boolean</td>
<td></td>
<td>True if this is a table and it has (or recently had) any indexes. This is set by CREATE INDEX, but not cleared immediately by DROP INDEX. VACUUM will clear if it finds the table has no indexes.</td>
</tr>
<tr>
<td>relisshared</td>
<td>boolean</td>
<td></td>
<td>True if this table is shared across all databases in the system. Only certain system catalog tables are shared.</td>
</tr>
<tr>
<td>relkind</td>
<td>char</td>
<td></td>
<td>The type of object r = heap or append-optimized table, i = index, S = sequence, v = view, c = composite type, t = TOAST value, o = internal append-optimized segment files and EOFs, c = composite type, u = uncataloged temporary heap table</td>
</tr>
<tr>
<td>relstorage</td>
<td>char</td>
<td></td>
<td>The storage mode of a table a = append-optimized, c = column-oriented, h = heap, v = virtual, x= external table.</td>
</tr>
<tr>
<td>relnatts</td>
<td>int2</td>
<td></td>
<td>Number of user columns in the relation (system columns not counted). There must be this many corresponding entries in pg_attribute.</td>
</tr>
<tr>
<td>relchecks</td>
<td>int2</td>
<td></td>
<td>Number of check constraints on the table.</td>
</tr>
<tr>
<td>reltriggers</td>
<td>int2</td>
<td></td>
<td>Number of triggers on the table.</td>
</tr>
<tr>
<td>relukeys</td>
<td>int2</td>
<td></td>
<td>Unused</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>-------------</td>
<td>----------</td>
<td>------------</td>
<td>--------------------------------------------------------------------</td>
</tr>
<tr>
<td>relfkeys</td>
<td>int2</td>
<td></td>
<td>Unused</td>
</tr>
<tr>
<td>relrefs</td>
<td>int2</td>
<td></td>
<td>Unused</td>
</tr>
<tr>
<td>relhasoids</td>
<td>boolean</td>
<td></td>
<td>True if an OID is generated for each row of the relation.</td>
</tr>
<tr>
<td>relhaspkey</td>
<td>boolean</td>
<td></td>
<td>True if the table has (or once had) a primary key.</td>
</tr>
<tr>
<td>relhasrules</td>
<td>boolean</td>
<td></td>
<td>True if table has rules.</td>
</tr>
<tr>
<td>relhassubclass</td>
<td>boolean</td>
<td></td>
<td>True if table has (or once had) any inheritance children.</td>
</tr>
<tr>
<td>relfrozenxid</td>
<td>xid</td>
<td></td>
<td>All transaction IDs before this one have been replaced with a permanent (frozen) transaction ID in this table. This is used to track whether the table needs to be vacuumed in order to prevent transaction ID wraparound or to allow pg_clog to be shrunk. Zero (InvalidTransactionId) if the relation is not a table.</td>
</tr>
<tr>
<td>relacl</td>
<td>aclitem[]</td>
<td></td>
<td>Access privileges assigned by GRANT and REVOKE.</td>
</tr>
<tr>
<td>reloptions</td>
<td>text[]</td>
<td></td>
<td>Access-method-specific options, as &quot;keyword=value&quot; strings.</td>
</tr>
</tbody>
</table>

**pg_compression**

The `pg_compression` system catalog table describes the compression methods available.

**Table 140: pg_catalog.pg_compression**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>modifiers</th>
<th>storage</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>compname</td>
<td>name</td>
<td>not null</td>
<td>plain</td>
<td>Name of the compression</td>
</tr>
<tr>
<td>compconstructor</td>
<td>regproc</td>
<td>not null</td>
<td>plain</td>
<td>Name of compression constructor</td>
</tr>
</tbody>
</table>
### pg_constraint

The `pg_constraint` system catalog table stores check, primary key, unique, and foreign key constraints on tables. Column constraints are not treated specially. Every column constraint is equivalent to some table constraint. Not-null constraints are represented in the `pg_attribute` catalog table. Check constraints on domains are stored here, too.

#### Table 141: pg_catalog.pg_constraint

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>conname</td>
<td>name</td>
<td></td>
<td>Constraint name (not necessarily unique!)</td>
</tr>
<tr>
<td>connamespace</td>
<td>oid</td>
<td><code>pg_namespace.oid</code></td>
<td>The OID of the namespace (schema) that contains this constraint.</td>
</tr>
<tr>
<td>contype</td>
<td>char</td>
<td></td>
<td>c = check constraint, f = foreign key constraint, p = primary key constraint, u = unique constraint.</td>
</tr>
<tr>
<td>condeferrable</td>
<td>boolean</td>
<td></td>
<td>Is the constraint deferrable?</td>
</tr>
<tr>
<td>condeferred</td>
<td>boolean</td>
<td></td>
<td>Is the constraint deferred by default?</td>
</tr>
<tr>
<td>conrelid</td>
<td>oid</td>
<td><code>pg_class.oid</code></td>
<td>The table this constraint is on; 0 if not a table constraint.</td>
</tr>
<tr>
<td>contypid</td>
<td>oid</td>
<td><code>pg_type.oid</code></td>
<td>The domain this constraint is on; 0 if not a domain constraint.</td>
</tr>
<tr>
<td>confrelid</td>
<td>oid</td>
<td><code>pg_class.oid</code></td>
<td>If a foreign key, the referenced table; else 0.</td>
</tr>
<tr>
<td>confupdtype</td>
<td>char</td>
<td></td>
<td>Foreign key update action code.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>-----------------</td>
<td>---------</td>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>confdeltype</td>
<td>char</td>
<td></td>
<td>Foreign key deletion action code.</td>
</tr>
<tr>
<td>confmatchtype</td>
<td>char</td>
<td></td>
<td>Foreign key match type.</td>
</tr>
<tr>
<td>conkey</td>
<td>int2[]</td>
<td>pg_attribute.attnum</td>
<td>If a table constraint, list of columns which the constraint constrains.</td>
</tr>
<tr>
<td>confkey</td>
<td>int2[]</td>
<td>pg_attribute.attnum</td>
<td>If a foreign key, list of the referenced columns.</td>
</tr>
<tr>
<td>conbin</td>
<td>text</td>
<td></td>
<td>If a check constraint, an internal representation of the expression.</td>
</tr>
<tr>
<td>consrc</td>
<td>text</td>
<td></td>
<td>If a check constraint, a human-readable representation of the expression.</td>
</tr>
<tr>
<td>conname</td>
<td>name</td>
<td></td>
<td>Conversion name (unique within a namespace).</td>
</tr>
<tr>
<td>connamespace</td>
<td>oid</td>
<td>pg_namespace.oid</td>
<td>The OID of the namespace (schema) that contains this conversion.</td>
</tr>
<tr>
<td>conowner</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>Owner of the conversion.</td>
</tr>
<tr>
<td>conforencoding</td>
<td>int4</td>
<td></td>
<td>Source encoding ID.</td>
</tr>
<tr>
<td>contoencoding</td>
<td>int4</td>
<td></td>
<td>Destination encoding ID.</td>
</tr>
<tr>
<td>conproc</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Conversion procedure.</td>
</tr>
<tr>
<td>condefault</td>
<td>boolean</td>
<td></td>
<td>True if this is the default conversion.</td>
</tr>
</tbody>
</table>

**pg_conversion**

The `pg_conversion` system catalog table describes the available encoding conversion procedures as defined by `CREATE CONVERSION`.

**Table 142: pg_catalog.pg_conversion**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>conname</td>
<td>name</td>
<td></td>
<td>Conversion name (unique within a namespace).</td>
</tr>
<tr>
<td>connamespace</td>
<td>oid</td>
<td>pg_namespace.oid</td>
<td>The OID of the namespace (schema) that contains this conversion.</td>
</tr>
<tr>
<td>conowner</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>Owner of the conversion.</td>
</tr>
<tr>
<td>conforencoding</td>
<td>int4</td>
<td></td>
<td>Source encoding ID.</td>
</tr>
<tr>
<td>contoencoding</td>
<td>int4</td>
<td></td>
<td>Destination encoding ID.</td>
</tr>
<tr>
<td>conproc</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Conversion procedure.</td>
</tr>
<tr>
<td>condefault</td>
<td>boolean</td>
<td></td>
<td>True if this is the default conversion.</td>
</tr>
</tbody>
</table>
**pg_database**

The `pg_database` system catalog table stores information about the available databases. Databases are created with the `CREATE DATABASE` SQL command. Unlike most system catalogs, `pg_database` is shared across all databases in the system. There is only one copy of `pg_database` per system, not one per database.

**Table 143: pg_catalog.pg_database**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>datname</td>
<td>name</td>
<td></td>
<td>Database name.</td>
</tr>
<tr>
<td>datdba</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>Owner of the database, usually the user who created it.</td>
</tr>
<tr>
<td>encoding</td>
<td>int4</td>
<td></td>
<td>Character encoding for this database. <code>pg_encoding_to_char()</code> can translate this number to the encoding name.</td>
</tr>
<tr>
<td>datistemplate</td>
<td>boolean</td>
<td></td>
<td>If true then this database can be used in the <code>TEMPLATE</code> clause of <code>CREATE DATABASE</code> to create a new database as a clone of this one.</td>
</tr>
<tr>
<td>datallowconn</td>
<td>boolean</td>
<td></td>
<td>If false then no one can connect to this database. This is used to protect the <code>template0</code> database from being altered.</td>
</tr>
<tr>
<td>datconnlimit</td>
<td>int4</td>
<td></td>
<td>Sets the maximum number of concurrent connections that can be made to this database. <code>-1</code> means no limit.</td>
</tr>
<tr>
<td>datlastsysoid</td>
<td>oid</td>
<td></td>
<td>Last system OID in the database.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>-------------</td>
<td>------------</td>
<td>------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>datfrozenxid</td>
<td>xid</td>
<td></td>
<td>All transaction IDs before this one have been replaced with a permanent (frozen) transaction ID in this database. This is used to track whether the database needs to be vacuumed in order to prevent transaction ID wraparound or to allow pg_clog to be shrunk. It is the minimum of the per-table pg_class. rewfrozenxid values.</td>
</tr>
<tr>
<td>dattablespace</td>
<td>oid</td>
<td>pg_tablespace.oid</td>
<td>The default tablespace for the database. Within this database, all tables for which pg_class. reltablespace is zero will be stored in this tablespace. All non-shared system catalogs will also be there.</td>
</tr>
<tr>
<td>datconfig</td>
<td>text[]</td>
<td></td>
<td>Session defaults for user-settable server configuration parameters.</td>
</tr>
<tr>
<td>datacl</td>
<td>aclitem[]</td>
<td></td>
<td>Database access privileges as given by GRANT and REVOKE.</td>
</tr>
</tbody>
</table>

**pg_depend**

The `pg_depend` system catalog table records the dependency relationships between database objects. This information allows DROP commands to find which other objects must be dropped by DROP CASCADE or prevent dropping in the DROP RESTRICT case. See also `pg_shdepend`, which performs a similar function for dependencies involving objects that are shared across a Greenplum system.

In all cases, a `pg_depend` entry indicates that the referenced object may not be dropped without also dropping the dependent object. However, there are several subflavors identified by `deptype`:

- **DEPENDENCY_NORMAL (n)** — A normal relationship between separately-created objects. The dependent object may be dropped without affecting the referenced object. The referenced object may only be dropped by specifying CASCADE, in which case the dependent object is dropped, too. Example: a table column has a normal dependency on its data type.

- **DEPENDENCY_AUTO (a)** — The dependent object can be dropped separately from the referenced object, and should be automatically dropped (regardless of RESTRICT or CASCADE mode) if the referenced object is dropped. Example: a named constraint on a table is made autodependent on the table, so that it will go away if the table is dropped.

- **DEPENDENCY_INTERNAL (i)** — The dependent object was created as part of creation of the referenced object, and is really just a part of its internal implementation. A DROP of the dependent object will be disallowed outright (we'll tell the user to issue a DROP against the referenced object, instead).
A DROP of the referenced object will be propagated through to drop the dependent object whether
CASCADE is specified or not.

- **DEPENDENCY_PIN (p)** — There is no dependent object; this type of entry is a signal that the system
itself depends on the referenced object, and so that object must never be deleted. Entries of this type
are created only by system initialization. The columns for the dependent object contain zeroes.

**Table 144: pg_catalog.pg_depend**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>classid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The OID of the system catalog the dependent object is in.</td>
</tr>
<tr>
<td>objid</td>
<td>oid</td>
<td>any OID column</td>
<td>The OID of the specific dependent object.</td>
</tr>
<tr>
<td>objsubid</td>
<td>int4</td>
<td></td>
<td>For a table column, this is the column number. For all other object types, this column is zero.</td>
</tr>
<tr>
<td>refclassid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The OID of the system catalog the referenced object is in.</td>
</tr>
<tr>
<td>refobjid</td>
<td>oid</td>
<td>any OID column</td>
<td>The OID of the specific referenced object.</td>
</tr>
<tr>
<td>refobjsubid</td>
<td>int4</td>
<td></td>
<td>For a table column, this is the referenced column number. For all other object types, this column is zero.</td>
</tr>
<tr>
<td>deptype</td>
<td>char</td>
<td></td>
<td>A code defining the specific semantics of this dependency relationship.</td>
</tr>
</tbody>
</table>

**pg_description**

The pg_description system catalog table stores optional descriptions (comments) for each database
object. Descriptions can be manipulated with the COMMENT command and viewed with psql's \d
meta-commands. Descriptions of many built-in system objects are provided in the initial contents of
pg_description. See also pg_shdescription, which performs a similar function for descriptions involving
objects that are shared across a Greenplum system.

**Table 145: pg_catalog.pg_description**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>objoid</td>
<td>oid</td>
<td>any OID column</td>
<td>The OID of the object this description pertains to.</td>
</tr>
</tbody>
</table>
### pg_enum

The `pg_enum` table contains entries matching enum types to their associated values and labels. The internal representation of a given enum value is actually the OID of its associated row in `pg_enum`. The OIDs for a particular enum type are guaranteed to be ordered in the way the type should sort, but there is no guarantee about the ordering of OIDs of unrelated enum types.

**Table 146: pg_catalog.pg_enum**

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>References</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>enumtypid</td>
<td>oid</td>
<td>pgtype.oid</td>
<td>The OID of the <code>pg_type</code> entry owning this enum value</td>
</tr>
<tr>
<td>enumlabel</td>
<td>name</td>
<td></td>
<td>The textual label for this enum value</td>
</tr>
</tbody>
</table>

### pg_extension

The system catalog table `pg_extension` stores information about installed extensions.

**Table 147: pg_catalog.pg_extension**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>extname</td>
<td>name</td>
<td></td>
<td>Name of the extension.</td>
</tr>
<tr>
<td>extowner</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>Owner of the extension</td>
</tr>
<tr>
<td>extnamespace</td>
<td>oid</td>
<td>pg_namespace.oid</td>
<td>Schema containing the extension exported objects.</td>
</tr>
<tr>
<td>extrelocatable</td>
<td>boolean</td>
<td></td>
<td>True if the extension can be relocated to another schema.</td>
</tr>
<tr>
<td>extversion</td>
<td>text</td>
<td></td>
<td>Version name for the extension.</td>
</tr>
</tbody>
</table>
column | type | references | description
--- | --- | --- | ---
extconfig | oid[] | pg_class.oid | Array of regclass OIDs for the extension configuration tables, or NULL if none.
extcondition | text[] | | Array of WHERE-clause filter conditions for the extension configuration tables, or NULL if none.

Unlike most catalogs with a namespace column, extnamespace does not imply that the extension belongs to that schema. Extension names are never schema-qualified. The extnamespace schema indicates the schema that contains most or all of the extension objects. If extrelocatable is true, then this schema must contain all schema-qualifiable objects that belong to the extension.

**pg_exttable**

The pg_exttable system catalog table is used to track external tables and web tables created by the CREATE EXTERNAL TABLE command.

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>reloid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The OID of this external table.</td>
</tr>
<tr>
<td>urilocation</td>
<td>text[]</td>
<td></td>
<td>The URI location(s) of the external table files.</td>
</tr>
<tr>
<td>execlocation</td>
<td>text[]</td>
<td></td>
<td>The ON segment locations defined for the external table.</td>
</tr>
<tr>
<td>fmttype</td>
<td>char</td>
<td></td>
<td>Format of the external table files: t for text, or c for csv.</td>
</tr>
<tr>
<td>fmtopts</td>
<td>text</td>
<td></td>
<td>Formatting options of the external table files, such as the field delimiter, null string, escape character, etc.</td>
</tr>
<tr>
<td>options</td>
<td>text[]</td>
<td></td>
<td>The options defined for the external table.</td>
</tr>
<tr>
<td>command</td>
<td>text</td>
<td></td>
<td>The OS command to execute when the external table is accessed.</td>
</tr>
<tr>
<td>rejectlimit</td>
<td>integer</td>
<td></td>
<td>The per segment reject limit for rows with errors, after which the load will fail.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>------------</td>
<td>--------</td>
<td>------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>rejectlimittype</td>
<td>char</td>
<td></td>
<td>Type of reject limit threshold: ( r ) for number of rows.</td>
</tr>
<tr>
<td>fmterrtbl</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The object id of the error table where format errors will be logged. <strong>NOTE:</strong> This column is no longer used and will be removed in a future release.</td>
</tr>
<tr>
<td>encoding</td>
<td>text</td>
<td></td>
<td>The client encoding.</td>
</tr>
<tr>
<td>writable</td>
<td>boolean</td>
<td></td>
<td>0 for readable external tables, 1 for writable external tables.</td>
</tr>
</tbody>
</table>

**pg_filespace**

The `pg_filespace` table contains information about the filespaces created in a Greenplum Database system. Every system contains a default filespace, `pg_system`, which is a collection of all the data directory locations created at system initialization time.

A tablespace requires a file system location to store its database files. In Greenplum Database, the master and each segment (primary and mirror) needs its own distinct storage location. This collection of file system locations for all components in a Greenplum system is referred to as a **filespace**.

**Table 149: pg_catalog.pg_filespace**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>fsname</td>
<td>name</td>
<td></td>
<td>The name of the filespace.</td>
</tr>
<tr>
<td>fsowner</td>
<td>oid</td>
<td>pg_roles.oid</td>
<td>The object id of the role that created the filespace.</td>
</tr>
</tbody>
</table>

**pg_filespace_entry**

A tablespace requires a file system location to store its database files. In Greenplum Database, the master and each segment (primary and mirror) needs its own distinct storage location. This collection of file system locations for all components in a Greenplum system is referred to as a **filesystem**. The `pg_filespace_entry` table contains information about the collection of file system locations across a Greenplum Database system that comprise a Greenplum Database filesystem.

**Table 150: pg_catalog.pg_filespace_entry**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>fsefsoid</td>
<td>OID</td>
<td>pg_filespace.oid</td>
<td>Object id of the filesystem.</td>
</tr>
<tr>
<td>fsedbid</td>
<td>integer</td>
<td>gp_segment_configuration.dbid</td>
<td>Segment id.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>fselocation</td>
<td>text</td>
<td></td>
<td>File system location for this segment id.</td>
</tr>
</tbody>
</table>

**pg_index**

The `pg_index` system catalog table contains part of the information about indexes. The rest is mostly in `pg_class`.

**Table 151: pg_catalog.pg_index**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>indexrelid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The OID of the pg_class entry for this index.</td>
</tr>
<tr>
<td>indrelid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The OID of the pg_class entry for the table this index is for.</td>
</tr>
<tr>
<td>indnatts</td>
<td>int2</td>
<td></td>
<td>The number of columns in the index (duplicates pg_class.relnatts).</td>
</tr>
<tr>
<td>indisunique</td>
<td>boolean</td>
<td></td>
<td>If true, this is a unique index.</td>
</tr>
<tr>
<td>indisprimary</td>
<td>boolean</td>
<td></td>
<td>If true, this index represents the primary key of the table. (indisunique should always be true when this is true.)</td>
</tr>
<tr>
<td>indisclustered</td>
<td>boolean</td>
<td></td>
<td>If true, the table was last clustered on this index via the CLUSTER command.</td>
</tr>
<tr>
<td>indisvalid</td>
<td>boolean</td>
<td></td>
<td>If true, the index is currently valid for queries. False means the index is possibly incomplete: it must still be modified by INSERT/UPDATE operations, but it cannot safely be used for queries.</td>
</tr>
</tbody>
</table>
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**indkey**

This is an array of indnatts values that indicate which table columns this index indexes. For example a value of 1 3 would mean that the first and the third table columns make up the index key. A zero in this array indicates that the corresponding index attribute is an expression over the table columns, rather than a simple column reference.

**indclass**

For each column in the index key this contains the OID of the operator class to use.

**indexprs**

Expression trees (in nodeToString() representation) for index attributes that are not simple column references. This is a list with one element for each zero entry in indkey. NULL if all index attributes are simple references.

**indpred**

Expression tree (in nodeToString() representation) for partial index predicate. NULL if not a partial index.

---

**pg_inherits**

The pg_inherits system catalog table records information about table inheritance hierarchies. There is one entry for each direct child table in the database. (Indirect inheritance can be determined by following chains of entries.) In Greenplum Database, inheritance relationships are created by both the INHERITS clause (standalone inheritance) and the PARTITION BY clause (partitioned child table inheritance) of CREATE TABLE.

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>inhrelid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The OID of the child table.</td>
</tr>
</tbody>
</table>
### pg_language

The `pg_language` system catalog table registers languages in which you can write functions or stored procedures. It is populated by `CREATE LANGUAGE`.

#### Table 153: pg_catalog.pg_language

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>lanname</td>
<td>name</td>
<td></td>
<td>Name of the language.</td>
</tr>
<tr>
<td>lanowner</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>Owner of the language.</td>
</tr>
<tr>
<td>lanispl</td>
<td>boolean</td>
<td></td>
<td>This is false for internal languages (such as SQL) and true for user-defined languages. Currently, <code>pg_dump</code> still uses this to determine which languages need to be dumped, but this may be replaced by a different mechanism in the future.</td>
</tr>
<tr>
<td>lanpltrusted</td>
<td>boolean</td>
<td></td>
<td>True if this is a trusted language, which means that it is believed not to grant access to anything outside the normal SQL execution environment. Only superusers may create functions in untrusted languages.</td>
</tr>
<tr>
<td>lanplcallfoid</td>
<td>oid</td>
<td>pg_proc.oid</td>
<td>For noninternal languages this references the language handler, which is a special function that is responsible for executing all functions that are written in the particular language.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>-------------</td>
<td>------------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>laninline</td>
<td>oid</td>
<td>pg_proc.oid</td>
<td>This references a function that is responsible for executing inline anonymous code blocks (see the <strong>DO</strong> command). Zero if anonymous blocks are not supported.</td>
</tr>
<tr>
<td>lanvalidator</td>
<td>oid</td>
<td>pg_proc.oid</td>
<td>This references a language validator function that is responsible for checking the syntax and validity of new functions when they are created. Zero if no validator is provided.</td>
</tr>
<tr>
<td>lanacl</td>
<td>aclitem[]</td>
<td></td>
<td>Access privileges for the language.</td>
</tr>
</tbody>
</table>

**pg_largeobject**

The **pg_largeobject** system catalog table holds the data making up 'large objects'. A large object is identified by an OID assigned when it is created. Each large object is broken into segments or 'pages' small enough to be conveniently stored as rows in **pg_largeobject**. The amount of data per page is defined to be **LOBLKSIZE** (which is currently **BLCKSZ/4**, or typically 8K).

Each row of **pg_largeobject** holds data for one page of a large object, beginning at byte offset (pageno * LOBLKSIZE) within the object. The implementation allows sparse storage: pages may be missing, and may be shorter than **LOBLKSIZE** bytes even if they are not the last page of the object. Missing regions within a large object read as zeroes.

**Table 154: pg_catalog.pg_largeobject**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>loid</td>
<td>oid</td>
<td></td>
<td>Identifier of the large object that includes this page.</td>
</tr>
<tr>
<td>pageno</td>
<td>int4</td>
<td></td>
<td>Page number of this page within its large object (counting from zero).</td>
</tr>
<tr>
<td>data</td>
<td>bytea</td>
<td></td>
<td>Actual data stored in the large object. This will never be more than <strong>LOBLKSIZE</strong> bytes and may be less.</td>
</tr>
</tbody>
</table>

**pg_listener**

The **pg_listener** system catalog table supports the **LISTEN** and **NOTIFY** commands. A listener creates an entry in **pg_listener** for each notification name it is listening for. A notifier scans and updates each
matching entry to show that a notification has occurred. The notifier also sends a signal (using the PID recorded in the table) to awaken the listener from sleep.

This table is not currently used in Greenplum Database.

Table 155: pg_catalog.pg_listener

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>relname</td>
<td>name</td>
<td></td>
<td>Notify condition name. (The name need not match any actual relation in the database.</td>
</tr>
<tr>
<td>listenerpid</td>
<td>int4</td>
<td></td>
<td>PID of the server process that created this entry.</td>
</tr>
<tr>
<td>notification</td>
<td>int4</td>
<td></td>
<td>Zero if no event is pending for this listener. If an event is pending, the PID of the server process that sent the notification.</td>
</tr>
</tbody>
</table>

pg_locks

The pg_locks view provides access to information about the locks held by open transactions within Greenplum Database.

pg_locks contains one row per active lockable object, requested lock mode, and relevant transaction. Thus, the same lockable object may appear many times if multiple transactions are holding or waiting for locks on it. An object with no current locks on it will not appear in the view at all.

There are several distinct types of lockable objects: whole relations (such as tables), individual pages of relations, individual tuples of relations, transaction IDs (both virtual and permanent IDs), and general database objects. Also, the right to extend a relation is represented as a separate lockable object.

Table 156: pg_catalog.pg_locks

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>locktype</td>
<td>text</td>
<td></td>
<td>Type of the lockable object: relation, extend, page, tuple, transactionid, object, userlock, resource queue, or advisory</td>
</tr>
<tr>
<td>database</td>
<td>oid</td>
<td>pg_database.oid</td>
<td>OID of the database in which the object exists, zero if the object is a shared object, or NULL if the object is a transaction ID</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>----------------</td>
<td>--------</td>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>relation</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>OID of the relation, or NULL if the object is not a relation or part of a relation</td>
</tr>
<tr>
<td>page</td>
<td>integer</td>
<td></td>
<td>Page number within the relation, or NULL if the object is not a tuple or relation page</td>
</tr>
<tr>
<td>tuple</td>
<td>smallint</td>
<td></td>
<td>Tuple number within the page, or NULL if the object is not a tuple</td>
</tr>
<tr>
<td>virtualxid</td>
<td>text</td>
<td></td>
<td>Virtual ID of a transaction, or NULL if the object is not a virtual transaction ID</td>
</tr>
<tr>
<td>transactionid</td>
<td>xid</td>
<td></td>
<td>ID of a transaction, or NULL if the object is not a transaction ID</td>
</tr>
<tr>
<td>classid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>OID of the system catalog containing the object, or NULL if the object is not a general database object</td>
</tr>
<tr>
<td>objid</td>
<td>oid</td>
<td>any OID column</td>
<td>OID of the object within its system catalog, or NULL if the object is not a general database object</td>
</tr>
<tr>
<td>objsubid</td>
<td>smallint</td>
<td></td>
<td>For a table column, this is the column number (the classid and objid refer to the table itself). For all other object types, this column is zero. NULL if the object is not a general database object</td>
</tr>
<tr>
<td>virtualtransaction</td>
<td>text</td>
<td></td>
<td>Virtual ID of the transaction that is holding or awaiting this lock</td>
</tr>
<tr>
<td>pid</td>
<td>integer</td>
<td></td>
<td>Process ID of the server process holding or awaiting this lock. NULL if the lock is held by a prepared transaction</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>------------</td>
<td>--------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>mode</td>
<td>text</td>
<td></td>
<td>Name of the lock mode held or desired by this process</td>
</tr>
<tr>
<td>granted</td>
<td>boolean</td>
<td></td>
<td>True if lock is held, false if lock is awaited.</td>
</tr>
<tr>
<td>mppsessionid</td>
<td>integer</td>
<td></td>
<td>The id of the client session associated with this lock.</td>
</tr>
<tr>
<td>mppiswriter</td>
<td>boolean</td>
<td></td>
<td>Specifies whether the lock is held by a writer process.</td>
</tr>
<tr>
<td>gp_segment_id</td>
<td>integer</td>
<td></td>
<td>The Greenplum segment id (dbid) where the lock is held.</td>
</tr>
</tbody>
</table>

### pg_max_external_files

The `pg_max_external_files` view shows the maximum number of external table files allowed per segment host when using the external table file protocol.

**Table 157: pg_catalog.pg_max_external_files**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>hostname</td>
<td>name</td>
<td></td>
<td>The host name used to access a particular segment instance on a segment host.</td>
</tr>
<tr>
<td>maxfiles</td>
<td>bigint</td>
<td></td>
<td>Number of primary segment instances on the host.</td>
</tr>
</tbody>
</table>

### pg_namespace

The `pg_namespace` system catalog table stores namespaces. A namespace is the structure underlying SQL schemas: each namespace can have a separate collection of relations, types, etc. without name conflicts.

**Table 158: pg_catalog.pg_namespace**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>nspname</td>
<td>name</td>
<td></td>
<td>Name of the namespace</td>
</tr>
<tr>
<td>nspowner</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>Owner of the namespace</td>
</tr>
<tr>
<td>nspacl</td>
<td>aclitem[]</td>
<td></td>
<td>Access privileges as given by GRANT and REVOKE.</td>
</tr>
</tbody>
</table>
**pg_opclass**

The `pg_opclass` system catalog table defines index access method operator classes. Each operator class defines semantics for index columns of a particular data type and a particular index access method. Note that there can be multiple operator classes for a given data type/access method combination, thus supporting multiple behaviors. The majority of the information defining an operator class is actually not in its `pg_opclass` row, but in the associated rows in `pg_amop` and `pg_amproc`. Those rows are considered to be part of the operator class definition — this is not unlike the way that a relation is defined by a single `pg_class` row plus associated rows in `pg_attribute` and other tables.

### Table 159: `pg_catalog.pg_opclass`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>opcamid</td>
<td>oid</td>
<td><code>pg_am.oid</code></td>
<td>Index access method operator class is for.</td>
</tr>
<tr>
<td>opcname</td>
<td>name</td>
<td></td>
<td>Name of this operator class</td>
</tr>
<tr>
<td>opcnamespace</td>
<td>oid</td>
<td><code>pg_namespace.oid</code></td>
<td>Namespace of this operator class</td>
</tr>
<tr>
<td>opcowner</td>
<td>oid</td>
<td><code>pg_authid.oid</code></td>
<td>Owner of the operator class</td>
</tr>
<tr>
<td>opcintype</td>
<td>oid</td>
<td><code>pg_type.oid</code></td>
<td>Data type that the operator class indexes.</td>
</tr>
<tr>
<td>opcdefault</td>
<td>boolean</td>
<td></td>
<td>True if this operator class is the default for the data type opcintype.</td>
</tr>
<tr>
<td>opckeytype</td>
<td>oid</td>
<td><code>pg_type.oid</code></td>
<td>Type of data stored in index, or zero if same as opcintype.</td>
</tr>
</tbody>
</table>

**pg_operator**

The `pg_operator` system catalog table stores information about operators, both built-in and those defined by `CREATE OPERATOR`. Unused column contain zeroes. For example, `oprleft` is zero for a prefix operator.

### Table 160: `pg_catalog.pg_operator`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>oprname</td>
<td>name</td>
<td></td>
<td>Name of the operator.</td>
</tr>
<tr>
<td>oprnamespace</td>
<td>oid</td>
<td><code>pg_namespace.oid</code></td>
<td>The OID of the namespace that contains this operator.</td>
</tr>
<tr>
<td>oprowner</td>
<td>oid</td>
<td><code>pg_authid.oid</code></td>
<td>Owner of the operator.</td>
</tr>
<tr>
<td>oprkind</td>
<td>char</td>
<td></td>
<td>(b = \text{infix (both)}, l = \text{prefix (left)}, r = \text{postfix (right)})</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>oprcanhash</td>
<td>boolean</td>
<td></td>
<td>This operator supports hash joins.</td>
</tr>
<tr>
<td>oprleft</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>Type of the left operand.</td>
</tr>
<tr>
<td>oprright</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>Type of the right operand.</td>
</tr>
<tr>
<td>oprresult</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>Type of the result.</td>
</tr>
<tr>
<td>oprcom</td>
<td>oid</td>
<td>pg_operator.oid</td>
<td>Commutator of this operator, if any.</td>
</tr>
<tr>
<td>oprnegate</td>
<td></td>
<td>pg_operator.oid</td>
<td>Negator of this operator, if any.</td>
</tr>
<tr>
<td>oprlsortop</td>
<td>oid</td>
<td>pg_operator.oid</td>
<td>If this operator supports merge joins, the operator that sorts the type of the left-hand operand (L&lt;≤L),</td>
</tr>
<tr>
<td>oprrsortop</td>
<td>oid</td>
<td>pg_operator.oid</td>
<td>If this operator supports merge joins, the operator that sorts the type of the right-hand operand (R&lt;≤R).</td>
</tr>
<tr>
<td>oprltcmpop</td>
<td>oid</td>
<td>pg_operator.oid</td>
<td>If this operator supports merge joins, the less-than operator that compares the left and right operand types (L&lt;≤R),</td>
</tr>
<tr>
<td>oprgtcmpop</td>
<td>oid</td>
<td>pg_operator.oid</td>
<td>If this operator supports merge joins, the greater-than operator that compares the left and right operand types (L&gt;≥R).</td>
</tr>
<tr>
<td>oprcode</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Function that implements this operator.</td>
</tr>
<tr>
<td>oprrest</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Restriction selectivity estimation function for this operator.</td>
</tr>
<tr>
<td>oprjoin</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Join selectivity estimation function for this operator.</td>
</tr>
</tbody>
</table>

**pg_partition**

The `pg_partition` system catalog table is used to track partitioned tables and their inheritance level relationships. Each row of `pg_partition` represents either the level of a partitioned table in the partition hierarchy, or a subpartition template description. The value of the attribute `paristemplate` determines what a particular row represents.
Table 161: pg_catalog.pg_partition

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>parrelid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The object identifier of the table.</td>
</tr>
<tr>
<td>parkind</td>
<td>char</td>
<td></td>
<td>The partition type - R for range or L for list.</td>
</tr>
<tr>
<td>parlevel</td>
<td>smallint</td>
<td></td>
<td>The partition level of this row: 0 for the top-level parent table, 1 for the first level under the parent table, 2 for the second level, and so on.</td>
</tr>
<tr>
<td>paristemplate</td>
<td>boolean</td>
<td></td>
<td>Whether or not this row represents a subpartition template definition (true) or an actual partitioning level (false).</td>
</tr>
<tr>
<td>parnatts</td>
<td>smallint</td>
<td></td>
<td>The number of attributes that define this level.</td>
</tr>
<tr>
<td>paratts</td>
<td>smallint()</td>
<td></td>
<td>An array of the attribute numbers (as in pg_attribute.attnum) of the attributes that participate in defining this level.</td>
</tr>
<tr>
<td>parclass</td>
<td>oidvector</td>
<td>pg_opclass.oid</td>
<td>The operator class identifier(s) of the partition columns.</td>
</tr>
</tbody>
</table>

pg_partition_columns

The pg_partition_columns system view is used to show the partition key columns of a partitioned table.

Table 162: pg_catalog.pg_partition_columns

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>schemaname</td>
<td>name</td>
<td></td>
<td>The name of the schema the partitioned table is in.</td>
</tr>
<tr>
<td>tablename</td>
<td>name</td>
<td></td>
<td>The table name of the top-level parent table.</td>
</tr>
<tr>
<td>columnname</td>
<td>name</td>
<td></td>
<td>The name of the partition key column.</td>
</tr>
<tr>
<td>partitionlevel</td>
<td>smallint</td>
<td></td>
<td>The level of this subpartition in the hierarchy.</td>
</tr>
</tbody>
</table>
column | type | references | description
--- | --- | --- | ---
position_in_partition_key | integer |  | For list partitions you can have a composite (multi-column) partition key. This shows the position of the column in a composite key.

**pg_partition_encoding**

The `pg_partition_encoding` system catalog table describes the available column compression options for a partition template.

Table 163: `pg_catalog.pg_attribute_encoding`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>modifiers</th>
<th>storage</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>parencoid</td>
<td>oid</td>
<td>not null</td>
<td>plain</td>
<td></td>
</tr>
<tr>
<td>parncatnum</td>
<td>smallint</td>
<td>not null</td>
<td>plain</td>
<td></td>
</tr>
<tr>
<td>parncattoptions</td>
<td>text [ ]</td>
<td></td>
<td>extended</td>
<td></td>
</tr>
</tbody>
</table>

**pg_partition_rule**

The `pg_partition_rule` system catalog table is used to track partitioned tables, their check constraints, and data containment rules. Each row of `pg_partition_rule` represents either a leaf partition (the bottom level partitions that contain data), or a branch partition (a top or mid-level partition that is used to define the partition hierarchy, but does not contain any data).

Table 164: `pg_catalog.pg_partition_rule`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>paroid</td>
<td>oid</td>
<td><code>pg_partition.oid</code></td>
<td>Row identifier of the partitioning level (from <code>pg_partition</code>) to which this partition belongs. In the case of a branch partition, the corresponding table (identified by <code>pg_partition_rule</code>) is an empty container table. In case of a leaf partition, the table contains the rows for that partition containment rule.</td>
</tr>
<tr>
<td>parchildreloid</td>
<td>oid</td>
<td><code>pg_class.oid</code></td>
<td>The table identifier of the partition (child table).</td>
</tr>
<tr>
<td>parparentrule</td>
<td>oid</td>
<td><code>pg_partition_rule.paroid</code></td>
<td>The row identifier of the rule associated with the parent table of this partition.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>------------------</td>
<td>---------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>parname</td>
<td>name</td>
<td></td>
<td>The given name of this partition.</td>
</tr>
<tr>
<td>parisdefault</td>
<td>boolean</td>
<td></td>
<td>Whether or not this partition is a default partition.</td>
</tr>
<tr>
<td>parruleord</td>
<td>smallint</td>
<td></td>
<td>For range partitioned tables, the rank of this partition on this level of</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>the partition hierarchy.</td>
</tr>
<tr>
<td>parrangestartincl</td>
<td>boolean</td>
<td></td>
<td>For range partitioned tables, whether or not the starting value is</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>inclusive.</td>
</tr>
<tr>
<td>parrangeendincl</td>
<td>boolean</td>
<td></td>
<td>For range partitioned tables, whether or not the ending value is</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>inclusive.</td>
</tr>
<tr>
<td>parrangestart</td>
<td>text</td>
<td></td>
<td>For range partitioned tables, the starting value of the range.</td>
</tr>
<tr>
<td>parrangeend</td>
<td>text</td>
<td></td>
<td>For range partitioned tables, the ending value of the range.</td>
</tr>
<tr>
<td>parrangeevery</td>
<td>text</td>
<td></td>
<td>For range partitioned tables, the interval value of the EVERY clause.</td>
</tr>
<tr>
<td>parlistvalues</td>
<td>text</td>
<td></td>
<td>For list partitioned tables, the list of values assigned to this partition.</td>
</tr>
<tr>
<td>parreloptions</td>
<td>text</td>
<td></td>
<td>An array describing the storage characteristics of the particular partition.</td>
</tr>
</tbody>
</table>

**pg_partition_templates**

The `pg_partition_templates` system view is used to show the subpartitions that were created using a subpartition template.

**Table 165: pg_catalog.pg_partition_templates**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>schemaname</td>
<td>name</td>
<td></td>
<td>The name of the schema the partitioned table is in.</td>
</tr>
<tr>
<td>tablename</td>
<td>name</td>
<td></td>
<td>The table name of the top-level parent table.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------</td>
<td>------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>partitionname</td>
<td>name</td>
<td></td>
<td>The name of the subpartition (this is the name to use if referring to the partition in an ALTER TABLE command). NULL if the partition was not given a name at create time or generated by an EVERY clause.</td>
</tr>
<tr>
<td>partitiontype</td>
<td>text</td>
<td></td>
<td>The type of subpartition (range or list).</td>
</tr>
<tr>
<td>partitionlevel</td>
<td>smallint</td>
<td></td>
<td>The level of this subpartition in the hierarchy.</td>
</tr>
<tr>
<td>partitionrank</td>
<td>bigint</td>
<td></td>
<td>For range partitions, the rank of the partition compared to other partitions of the same level.</td>
</tr>
<tr>
<td>partitionposition</td>
<td>smallint</td>
<td></td>
<td>The rule order position of this subpartition.</td>
</tr>
<tr>
<td>partitionlistvalues</td>
<td>text</td>
<td></td>
<td>For list partitions, the list value(s) associated with this subpartition.</td>
</tr>
<tr>
<td>partitionrangestart</td>
<td>text</td>
<td></td>
<td>For range partitions, the start value of this subpartition.</td>
</tr>
<tr>
<td>partitionstartinclusive</td>
<td>boolean</td>
<td></td>
<td>T if the start value is included in this subpartition. F if it is excluded.</td>
</tr>
<tr>
<td>partitionrangeend</td>
<td>text</td>
<td></td>
<td>For range partitions, the end value of this subpartition.</td>
</tr>
<tr>
<td>partitionendinclusive</td>
<td>boolean</td>
<td></td>
<td>T if the end value is included in this subpartition. F if it is excluded.</td>
</tr>
<tr>
<td>partitioneveryclause</td>
<td>text</td>
<td></td>
<td>The EVERY clause (interval) of this subpartition.</td>
</tr>
<tr>
<td>partitionisdefault</td>
<td>boolean</td>
<td></td>
<td>T if this is a default subpartition, otherwise F.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>partitionboundary</td>
<td>text</td>
<td></td>
<td>The entire partition specification for this subpartition.</td>
</tr>
</tbody>
</table>

**pg_partitions**

The `pg_partitions` system view is used to show the structure of a partitioned table.

**Table 166: `pg_catalog.pg_partitions`**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>schemaname</td>
<td>name</td>
<td></td>
<td>The name of the schema the partitioned table is in.</td>
</tr>
<tr>
<td>tablename</td>
<td>name</td>
<td></td>
<td>The name of the top-level parent table.</td>
</tr>
<tr>
<td>partitiontablename</td>
<td>name</td>
<td></td>
<td>The relation name of the partitioned table (this is the table name to use if accessing the partition directly).</td>
</tr>
<tr>
<td>partitionname</td>
<td>name</td>
<td></td>
<td>The name of the partition (this is the name to use if referring to the partition in an <code>ALTER TABLE</code> command). <code>NULL</code> if the partition was not given a name at create time or generated by an <code>EVERY</code> clause.</td>
</tr>
<tr>
<td>parentpartitiontablename</td>
<td>name</td>
<td></td>
<td>The relation name of the parent table one level up from this partition.</td>
</tr>
<tr>
<td>parentpartitionname</td>
<td>name</td>
<td></td>
<td>The given name of the parent table one level up from this partition.</td>
</tr>
<tr>
<td>partitiontype</td>
<td>text</td>
<td></td>
<td>The type of partition (range or list).</td>
</tr>
<tr>
<td>partitionlevel</td>
<td>smallint</td>
<td></td>
<td>The level of this partition in the hierarchy.</td>
</tr>
<tr>
<td>partitionrank</td>
<td>bigint</td>
<td></td>
<td>For range partitions, the rank of the partition compared to other partitions of the same level.</td>
</tr>
<tr>
<td>partitionposition</td>
<td>smallint</td>
<td></td>
<td>The rule order position of this partition.</td>
</tr>
</tbody>
</table>
### Table 167: pg_catalog.pg_pltemplate

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tmplname</td>
<td>name</td>
<td></td>
<td>Name of the language this template is for</td>
</tr>
<tr>
<td>tmpltrusted</td>
<td>boolean</td>
<td></td>
<td>True if language is considered trusted</td>
</tr>
<tr>
<td>tmplhandler</td>
<td>text</td>
<td></td>
<td>Name of call handler function</td>
</tr>
<tr>
<td>tmplvalidator</td>
<td>text</td>
<td></td>
<td>Name of validator function, or NULL if none</td>
</tr>
</tbody>
</table>

**pg_pltemplate**

The **pg_pltemplate** system catalog table stores template information for procedural languages. A template for a language allows the language to be created in a particular database by a simple `CREATE LANGUAGE` command, with no need to specify implementation details. Unlike most system catalogs, **pg_pltemplate** is shared across all databases of Greenplum system: there is only one copy of **pg_pltemplate** per system, not one per database. This allows the information to be accessible in each database as it is needed.

There are not currently any commands that manipulate procedural language templates; to change the built-in information, a superuser must modify the table using ordinary `INSERT`, `DELETE`, or `UPDATE` commands.
**tmpllibrary** | **text** | **description** | Path of shared library that implements language

**tmplacl** | **aclitem[]** | **description** | Access privileges for template (not yet implemented).

---

**pg_proc**

The `pg_proc` system catalog table stores information about functions (or procedures), both built-in functions and those defined by `CREATE FUNCTION`. The table contains data for aggregate and window functions as well as plain functions. If `proisagg` is true, there should be a matching row in `pg_aggregate`. If `proiswin` is true, there should be a matching row in `pg_window`.

For compiled functions, both built-in and dynamically loaded, `prosrc` contains the function's C-language name (link symbol). For all other currently-known language types, `prosrc` contains the function's source text. `probin` is unused except for dynamically-loaded C functions, for which it gives the name of the shared library file containing the function.

### Table 168: pg_catalog.pg_proc

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>proname</strong></td>
<td>name</td>
<td></td>
<td>Name of the function.</td>
</tr>
<tr>
<td><strong>pronamespace</strong></td>
<td>oid</td>
<td><code>pg_namespace.oid</code></td>
<td>The OID of the namespace that contains this function.</td>
</tr>
<tr>
<td><strong>proowner</strong></td>
<td>oid</td>
<td><code>pg_authid.oid</code></td>
<td>Owner of the function.</td>
</tr>
<tr>
<td><strong>prolang</strong></td>
<td>oid</td>
<td><code>pg_language.oid</code></td>
<td>Implementation language or call interface of this function.</td>
</tr>
<tr>
<td><strong>procost</strong></td>
<td>float4</td>
<td></td>
<td>Estimated execution cost (in <code>cpu_operator_cost</code> units); if <code>proretset</code> is true, identifies the cost per row returned.</td>
</tr>
<tr>
<td><strong>prorows</strong></td>
<td>float4</td>
<td></td>
<td>Estimated number of result rows (zero if not proretset)</td>
</tr>
<tr>
<td><strong>provariadic</strong></td>
<td>oid</td>
<td><code>pg_type.oid</code></td>
<td>Data type of the variadic array parameter's elements, or zero if the function does not have a variadic parameter.</td>
</tr>
<tr>
<td><strong>proisagg</strong></td>
<td>boolean</td>
<td></td>
<td>Function is an aggregate function.</td>
</tr>
<tr>
<td><strong>prosecdef</strong></td>
<td>boolean</td>
<td></td>
<td>Function is a security definer (for example, a 'setuid' function).</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>-------------</td>
<td>----------</td>
<td>---------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>proisstrict</td>
<td>boolean</td>
<td></td>
<td>Function returns NULL if any call argument is NULL. In that case the function will not actually be called at all. Functions that are not strict must be prepared to handle NULL inputs.</td>
</tr>
<tr>
<td>proretset</td>
<td>boolean</td>
<td></td>
<td>Function returns a set (multiple values of the specified data type).</td>
</tr>
<tr>
<td>provolatile</td>
<td>char</td>
<td></td>
<td>Tells whether the function's result depends only on its input arguments, or is affected by outside factors. i = immutable (always delivers the same result for the same inputs), s = stable (results for fixed inputs do not change within a scan), or v = volatile (results may change at any time or functions with side-effects).</td>
</tr>
<tr>
<td>pronargs</td>
<td>int2</td>
<td></td>
<td>Number of arguments.</td>
</tr>
<tr>
<td>pronargdefaults</td>
<td>int2</td>
<td></td>
<td>Number of arguments that have default values.</td>
</tr>
<tr>
<td>prorettype</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>Data type of the return value.</td>
</tr>
<tr>
<td>proiswin</td>
<td>boolean</td>
<td></td>
<td>Function is neither an aggregate nor a scalar function, but a pure window function.</td>
</tr>
<tr>
<td>proargtypes</td>
<td>oidvector</td>
<td>pg_type.oid</td>
<td>An array with the data types of the function arguments. This includes only input arguments (including INOUT and VARIADIC arguments), and thus represents the call signature of the function.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>proallargtypes</td>
<td>oid[]</td>
<td>pg_type.oid</td>
<td>An array with the data types of the function arguments. This includes all arguments (including OUT and INOUT arguments); however, if all the arguments are IN arguments, this field will be null. Note that subscripting is 1-based, whereas for historical reasons proargtypes is subscripted from 0.</td>
</tr>
<tr>
<td>proargmodes</td>
<td>char[]</td>
<td></td>
<td>An array with the modes of the function arguments: i = IN, o = OUT, b = INOUT, v = VARIADIC. If all the arguments are IN arguments, this field will be null. Note that subscripts correspond to positions of proallargtypes not proargtypes.</td>
</tr>
<tr>
<td>proargnames</td>
<td>text[]</td>
<td></td>
<td>An array with the names of the function arguments. Arguments without a name are set to empty strings in the array. If none of the arguments have a name, this field will be null. Note that subscripts correspond to positions of proallargtypes not proargtypes.</td>
</tr>
<tr>
<td>proargdefaults</td>
<td>text</td>
<td></td>
<td>Expression trees for default argument values. This is a list with proargdefaults elements, corresponding to the last $N$ input arguments (i.e., the last $N$ proargtypes positions). If none of the arguments have defaults, this field is empty.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>prosrc</td>
<td>text</td>
<td></td>
<td>This tells the function handler how to invoke the function. It might be the actual source code of the function for interpreted languages, a link symbol, a file name, or just about anything else, depending on the implementation language/call convention.</td>
</tr>
<tr>
<td>probin</td>
<td>bytea</td>
<td></td>
<td>Additional information about how to invoke the function. Again, the interpretation is language-specific.</td>
</tr>
<tr>
<td>proacl</td>
<td>aclitem[]</td>
<td></td>
<td>Access privileges for the function as given by GRANT/REVOKE.</td>
</tr>
</tbody>
</table>

**pg_resgroup**

Note: The `pg_resgroup` system catalog table is valid only when resource group-based resource management is active.

The `pg_resgroup` system catalog table contains information about Greenplum Database resource groups, which are used for managing concurrent statements, CPU, and memory resources. This table, defined in the `pg_global` tablespace, is globally shared across all databases in the system.

**Table 169: pg_catalog.pg_resgroup**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rsgname</td>
<td>name</td>
<td></td>
<td>The name of the resource group.</td>
</tr>
<tr>
<td>parent</td>
<td>oid</td>
<td></td>
<td>Unused; reserved for future use.</td>
</tr>
</tbody>
</table>

**pg_resgroupcapability**

Note: The `pg_resgroupcapability` system catalog table is valid only when resource group-based resource management is active.

The `pg_resgroupcapability` system catalog table contains information about the capabilities and limits of defined Greenplum Database resource groups. You can join this table to the `pg_resgroup` table by resource group object ID.

The `pg_resgroupcapability` table, defined in the `pg_global` tablespace, is globally shared across all databases in the system.
Table 170: pg_catalog.pg_resgroupcapability

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>resgroupid</td>
<td>oid</td>
<td>pg_resgroup.oid</td>
<td>The object ID of the associated resource group.</td>
</tr>
<tr>
<td>reslimittype</td>
<td>smallint</td>
<td></td>
<td>The resource group limit type:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 - Unknown</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 - Concurrency</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 - CPU</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 - Memory</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4 - Memory shared quota</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 - Memory spill ratio</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6 - Memory auditor</td>
</tr>
<tr>
<td>value</td>
<td>opaque type</td>
<td></td>
<td>The specific value set for the resource limit referenced in this record.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>This value has the fixed type text, and will be converted to a different</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>data type depending upon the limit referenced.</td>
</tr>
<tr>
<td>proposed</td>
<td>opaque type</td>
<td></td>
<td>If you altered a resource limit and the limit cannot be updated immediately,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>the proposed value for the limit referenced in this record. Otherwise, the</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>currently set value.</td>
</tr>
</tbody>
</table>

pg_resourcetype

The pg_resourcetype system catalog table contains information about the extended attributes that can be assigned to Greenplum Database resource queues. Each row details an attribute and inherent qualities such as its default setting, whether it is required, and the value to disable it (when allowed).

This table is populated only on the master. This table is defined in the pg_global tablespace, meaning it is globally shared across all databases in the system.

Table 171: pg_catalog.pg_resourcetype

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>restypid</td>
<td>smallint</td>
<td></td>
<td>The resource type ID.</td>
</tr>
<tr>
<td>resname</td>
<td>name</td>
<td></td>
<td>The name of the resource type.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>resrequired</td>
<td>boolean</td>
<td></td>
<td>Whether the resource type is required for a valid resource queue.</td>
</tr>
<tr>
<td>reshasdefault</td>
<td>boolean</td>
<td></td>
<td>Whether the resource type has a default value. When true, the default value is specified in reshasdefaultsetting.</td>
</tr>
<tr>
<td>rescandisable</td>
<td>boolean</td>
<td></td>
<td>Whether the type can be removed or disabled. When true, the default value is specified in rescandisablesetting.</td>
</tr>
<tr>
<td>resdefaultsetting</td>
<td>text</td>
<td></td>
<td>Default setting for the resource type, when applicable.</td>
</tr>
<tr>
<td>resdisabledsetting</td>
<td>text</td>
<td></td>
<td>The value that disables this resource type (when allowed).</td>
</tr>
</tbody>
</table>

**pg_resqueue**

*Note:* The `pg_resqueue` system catalog table is valid only when resource queue-based resource management is active.

The `pg_resqueue` system catalog table contains information about Greenplum Database resource queues, which are used for the resource management feature. This table is populated only on the master. This table is defined in the `pg_global` tablespace, meaning it is globally shared across all databases in the system.

**Table 172: pg_catalog.pg_resqueue**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rsqname</td>
<td>name</td>
<td></td>
<td>The name of the resource queue.</td>
</tr>
<tr>
<td>rsqcountlimit</td>
<td>real</td>
<td></td>
<td>The active query threshold of the resource queue.</td>
</tr>
<tr>
<td>rsqcostlimit</td>
<td>real</td>
<td></td>
<td>The query cost threshold of the resource queue.</td>
</tr>
<tr>
<td>rsqovercommit</td>
<td>boolean</td>
<td></td>
<td>Allows queries that exceed the cost threshold to run when the system is idle.</td>
</tr>
</tbody>
</table>
### rsqignorecostlimit

- **Type**: real
- **Description**: The query cost limit of what is considered a 'small query'. Queries with a cost under this limit will not be queued and run immediately.

### pg_resqueue_attributes

**Note**: The `pg_resqueue_attributes` view is valid only when resource queue-based resource management is active.

The `pg_resqueue_attributes` view allows administrators to see the attributes set for a resource queue, such as its active statement limit, query cost limits, and priority.

**Table 173: pg_catalog.pg_resqueue_attributes**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rsqname</td>
<td>name</td>
<td>pg_resqueue.rsqname</td>
<td>The name of the resource queue.</td>
</tr>
<tr>
<td>resname</td>
<td>text</td>
<td></td>
<td>The name of the resource queue attribute.</td>
</tr>
<tr>
<td>ressetting</td>
<td>text</td>
<td></td>
<td>The current value of a resource queue attribute.</td>
</tr>
<tr>
<td>restypid</td>
<td>integer</td>
<td></td>
<td>System assigned resource type id.</td>
</tr>
</tbody>
</table>

### pg_resqueuecapability

**Note**: The `pg_resqueuecapability` system catalog table is valid only when resource queue-based resource management is active.

The `pg_resqueuecapability` system catalog table contains information about the extended attributes, or capabilities, of existing Greenplum Database resource queues. Only resource queues that have been assigned an extended capability, such as a priority setting, are recorded in this table. This table is joined to the `pg_resqueue` table by resource queue object ID, and to the `pg_resourcetype` table by resource type ID (restypid).

This table is populated only on the master. This table is defined in the `pg_global` tablespace, meaning it is globally shared across all databases in the system.

**Table 174: pg_catalog.pg_resqueuecapability**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rsqueueid</td>
<td>oid</td>
<td>pg_resqueue.oid</td>
<td>The object ID of the associated resource queue.</td>
</tr>
<tr>
<td>restypid</td>
<td>smallint</td>
<td>pg_resourcetype. restypid</td>
<td>The resource type, derived from the <code>pg_resqueuecapability</code> system table.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------</td>
<td>------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ressetting</td>
<td>opaque type</td>
<td></td>
<td>The specific value set for the capability referenced in this record. Depending on the actual resource type, this value may have different data types.</td>
</tr>
</tbody>
</table>

**pg_rewrite**

The `pg_rewrite` system catalog table stores rewrite rules for tables and views. `pg_class.relhasrules` must be true if a table has any rules in this catalog.

**Table 175: pg_catalog.pg_rewrite**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rulename</td>
<td>name</td>
<td></td>
<td>Rule name.</td>
</tr>
<tr>
<td>ev_class</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The table this rule is for.</td>
</tr>
<tr>
<td>ev_attr</td>
<td>int2</td>
<td></td>
<td>The column this rule is for (currently, always zero to indicate the whole table).</td>
</tr>
<tr>
<td>ev_type</td>
<td>char</td>
<td></td>
<td>Event type that the rule is for: 1 = SELECT, 2 = UPDATE, 3 = INSERT, 4 = DELETE.</td>
</tr>
<tr>
<td>is_instead</td>
<td>boolean</td>
<td></td>
<td>True if the rule is an INSTEAD rule.</td>
</tr>
<tr>
<td>ev_qual</td>
<td>text</td>
<td></td>
<td>Expression tree (in the form of a <code>nodeToString()</code> representation) for the rule's qualifying condition.</td>
</tr>
<tr>
<td>ev_action</td>
<td>text</td>
<td></td>
<td>Query tree (in the form of a <code>nodeToString()</code> representation) for the rule's action.</td>
</tr>
</tbody>
</table>

**pg_roles**

The view `pg_roles` provides access to information about database roles. This is simply a publicly readable view of `pg_authid` that blanks out the password field. This view explicitly exposes the OID column of the underlying table, since that is needed to do joins to other catalogs.

**Table 176: pg_catalog.pg_roles**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rolname</td>
<td>name</td>
<td></td>
<td>Role name</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>rolsuper</td>
<td>bool</td>
<td></td>
<td>Role has superuser privileges</td>
</tr>
<tr>
<td>rolinherit</td>
<td>bool</td>
<td></td>
<td>Role automatically inherits privileges of roles it is a member of</td>
</tr>
<tr>
<td>rolcreaterole</td>
<td>bool</td>
<td></td>
<td>Role may create more roles</td>
</tr>
<tr>
<td>rolcreatedb</td>
<td>bool</td>
<td></td>
<td>Role may create databases</td>
</tr>
<tr>
<td>rolcatupdate</td>
<td>bool</td>
<td></td>
<td>Role may update system catalogs directly. (Even a superuser may not do this unless this column is true.)</td>
</tr>
<tr>
<td>rolcanlogin</td>
<td>bool</td>
<td></td>
<td>Role may log in. That is, this role can be given as the initial session authorization identifier</td>
</tr>
<tr>
<td>rolconnlimit</td>
<td>int4</td>
<td></td>
<td>For roles that can log in, this sets maximum number of concurrent connections this role can make. -1 means no limit</td>
</tr>
<tr>
<td>rolpassword</td>
<td>text</td>
<td></td>
<td>Not the password (always reads as ********)</td>
</tr>
<tr>
<td>rolvaliduntil</td>
<td>timestamp</td>
<td></td>
<td>Password expiry time (only used for password authentication); NULL if no expiration</td>
</tr>
<tr>
<td>rolconfig</td>
<td>text[]</td>
<td></td>
<td>Session defaults for run-time configuration variables</td>
</tr>
<tr>
<td>rolresqueue</td>
<td>oid</td>
<td>pg_resqueue.oid</td>
<td>Object ID of the resource queue this role is assigned to.</td>
</tr>
<tr>
<td>oid</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>Object ID of role</td>
</tr>
<tr>
<td>rolcreaterextgpfd</td>
<td>bool</td>
<td></td>
<td>Role may create readable external tables that use the gpfdist protocol.</td>
</tr>
<tr>
<td>rolcreaterexhttp</td>
<td>bool</td>
<td></td>
<td>Role may create readable external tables that use the http protocol.</td>
</tr>
</tbody>
</table>
### Greenplum Database Reference Guide

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rolcreatelgtgpfd</td>
<td>bool</td>
<td></td>
<td>Role may create writable external tables that use the gpfdist protocol.</td>
</tr>
<tr>
<td>rolcreaterexthdfs</td>
<td>bool</td>
<td></td>
<td>Role may create readable external tables that use the gphdfs protocol.</td>
</tr>
<tr>
<td>rolcreatelgtghdfs</td>
<td>bool</td>
<td></td>
<td>Role may create writable external tables that use the gphdfs protocol.</td>
</tr>
<tr>
<td>rolresgroup</td>
<td>oid</td>
<td>pg_resgroup.oid</td>
<td>Object ID of the resource group to which this role is assigned.</td>
</tr>
</tbody>
</table>

#### pg_shdepend

The **pg_shdepend** system catalog table records the dependency relationships between database objects and shared objects, such as roles. This information allows Greenplum Database to ensure that those objects are unreferenced before attempting to delete them. See also **pg.depend**, which performs a similar function for dependencies involving objects within a single database. Unlike most system catalogs, **pg_shdepend** is shared across all databases of Greenplum system: there is only one copy of **pg_shdepend** per system, not one per database.

In all cases, a **pg_shdepend** entry indicates that the referenced object may not be dropped without also dropping the dependent object. However, there are several subflavors identified by **deptype**:

- **SHARED_DEPENDENCY_OWNER (o)** — The referenced object (which must be a role) is the owner of the dependent object.
- **SHARED_DEPENDENCY_ACL (a)** — The referenced object (which must be a role) is mentioned in the ACL (access control list) of the dependent object.
- **SHARED_DEPENDENCY_PIN (p)** — There is no dependent object; this type of entry is a signal that the system itself depends on the referenced object, and so that object must never be deleted. Entries of this type are created only by system initialization. The columns for the dependent object contain zeroes.

#### Table 177: pg_catalog.pg_shdepend

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>dbid</td>
<td>oid</td>
<td>pg_database.oid</td>
<td>The OID of the database the dependent object is in, or zero for a shared object.</td>
</tr>
<tr>
<td>classid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The OID of the system catalog the dependent object is in.</td>
</tr>
<tr>
<td>objid</td>
<td>oid</td>
<td>any OID column</td>
<td>The OID of the specific dependent object.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
<td>---------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>objsubid</td>
<td>int4</td>
<td></td>
<td>For a table column, this is the column number. For all other object types, this column is zero.</td>
</tr>
<tr>
<td>reftclassid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The OID of the system catalog the referenced object is in (must be a shared catalog).</td>
</tr>
<tr>
<td>refobjid</td>
<td>oid</td>
<td>any OID column</td>
<td>The OID of the specific referenced object.</td>
</tr>
<tr>
<td>refobjsubid</td>
<td>int4</td>
<td></td>
<td>For a table column, this is the referenced column number. For all other object types, this column is zero.</td>
</tr>
<tr>
<td>deptype</td>
<td>char</td>
<td></td>
<td>A code defining the specific semantics of this dependency relationship.</td>
</tr>
</tbody>
</table>

**pg_shdescription**

The `pg_shdescription` system catalog table stores optional descriptions (comments) for shared database objects. Descriptions can be manipulated with the `COMMENT` command and viewed with `psql`'s `\d` meta-commands. See also `pg_description`, which performs a similar function for descriptions involving objects within a single database. Unlike most system catalogs, `pg_shdescription` is shared across all databases of a Greenplum system: there is only one copy of `pg_shdescription` per system, not one per database.

Table 178: pg_catalog.pg_shdescription

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>objoid</td>
<td>oid</td>
<td>any OID column</td>
<td>The OID of the object this description pertains to.</td>
</tr>
<tr>
<td>classoid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The OID of the system catalog this object appears in</td>
</tr>
<tr>
<td>description</td>
<td>text</td>
<td></td>
<td>Arbitrary text that serves as the description of this object.</td>
</tr>
</tbody>
</table>

**pg_stat_activity**

The view `pg_stat_activity` shows one row per server process and details about it associated user session and query. The columns that report data on the current query are available unless the parameter `stats_command_string` has been turned off. Furthermore, these columns are only visible if the user examining the view is a superuser or the same as the user owning the process being reported on.
The maximum length of the query text string stored in the column `current_query` can be controlled with the server configuration parameter `pgstat_track_activity_query_size`.

Table 179: `pg_catalog.pg_stat_activity`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>datid</td>
<td>oid</td>
<td><code>pg_database.oid</code></td>
<td>Database OID</td>
</tr>
<tr>
<td>datname</td>
<td>name</td>
<td></td>
<td>Database name</td>
</tr>
<tr>
<td>procpid</td>
<td>integer</td>
<td></td>
<td>Process ID of the server process</td>
</tr>
<tr>
<td>sess_id</td>
<td>integer</td>
<td></td>
<td>Session ID</td>
</tr>
<tr>
<td>usesysid</td>
<td>oid</td>
<td><code>pg_authid.oid</code></td>
<td>Role OID</td>
</tr>
<tr>
<td>usename</td>
<td>name</td>
<td></td>
<td>Role name</td>
</tr>
<tr>
<td>current_query</td>
<td>text</td>
<td></td>
<td>Current query that process is running</td>
</tr>
<tr>
<td>waiting</td>
<td>boolean</td>
<td></td>
<td>True if waiting on a lock, false if not waiting</td>
</tr>
<tr>
<td>query_start</td>
<td><code>timestamptz</code></td>
<td></td>
<td>Time query began execution</td>
</tr>
<tr>
<td>backend_start</td>
<td><code>timestamptz</code></td>
<td></td>
<td>Time backend process was started</td>
</tr>
<tr>
<td>client_addr</td>
<td><code>inet</code></td>
<td></td>
<td>Client address</td>
</tr>
<tr>
<td>client_port</td>
<td>integer</td>
<td></td>
<td>Client port</td>
</tr>
<tr>
<td>application_name</td>
<td>text</td>
<td></td>
<td>Client application name</td>
</tr>
<tr>
<td>xact_start</td>
<td><code>timestamptz</code></td>
<td></td>
<td>Transaction start time</td>
</tr>
<tr>
<td>waiting_reason</td>
<td>text</td>
<td></td>
<td>Reason the server process is waiting. The value can be: lock, replication, or resgroup</td>
</tr>
<tr>
<td>rsgid</td>
<td>oid</td>
<td><code>pg_resgroup.oid</code></td>
<td>Resource group OID</td>
</tr>
<tr>
<td>rsurname</td>
<td>text</td>
<td><code>pg_resgroup.rsgname</code></td>
<td>Resource group name</td>
</tr>
<tr>
<td>rsgqueueduration</td>
<td><code>interval</code></td>
<td></td>
<td>For a queued query, the total time the query has been queued.</td>
</tr>
</tbody>
</table>

**pg_stat_last_operation**

The `pg_stat_last_operation` table contains metadata tracking information about database objects (tables, views, etc.).
### Table 180: pg_catalog.pg_stat_last_operation

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>classid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>OID of the system catalog containing the object.</td>
</tr>
<tr>
<td>objid</td>
<td>oid</td>
<td>any OID column</td>
<td>OID of the object within its system catalog.</td>
</tr>
<tr>
<td>staactionname</td>
<td>name</td>
<td></td>
<td>The action that was taken on the object.</td>
</tr>
<tr>
<td>stasysid</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>A foreign key to pg_authid.oid.</td>
</tr>
<tr>
<td>stausename</td>
<td>name</td>
<td></td>
<td>The name of the role that performed the operation on this object.</td>
</tr>
<tr>
<td>stasubtype</td>
<td>text</td>
<td></td>
<td>The type of object operated on or the subclass of operation performed.</td>
</tr>
<tr>
<td>statime</td>
<td>timestamp with timezone</td>
<td></td>
<td>The timestamp of the operation. This is the same timestamp that is written to the Greenplum Database server log files in case you need to look up more detailed information about the operation in the logs.</td>
</tr>
</tbody>
</table>

### pg_stat_last_shoperation

The `pg_stat_last_shoperation` table contains metadata tracking information about global objects (roles, tablespaces, etc.).

### Table 181: pg_catalog.pg_stat_last_shoperation

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>classid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>OID of the system catalog containing the object.</td>
</tr>
<tr>
<td>objid</td>
<td>oid</td>
<td>any OID column</td>
<td>OID of the object within its system catalog.</td>
</tr>
<tr>
<td>staactionname</td>
<td>name</td>
<td></td>
<td>The action that was taken on the object.</td>
</tr>
<tr>
<td>stasysid</td>
<td>oid</td>
<td></td>
<td>The name of the role that performed the operation on this object.</td>
</tr>
<tr>
<td>stausename</td>
<td>name</td>
<td></td>
<td>The name of the role that performed the operation on this object.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>stasubtype</td>
<td>text</td>
<td></td>
<td>The type of object operated on or the subclass of operation performed.</td>
</tr>
<tr>
<td>statime</td>
<td>timestamp with timezone</td>
<td></td>
<td>The timestamp of the operation. This is the same timestamp that is written to the Greenplum Database server log files in case you need to look up more detailed information about the operation in the logs.</td>
</tr>
</tbody>
</table>

**pg_stat_operations**

The view **pg_stat_operations** shows details about the last operation performed on a database object (such as a table, index, view or database) or a global object (such as a role).

Table 182: pg_catalog.pg_stat_operations

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>classname</td>
<td>text</td>
<td></td>
<td>The name of the system table in the pg_catalog schema where the record about this object is stored (pg_class=relations, pg_class=databases, pg_namespace=schemas, pg_authid=roles)</td>
</tr>
<tr>
<td>objname</td>
<td>name</td>
<td></td>
<td>The name of the object.</td>
</tr>
<tr>
<td>objid</td>
<td>oid</td>
<td></td>
<td>The OID of the object.</td>
</tr>
<tr>
<td>schemaname</td>
<td>name</td>
<td></td>
<td>The name of the schema where the object resides.</td>
</tr>
<tr>
<td>usestatus</td>
<td>text</td>
<td></td>
<td>The status of the role who performed the last operation on the object (CURRENT=a currently active role in the system, DROPPED=a role that no longer exists in the system, CHANGED=a role name that exists in the system, but has changed since the last operation was performed).</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>----------------</td>
<td>--------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>usename</td>
<td>name</td>
<td></td>
<td>The name of the role that performed the operation on this object.</td>
</tr>
<tr>
<td>actionname</td>
<td>name</td>
<td></td>
<td>The action that was taken on the object.</td>
</tr>
<tr>
<td>subtype</td>
<td>text</td>
<td></td>
<td>The type of object operated on or the subclass of operation performed.</td>
</tr>
<tr>
<td>statime</td>
<td>timestamp</td>
<td></td>
<td>The timestamp of the operation. This is the same timestamp that is written to the Greenplum Database server log files in case you need to look up more detailed information about the operation in the logs.</td>
</tr>
</tbody>
</table>

**pg_stat_partition_operations**

The **pg_stat_partition_operations** view shows details about the last operation performed on a partitioned table.

**Table 183: pg_catalog.pg_stat_partition_operations**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>classname</td>
<td>text</td>
<td></td>
<td>The name of the system table in the pg_catalog schema where the record about this object is stored (always pg_class for tables and partitions).</td>
</tr>
<tr>
<td>objname</td>
<td>name</td>
<td></td>
<td>The name of the object.</td>
</tr>
<tr>
<td>objid</td>
<td>oid</td>
<td></td>
<td>The OID of the object.</td>
</tr>
<tr>
<td>schemaname</td>
<td>name</td>
<td></td>
<td>The name of the schema where the object resides.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------</td>
<td>------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>usestatus</td>
<td>text</td>
<td></td>
<td>The status of the role who performed the last operation on the object (CURRENT=a currently active role in the system, DROPPED=a role that no longer exists in the system, CHANGED=a role name that exists in the system, but its definition has changed since the last operation was performed).</td>
</tr>
<tr>
<td>usename</td>
<td>name</td>
<td></td>
<td>The name of the role that performed the operation on this object.</td>
</tr>
<tr>
<td>actionname</td>
<td>name</td>
<td></td>
<td>The action that was taken on the object.</td>
</tr>
<tr>
<td>subtype</td>
<td>text</td>
<td></td>
<td>The type of object operated on or the subclass of operation performed.</td>
</tr>
<tr>
<td>statime</td>
<td>timestamptz</td>
<td></td>
<td>The timestamp of the operation. This is the same timestamp that is written to the Greenplum Database server log files in case you need to look up more detailed information about the operation in the logs.</td>
</tr>
<tr>
<td>partitionlevel</td>
<td>smallint</td>
<td></td>
<td>The level of this partition in the hierarchy.</td>
</tr>
<tr>
<td>parenttablename</td>
<td>name</td>
<td></td>
<td>The relation name of the parent table one level up from this partition.</td>
</tr>
<tr>
<td>parentschemaname</td>
<td>name</td>
<td></td>
<td>The name of the schema where the parent table resides.</td>
</tr>
<tr>
<td>parent_relid</td>
<td>oid</td>
<td></td>
<td>The OID of the parent table one level up from this partition.</td>
</tr>
</tbody>
</table>

**pg_stat_replication**

The `pg_stat_replication` view contains metadata of the `walsender` process that is used for Greenplum Database master mirroring.
Table 184: `pg_catalog.pg_stat_replication`

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>procpid</code></td>
<td>integer</td>
<td></td>
<td>Process ID of WAL sender backend process.</td>
</tr>
<tr>
<td><code>usesysid</code></td>
<td>integer</td>
<td></td>
<td>User system ID that runs the WAL sender backend process.</td>
</tr>
<tr>
<td><code>username</code></td>
<td>name</td>
<td></td>
<td>User name that runs WAL sender backend process.</td>
</tr>
<tr>
<td><code>application_name</code></td>
<td>oid</td>
<td></td>
<td>Client application name.</td>
</tr>
<tr>
<td><code>client_addr</code></td>
<td>name</td>
<td></td>
<td>Client IP address.</td>
</tr>
<tr>
<td><code>client_port</code></td>
<td>integer</td>
<td></td>
<td>Client port number.</td>
</tr>
<tr>
<td><code>backend_start</code></td>
<td>timestamp</td>
<td></td>
<td>Operation start timestamp.</td>
</tr>
<tr>
<td><code>state</code></td>
<td>text</td>
<td></td>
<td>WAL sender state. The value can be: startup, backup, catchup, streaming</td>
</tr>
<tr>
<td><code>sent_location</code></td>
<td>text</td>
<td></td>
<td>WAL sender xlog record sent location.</td>
</tr>
<tr>
<td><code>write_location</code></td>
<td>text</td>
<td></td>
<td>WAL receiver xlog record write location.</td>
</tr>
<tr>
<td><code>flush_location</code></td>
<td>text</td>
<td></td>
<td>WAL receiver xlog record flush location.</td>
</tr>
<tr>
<td><code>replay_location</code></td>
<td>text</td>
<td></td>
<td>Standby xlog record replay location.</td>
</tr>
<tr>
<td><code>sync_priority</code></td>
<td>text</td>
<td></td>
<td>Priority. The value is 1.</td>
</tr>
<tr>
<td><code>sync_state</code></td>
<td>text</td>
<td></td>
<td>WAL sender synchronization state. The value is sync.</td>
</tr>
</tbody>
</table>

**pg_statistic**

The `pg_statistic` system catalog table stores statistical data about the contents of the database. Entries are created by `ANALYZE` and subsequently used by the query optimizer. There is one entry for each table column that has been analyzed. Note that all the statistical data is inherently approximate, even assuming that it is up-to-date.

`pg_statistic` also stores statistical data about the values of index expressions. These are described as if they were actual data columns; in particular, `starelid` references the index. No entry is made for
an ordinary non-expression index column, however, since it would be redundant with the entry for the underlying table column.

Since different kinds of statistics may be appropriate for different kinds of data, \texttt{pg\_statistic} is designed not to assume very much about what sort of statistics it stores. Only extremely general statistics (such as nullness) are given dedicated columns in \texttt{pg\_statistic}. Everything else is stored in slots, which are groups of associated columns whose content is identified by a code number in one of the slot's columns.

\texttt{pg\_statistic} should not be readable by the public, since even statistical information about a table's contents may be considered sensitive (for example: minimum and maximum values of a salary column). \texttt{pg\_stats} is a publicly readable view on \texttt{pg\_statistic} that only exposes information about those tables that are readable by the current user.

### Table 185: \texttt{pg\_catalog.pg\_statistic}

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>starelid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The table or index that the described column belongs to.</td>
</tr>
<tr>
<td>staattnum</td>
<td>int2</td>
<td>pg_attribute.attnum</td>
<td>The number of the described column.</td>
</tr>
<tr>
<td>stanullfrac</td>
<td>float4</td>
<td></td>
<td>The fraction of the column's entries that are null.</td>
</tr>
<tr>
<td>stawidth</td>
<td>int4</td>
<td></td>
<td>The average stored width, in bytes, of nonnull entries.</td>
</tr>
<tr>
<td>stadistinct</td>
<td>float4</td>
<td></td>
<td>The number of distinct nonnull data values in the column. A value greater than zero is the actual number of distinct values. A value less than zero is the negative of a fraction of the number of rows in the table (for example, a column in which values appear about twice on the average could be represented by stadistinct = -0.5). A zero value means the number of distinct values is unknown.</td>
</tr>
<tr>
<td>stakindN</td>
<td>int2</td>
<td></td>
<td>A code number indicating the kind of statistics stored in the Nth slot of the \texttt{pg_statistic} row.</td>
</tr>
</tbody>
</table>
### staop\(N\)
- **type**: oid
- **references**: pg_operator.oid
- **description**: An operator used to derive the statistics stored in the \(N\)th slot. For example, a histogram slot would show the \(<\) operator that defines the sort order of the data.

### stanumbers\(N\)
- **type**: float4[]
- **description**: Numerical statistics of the appropriate kind for the \(N\)th slot, or NULL if the slot kind does not involve numerical values.

### stavalues\(N\)
- **type**: anyarray
- **description**: Column data values of the appropriate kind for the \(N\)th slot, or NULL if the slot kind does not store any data values. Each array's element values are actually of the specific column's data type, so there is no way to define these columns' type more specifically than anyarray.

### pg_stat_resqueues

**Note:** The pg_stat_resqueues view is valid only when resource queue-based resource management is active.

The pg_stat_resqueues view allows administrators to view metrics about a resource queue's workload over time. To allow statistics to be collected for this view, you must enable the stats_queue_level server configuration parameter on the Greenplum Database master instance. Enabling the collection of these metrics does incur a small performance penalty, as each statement submitted through a resource queue must be logged in the system catalog tables.

**Table 186: pg_catalog.pg_stat_resqueues**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>queueoid</td>
<td>oid</td>
<td></td>
<td>The OID of the resource queue.</td>
</tr>
<tr>
<td>queuename</td>
<td>name</td>
<td></td>
<td>The name of the resource queue.</td>
</tr>
<tr>
<td>n_queries_exec</td>
<td>bigint</td>
<td></td>
<td>Number of queries submitted for execution from this resource queue.</td>
</tr>
</tbody>
</table>
### Table 187: pg_catalog.pg_tablespace

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>spcname</td>
<td>name</td>
<td></td>
<td>Tablespace name.</td>
</tr>
<tr>
<td>spcowner</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>Owner of the tablespace, usually the user who created it.</td>
</tr>
<tr>
<td>spclocation</td>
<td>text[]</td>
<td></td>
<td>Deprecated.</td>
</tr>
<tr>
<td>spcaccess</td>
<td>aclitem[]</td>
<td></td>
<td>Tablespace access privileges.</td>
</tr>
<tr>
<td>spcprivlocations</td>
<td>text[]</td>
<td></td>
<td>Deprecated.</td>
</tr>
<tr>
<td>spcmaxlocations</td>
<td>text[]</td>
<td></td>
<td>Deprecated.</td>
</tr>
<tr>
<td>spcfsoid</td>
<td>oid</td>
<td>pg_filesystem.oid</td>
<td>The object id of the filesystem used by this tablespace. A filesystem defines directory locations on the primary, mirror and master segments.</td>
</tr>
</tbody>
</table>

### pg_trigger

The `pg_trigger` system catalog table stores triggers on tables.

**Note:** Greenplum Database does not support triggers.
Table 188: pg_catalog.pg_trigger

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tgrelid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The table this trigger is on.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note that Greenplum Database does not enforce referential integrity.</td>
<td></td>
</tr>
<tr>
<td>tgname</td>
<td>name</td>
<td></td>
<td>Trigger name (must be unique among triggers of same table).</td>
</tr>
<tr>
<td>tgfoid</td>
<td>oid</td>
<td>pg_proc.oid</td>
<td>The function to be called.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note that Greenplum Database does not enforce referential integrity.</td>
<td></td>
</tr>
<tr>
<td>tctype</td>
<td>int2</td>
<td></td>
<td>Bit mask identifying trigger conditions.</td>
</tr>
<tr>
<td>tgenabled</td>
<td>boolean</td>
<td></td>
<td>True if trigger is enabled.</td>
</tr>
<tr>
<td>tgisconstraint</td>
<td>boolean</td>
<td></td>
<td>True if trigger implements a referential integrity constraint.</td>
</tr>
<tr>
<td>tgconstrname</td>
<td>name</td>
<td></td>
<td>Referential integrity constraint name.</td>
</tr>
<tr>
<td>tgconstrrelid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>The table referenced by an referential integrity constraint.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note that Greenplum Database does not enforce referential integrity.</td>
<td></td>
</tr>
<tr>
<td>tgdeferrable</td>
<td>boolean</td>
<td></td>
<td>True if deferrable.</td>
</tr>
<tr>
<td>tginitdeferred</td>
<td>boolean</td>
<td></td>
<td>True if initially deferred.</td>
</tr>
<tr>
<td>tgnargs</td>
<td>int2</td>
<td></td>
<td>Number of argument strings passed to trigger function.</td>
</tr>
<tr>
<td>tgattr</td>
<td>int2vector</td>
<td></td>
<td>Currently not used.</td>
</tr>
<tr>
<td>tgargs</td>
<td>bytea</td>
<td></td>
<td>Argument strings to pass to trigger, each NULL-terminated.</td>
</tr>
</tbody>
</table>

pg_type

The pg_type system catalog table stores information about data types. Base types (scalar types) are created with CREATE TYPE, and domains with CREATE DOMAIN. A composite type is automatically created for each table in the database, to represent the row structure of the table. It is also possible to create composite types with CREATE TYPE AS.
<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>typname</td>
<td>name</td>
<td></td>
<td>Data type name.</td>
</tr>
<tr>
<td>typnamespace</td>
<td>oid</td>
<td>pg_namespace.oid</td>
<td>The OID of the namespace that contains this type.</td>
</tr>
<tr>
<td>typowner</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>Owner of the type.</td>
</tr>
<tr>
<td>typlen</td>
<td>int2</td>
<td></td>
<td>For a fixed-size type, typlen is the number of bytes in the internal representation of the type. But for a variable-length type, typlen is negative. -1 indicates a ‘varlena’ type (one that has a length word), -2 indicates a null-terminated C string.</td>
</tr>
<tr>
<td>typbyval</td>
<td>boolean</td>
<td></td>
<td>Determines whether internal routines pass a value of this type by value or by reference. typbyval had better be false if typlen is not 1, 2, or 4 (or 8 on machines where Datum is 8 bytes). Variable-length types are always passed by reference. Note that typbyval can be false even if the length would allow pass-by-value; this is currently true for type float4, for example.</td>
</tr>
<tr>
<td>typtype</td>
<td>char</td>
<td></td>
<td>b for a base type, c for a composite type, d for a domain, e for an enum type, or p for a pseudo-type.</td>
</tr>
<tr>
<td>typisdefined</td>
<td>boolean</td>
<td></td>
<td>True if the type is defined, false if this is a placeholder entry for a not-yet-defined type. When false, nothing except the type name, namespace, and OID can be relied on.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------</td>
<td>--------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>typdelim</td>
<td>char</td>
<td></td>
<td>Character that separates two values of this type when parsing array input. Note that the delimiter is associated with the array element data type, not the array data type.</td>
</tr>
<tr>
<td>typrelid</td>
<td>oid</td>
<td>pg_class.oid</td>
<td>If this is a composite type, then this column points to the pg_class entry that defines the corresponding table. (For a free-standing composite type, the pg_class entry does not really represent a table, but it is needed anyway for the type's pg_attribute entries to link to.) Zero for non-composite types.</td>
</tr>
<tr>
<td>typelem</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>If not 0 then it identifies another row in pg_type. The current type can then be subscripted like an array yielding values of type typelem. A true array type is variable length (typlen = -1), but some fixed-length (tylpen &gt; 0) types also have nonzero typelem, for example name and point. If a fixed-length type has a typelem then its internal representation must be some number of values of the typelem data type with no other data. Variable-length array types have a header defined by the array subroutines.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>--------------</td>
<td>--------</td>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>typarray</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>If not 0, identifies another row in pg_type, which is the &quot;true&quot; array type having this type as its element. Use pg_type.typarray to locate the array type associated with a specific type.</td>
</tr>
<tr>
<td>typinput</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Input conversion function (text format).</td>
</tr>
<tr>
<td>typoutput</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Output conversion function (text format).</td>
</tr>
<tr>
<td>typreceive</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Input conversion function (binary format), or 0 if none.</td>
</tr>
<tr>
<td>typesend</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Output conversion function (binary format), or 0 if none.</td>
</tr>
<tr>
<td>typmodin</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Type modifier input function, or 0 if the type does not support modifiers.</td>
</tr>
<tr>
<td>typmodout</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Type modifier output function, or 0 to use the standard format.</td>
</tr>
<tr>
<td>typanalyze</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>Custom ANALYZE function, or 0 to use the standard function.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>--------</td>
<td>-------</td>
<td>------------</td>
<td>-------------</td>
</tr>
</tbody>
</table>
| typalign | char |            | The alignment required when storing a value of this type. It applies to storage on disk as well as most representations of the value inside Greenplum Database. When multiple values are stored consecutively, such as in the representation of a complete row on disk, padding is inserted before a datum of this type so that it begins on the specified boundary. The alignment reference is the beginning of the first datum in the sequence. Possible values are:  
  - c = char alignment (no alignment needed).  
  - s = short alignment (2 bytes on most machines).  
  - i = int alignment (4 bytes on most machines).  
  - d = double alignment (8 bytes on many machines, but not all). |
<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
</table>
| typstorage   | char  |            | For varlena types (those with `typlen = -1`) tells if the type is prepared for toasting and what the default strategy for attributes of this type should be. Possible values are:  
  p: Value must always be stored plain.  
  e: Value can be stored in a secondary relation (if relation has one, see `pg_class.reloastrelid`).  
  m: Value can be stored compressed inline.  
  x: Value can be stored compressed inline or stored in secondary storage.  
  Note that m columns can also be moved out to secondary storage, but only as a last resort (e and x columns are moved first). |
<p>| typnotnull   | boolean |            | Represents a not-null constraint on a type. Used for domains only.                                                                           |
| typbasetype  | oid   | <code>pg_type.oid</code> | Identifies the type that a domain is based on. Zero if this type is not a domain.                                                           |
| typtypmod    | int4  |            |Domains use typtypmod to record the typmod to be applied to their base type (-1 if base type does not use a typmod). -1 if this type is not a domain. |</p>
<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>typndims</td>
<td>int4</td>
<td></td>
<td>The number of array dimensions for a domain that is an array (if typbasetype is an array type; the domain's typelem will match the base type's typelem). Zero for types other than array domains.</td>
</tr>
<tr>
<td>typdefaultbin</td>
<td>text</td>
<td></td>
<td>If not null, it is the nodeToString() representation of a default expression for the type. This is only used for domains.</td>
</tr>
<tr>
<td>typdefault</td>
<td>text</td>
<td></td>
<td>Null if the type has no associated default value. If not null, typdefault must contain a human-readable version of the default expression represented by typdefaultbin. If typdefaultbin is null and typdefault is not, then typdefault is the external representation of the type's default value, which may be fed to the type's input converter to produce a constant.</td>
</tr>
</tbody>
</table>

### pg_type_encoding

The pg_type_encoding system catalog table contains the column storage type information.

**Table 190: pg_catalog.pg_type_encoding**

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>modifiers</th>
<th>storage</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>typeid</td>
<td>oid</td>
<td>not null</td>
<td>plain</td>
<td>Foreign key to pg_attribute</td>
</tr>
<tr>
<td>typoptions</td>
<td>text [ ]</td>
<td></td>
<td>extended</td>
<td>The actual options</td>
</tr>
</tbody>
</table>

### pg_user_mapping

The pg_user_mapping catalog table stores the mappings from local users to remote users. You must have administrator privileges to view this catalog.
Table 191: pg_catalog.pg_user_mapping

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>umuser</td>
<td>oid</td>
<td>pg_authid.oid</td>
<td>OID of the local role being mapped, 0 if the user mapping is public</td>
</tr>
<tr>
<td>umserver</td>
<td>oid</td>
<td>pg_foreign_server.oid</td>
<td>The OID of the foreign server that contains this mapping</td>
</tr>
<tr>
<td>umoptions</td>
<td>text [ ]</td>
<td></td>
<td>User mapping specific options, as “keyword=value” strings.</td>
</tr>
</tbody>
</table>

**pg_window**

The pg_window table stores information about window functions. Window functions are often used to compose complex OLAP (online analytical processing) queries. Window functions are applied to partitioned result sets within the scope of a single query expression. A window partition is a subset of rows returned by a query, as defined in a special OVER() clause. Typical window functions are rank, dense_rank, and row_number. Each entry in pg_window is an extension of an entry in pg_proc. The pg_proc entry carries the window function's name, input and output data types, and other information that is similar to ordinary functions.

Table 192: pg_catalog.pg_window

<table>
<thead>
<tr>
<th>column</th>
<th>type</th>
<th>references</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>winfnoid</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>The OID in pg_proc of the window function.</td>
</tr>
<tr>
<td>winrequireorder</td>
<td>boolean</td>
<td></td>
<td>The window function requires its window specification to have an ORDER BY clause.</td>
</tr>
<tr>
<td>winallowframe</td>
<td>boolean</td>
<td></td>
<td>The window function permits its window specification to have a ROWS or RANGE framing clause.</td>
</tr>
<tr>
<td>winpeercount</td>
<td>boolean</td>
<td></td>
<td>The peer group row count is required to compute this window function, so the Window node implementation must 'look ahead' as necessary to make this available in its internal state.</td>
</tr>
<tr>
<td>wincount</td>
<td>boolean</td>
<td></td>
<td>The partition row count is required to compute this window function.</td>
</tr>
<tr>
<td>column</td>
<td>type</td>
<td>references</td>
<td>description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------</td>
<td>------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>winfunc</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>The OID in <code>pg_proc</code> of a function to compute the value of an immediate-type window function.</td>
</tr>
<tr>
<td>winprefunc</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>The OID in <code>pg_proc</code> of a preliminary window function to compute the partial value of a deferred-type window function.</td>
</tr>
<tr>
<td>winpretype</td>
<td>oid</td>
<td>pg_type.oid</td>
<td>The OID in <code>pg_type</code> of the preliminary window function's result type.</td>
</tr>
<tr>
<td>winfinfunc</td>
<td>regproc</td>
<td>pg_proc.oid</td>
<td>The OID in <code>pg_proc</code> of a function to compute the final value of a deferred-type window function from the partition row count and the result of <code>winprefunc</code>.</td>
</tr>
<tr>
<td>winkind</td>
<td>char</td>
<td></td>
<td>A character indicating membership of the window function in a class of related functions:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>w - ordinary window functions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>n - NTILE functions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>f - FIRST_VALUE functions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>l - LAST_VALUE functions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>g - LAG functions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>d - LEAD functions</td>
</tr>
</tbody>
</table>
The gp_toolkit Administrative Schema

Greenplum Database provides an administrative schema called gp_toolkit that you can use to query the system catalogs, log files, and operating environment for system status information. The gp_toolkit schema contains a number of views that you can access using SQL commands. The gp_toolkit schema is accessible to all database users, although some objects may require superuser permissions. For convenience, you may want to add the gp_toolkit schema to your schema search path. For example:

```sql
=> ALTER ROLE myrole SET search_path TO myschema, gp_toolkit;
```

This documentation describes the most useful views in gp_toolkit. You may notice other objects (views, functions, and external tables) within the gp_toolkit schema that are not described in this documentation (these are supporting objects to the views described in this section).

**Warning:** Do not change database objects in the gp_toolkit schema. Do not create database objects in the schema. Changes to objects in the schema might affect the accuracy of administrative information returned by schema objects. Any changes made in the gp_toolkit schema are lost when the database is backed up and then restored with the gpcrondump and gpdbrestore utilities.

These are the categories for views in the gp_toolkit schema.

### Checking for Tables that Need Routine Maintenance

The following views can help identify tables that need routine table maintenance (VACUUM and/or ANALYZE).

- gp_bloat_diag
- gp_stats_missing

The VACUUM or VACUUM FULL command recclaims disk space occupied by deleted or obsolete rows. Because of the MVCC transaction concurrency model used in Greenplum Database, data rows that are deleted or updated still occupy physical space on disk even though they are not visible to any new transactions. Expired rows increase table size on disk and eventually slow down scans of the table.

The ANALYZE command collects column-level statistics needed by the query optimizer. Greenplum Database uses a cost-based query optimizer that relies on database statistics. Accurate statistics allow the query optimizer to better estimate selectivity and the number of rows retrieved by a query operation in order to choose the most efficient query plan.

### gp_bloat_diag

This view shows regular heap-storage tables that have bloat (the actual number of pages on disk exceeds the expected number of pages given the table statistics). Tables that are bloated require a VACUUM or a VACUUM FULL in order to reclaim disk space occupied by deleted or obsolete rows. This view is accessible to all users, however non-superusers will only be able to see the tables that they have permission to access.

**Note:** For diagnostic functions that return append-optimized table information, see Checking Append-Optimized Tables.

<table>
<thead>
<tr>
<th>Table 193: gp_bloat_diag view</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column</td>
</tr>
<tr>
<td>bdirelid</td>
</tr>
</tbody>
</table>
### Column Description

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bdinspname</td>
<td>Schema name.</td>
</tr>
<tr>
<td>bdirelname</td>
<td>Table name.</td>
</tr>
<tr>
<td>bdirelpages</td>
<td>Actual number of pages on disk.</td>
</tr>
<tr>
<td>bdiexppages</td>
<td>Expected number of pages given the table data.</td>
</tr>
<tr>
<td>bdidiag</td>
<td>Bloat diagnostic message.</td>
</tr>
</tbody>
</table>

### gp_stats_missing

This view shows tables that do not have statistics and therefore may require an **ANALYZE** be run on the table.

**Table 194: gp_stats_missing view**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>smischema</td>
<td>Schema name.</td>
</tr>
<tr>
<td>smitable</td>
<td>Table name.</td>
</tr>
<tr>
<td>smisize</td>
<td>Does this table have statistics? False if the table does not have row count and row sizing statistics recorded in the system catalog, which may indicate that the table needs to be analyzed. This will also be false if the table does not contain any rows. For example, the parent tables of partitioned tables are always empty and will always return a false result.</td>
</tr>
<tr>
<td>smicols</td>
<td>Number of columns in the table.</td>
</tr>
<tr>
<td>smirecs</td>
<td>Number of rows in the table.</td>
</tr>
</tbody>
</table>

### Checking for Locks

When a transaction accesses a relation (such as a table), it acquires a lock. Depending on the type of lock acquired, subsequent transactions may have to wait before they can access the same relation. For more information on the types of locks, see "Managing Data" in the *Greenplum Database Administrator Guide*. Greenplum Database resource queues (used for resource management) also use locks to control the admission of queries into the system.

The **gp_locks_** family of views can help diagnose queries and sessions that are waiting to access an object due to a lock.

- **gp_locks_on_relation**
- **gp_locks_on_resqueue**

### gp_locks_on_relation

This view shows any locks currently being held on a relation, and the associated session information about the query associated with the lock. For more information on the types of locks, see "Managing Data" in the *Greenplum Database Administrator Guide*. This view is accessible to all users, however non-superusers will only be able to see the locks for relations that they have permission to access.
Table 195: gp_locks_on_relation view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>lortype</td>
<td>Type of the lockable object: relation, extend, page, tuple, transactionid, object, userlock, resource queue, or advisory</td>
</tr>
<tr>
<td>lordatabase</td>
<td>Object ID of the database in which the object exists, zero if the object is a shared object.</td>
</tr>
<tr>
<td>lorrelname</td>
<td>The name of the relation.</td>
</tr>
<tr>
<td>lorrelation</td>
<td>The object ID of the relation.</td>
</tr>
<tr>
<td>lortransaction</td>
<td>The transaction ID that is affected by the lock.</td>
</tr>
<tr>
<td>lorpid</td>
<td>Process ID of the server process holding or awaiting this lock. NULL if the lock is held by a prepared transaction.</td>
</tr>
<tr>
<td>lormode</td>
<td>Name of the lock mode held or desired by this process.</td>
</tr>
<tr>
<td>lorgranted</td>
<td>Displays whether the lock is granted (true) or not granted (false).</td>
</tr>
<tr>
<td>lorcurrentquery</td>
<td>The current query in the session.</td>
</tr>
</tbody>
</table>

gp_locks_on_resqueue

Note: The gp_locks_on_resqueue view is valid only when resource queue-based resource management is active.

This view shows any locks currently being held on a resource queue, and the associated session information about the query associated with the lock. This view is accessible to all users, however non-superusers will only be able to see the locks associated with their own sessions.

Table 196: gp_locks_on_resqueue view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>lorusename</td>
<td>Name of the user executing the session.</td>
</tr>
<tr>
<td>lorrqname</td>
<td>The resource queue name.</td>
</tr>
<tr>
<td>lorlocktype</td>
<td>Type of the lockable object: resource queue</td>
</tr>
<tr>
<td>lorobjid</td>
<td>The ID of the locked transaction.</td>
</tr>
<tr>
<td>lortransaction</td>
<td>The ID of the transaction that is affected by the lock.</td>
</tr>
<tr>
<td>lorpid</td>
<td>The process ID of the transaction that is affected by the lock.</td>
</tr>
<tr>
<td>lormode</td>
<td>The name of the lock mode held or desired by this process.</td>
</tr>
<tr>
<td>lorgranted</td>
<td>Displays whether the lock is granted (true) or not granted (false).</td>
</tr>
<tr>
<td>lorwaiting</td>
<td>Displays whether or not the session is waiting.</td>
</tr>
</tbody>
</table>
Checking Append-Optimized Tables

The `gp_toolkit` schema includes a set of diagnostic functions you can use to investigate the state of append-optimized tables.

When an append-optimized table (or column-oriented append-optimized table) is created, another table is implicitly created, containing metadata about the current state of the table. The metadata includes information such as the number of records in each of the table’s segments.

Append-optimized tables may have non-visible rows—rows that have been updated or deleted, but remain in storage until the table is compacted using `VACUUM`. The hidden rows are tracked using an auxiliary visibility map table, or visimap.

The following functions let you access the metadata for append-optimized and column-oriented tables and view non-visible rows. Some of the functions have two versions: one that takes the `oid` of the table, and one that takes the name of the table. The latter version has "_name" appended to the function name.

`__gp_aovisimap_compaction_info(oid)`

This function displays compaction information for an append-optimized table. The information is for the on-disk data files on Greenplum Database segments that store the table data. You can use the information to determine the data files that will be compacted by a `VACUUM` operation on an append-optimized table.

**Note:** Until a `VACUUM` operation deletes the row from the data file, deleted or updated data rows occupy physical space on disk even though they are hidden to new transactions. The configuration parameter `gp_appendonly_compaction` controls the functionality of the `VACUUM` command.

This table describes the `__gp_aovisimap_compaction_info` function output table.

**Table 197: __gp_aovisimap_compaction_info output table**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>content</td>
<td>Greenplum Database segment ID.</td>
</tr>
<tr>
<td>datafile</td>
<td>ID of the data file on the segment.</td>
</tr>
<tr>
<td>compaction_possible</td>
<td>The value is either <code>t</code> or <code>f</code>. The value <code>t</code> indicates that the data in data file be compacted when a <code>VACUUM</code> operation is performed. The server configuration parameter <code>gp_appendonly_compaction_threshold</code> affects this value.</td>
</tr>
<tr>
<td>hidden_tupcount</td>
<td>In the data file, the number of hidden (deleted or updated) rows.</td>
</tr>
<tr>
<td>total_tupcount</td>
<td>In the data file, the total number of rows.</td>
</tr>
<tr>
<td>percent_hidden</td>
<td>In the data file, the ratio (as a percentage) of hidden (deleted or updated) rows to total rows.</td>
</tr>
</tbody>
</table>

`__gp_aoseg_name('table_name')`

This function returns metadata information contained in the append-optimized table’s on-disk segment file.
Table 198: __gp_aoseg_name output table

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>segno</td>
<td>The file segment number.</td>
</tr>
<tr>
<td>eof</td>
<td>The effective end of file for this file segment.</td>
</tr>
<tr>
<td>tupcount</td>
<td>The total number of tuples in the segment, including invisible tuples.</td>
</tr>
<tr>
<td>varblockcount</td>
<td>The total number of varblocks in the file segment.</td>
</tr>
<tr>
<td>eof_uncompressed</td>
<td>The end of file if the file segment were uncompressed.</td>
</tr>
<tr>
<td>modcount</td>
<td>The number of data modification operations.</td>
</tr>
<tr>
<td>state</td>
<td>The state of the file segment. Indicates if the segment is active or ready to be dropped after compaction.</td>
</tr>
</tbody>
</table>

__gp_aoseg_history(oid)

This function returns metadata information contained in the append-optimized table's on-disk segment file. It displays all different versions (heap tuples) of the aoseg meta information. The data is complex, but users with a deep understanding of the system may find it useful for debugging.

The input argument is the oid of the append-optimized table.

Call __gp_aoseg_history_name('table_name') to get the same result with the table name as an argument.

Table 199: __gp_aoseg_history output table

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>gp_tid</td>
<td>The id of the tuple.</td>
</tr>
<tr>
<td>gp_xmin</td>
<td>The id of the earliest transaction.</td>
</tr>
<tr>
<td>gp_xmin_status</td>
<td>Status of the gp_xmin transaction.</td>
</tr>
<tr>
<td>gp_xmin_commit_</td>
<td>The commit distribution id of the gp_xmin transaction.</td>
</tr>
<tr>
<td>gp_xmax</td>
<td>The id of the latest transaction.</td>
</tr>
<tr>
<td>gp_xmax_status</td>
<td>The status of the latest transaction.</td>
</tr>
<tr>
<td>gp_xmax_commit_</td>
<td>The commit distribution id of the gp_xmax transaction.</td>
</tr>
<tr>
<td>gp_command_id</td>
<td>The id of the query command.</td>
</tr>
<tr>
<td>gp_infomask</td>
<td>A bitmap containing state information.</td>
</tr>
<tr>
<td>gp_update_tid</td>
<td>The ID of the newer tuple if the row is updated.</td>
</tr>
<tr>
<td>gp_visibility</td>
<td>The tuple visibility status.</td>
</tr>
<tr>
<td>segno</td>
<td>The number of the segment in the segment file.</td>
</tr>
<tr>
<td>tupcount</td>
<td>The number of tuples, including hidden tuples.</td>
</tr>
<tr>
<td>eof</td>
<td>The effective end of file for the segment.</td>
</tr>
<tr>
<td>Column</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------------------------------------------------------</td>
</tr>
<tr>
<td>eof_uncompressed</td>
<td>The end of file for the segment if data were uncompressed.</td>
</tr>
<tr>
<td>modcount</td>
<td>A count of data modifications.</td>
</tr>
<tr>
<td>state</td>
<td>The status of the segment.</td>
</tr>
</tbody>
</table>

__gp_aocsseg(oid)\n
This function returns metadata information contained in a column-oriented append-optimized table's on-disk segment file, excluding non-visible rows. Each row describes a segment for a column in the table.

The input argument is the oid of a column-oriented append-optimized table. Call as __gp_aocsseg_name('table_name') to get the same result with the table name as an argument.

Table 200: __gp_aocsseg(oid) output table

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>gp_tid</td>
<td>The table id.</td>
</tr>
<tr>
<td>segno</td>
<td>The segment number.</td>
</tr>
<tr>
<td>column_num</td>
<td>The column number.</td>
</tr>
<tr>
<td>physical_segno</td>
<td>The number of the segment in the segment file.</td>
</tr>
<tr>
<td>tupcount</td>
<td>The number of rows in the segment, excluding hidden tuples.</td>
</tr>
<tr>
<td>eof</td>
<td>The effective end of file for the segment.</td>
</tr>
<tr>
<td>eof_uncompressed</td>
<td>The end of file for the segment if the data were uncompressed.</td>
</tr>
<tr>
<td>modcount</td>
<td>A count of data modification operations for the segment.</td>
</tr>
<tr>
<td>state</td>
<td>The status of the segment.</td>
</tr>
</tbody>
</table>

__gp_aocsseg_history(oid)\n
This function returns metadata information contained in a column-oriented append-optimized table's on-disk segment file. Each row describes a segment for a column in the table. The data is complex, but users with a deep understanding of the system may find it useful for debugging.

The input argument is the oid of a column-oriented append-optimized table. Call as __gp_aocsseg_history_name('table_name') to get the same result with the table name as argument.

Table 201: __gp_aocsseg_history output table

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>gp_tid</td>
<td>The oid of the tuple.</td>
</tr>
<tr>
<td>gp_xmin</td>
<td>The earliest transaction.</td>
</tr>
<tr>
<td>gp_xmin_status</td>
<td>The status of the gp_xmin transaction.</td>
</tr>
<tr>
<td>gp_xmin_</td>
<td>Text representation of gp_xmin.</td>
</tr>
<tr>
<td>Column</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>gp_xmax</td>
<td>The latest transaction.</td>
</tr>
<tr>
<td>gp_xmax_status</td>
<td>The status of the gp_xmax transaction.</td>
</tr>
<tr>
<td>gp_xmax_</td>
<td>Text representation of gp_max.</td>
</tr>
<tr>
<td>gp_command_id</td>
<td>ID of the command operating on the tuple.</td>
</tr>
<tr>
<td>gp_inomask</td>
<td>A bitmap containing state information.</td>
</tr>
<tr>
<td>gp_update_tid</td>
<td>The ID of the newer tuple if the row is updated.</td>
</tr>
<tr>
<td>gp_visibility</td>
<td>The tuple visibility status.</td>
</tr>
<tr>
<td>segno</td>
<td>The segment number in the segment file.</td>
</tr>
<tr>
<td>column_num</td>
<td>The column number.</td>
</tr>
<tr>
<td>physical_segno</td>
<td>The segment containing data for the column.</td>
</tr>
<tr>
<td>tupcount</td>
<td>The total number of tuples in the segment.</td>
</tr>
<tr>
<td>eof</td>
<td>The effective end of file for the segment.</td>
</tr>
<tr>
<td>eof_uncompressed</td>
<td>The end of file for the segment if the data were uncompressed.</td>
</tr>
<tr>
<td>modcount</td>
<td>A count of the data modification operations.</td>
</tr>
<tr>
<td>state</td>
<td>The state of the segment.</td>
</tr>
</tbody>
</table>

**__gp_aovisimap(oid)***

This function returns the tuple id, the segment file, and the row number of each non-visible tuple according to the visibility map.

The input argument is the oid of an append-optimized table.

Use __gp_aovisimap_name('table_name') to get the same result with the table name as argument.

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tid</td>
<td>The tuple id.</td>
</tr>
<tr>
<td>segno</td>
<td>The number of the segment file.</td>
</tr>
<tr>
<td>row_num</td>
<td>The row number of a row that has been deleted or updated.</td>
</tr>
</tbody>
</table>

**__gp_aovisimap_hidden_info(oid)***

This function returns the numbers of hidden and visible tuples in the segment files for an append-optimized table.

The input argument is the oid of the append-optimized table.

Call __gp_aovisimap_hidden_info_name('table_name') to get the same result with a table name argument.

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>segno</td>
<td>The number of the segment file.</td>
</tr>
<tr>
<td>hidden_tupcount</td>
<td>The number of hidden tuples in the segment file.</td>
</tr>
</tbody>
</table>
Column | Description
--- | ---
total_tupcount | The total number of tuples in the segment file.

`__gp_aovisimap_entry(oid)`

This function returns information about each visibility map entry for the table. The input argument is the oid of an append-optimized table. Call `__gp_aovisimap_entry_name('table_name')` to get the same result with a table name argument.

Table 202: `__gp_aovisimap_entry` output table

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>segno</td>
<td>Segment number of the visibility map entry.</td>
</tr>
<tr>
<td>first_row_num</td>
<td>The first row number of the entry.</td>
</tr>
<tr>
<td>hidden_tupcount</td>
<td>The number of hidden tuples in the entry.</td>
</tr>
<tr>
<td>bitmap</td>
<td>A text representation of the visibility bitmap.</td>
</tr>
</tbody>
</table>

**Viewing Greenplum Database Server Log Files**

Each component of a Greenplum Database system (master, standby master, primary segments, and mirror segments) keeps its own server log files. The `gp_log_*` family of views allows you to issue SQL queries against the server log files to find particular entries of interest. The use of these views require superuser permissions.

- `gp_log_command_timings`
- `gp_log_database`
- `gp_log_master_concise`
- `gp_log_system`

**gp_log_command_timings**

This view uses an external table to read the log files on the master and report the execution time of SQL commands executed in a database session. The use of this view requires superuser permissions.

Table 203: `gp_log_command_timings` view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>logsession</td>
<td>The session identifier (prefixed with &quot;con&quot;).</td>
</tr>
<tr>
<td>logcmdcount</td>
<td>The command number within a session (prefixed with &quot;cmd&quot;).</td>
</tr>
<tr>
<td>logdatabase</td>
<td>The name of the database.</td>
</tr>
<tr>
<td>loguser</td>
<td>The name of the database user.</td>
</tr>
<tr>
<td>logpid</td>
<td>The process id (prefixed with &quot;p&quot;).</td>
</tr>
<tr>
<td>logtimemin</td>
<td>The time of the first log message for this command.</td>
</tr>
<tr>
<td>logtimemax</td>
<td>The time of the last log message for this command.</td>
</tr>
<tr>
<td>logduration</td>
<td>Statement duration from start to end time.</td>
</tr>
</tbody>
</table>
**gp_log_database**

This view uses an external table to read the server log files of the entire Greenplum system (master, segments, and mirrors) and lists log entries associated with the current database. Associated log entries can be identified by the session id (logsession) and command id (logcmdcount). The use of this view requires superuser permissions.

**Table 204: gp_log_database view**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>logtime</td>
<td>The timestamp of the log message.</td>
</tr>
<tr>
<td>loguser</td>
<td>The name of the database user.</td>
</tr>
<tr>
<td>logdatabase</td>
<td>The name of the database.</td>
</tr>
<tr>
<td>logpid</td>
<td>The associated process id (prefixed with &quot;p&quot;).</td>
</tr>
<tr>
<td>logthread</td>
<td>The associated thread count (prefixed with &quot;th&quot;).</td>
</tr>
<tr>
<td>loghost</td>
<td>The segment or master host name.</td>
</tr>
<tr>
<td>logport</td>
<td>The segment or master port.</td>
</tr>
<tr>
<td>logsessiontime</td>
<td>Time session connection was opened.</td>
</tr>
<tr>
<td>logtransaction</td>
<td>Global transaction id.</td>
</tr>
<tr>
<td>logsession</td>
<td>The session identifier (prefixed with &quot;con&quot;).</td>
</tr>
<tr>
<td>logcmdcount</td>
<td>The command number within a session (prefixed with &quot;cmd&quot;).</td>
</tr>
<tr>
<td>logsegment</td>
<td>The segment content identifier (prefixed with &quot;seg&quot; for primary or &quot;mir&quot; for mirror. The master always has a content id of -1).</td>
</tr>
<tr>
<td>logslice</td>
<td>The slice id (portion of the query plan being executed).</td>
</tr>
<tr>
<td>logdistxact</td>
<td>Distributed transaction id.</td>
</tr>
<tr>
<td>loglocalxact</td>
<td>Local transaction id.</td>
</tr>
<tr>
<td>logsubxact</td>
<td>Subtransaction id.</td>
</tr>
<tr>
<td>logseverity</td>
<td>LOG, ERROR, FATAL, PANIC, DEBUG1 or DEBUG2.</td>
</tr>
<tr>
<td>logstate</td>
<td>SQL state code associated with the log message.</td>
</tr>
<tr>
<td>logmessage</td>
<td>Log or error message text.</td>
</tr>
<tr>
<td>logdetail</td>
<td>Detail message text associated with an error message.</td>
</tr>
<tr>
<td>loghint</td>
<td>Hint message text associated with an error message.</td>
</tr>
<tr>
<td>logquery</td>
<td>The internally-generated query text.</td>
</tr>
<tr>
<td>logquerypos</td>
<td>The cursor index into the internally-generated query text.</td>
</tr>
</tbody>
</table>
### gp_log_master_concise

This view uses an external table to read a subset of the log fields from the master log file. The use of this view requires superuser permissions.

**Table 205: gp_log_master_concise view**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>logtime</td>
<td>The timestamp of the log message.</td>
</tr>
<tr>
<td>logdatabase</td>
<td>The name of the database.</td>
</tr>
<tr>
<td>logsession</td>
<td>The session identifier (prefixed with &quot;con&quot;).</td>
</tr>
<tr>
<td>logcmdcount</td>
<td>The command number within a session (prefixed with &quot;cmd&quot;).</td>
</tr>
<tr>
<td>logmessage</td>
<td>Log or error message text.</td>
</tr>
</tbody>
</table>

### gp_log_system

This view uses an external table to read the server log files of the entire Greenplum system (master, segments, and mirrors) and lists all log entries. Associated log entries can be identified by the session id (logsession) and command id (logcmdcount). The use of this view requires superuser permissions.

**Table 206: gp_log_system view**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>logtime</td>
<td>The timestamp of the log message.</td>
</tr>
<tr>
<td>loguser</td>
<td>The name of the database user.</td>
</tr>
<tr>
<td>logdatabase</td>
<td>The name of the database.</td>
</tr>
<tr>
<td>logpid</td>
<td>The associated process id (prefixed with &quot;p&quot;).</td>
</tr>
<tr>
<td>logthread</td>
<td>The associated thread count (prefixed with &quot;th&quot;).</td>
</tr>
<tr>
<td>loghost</td>
<td>The segment or master host name.</td>
</tr>
<tr>
<td>logport</td>
<td>The segment or master port.</td>
</tr>
<tr>
<td>logsessiontime</td>
<td>Time session connection was opened.</td>
</tr>
<tr>
<td>Column</td>
<td>Description</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>logtransaction</td>
<td>Global transaction id.</td>
</tr>
<tr>
<td>logsession</td>
<td>The session identifier (prefixed with &quot;con&quot;).</td>
</tr>
<tr>
<td>logcmdcount</td>
<td>The command number within a session (prefixed with &quot;cmd&quot;).</td>
</tr>
<tr>
<td>logsegment</td>
<td>The segment content identifier (prefixed with &quot;seg&quot; for primary or &quot;mir&quot; for mirror. The master always has a content id of -1).</td>
</tr>
<tr>
<td>logslice</td>
<td>The slice id (portion of the query plan being executed).</td>
</tr>
<tr>
<td>logdistxact</td>
<td>Distributed transaction id.</td>
</tr>
<tr>
<td>loglocalxact</td>
<td>Local transaction id.</td>
</tr>
<tr>
<td>logsubxact</td>
<td>Subtransaction id.</td>
</tr>
<tr>
<td>logseverity</td>
<td>LOG, ERROR, FATAL, PANIC, DEBUG1 or DEBUG2.</td>
</tr>
<tr>
<td>logstate</td>
<td>SQL state code associated with the log message.</td>
</tr>
<tr>
<td>logmessage</td>
<td>Log or error message text.</td>
</tr>
<tr>
<td>logdetail</td>
<td>Detail message text associated with an error message.</td>
</tr>
<tr>
<td>loghint</td>
<td>Hint message text associated with an error message.</td>
</tr>
<tr>
<td>logquery</td>
<td>The internally-generated query text.</td>
</tr>
<tr>
<td>logquerypos</td>
<td>The cursor index into the internally-generated query text.</td>
</tr>
<tr>
<td>logcontext</td>
<td>The context in which this message gets generated.</td>
</tr>
<tr>
<td>logdebug</td>
<td>Query string with full detail for debugging.</td>
</tr>
<tr>
<td>logcursorpos</td>
<td>The cursor index into the query string.</td>
</tr>
<tr>
<td>logfunction</td>
<td>The function in which this message is generated.</td>
</tr>
<tr>
<td>logfile</td>
<td>The log file in which this message is generated.</td>
</tr>
<tr>
<td>logline</td>
<td>The line in the log file in which this message is generated.</td>
</tr>
<tr>
<td>logstack</td>
<td>Full text of the stack trace associated with this message.</td>
</tr>
</tbody>
</table>

**Checking Server Configuration Files**

Each component of a Greenplum Database system (master, standby master, primary segments, and mirror segments) has its own server configuration file (`postgresql.conf`). The following `gp_toolkit` objects can be used to check parameter settings across all primary `postgresql.conf` files in the system:

- `gp_param_setting('parameter_name')`
- `gp_param_settings_seg_value_diffs`
**gp_param_setting('parameter_name')**

This function takes the name of a server configuration parameter and returns the `postgresql.conf` value for the master and each active segment. This function is accessible to all users.

**Table 207: gp_param_setting('parameter_name') function**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>paramsegment</td>
<td>The segment content id (only active segments are shown). The master content id is always -1.</td>
</tr>
<tr>
<td>paramname</td>
<td>The name of the parameter.</td>
</tr>
<tr>
<td>paramvalue</td>
<td>The value of the parameter.</td>
</tr>
</tbody>
</table>

**Example:**

```
SELECT * FROM gp_param_setting('max_connections');
```

**gp_param_settings_seg_value_diffs**

Server configuration parameters that are classified as *local* parameters (meaning each segment gets the parameter value from its own `postgresql.conf` file), should be set identically on all segments. This view shows local parameter settings that are inconsistent. Parameters that are supposed to have different values (such as `port`) are not included. This view is accessible to all users.

**Table 208: gp_param_settings_seg_value_diffs view**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>psdname</td>
<td>The name of the parameter.</td>
</tr>
<tr>
<td>psdvalue</td>
<td>The value of the parameter.</td>
</tr>
<tr>
<td>psdcount</td>
<td>The number of segments that have this value.</td>
</tr>
</tbody>
</table>

**Checking for Failed Segments**

The `gp_pgdatabase_invalid` view can be used to check for down segments.

**gp_pgdatabase_invalid**

This view shows information about segments that are marked as down in the system catalog. This view is accessible to all users.

**Table 209: gp_pgdatabase_invalid view**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pgdbidbid</td>
<td>The segment dbid. Every segment has a unique dbid.</td>
</tr>
<tr>
<td>pgdbiisprimary</td>
<td>Is the segment currently acting as the primary (active) segment? (t or f)</td>
</tr>
<tr>
<td>pgdbicontent</td>
<td>The content id of this segment. A primary and mirror will have the same content id.</td>
</tr>
</tbody>
</table>
Checking Resource Group Activity and Status

Note: The resource group activity and status views described in this section are valid only when resource group-based resource management is active.

Resource groups manage transactions to avoid exhausting system CPU and memory resources. Every database user is assigned a resource group. Greenplum Database evaluates every transaction submitted by a user against the limits configured for the user's resource group before running the transaction.

You can use the `gp_resgroup_config` view to check the configuration of each resource group. You can use the `gp_resgroup_status` view to display the current transaction status and resource usage of each resource group.

- `gp_resgroup_config`
- `gp_resgroup_status`

**gp_resgroup_config**

The `gp_resgroup_config` view allows administrators to see the current CPU, memory, and concurrency limits for a resource group. The view also displays proposed limit settings. A proposed limit will differ from the current limit when the limit has been altered, but the new value could not be immediately applied.

This view is accessible to all users.

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>groupid</td>
<td>The ID of the resource group.</td>
</tr>
<tr>
<td>groupname</td>
<td>The name of the resource group.</td>
</tr>
<tr>
<td>concurrency</td>
<td>The concurrency (CONCURRENCY) value specified for the resource group.</td>
</tr>
<tr>
<td>proposed_concurrency</td>
<td>The pending concurrency value for the resource group.</td>
</tr>
<tr>
<td>cpu_rate_limit</td>
<td>The CPU limit (CPU_RATE_LIMIT) value specified for the resource group.</td>
</tr>
<tr>
<td>memory_limit</td>
<td>The memory limit (MEMORY_LIMIT) value specified for the resource group.</td>
</tr>
<tr>
<td>proposed_memory_limit</td>
<td>The pending memory limit value for the resource group.</td>
</tr>
<tr>
<td>memory_shared_quota</td>
<td>The shared memory quota (MEMORY_SHARED_QUOTA) value specified for the resource group.</td>
</tr>
<tr>
<td>proposed_memory_shared_quota</td>
<td>The pending shared memory quota value for the resource group.</td>
</tr>
<tr>
<td>memory_spill_ratio</td>
<td>The memory spill ratio (MEMORY_SPILL_RATIO) value specified for the resource group.</td>
</tr>
<tr>
<td>Column</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>proposed_memory_spill_ratio</td>
<td>The pending memory spill ratio value for the resource group.</td>
</tr>
</tbody>
</table>

**gp_resgroup_status**

The `gp_resgroup_status` view allows administrators to see status and activity for a resource group. It shows how many queries are waiting to run and how many queries are currently active in the system for each resource group. The view also displays current memory and CPU usage for the resource group.

This view is accessible to all users.

**Table 211: gp_resgroup_status view**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rsgname</td>
<td>The name of the resource group.</td>
</tr>
<tr>
<td>groupid</td>
<td>The ID of the resource group.</td>
</tr>
<tr>
<td>num_running</td>
<td>The number of transactions currently executing in the resource group.</td>
</tr>
<tr>
<td>num_queueing</td>
<td>The number of currently queued transactions for the resource group.</td>
</tr>
<tr>
<td>num_queued</td>
<td>The total number of queued transactions for the resource group since the Greenplum Database cluster was last started, excluding the num_queueing.</td>
</tr>
<tr>
<td>num_executed</td>
<td>The total number of executed transactions in the resource group since the Greenplum Database cluster was last started, excluding the num_running.</td>
</tr>
<tr>
<td>total_queue_duration</td>
<td>The total time any transaction was queued since the Greenplum Database cluster was last started.</td>
</tr>
<tr>
<td>cpu_usage</td>
<td>The real-time CPU usage of the resource group on each Greenplum Database segment's host.</td>
</tr>
<tr>
<td>memory_usage</td>
<td>The real-time memory usage of the resource group on each Greenplum Database segment's host.</td>
</tr>
</tbody>
</table>

The `cpu_usage` field is a JSON-formatted, key:value string that identifies, for each resource group, the per-segment CPU usage percentage. The key is segment id, the value is the percentage of CPU usage by the resource group on the segment host. The total CPU usage of all segments running on a segment host should not exceed the `gp_resource_group_cpu_limit`. Example `cpu_usage` column output:

```json
{"-1":0.01, "0":0.31, "1":0.31}
```

In this example, segment 0 and segment 1 are running on the same host; their CPU usage is the same.

The `memory_usage` field is also a JSON-formatted, key:value string. The string contents differ depending upon the type of resource group. For each resource group that you assign to a role (default memory auditor vmtracker), this string identifies the used, available, granted, and proposed fixed and shared memory quota allocations on each segment. The key is segment id. The values are memory values.
displayed in MB units. The following example shows memory_usage column output for a single segment for a resource group that you assign to a role:

```
"0":{"used":0, "available":76, "quota_used":-1, "quota_available":60,  
"quota_granted":60, "quota_proposed":60, "shared_used":0,  
"shared_available":16, "shared_granted":16, "shared_proposed":16}
```

For each resource group that you assign to an external component, the memory_usage JSON-formatted string identifies the memory used and the memory limit on each segment. The following example shows memory_usage column output for an external component resource group for a single segment:

```
"1":{"used":11, "limit_granted":15}
```

## Checking Resource Queue Activity and Status

**Note:** The resource queue activity and status views described in this section are valid only when resource queue-based resource management is active.

The purpose of resource queues is to limit the number of active queries in the system at any given time in order to avoid exhausting system resources such as memory, CPU, and disk I/O. All database users are assigned to a resource queue, and every statement submitted by a user is first evaluated against the resource queue limits before it can run. The `gp_resq_*` family of views can be used to check the status of statements currently submitted to the system through their respective resource queue. Note that statements issued by superusers are exempt from resource queuing.

- `gp_resq_activity`
- `gp_resq_activity_by_queue`
- `gp_resq_priority_statement`
- `gp_resq_role`
- `gp_resqueue_status`

### gp_resq_activity

For the resource queues that have active workload, this view shows one row for each active statement submitted through a resource queue. This view is accessible to all users.

**Table 212: gp_resq_activity view**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>resqprocpid</td>
<td>Process ID assigned to this statement (on the master).</td>
</tr>
<tr>
<td>resqrole</td>
<td>User name.</td>
</tr>
<tr>
<td>resqoid</td>
<td>Resource queue object id.</td>
</tr>
<tr>
<td>resqname</td>
<td>Resource queue name.</td>
</tr>
<tr>
<td>resqstart</td>
<td>Time statement was issued to the system.</td>
</tr>
<tr>
<td>resqstatus</td>
<td>Status of statement: running, waiting or cancelled.</td>
</tr>
</tbody>
</table>

### gp_resq_activity_by_queue

For the resource queues that have active workload, this view shows a summary of queue activity. This view is accessible to all users.
### Table 213: gp_resq_activity_by_queue Column

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>resqoid</td>
<td>Resource queue object id.</td>
</tr>
<tr>
<td>resqname</td>
<td>Resource queue name.</td>
</tr>
<tr>
<td>resqlast</td>
<td>Time of the last statement issued to the queue.</td>
</tr>
<tr>
<td>resqstatus</td>
<td>Status of last statement: running, waiting or cancelled.</td>
</tr>
<tr>
<td>resqtotal</td>
<td>Total statements in this queue.</td>
</tr>
</tbody>
</table>

### gp_resq_priority_statement

This view shows the resource queue priority, session ID, and other information for all statements currently running in the Greenplum Database system. This view is accessible to all users.

### Table 214: gp_resq_priority_statement view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rqpdatname</td>
<td>The database name that the session is connected to.</td>
</tr>
<tr>
<td>rqpusename</td>
<td>The user who issued the statement.</td>
</tr>
<tr>
<td>rqpsession</td>
<td>The session ID.</td>
</tr>
<tr>
<td>rqpcommand</td>
<td>The number of the statement within this session (the command id and session id uniquely identify a statement).</td>
</tr>
<tr>
<td>rqppriority</td>
<td>The resource queue priority for this statement (MAX, HIGH, MEDIUM, LOW).</td>
</tr>
<tr>
<td>rqpweight</td>
<td>An integer value associated with the priority of this statement.</td>
</tr>
<tr>
<td>rqpquery</td>
<td>The query text of the statement.</td>
</tr>
</tbody>
</table>

### gp_resq_role

This view shows the resource queues associated with a role. This view is accessible to all users.

### Table 215: gp_resq_role view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rrrolname</td>
<td>Role (user) name.</td>
</tr>
<tr>
<td>rrsqname</td>
<td>The resource queue name assigned to this role. If a role has not been explicitly assigned to a resource queue, it will be in the default resource queue (pg_default).</td>
</tr>
</tbody>
</table>
gp_resqueue_status

This view allows administrators to see status and activity for a resource queue. It shows how many queries are waiting to run and how many queries are currently active in the system from a particular resource queue.

Table 216: gp_resqueue_status view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>queueid</td>
<td>The ID of the resource queue.</td>
</tr>
<tr>
<td>rsqname</td>
<td>The name of the resource queue.</td>
</tr>
<tr>
<td>rsqcountlimit</td>
<td>The active query threshold of the resource queue. A value of -1 means no limit.</td>
</tr>
<tr>
<td>rsqcountvalue</td>
<td>The number of active query slots currently being used in the resource queue.</td>
</tr>
<tr>
<td>rsqcostlimit</td>
<td>The query cost threshold of the resource queue. A value of -1 means no limit.</td>
</tr>
<tr>
<td>rsqcostvalue</td>
<td>The total cost of all statements currently in the resource queue.</td>
</tr>
<tr>
<td>rsqmemorylimit</td>
<td>The memory limit for the resource queue.</td>
</tr>
<tr>
<td>rsqmemoryvalue</td>
<td>The total memory used by all statements currently in the resource queue.</td>
</tr>
<tr>
<td>rsqwaiters</td>
<td>The number of statements currently waiting in the resource queue.</td>
</tr>
<tr>
<td>rsqholders</td>
<td>The number of statements currently running on the system from this resource queue.</td>
</tr>
</tbody>
</table>

Checking Query Disk Spill Space Usage

The gp_workfile_* views show information about all the queries that are currently using disk spill space. Greenplum Database creates work files on disk if it does not have sufficient memory to execute the query in memory. This information can be used for troubleshooting and tuning queries. The information in the views can also be used to specify the values for the Greenplum Database configuration parameters gp_workfile_limit_per_query and gp_workfile_limit_per_segment.

• gp_workfile_entries
• gp_workfile_usage_per_query
• gp_workfile_usage_per_segment

gp_workfile_entries

This view contains one row for each operator using disk space for workfiles on a segment at the current time. The view is accessible to all users, however non-superusers only to see information for the databases that they have permission to access.
Table 217: gp_workfile_entries

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>References</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>command_cnt</td>
<td>integer</td>
<td></td>
<td>Command ID of the query.</td>
</tr>
<tr>
<td>content</td>
<td>smallint</td>
<td></td>
<td>The content identifier for a segment instance.</td>
</tr>
<tr>
<td>current_query</td>
<td>text</td>
<td></td>
<td>Current query that the process is running.</td>
</tr>
<tr>
<td>datname</td>
<td>name</td>
<td></td>
<td>Greenplum database name.</td>
</tr>
<tr>
<td>directory</td>
<td>text</td>
<td></td>
<td>Path to the work file.</td>
</tr>
<tr>
<td>optype</td>
<td>text</td>
<td></td>
<td>The query operator type that created the work file.</td>
</tr>
<tr>
<td>procpid</td>
<td>integer</td>
<td></td>
<td>Process ID of the server process.</td>
</tr>
<tr>
<td>sess_id</td>
<td>integer</td>
<td></td>
<td>Session ID.</td>
</tr>
<tr>
<td>size</td>
<td>bigint</td>
<td></td>
<td>The size of the work file in bytes.</td>
</tr>
<tr>
<td>numfiles</td>
<td>bigint</td>
<td></td>
<td>The number of files created.</td>
</tr>
<tr>
<td>slice</td>
<td>smallint</td>
<td></td>
<td>The query plan slice. The portion of the query plan that is being executed.</td>
</tr>
<tr>
<td>state</td>
<td>text</td>
<td></td>
<td>The state of the query that created the work file.</td>
</tr>
<tr>
<td>usename</td>
<td>name</td>
<td></td>
<td>Role name.</td>
</tr>
<tr>
<td>workmem</td>
<td>integer</td>
<td></td>
<td>The amount of memory allocated to the operator in KB.</td>
</tr>
</tbody>
</table>

gp_workfile_usage_per_query

This view contains one row for each query using disk space for workfiles on a segment at the current time. The view is accessible to all users, however non-superusers only to see information for the databases that they have permission to access.

Table 218: gp_workfile_usage_per_query

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>References</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>command_cnt</td>
<td>integer</td>
<td></td>
<td>Command ID of the query.</td>
</tr>
<tr>
<td>Column</td>
<td>Type</td>
<td>References</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>---------</td>
<td>------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>content</td>
<td>smallint</td>
<td></td>
<td>The content identifier for a segment instance.</td>
</tr>
<tr>
<td>current_query</td>
<td>text</td>
<td></td>
<td>Current query that the process is running.</td>
</tr>
<tr>
<td>datname</td>
<td>name</td>
<td></td>
<td>Greenplum database name.</td>
</tr>
<tr>
<td>procpid</td>
<td>integer</td>
<td></td>
<td>Process ID of the server process.</td>
</tr>
<tr>
<td>sess_id</td>
<td>integer</td>
<td></td>
<td>Session ID.</td>
</tr>
<tr>
<td>size</td>
<td>bigint</td>
<td></td>
<td>The size of the work file in bytes.</td>
</tr>
<tr>
<td>numfiles</td>
<td>bigint</td>
<td></td>
<td>The number of files created.</td>
</tr>
<tr>
<td>state</td>
<td>text</td>
<td></td>
<td>The state of the query that created the work file.</td>
</tr>
<tr>
<td>usename</td>
<td>name</td>
<td></td>
<td>Role name.</td>
</tr>
</tbody>
</table>

**gp_workfile_usage_per_segment**

This view contains one row for each segment. Each row displays the total amount of disk space used for workfiles on the segment at the current time. The view is accessible to all users, however non-superusers only to see information for the databases that they have permission to access.

**Table 219: gp_workfile_usage_per_segment**

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>References</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>content</td>
<td>smallint</td>
<td></td>
<td>The content identifier for a segment instance.</td>
</tr>
<tr>
<td>size</td>
<td>bigint</td>
<td></td>
<td>The total size of the work files on a segment.</td>
</tr>
<tr>
<td>numfiles</td>
<td>bigint</td>
<td></td>
<td>The number of files created.</td>
</tr>
</tbody>
</table>

**Viewing Users and Groups (Roles)**

It is frequently convenient to group users (roles) together to ease management of object privileges: that way, privileges can be granted to, or revoked from, a group as a whole. In Greenplum Database this is done by creating a role that represents the group, and then granting membership in the group role to individual user roles.

The *gp_roles_assigned* view can be used to see all of the roles in the system, and their assigned members (if the role is also a group role).

**gp_roles_assigned**

This view shows all of the roles in the system, and their assigned members (if the role is also a group role). This view is accessible to all users.
Table 220: gp_roles_assigned view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>raroleid</td>
<td>The role object ID. If this role has members (users), it is considered a group role.</td>
</tr>
<tr>
<td>rarolename</td>
<td>The role (user or group) name.</td>
</tr>
<tr>
<td>ramemberid</td>
<td>The role object ID of the role that is a member of this role.</td>
</tr>
<tr>
<td>ramembername</td>
<td>Name of the role that is a member of this role.</td>
</tr>
</tbody>
</table>

Checking Database Object Sizes and Disk Space

The gp_size_* family of views can be used to determine the disk space usage for a distributed Greenplum Database, schema, table, or index. The following views calculate the total size of an object across all primary segments (mirrors are not included in the size calculations).

- gp_size_of_all_table_indexes
- gp_size_of_database
- gp_size_of_index
- gp_size_of_partition_and_indexes_disk
- gp_size_of_schema_disk
- gp_size_of_table_and_indexes_disk
- gp_size_of_table_and_indexes_licensing
- gp_size_of_table_disk
- gp_size_of_table_uncompressed
- gp_disk_free

The table and index sizing views list the relation by object ID (not by name). To check the size of a table or index by name, you must look up the relation name (relname) in the pg_class table. For example:

```
SELECT relname as name, sotdsize as size, sotdtoastsize as toast, sotdadditionalsize as other
FROM gp_size_of_table_disk as sotd, pg_class
WHERE sotd.sotdoid=pg_class.oid ORDER BY relname;
```

gp_size_of_all_table_indexes

This view shows the total size of all indexes for a table. This view is accessible to all users, however non-superusers will only be able to see relations that they have permission to access.

Table 221: gp_size_of_all_table_indexes view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>soatioid</td>
<td>The object ID of the table</td>
</tr>
<tr>
<td>soatisize</td>
<td>The total size of all table indexes in bytes</td>
</tr>
<tr>
<td>soatischemaname</td>
<td>The schema name</td>
</tr>
<tr>
<td>soatitablename</td>
<td>The table name</td>
</tr>
</tbody>
</table>
**gp_size_of_database**

This view shows the total size of a database. This view is accessible to all users, however non-superusers will only be able to see databases that they have permission to access.

**Table 222: gp_size_of_database view**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sodddatname</td>
<td>The name of the database</td>
</tr>
<tr>
<td>sodddatsize</td>
<td>The size of the database in bytes</td>
</tr>
</tbody>
</table>

**gp_size_of_index**

This view shows the total size of an index. This view is accessible to all users, however non-superusers will only be able to see relations that they have permission to access.

**Table 223: gp_size_of_index view**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>soioid</td>
<td>The object ID of the index</td>
</tr>
<tr>
<td>soitableoid</td>
<td>The object ID of the table to which the index belongs</td>
</tr>
<tr>
<td>soisize</td>
<td>The size of the index in bytes</td>
</tr>
<tr>
<td>soiindexschemaname</td>
<td>The name of the index schema</td>
</tr>
<tr>
<td>soiindexname</td>
<td>The name of the index</td>
</tr>
<tr>
<td>soitableschemaname</td>
<td>The name of the table schema</td>
</tr>
<tr>
<td>soitablename</td>
<td>The name of the table</td>
</tr>
</tbody>
</table>

**gp_size_of_partition_and_indexes_disk**

This view shows the size on disk of partitioned child tables and their indexes. This view is accessible to all users, however non-superusers will only be able to see relations that they have permission to access.

**Table 224: gp_size_of_partition_and_indexes_disk view**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sopaidparentoid</td>
<td>The object ID of the parent table</td>
</tr>
<tr>
<td>sopaidpartitionoid</td>
<td>The object ID of the partition table</td>
</tr>
<tr>
<td>sopaidpartitiontablesize</td>
<td>The partition table size in bytes</td>
</tr>
<tr>
<td>sopaidpartitionindexessize</td>
<td>The total size of all indexes on this partition</td>
</tr>
<tr>
<td>Sopaidparentschemaname</td>
<td>The name of the parent schema</td>
</tr>
<tr>
<td>Sopaidparenttablename</td>
<td>The name of the parent table</td>
</tr>
<tr>
<td>Sopaidpartitionschemaname</td>
<td>The name of the partition schema</td>
</tr>
<tr>
<td>sopaidpartitiontablename</td>
<td>The name of the partition table</td>
</tr>
</tbody>
</table>
gp_size_of_schema_disk

This view shows schema sizes for the public schema and the user-created schemas in the current database. This view is accessible to all users, however non-superusers will be able to see only the schemas that they have permission to access.

Table 225: gp_size_of_schema_disk view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sosdsnsp</td>
<td>The name of the schema</td>
</tr>
<tr>
<td>sosdschematablesize</td>
<td>The total size of tables in the schema in bytes</td>
</tr>
<tr>
<td>sosdschemaidxsizex</td>
<td>The total size of indexes in the schema in bytes</td>
</tr>
</tbody>
</table>

gp_size_of_table_and_indexes_disk

This view shows the size on disk of tables and their indexes. This view is accessible to all users, however non-superusers will only be able to see relations that they have permission to access.

Table 226: gp_size_of_table_and_indexes_disk view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sotaidoid</td>
<td>The object ID of the parent table</td>
</tr>
<tr>
<td>sotaidtablesize</td>
<td>The disk size of the table</td>
</tr>
<tr>
<td>sotaididxsizex</td>
<td>The total size of all indexes on the table</td>
</tr>
<tr>
<td>sotaidscemataname</td>
<td>The name of the schema</td>
</tr>
<tr>
<td>sotaidtablename</td>
<td>The name of the table</td>
</tr>
</tbody>
</table>

gp_size_of_table_and_indexes_licensing

This view shows the total size of tables and their indexes for licensing purposes. The use of this view requires superuser permissions.

Table 227: gp_size_of_table_and_indexes_licensing view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sotailoid</td>
<td>The object ID of the table</td>
</tr>
<tr>
<td>sotailtablesize</td>
<td>The total disk size of the table</td>
</tr>
<tr>
<td>sotailtablesizeuncompressed</td>
<td>If the table is a compressed append-optimized table, shows the uncompressed table size in bytes.</td>
</tr>
<tr>
<td>sotailindexessize</td>
<td>The total size of all indexes in the table</td>
</tr>
<tr>
<td>sotailschemaname</td>
<td>The schema name</td>
</tr>
<tr>
<td>sotailtablename</td>
<td>The table name</td>
</tr>
</tbody>
</table>

gp_size_of_table_disk

This view shows the size of a table on disk. This view is accessible to all users, however non-superusers will only be able to see tables that they have permission to access.
Table 228: gp_size_of_table_disk view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sotdoid</td>
<td>The object ID of the table</td>
</tr>
<tr>
<td>sotdsize</td>
<td>The size of the table in bytes. The size is only the main table size. The size does not include auxiliary objects such as oversized (toast) attributes, or additional storage objects for AO tables.</td>
</tr>
<tr>
<td>sotdtoastsize</td>
<td>The size of the TOAST table (oversized attribute storage), if there is one.</td>
</tr>
<tr>
<td>sotdadditionalsize</td>
<td>Reflects the segment and block directory table sizes for append-optimized (AO) tables.</td>
</tr>
<tr>
<td>sotdschemaname</td>
<td>The schema name</td>
</tr>
<tr>
<td>sotdtablename</td>
<td>The table name</td>
</tr>
</tbody>
</table>

gp_size_of_table_uncompressed

This view shows the uncompressed table size for append-optimized (AO) tables. Otherwise, the table size on disk is shown. The use of this view requires superuser permissions.

Table 229: gp_size_of_table_uncompressed view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sotuoid</td>
<td>The object ID of the table</td>
</tr>
<tr>
<td>sotusize</td>
<td>The uncompressed size of the table in bytes if it is a compressed AO table. Otherwise, the table size on disk.</td>
</tr>
<tr>
<td>sotuschemaname</td>
<td>The schema name</td>
</tr>
<tr>
<td>sotutablename</td>
<td>The table name</td>
</tr>
</tbody>
</table>

gp_disk_free

This external table runs the `df` (disk free) command on the active segment hosts and reports back the results. Inactive mirrors are not included in the calculation. The use of this external table requires superuser permissions.

Table 230: gp_disk_free external table

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>dfsegment</td>
<td>The content id of the segment (only active segments are shown)</td>
</tr>
<tr>
<td>dfhostname</td>
<td>The hostname of the segment host</td>
</tr>
<tr>
<td>dfdevice</td>
<td>The device name</td>
</tr>
<tr>
<td>dfspace</td>
<td>Free disk space in the segment file system in kilobytes</td>
</tr>
</tbody>
</table>
Checking for Uneven Data Distribution

All tables in Greenplum Database are distributed, meaning their data is divided across all of the segments in the system. If the data is not distributed evenly, then query processing performance may suffer. The following views can help diagnose if a table has uneven data distribution:

- `gp_skew_coefficients`
- `gp_skew_idle_fractions`

**gp_skew_coefficients**

This view shows data distribution skew by calculating the coefficient of variation (CV) for the data stored on each segment. This view is accessible to all users, however non-superusers will only be able to see tables that they have permission to access.

Table 231: gp_skew_coefficients view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>skcoid</td>
<td>The object id of the table.</td>
</tr>
<tr>
<td>skcnamespace</td>
<td>The namespace where the table is defined.</td>
</tr>
<tr>
<td>skcrelname</td>
<td>The table name.</td>
</tr>
<tr>
<td>skccoeff</td>
<td>The coefficient of variation (CV) is calculated as the standard deviation divided by the average. It takes into account both the average and variability around the average of a data series. The lower the value, the better. Higher values indicate greater data skew.</td>
</tr>
</tbody>
</table>

**gp_skew_idle_fractions**

This view shows data distribution skew by calculating the percentage of the system that is idle during a table scan, which is an indicator of processing data skew. This view is accessible to all users, however non-superusers will only be able to see tables that they have permission to access.

Table 232: gp_skew_idle_fractions view

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sifoid</td>
<td>The object id of the table.</td>
</tr>
<tr>
<td>sifnamespace</td>
<td>The namespace where the table is defined.</td>
</tr>
<tr>
<td>sifrelname</td>
<td>The table name.</td>
</tr>
<tr>
<td>siffraction</td>
<td>The percentage of the system that is idle during a table scan, which is an indicator of uneven data distribution or query processing skew. For example, a value of 0.1 indicates 10% skew, a value of 0.5 indicates 50% skew, and so on. Tables that have more than 10% skew should have their distribution policies evaluated.</td>
</tr>
</tbody>
</table>
The gpperfmon Database

The gpperfmon database is a dedicated database where data collection agents on Greenplum segment hosts save query and system statistics. The optional Greenplum Command Center management tool depends upon the gpperfmon database.

The gpperfmon database is created using the gpperfmon_install command-line utility. The utility creates the database and the gpmn database role and enables the data collection agents on the master and segment hosts. See the gpperfmon_install reference in the Greenplum Database Utility Guide for information about using the utility and configuring the data collection agents.

The gpperfmon database consists of three sets of tables that capture query and system status information at different stages.

- _now tables store current system metrics such as active queries.
- _tail tables are used to stage data before it is saved to the _history tables. The _tail tables are for internal use only and not to be queried by users.
- _history tables store historical metrics.

The data for _now and _tail tables are stored as text files on the master host file system, and are accessed in the gpperfmon database via external tables. The _history tables are regular heap database tables in the gpperfmon database. History is saved only for queries that run for a minimum number of seconds, 20 by default. You can set this threshold to another value by setting the min_query_time parameter in the $MASTER_DATA_DIRECTORY/gpperfmon/conf/gpperfmon.conf configuration file. Setting the value to 0 saves history for all queries.

The _history tables are partitioned by month. See History Table Partition Retention for information about removing old partitions.

The database contains the following categories of tables:

- The database_* tables store query workload information for a Greenplum Database instance.
- The diskspace_* tables store diskspace metrics.
- The log_alert_* tables store error and warning messages from pg_log.
- The queries_* tables store high-level query status information.
- The segment_* tables store memory allocation statistics for the Greenplum Database segment instances.
- The socket_stats_* tables store statistical metrics about socket usage for a Greenplum Database instance. Note: These tables are in place for future use and are not currently populated.
- The system_* tables store system utilization metrics.

The gpperfmon database also contains the following views:

- The dynamic_memory_info view shows an aggregate of all the segments per host and the amount of dynamic memory used per host.
- The memory_info view shows per-host memory information from the system_history and segment_history tables.

History Table Partition Retention

The _history tables in the gpperfmon database are partitioned by month. Partitions are automatically added in two month increments as needed.

The partition_age parameter in the $MASTER_DATA_DIRECTORY/gpperfmon/conf/gpperfmon.conf file can be set to the maximum number of monthly partitions to keep. Partitions older than the specified value are removed automatically when new partitions are added.
The default value for partition_age is 0, which means that administrators must manually remove unneeded partitions.

Alert Log Processing and Log Rotation

When the gp_gpperfmon_enable server configuration parameter is set to true, the Greenplum Database syslogger writes alert messages to a .csv file in the $MASTER_DATA_DIRECTORY/gpperfmon/logs directory.

The level of messages written to the log can be set to none, warning, error, fatal, or panic by setting the gpperfmon_log_alert_level server configuration parameter in postgresql.conf. The default message level is warning.

The directory where the log is written can be changed by setting the log_location configuration variable in the $MASTER_DATA_DIRECTORY/gpperfmon/conf/gpperfmon.conf configuration file.

The syslogger rotates the alert log every 24 hours or when the current log file reaches or exceeds 1MB. A rotated log file can exceed 1MB if a single error message contains a large SQL statement or a large stack trace. Also, the syslogger processes error messages in chunks, with a separate chunk for each logging process. The size of a chunk is OS-dependent; on Red Hat Enterprise Linux, for example, it is 4096 bytes. If many Greenplum Database sessions generate error messages at the same time, the log file can grow significantly before its size is checked and log rotation is triggered.

gpperfmon Data Collection Process

When Greenplum Database starts up with gpperfmon support enabled, it forks a gpmmon agent process. gpmmon then starts a gpsmon agent process on the master host and every segment host in the Greenplum Database cluster. The Greenplum Database postmaster process monitors the gpmmon process and restarts it if needed, and the gpmmon process monitors and restarts gpsmon processes as needed.

The gpmmon process runs in a loop and at configurable intervals retrieves data accumulated by the gpsmon processes, adds it to the data files for the _now and _tail external database tables, and then into the _history regular heap database tables.

Note: The log_alert tables in the gpperfmon database follow a different process, since alert messages are delivered by the Greenplum Database system logger instead of through gpsmon. See Alert Log Processing and Log Rotation for more information.

Two configuration parameters in the $MASTER_DATA_DIRECTORY/gpperfmon/conf/gpperfmon.conf configuration file control how often gpmmon activities are triggered:

- The quantum parameter is how frequently, in seconds, gpmmon requests data from the gpsmon agents on the segment hosts and adds retrieved data to the _now and _tail external table data files. Valid values for the quantum parameter are 10, 15, 20, 30, and 60. The default is 15.
- The harvest_interval parameter is how frequently, in seconds, data in the _tail tables is moved to the _history tables. The harvest_interval must be at least 30. The default is 120.

See the gpperfmon_install management utility reference in the Greenplum Database Utility Guide for the complete list of gpperfmon configuration parameters.

The following steps describe the flow of data from Greenplum Database into the gpperfmon database when gpperfmon support is enabled.

1. While executing queries, the Greenplum Database query dispatcher and query executor processes send out query status messages in UDP datagrams. The gp_gpperfmon_send_interval server configuration variable determines how frequently the database sends these messages. The default is every second.
2. The gpsmon process on each host receives the UDP packets, consolidates and summarizes the data they contain, and adds additional host metrics, such as CPU and memory usage.
3. The gpsmon processes continue to accumulate data until they receive a dump command from gpmmon.
4. The `gpsmon` processes respond to a dump command by sending their accumulated status data and log alerts to a listening `gpmmon` event handler thread.

5. The `gpmmon` event handler saves the metrics to `.txt` files in the `$MASTER_DATA_DIRECTORY/gpperfmon/data` directory on the master host.

At each quantum interval (15 seconds by default), `gpmmon` performs the following steps:

1. Sends a dump command to the `gpsmon` processes.
2. Gathers and converts the `.txt` files saved in the `$MASTER_DATA_DIRECTORY/gpperfmon/data` directory into `.dat` external data files for the `_now` and `_tail` external tables in the `gpperfmon` database.

   For example, disk space metrics are added to the `diskspace_now.dat` and `diskspace_tail.dat` delimited text files. These text files are accessed via the `diskspace_now` and `diskspace_tail` external tables in the `gpperfmon` database.

At each harvest interval (120 seconds by default), `gpmmon` performs the following steps for each `_tail` file:

1. Renames the `_tail` file to a `_stage` file.
3. Appends data from the `_stage` file into the `_tail` file.
4. Runs a SQL command to insert the data from the `_tail` external table into the corresponding `_history` table.

   For example, the contents of the `_database_tail` external table is inserted into the `database_history` regular (heap) table.

5. Deletes the `_tail` file after its contents have been loaded into the database table.
6. Gathers all of the `gpdb-alert-*.csv` files in the `$MASTER_DATA_DIRECTORY/gpperfmon/logs` directory (except the most recent, which the syslogger has open and is writing to) into a single file, `alert_log_stage`.
7. Loads the `alert_log_stage` file into the `log_alert_history` table in the `gpperfmon` database.
8. Truncates the `alert_log_stage` file.

The following topics describe the contents of the tables in the `gpperfmon` database.

### `database_*`

The `database_*` tables store query workload information for a Greenplum Database instance. There are three database tables, all having the same columns:

- **`database_now`** is an external table whose data files are stored in `$MASTER_DATA_DIRECTORY/gpperfmon/data`. Current query workload data is stored in `database_now` during the period between data collection from the data collection agents and automatic commitment to the `database_history` table.

- **`database_tail`** is an external table whose data files are stored in `$MASTER_DATA_DIRECTORY/gpperfmon/data`. This is a transitional table for query workload data that has been cleared from `database_now` but has not yet been committed to `database_history`. It typically only contains a few minutes worth of data.

- **`database_history`** is a regular table that stores historical database-wide query workload data. It is pre-partitioned into monthly partitions. Partitions are automatically added in two month increments as needed.

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ctime</td>
<td>timestamp</td>
<td>Time this row was created.</td>
</tr>
</tbody>
</table>
### Column Type Description

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>queries_total</td>
<td>int</td>
<td>The total number of queries in Greenplum Database at data collection time.</td>
</tr>
<tr>
<td>queries_running</td>
<td>int</td>
<td>The number of active queries running at data collection time.</td>
</tr>
<tr>
<td>queriesqueued</td>
<td>int</td>
<td>The number of queries waiting in a resource group or resource queue, depending upon which resource management scheme is active, at data collection time.</td>
</tr>
</tbody>
</table>

#### diskspace_

The diskspace_* tables store diskspace metrics.

- diskspace_now is an external table whose data files are stored in $MASTER\_DATA\_DIRECTORY/gpperfmon/data. Current diskspace metrics are stored in database_now during the period between data collection from the gpperfmon agents and automatic commitment to the diskspace_history table.
- diskspace_tail is an external table whose data files are stored in $MASTER\_DATA\_DIRECTORY/gpperfmon/data. This is a transitional table for diskspace metrics that have been cleared from diskspace_now but has not yet been committed to diskspace_history. It typically only contains a few minutes worth of data.
- diskspace_history is a regular table that stores historical diskspace metrics. It is pre-partitioned into monthly partitions. Partitions are automatically added in two month increments as needed.

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ctime</td>
<td>timestamp(0) without time zone</td>
<td>Time of diskspace measurement.</td>
</tr>
<tr>
<td>hostname</td>
<td>varchar(64)</td>
<td>The hostname associated with the diskspace measurement.</td>
</tr>
<tr>
<td>Filesystem</td>
<td>text</td>
<td>Name of the filesystem for the diskspace measurement.</td>
</tr>
<tr>
<td>total_bytes</td>
<td>bigint</td>
<td>Total bytes in the file system.</td>
</tr>
<tr>
<td>bytes_used</td>
<td>bigint</td>
<td>Total bytes used in the file system.</td>
</tr>
<tr>
<td>bytes_available</td>
<td>bigint</td>
<td>Total bytes available in file system.</td>
</tr>
</tbody>
</table>

#### interface_stats_

The interface_stats_* tables store statistical metrics about communications over each active interface for a Greenplum Database instance.

These tables are in place for future use and are not currently populated.

There are three interface_stats tables, all having the same columns:

- interface_stats_now is an external table whose data files are stored in $MASTER\_DATA\_DIRECTORY/gpperfmon/data.
- interface_stats_tail is an external table whose data files are stored in $MASTER\_DATA\_DIRECTORY/gpperfmon/data. This is a transitional table for statistical interface
metrics that has been cleared from **interface_stats_now** but has not yet been committed to **interface_stats_history**. It typically only contains a few minutes worth of data.

- **interface_stats_history** is a regular table that stores statistical interface metrics. It is pre-partitioned into monthly partitions. Partitions are automatically added in one month increments as needed.

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>interface_name</td>
<td>string</td>
<td>Name of the interface. For example: eth0, eth1, lo.</td>
</tr>
<tr>
<td>bytes_received</td>
<td>bigint</td>
<td>Amount of data received in bytes.</td>
</tr>
<tr>
<td>packets_received</td>
<td>bigint</td>
<td>Number of packets received.</td>
</tr>
<tr>
<td>receive_errors</td>
<td>bigint</td>
<td>Number of errors encountered while data was being received.</td>
</tr>
<tr>
<td>receive_drops</td>
<td>bigint</td>
<td>Number of times packets were dropped while data was being received.</td>
</tr>
<tr>
<td>receive_fifo_errors</td>
<td>bigint</td>
<td>Number of times FIFO (first in first out) errors were encountered while data was being received.</td>
</tr>
<tr>
<td>receive_frame_errors</td>
<td>bigint</td>
<td>Number of frame errors while data was being received.</td>
</tr>
<tr>
<td>receive_compressed_packets</td>
<td>int</td>
<td>Number of packets received in compressed format.</td>
</tr>
<tr>
<td>receive_multicast_packets</td>
<td>int</td>
<td>Number of multicast packets received.</td>
</tr>
<tr>
<td>bytes_transmitted</td>
<td>bigint</td>
<td>Amount of data transmitted in bytes.</td>
</tr>
<tr>
<td>packets_transmitted</td>
<td>bigint</td>
<td>Amount of data transmitted in bytes.</td>
</tr>
<tr>
<td>packets_transmitted</td>
<td>bigint</td>
<td>Number of packets transmitted.</td>
</tr>
<tr>
<td>transmit_errors</td>
<td>bigint</td>
<td>Number of errors encountered during data transmission.</td>
</tr>
<tr>
<td>transmit_drops</td>
<td>bigint</td>
<td>Number of times packets were dropped during data transmission.</td>
</tr>
<tr>
<td>transmit_fifo_errors</td>
<td>bigint</td>
<td>Number of times fifo errors were encountered during data transmission.</td>
</tr>
<tr>
<td>transmit_collision_errors</td>
<td>bigint</td>
<td>Number of times collision errors were encountered during data transmission.</td>
</tr>
<tr>
<td>transmit_carrier_errors</td>
<td>bigint</td>
<td>Number of times carrier errors were encountered during data transmission.</td>
</tr>
<tr>
<td>Column</td>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>transmit_compressed_packets</td>
<td>int</td>
<td>Number of packets transmitted in compressed format.</td>
</tr>
</tbody>
</table>

**log_alert***

The log_alert* tables store pg_log errors and warnings.

See Alert Log Processing and Log Rotation for information about configuring the system logger for gpperfmon.

There are three log_alert tables, all having the same columns:

- **log_alert_now** is an external table whose data is stored in .csv files in the $MASTER_DATA_DIRECTORY/gpperfmon/logs directory. Current pg_log errors and warnings data are available in log_alert_now during the period between data collection from the gpperfmon agents and automatic commitment to the log_alert_history table.

- **log_alert_tail** is an external table with data stored in $MASTER_DATA_DIRECTORY/gpperfmon/logs/alert_log_stage. This is a transitional table for data that has been cleared from log_alert_now but has not yet been committed to log_alert_history. The table includes records from all alert logs except the most recent. It typically contains only a few minutes' worth of data.

- **log_alert_history** is a regular table that stores historical database-wide errors and warnings data. It is pre-partitioned into monthly partitions. Partitions are automatically added in two month increments as needed.

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>logtime</td>
<td>timestamp with time zone</td>
<td>Timestamp for this log</td>
</tr>
<tr>
<td>loguser</td>
<td>text</td>
<td>User of the query</td>
</tr>
<tr>
<td>logdatabase</td>
<td>text</td>
<td>The accessed database</td>
</tr>
<tr>
<td>logpid</td>
<td>text</td>
<td>Process id</td>
</tr>
<tr>
<td>logthread</td>
<td>text</td>
<td>Thread number</td>
</tr>
<tr>
<td>loghost</td>
<td>text</td>
<td>Host name or ip address</td>
</tr>
<tr>
<td>logport</td>
<td>text</td>
<td>Port number</td>
</tr>
<tr>
<td>logsessiontime</td>
<td>timestamp with time zone</td>
<td>Session timestamp</td>
</tr>
<tr>
<td>logtransaction</td>
<td>integer</td>
<td>Transaction id</td>
</tr>
<tr>
<td>logsession</td>
<td>text</td>
<td>Session id</td>
</tr>
<tr>
<td>logcmdcount</td>
<td>text</td>
<td>Command count</td>
</tr>
<tr>
<td>logsegment</td>
<td>text</td>
<td>Segment number</td>
</tr>
<tr>
<td>logslice</td>
<td>text</td>
<td>Slice number</td>
</tr>
<tr>
<td>logdistxact</td>
<td>text</td>
<td>Distributed transaction</td>
</tr>
<tr>
<td>loglocalxact</td>
<td>text</td>
<td>Local transaction</td>
</tr>
<tr>
<td>logsubxact</td>
<td>text</td>
<td>Subtransaction</td>
</tr>
<tr>
<td>logseverity</td>
<td>text</td>
<td>Log severity</td>
</tr>
<tr>
<td>logstate</td>
<td>text</td>
<td>State</td>
</tr>
<tr>
<td>logmessage</td>
<td>text</td>
<td>Log message</td>
</tr>
<tr>
<td>Column</td>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>logdetail</td>
<td>text</td>
<td>Detailed message</td>
</tr>
<tr>
<td>loghint</td>
<td>text</td>
<td>Hint info</td>
</tr>
<tr>
<td>logquery</td>
<td>text</td>
<td>Executed query</td>
</tr>
<tr>
<td>logquerypos</td>
<td>text</td>
<td>Query position</td>
</tr>
<tr>
<td>logcontext</td>
<td>text</td>
<td>Context info</td>
</tr>
<tr>
<td>logdebug</td>
<td>text</td>
<td>Debug</td>
</tr>
<tr>
<td>logcursorpos</td>
<td>text</td>
<td>Cursor position</td>
</tr>
<tr>
<td>logfunction</td>
<td>text</td>
<td>Function info</td>
</tr>
<tr>
<td>logfile</td>
<td>text</td>
<td>Source code file</td>
</tr>
<tr>
<td>logline</td>
<td>text</td>
<td>Source code line</td>
</tr>
<tr>
<td>logstack</td>
<td>text</td>
<td>Stack trace</td>
</tr>
</tbody>
</table>

**queries_***

The queries_* tables store high-level query status information. The tmid, ssid and ccnt columns are the composite key that uniquely identifies a particular query.

There are three queries tables, all having the same columns:

- **queries_now** is an external table whose data files are stored in $MASTER_DATA_DIRECTORY/gpperfmon/data. Current query status is stored in queries_now during the period between data collection from the gpperfmon agents and automatic commitment to the queries_history table.
- **queries_tail** is an external table whose data files are stored in $MASTER_DATA_DIRECTORY/gpperfmon/data. This is a transitional table for query status data that has been cleared from queries_now but has not yet been committed to queries_history. It typically only contains a few minutes worth of data.
- **queries_history** is a regular table that stores historical query status data. It is pre-partitioned into monthly partitions. Partitions are automatically added in two month increments as needed.

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ctime</td>
<td>timestamp</td>
<td>Time this row was created.</td>
</tr>
<tr>
<td>tmid</td>
<td>int</td>
<td>A time identifier for a particular query. All records associated with the query will have the same tmid.</td>
</tr>
<tr>
<td>ssid</td>
<td>int</td>
<td>The session id as shown by gp_session_id. All records associated with the query will have the same ssid.</td>
</tr>
<tr>
<td>ccnt</td>
<td>int</td>
<td>The command number within this session as shown by gp_command_count. All records associated with the query will have the same ccnt.</td>
</tr>
<tr>
<td>Column</td>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>username</td>
<td>varchar(64)</td>
<td>Greenplum role name that issued this query.</td>
</tr>
<tr>
<td>db</td>
<td>varchar(64)</td>
<td>Name of the database queried.</td>
</tr>
<tr>
<td>cost</td>
<td>int</td>
<td>Not implemented in this release.</td>
</tr>
<tr>
<td>tsubmit</td>
<td>timestamp</td>
<td>Time the query was submitted.</td>
</tr>
<tr>
<td>tstart</td>
<td>timestamp</td>
<td>Time the query was started.</td>
</tr>
<tr>
<td>tfinish</td>
<td>timestamp</td>
<td>Time the query finished.</td>
</tr>
<tr>
<td>status</td>
<td>varchar(64)</td>
<td>Status of the query -- start, done, or abort.</td>
</tr>
<tr>
<td>rows_out</td>
<td>bigint</td>
<td>Rows out for the query.</td>
</tr>
<tr>
<td>cpu_elapsed</td>
<td>bigint</td>
<td>CPU usage by all processes across all segments executing this query (in seconds). It is the sum of the CPU usage values taken from all active primary segments in the database system. Note that the value is logged as 0 if the query runtime is shorter than the value for the quantum. This occurs even if the query runtime is greater than the value for min_query_time, and this value is lower than the value for the quantum.</td>
</tr>
<tr>
<td>cpu_currpct</td>
<td>float</td>
<td>Current CPU percent average for all processes executing this query. The percentages for all processes running on each segment are averaged, and then the average of all those values is calculated to render this metric. Current CPU percent average is always zero in historical and tail data.</td>
</tr>
<tr>
<td>Column</td>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>----------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>skew_cpu</td>
<td>float</td>
<td>Displays the amount of processing skew in the system for this query. Processing/CPU skew occurs when one segment performs a disproportionate amount of processing for a query. This value is the coefficient of variation in the CPU% metric across all segments for this query, multiplied by 100. For example, a value of .95 is shown as 95.</td>
</tr>
<tr>
<td>skew_rows</td>
<td>float</td>
<td>Displays the amount of row skew in the system. Row skew occurs when one segment produces a disproportionate number of rows for a query. This value is the coefficient of variation for the rows_in metric across all segments for this query, multiplied by 100. For example, a value of .95 is shown as 95.</td>
</tr>
<tr>
<td>query_hash</td>
<td>bigint</td>
<td>Not implemented in this release.</td>
</tr>
<tr>
<td>query_text</td>
<td>text</td>
<td>The SQL text of this query.</td>
</tr>
<tr>
<td>query_plan</td>
<td>text</td>
<td>Text of the query plan. Not implemented in this release.</td>
</tr>
<tr>
<td>application_name</td>
<td>varchar(64)</td>
<td>The name of the application.</td>
</tr>
<tr>
<td>rsqname</td>
<td>varchar(64)</td>
<td>If the resource queue-based resource management scheme is active, this column specifies the name of the resource queue.</td>
</tr>
<tr>
<td>rqppriority</td>
<td>varchar(64)</td>
<td>If the resource queue-based resource management scheme is active, this column specifies the priority of the query -- max, high, med, low, or min.</td>
</tr>
</tbody>
</table>

### segment_*

The `segment_*` tables contain memory allocation statistics for the Greenplum Database segment instances. This tracks the amount of memory consumed by all postgres processes of a particular segment instance, and the remaining amount of memory available to a segment as per the settings configured by the currently active resource management scheme (resource group-based or resource queue-based). See the *Greenplum Database Administrator Guide* for more information about resource management schemes.

There are three segment tables, all having the same columns:

- `segment_now` is an external table whose data files are stored in `$MASTER_DATA_DIRECTORY/gpperfmon/data`. Current memory allocation data is stored in `segment_now` during the
period between data collection from the gpperfmon agents and automatic commitment to the segment_history table.

- **segment_tail** is an external table whose data files are stored in $MASTER_DATA_DIRECTORY/gpperfmon/data. This is a transitional table for memory allocation data that has been cleared from segment_now but has not yet been committed to segment_history. It typically only contains a few minutes worth of data.

- **segment_history** is a regular table that stores historical memory allocation metrics. It is pre-partitioned into monthly partitions. Partitions are automatically added in two month increments as needed.

A particular segment instance is identified by its hostname and dbid (the unique segment identifier as per the gp_segment_configuration system catalog table).

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ctime</td>
<td>timestamp(0) (without time zone)</td>
<td>The time the row was created.</td>
</tr>
<tr>
<td>dbid</td>
<td>int</td>
<td>The segment ID (dbid from gp_segment_configuration).</td>
</tr>
<tr>
<td>hostname</td>
<td>charvar(64)</td>
<td>The segment hostname.</td>
</tr>
<tr>
<td>dynamic_memory_used</td>
<td>bigint</td>
<td>The amount of dynamic memory (in bytes) allocated to query processes running on this segment.</td>
</tr>
<tr>
<td>dynamic_memory_available</td>
<td>bigint</td>
<td>The amount of additional dynamic memory (in bytes) that the segment can request before reaching the limit set by the currently active resource management scheme (resource group-based or resource queue-based).</td>
</tr>
</tbody>
</table>

See also the views memory_info and dynamic_memory_info for aggregated memory allocation and utilization by host.

**socket_stats_**

The socket_stats_ tables store statistical metrics about socket usage for a Greenplum Database instance. There are three system tables, all having the same columns:

These tables are in place for future use and are not currently populated.

- **socket_stats_now** is an external table whose data files are stored in $MASTER_DATA_DIRECTORY/gpperfmon/data.
- **socket_stats_tail** is an external table whose data files are stored in $MASTER_DATA_DIRECTORY/gpperfmon/data. This is a transitional table for socket statistical metrics that has been cleared from socket_stats_now but has not yet been committed to socket_stats_history. It typically only contains a few minutes worth of data.
- **socket_stats_history** is a regular table that stores historical socket statistical metrics. It is pre-partitioned into monthly partitions. Partitions are automatically added in two month increments as needed.
### Column Type Description

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>total_sockets_used</td>
<td>int</td>
<td>Total sockets used in the system.</td>
</tr>
<tr>
<td>tcp_sockets_inuse</td>
<td>int</td>
<td>Number of TCP sockets in use.</td>
</tr>
<tr>
<td>tcp_sockets_orphan</td>
<td>int</td>
<td>Number of TCP sockets orphaned.</td>
</tr>
<tr>
<td>tcp_sockets_timewait</td>
<td>int</td>
<td>Number of TCP sockets in Time-Wait.</td>
</tr>
<tr>
<td>tcp_sockets.alloc</td>
<td>int</td>
<td>Number of TCP sockets allocated.</td>
</tr>
<tr>
<td>tcp_sockets_memusage_inbytes</td>
<td>int</td>
<td>Amount of memory consumed by TCP sockets.</td>
</tr>
<tr>
<td>udp_sockets_inuse</td>
<td>int</td>
<td>Number of UDP sockets in use.</td>
</tr>
<tr>
<td>udp_sockets_memusage_inbytes</td>
<td>int</td>
<td>Amount of memory consumed by UDP sockets.</td>
</tr>
<tr>
<td>raw_sockets_inuse</td>
<td>int</td>
<td>Number of RAW sockets in use.</td>
</tr>
<tr>
<td>frag_sockets_inuse</td>
<td>int</td>
<td>Number of FRAG sockets in use.</td>
</tr>
<tr>
<td>frag_sockets_memusage_inbytes</td>
<td>int</td>
<td>Amount of memory consumed by FRAG sockets.</td>
</tr>
</tbody>
</table>

**system_***

The `system_*` tables store system utilization metrics. There are three system tables, all having the same columns:

- **system_now** is an external table whose data files are stored in `$MASTER_DATA_DIRECTORY/gpperfmon/data`. Current system utilization data is stored in `system_now` during the period between data collection from the `gpperfmon` agents and automatic commitment to the `system_history` table.
- **system_tail** is an external table whose data files are stored in `$MASTER_DATA_DIRECTORY/gpperfmon/data`. This is a transitional table for system utilization data that has been cleared from `system_now` but has not yet been committed to `system_history`. It typically only contains a few minutes worth of data.
- **system_history** is a regular table that stores historical system utilization metrics. It is pre-partitioned into monthly partitions. Partitions are automatically added in two month increments as needed.

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ctime</td>
<td>timestamp</td>
<td>Time this row was created.</td>
</tr>
<tr>
<td>hostname</td>
<td>varchar(64)</td>
<td>Segment or master hostname associated with these system metrics.</td>
</tr>
<tr>
<td>mem_total</td>
<td>bigint</td>
<td>Total system memory in Bytes for this host.</td>
</tr>
<tr>
<td>mem_used</td>
<td>bigint</td>
<td>Used system memory in Bytes for this host.</td>
</tr>
<tr>
<td><strong>Column</strong></td>
<td><strong>Type</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>mem_actual_used</td>
<td>bigint</td>
<td>Used actual memory in Bytes for this host (not including the memory reserved for cache and buffers).</td>
</tr>
<tr>
<td>mem_actual_free</td>
<td>bigint</td>
<td>Free actual memory in Bytes for this host (not including the memory reserved for cache and buffers).</td>
</tr>
<tr>
<td>swap_total</td>
<td>bigint</td>
<td>Total swap space in Bytes for this host.</td>
</tr>
<tr>
<td>swap_used</td>
<td>bigint</td>
<td>Used swap space in Bytes for this host.</td>
</tr>
<tr>
<td>swap_page_in</td>
<td>bigint</td>
<td>Number of swap pages in.</td>
</tr>
<tr>
<td>swap_page_out</td>
<td>bigint</td>
<td>Number of swap pages out.</td>
</tr>
<tr>
<td>cpu_user</td>
<td>float</td>
<td>CPU usage by the Greenplum system user.</td>
</tr>
<tr>
<td>cpu_sys</td>
<td>float</td>
<td>CPU usage for this host.</td>
</tr>
<tr>
<td>cpu_idle</td>
<td>float</td>
<td>Idle CPU capacity at metric collection time.</td>
</tr>
<tr>
<td>load0</td>
<td>float</td>
<td>CPU load average for the prior one-minute period.</td>
</tr>
<tr>
<td>load1</td>
<td>float</td>
<td>CPU load average for the prior five-minute period.</td>
</tr>
<tr>
<td>load2</td>
<td>float</td>
<td>CPU load average for the prior fifteen-minute period.</td>
</tr>
<tr>
<td>quantum</td>
<td>int</td>
<td>Interval between metric collection for this metric entry.</td>
</tr>
<tr>
<td>disk_ro_rate</td>
<td>bigint</td>
<td>Disk read operations per second.</td>
</tr>
<tr>
<td>disk_wo_rate</td>
<td>bigint</td>
<td>Disk write operations per second.</td>
</tr>
<tr>
<td>disk_rb_rate</td>
<td>bigint</td>
<td>Bytes per second for disk read operations.</td>
</tr>
<tr>
<td>disk_wb_rate</td>
<td>bigint</td>
<td>Bytes per second for disk write operations.</td>
</tr>
<tr>
<td>net_rp_rate</td>
<td>bigint</td>
<td>Packets per second on the system network for read operations.</td>
</tr>
<tr>
<td>net_wp_rate</td>
<td>bigint</td>
<td>Packets per second on the system network for write operations.</td>
</tr>
<tr>
<td>net_rb_rate</td>
<td>bigint</td>
<td>Bytes per second on the system network for read operations.</td>
</tr>
<tr>
<td>Column</td>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>net_wb_rate</td>
<td>bigint</td>
<td>Bytes per second on the system network for write operations.</td>
</tr>
</tbody>
</table>

**dynamic_memory_info**

The **dynamic_memory_info** view shows a sum of the used and available dynamic memory for all segment instances on a segment host. Dynamic memory refers to the maximum amount of memory that Greenplum Database instance will allow the query processes of a single segment instance to consume before it starts cancelling processes. This limit, determined by the currently active resource management scheme (resource group-based or resource queue-based), is evaluated on a per-segment basis.

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ctime</td>
<td>timestamp(0) without time zone</td>
<td>Time this row was created in the segment_history table.</td>
</tr>
<tr>
<td>hostname</td>
<td>varchar(64)</td>
<td>Segment or master hostname associated with these system memory metrics.</td>
</tr>
<tr>
<td>dynamic_memory_used_mb</td>
<td>numeric</td>
<td>The amount of dynamic memory in MB allocated to query processes running on this segment.</td>
</tr>
<tr>
<td>dynamic_memory_available_mb</td>
<td>numeric</td>
<td>The amount of additional dynamic memory (in MB) available to the query processes running on this segment host. Note that this value is a sum of the available memory for all segments on a host. Even though this value reports available memory, it is possible that one or more segments on the host have exceeded their memory limit.</td>
</tr>
</tbody>
</table>

**memory_info**

The **memory_info** view shows per-host memory information from the system_history and segment_history tables. This allows administrators to compare the total memory available on a segment host, total memory used on a segment host, and dynamic memory used by query processes.

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ctime</td>
<td>timestamp(0) without time zone</td>
<td>Time this row was created in the segment_history table.</td>
</tr>
<tr>
<td>hostname</td>
<td>varchar(64)</td>
<td>Segment or master hostname associated with these system memory metrics.</td>
</tr>
<tr>
<td>mem_total_mb</td>
<td>numeric</td>
<td>Total system memory in MB for this segment host.</td>
</tr>
<tr>
<td>mem_used_mb</td>
<td>numeric</td>
<td>Total system memory used in MB for this segment host.</td>
</tr>
<tr>
<td>Column</td>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>---------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>mem_actual_used_mb</td>
<td>numeric</td>
<td>Actual system memory used in MB for this segment host.</td>
</tr>
<tr>
<td>mem_actual_free_mb</td>
<td>numeric</td>
<td>Actual system memory free in MB for this segment host.</td>
</tr>
<tr>
<td>swap_total_mb</td>
<td>numeric</td>
<td>Total swap space in MB for this segment host.</td>
</tr>
<tr>
<td>swap_used_mb</td>
<td>numeric</td>
<td>Total swap space used in MB for this segment host.</td>
</tr>
<tr>
<td>dynamic_memory_used_mb</td>
<td>numeric</td>
<td>The amount of dynamic memory in MB allocated to query processes running on this segment.</td>
</tr>
<tr>
<td>dynamic_memory_available_mb</td>
<td>numeric</td>
<td>The amount of additional dynamic memory (in MB) available to the query processes running on this segment host. Note that this value is a sum of the available memory for all segments on a host. Even though this value reports available memory, it is possible that one or more segments on the host have exceeded their memory limit.</td>
</tr>
</tbody>
</table>
Greenplum Database Data Types

Greenplum Database has a rich set of native data types available to users. Users may also define new data types using the `CREATE TYPE` command. This reference shows all of the built-in data types. In addition to the types listed here, there are also some internally used data types, such as `oid` (object identifier), but those are not documented in this guide.

Optional modules in the `contrib` directory may also install new data types. The `hstore` module, for example, introduces a new data type and associated functions for working with key-value pairs. See `hstore` Functions. The `citext` module adds a case-insensitive text data type. See `citext` Data Type.

The following data types are specified by SQL: `bit`, `bit varying`, `boolean`, `character varying`, `varchar`, `character`, `char`, `date`, `double precision`, `integer`, `interval`, `numeric`, `decimal`, `real`, `smallint`, `time` (with or without time zone), and `timestamp` (with or without time zone).

Each data type has an external representation determined by its input and output functions. Many of the built-in types have obvious external formats. However, several types are either unique to PostgreSQL (and Greenplum Database), such as geometric paths, or have several possibilities for formats, such as the date and time types. Some of the input and output functions are not invertible. That is, the result of an output function may lose accuracy when compared to the original input.

Table 233: Greenplum Database Built-in Data Types

<table>
<thead>
<tr>
<th>Name</th>
<th>Alias</th>
<th>Size</th>
<th>Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bigint</td>
<td>int8</td>
<td>8 bytes</td>
<td>-922337203 to 922337203</td>
<td>large range integer</td>
</tr>
<tr>
<td>bigserial</td>
<td>serial8</td>
<td>8 bytes</td>
<td>1 to 922337203</td>
<td>large autoincrementing integer</td>
</tr>
<tr>
<td>bit [ (n) ]</td>
<td></td>
<td></td>
<td>n bits</td>
<td><code>bit string constant</code></td>
</tr>
<tr>
<td>bit varying</td>
<td>varbit</td>
<td>actual number of bits</td>
<td><code>bit string constant</code></td>
<td></td>
</tr>
<tr>
<td>boolean</td>
<td>bool</td>
<td>1 byte</td>
<td>true/false, t/f, yes/no, y/n, 1/0</td>
<td>logical boolean (true/false)</td>
</tr>
<tr>
<td>box</td>
<td></td>
<td>32 bytes</td>
<td>((x1,y1),(x2,y2))</td>
<td>rectangular box in the plane - not allowed in distribution key columns.</td>
</tr>
<tr>
<td>bytea</td>
<td></td>
<td>1 byte + binary string</td>
<td>sequence of octets</td>
<td></td>
</tr>
<tr>
<td>character</td>
<td>char [ (n) ]</td>
<td>1 byte + n</td>
<td>strings up to n characters in length</td>
<td></td>
</tr>
</tbody>
</table>

9 For variable length data types, if the data is greater than or equal to 127 bytes, the storage overhead is 4 bytes instead of 1.
<table>
<thead>
<tr>
<th>Name</th>
<th>Alias</th>
<th>Size</th>
<th>Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>character varying { (n) }</td>
<td>varchar [ (n) ]</td>
<td>1 byte + string size</td>
<td>strings up to n characters in length</td>
<td>variable-length with limit</td>
</tr>
<tr>
<td>cidr</td>
<td></td>
<td>12 or 24 bytes</td>
<td></td>
<td>IPv4 and IPv6 networks</td>
</tr>
<tr>
<td>circle</td>
<td></td>
<td>24 bytes</td>
<td>&lt;(x,y),r&gt; (center and radius)</td>
<td>circle in the plane - not allowed in distribution key columns.</td>
</tr>
<tr>
<td>date</td>
<td></td>
<td>4 bytes</td>
<td>4713 BC - 294,277 AD</td>
<td>calendar date (year, month, day)</td>
</tr>
<tr>
<td>decimal [ (p, s) ]</td>
<td>numeric [ (p, s) ]</td>
<td>variable</td>
<td>no limit</td>
<td>user-specified precision, exact</td>
</tr>
<tr>
<td>double precision</td>
<td>float8</td>
<td>8 bytes</td>
<td>15 decimal digits precision</td>
<td>variable-precision, inexact</td>
</tr>
<tr>
<td>inet</td>
<td>int, int4</td>
<td>12 or 24 bytes</td>
<td></td>
<td>IPv4 and IPv6 hosts and networks</td>
</tr>
<tr>
<td>integer</td>
<td></td>
<td>4 bytes</td>
<td>-2147483648 to +2147483647</td>
<td>usual choice for integer</td>
</tr>
<tr>
<td>interval [ (p) ]</td>
<td></td>
<td>12 bytes</td>
<td>-178000000 years - 178000000 years</td>
<td>time span</td>
</tr>
<tr>
<td>json</td>
<td></td>
<td>1 byte + json size</td>
<td>json of any length</td>
<td>variable unlimited length</td>
</tr>
<tr>
<td>lseg</td>
<td></td>
<td>32 bytes</td>
<td>((x1,y1),(x2,y2))</td>
<td>line segment in the plane - not allowed in distribution key columns.</td>
</tr>
<tr>
<td>macaddr</td>
<td></td>
<td>6 bytes</td>
<td></td>
<td>MAC addresses</td>
</tr>
<tr>
<td>money</td>
<td></td>
<td>8 bytes</td>
<td>-9223372036854775.08 to +9223372036854775.07</td>
<td>currency amount</td>
</tr>
<tr>
<td>path</td>
<td></td>
<td>16+16n bytes</td>
<td>[(x1,y1),....]</td>
<td>geometric path in the plane - not allowed in distribution key columns.</td>
</tr>
<tr>
<td>point</td>
<td></td>
<td>16 bytes</td>
<td>(x,y)</td>
<td>geometric point in the plane - not allowed in distribution key columns.</td>
</tr>
<tr>
<td>Name</td>
<td>Alias</td>
<td>Size</td>
<td>Range</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
<td>----------------</td>
<td>---------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>polygon</td>
<td></td>
<td>40+16n bytes</td>
<td>((x1,y1),...)</td>
<td>closed geometric path in the plane - not allowed in distribution key columns.</td>
</tr>
<tr>
<td>real</td>
<td>float4</td>
<td>4 bytes</td>
<td>6 decimal digits precision</td>
<td>variable-precision, inexact</td>
</tr>
<tr>
<td>serial</td>
<td>serial4</td>
<td>4 bytes</td>
<td>1 to 2147483647</td>
<td>autoincrementing integer</td>
</tr>
<tr>
<td>smallint</td>
<td>int2</td>
<td>2 bytes</td>
<td>-32768 to +32767</td>
<td>small range integer</td>
</tr>
<tr>
<td>text</td>
<td></td>
<td>1 byte + string size</td>
<td>strings of any length</td>
<td>variable unlimited length</td>
</tr>
<tr>
<td>time</td>
<td></td>
<td>8 bytes</td>
<td>00:00:00[.000000] - 24:00:00[.000000]</td>
<td>time of day only</td>
</tr>
<tr>
<td>time zone</td>
<td></td>
<td></td>
<td></td>
<td>time of day only, with time zone</td>
</tr>
<tr>
<td>timestamp</td>
<td></td>
<td>8 bytes</td>
<td>4713 BC - 294,277 AD</td>
<td>both date and time</td>
</tr>
<tr>
<td>timestamp</td>
<td></td>
<td>8 bytes</td>
<td>4713 BC - 294,277 AD</td>
<td>both date and time, with time zone</td>
</tr>
<tr>
<td>uuid</td>
<td></td>
<td>32 bytes</td>
<td></td>
<td>Universally Unique Identifiers according to RFC 4122, ISO/IEC 9834-8:2005</td>
</tr>
<tr>
<td>xml</td>
<td></td>
<td>1 byte + xml size</td>
<td>xml of any length</td>
<td>variable unlimited length</td>
</tr>
<tr>
<td>txid_snapshot</td>
<td></td>
<td></td>
<td></td>
<td>user-level transaction ID snapshot</td>
</tr>
</tbody>
</table>

Pseudo-Types

Greenplum Database supports special-purpose data type entries that are collectively called *pseudo-types*. A pseudo-type cannot be used as a column data type, but it can be used to declare a function's argument or result type. Each of the available pseudo-types is useful in situations where a function's behavior does not correspond to simply taking or returning a value of a specific SQL data type.

Functions coded in procedural languages can use pseudo-types only as allowed by their implementation languages. The procedural languages all forbid use of a pseudo-type as an argument type, and allow only `void` and `record` as a result type.

A function with the pseudo-type `record` as a return data type returns an unspecified row type. The `record` represents an array of possibly-anonymous composite types. Since composite datums carry their own type identification, no extra knowledge is needed at the array level.

The pseudo-type `void` indicates that a function returns no value.

*Note:* Greenplum Database does not support triggers and the pseudo-type `trigger`.
The types *anyelement*, *anyarray*, *anynonarray*, and *anyenum* are pseudo-types called polymorphic types. Some procedural languages also support polymorphic functions using the types *anyarray*, *anyelement*, *anyenum*, and *anynonarray*.

For more information about pseudo-types, see the Postgres documentation about *Pseudo-Types*.

**Polymorphic Types**

Four pseudo-types types of special interest are *anyelement*, *anyarray*, *anynonarray*, and *anyenum*, which are collectively called *polymorphic* types. Any function declared using these types is said to be a polymorphic function. A polymorphic function can operate on many different data types, with the specific data types being determined by the data types actually passed to it at runtime.

Polymorphic arguments and results are tied to each other and are resolved to a specific data type when a query calling a polymorphic function is parsed. Each position (either argument or return value) declared as *anyelement* is allowed to have any specific actual data type, but in any given call they must all be the same actual type. Each position declared as *anyarray* can have any array data type, but similarly they must all be the same type. If there are positions declared *anynonarray* and others declared *anyelement*, the actual array type in the *anyarray* positions must be an array whose elements are the same type appearing in the *anyelement* positions. *anynonarray* is treated exactly the same as *anyelement*, but adds the additional constraint that the actual type must not be an array type. *anyenum* is treated exactly the same as *anyelement*, but adds the additional constraint that the actual type must be an *enum* type.

When more than one argument position is declared with a polymorphic type, the net effect is that only certain combinations of actual argument types are allowed. For example, a function declared as `equal(anyelement, anyelement)` takes any two input values, so long as they are of the same data type.

When the return value of a function is declared as a polymorphic type, there must be at least one argument position that is also polymorphic, and the actual data type supplied as the argument determines the actual result type for that call. For example, if there were not already an array subcripting mechanism, one could define a function that implements subscripting as `subscript(anyarray, integer) returns anyelement`. This declaration constrains the actual first argument to be an array type, and allows the parser to infer the correct result type from the actual first argument's type. Another example is that a function declared as `myfunc(anyarray) returns anyenum` will only accept arrays of *enum* types.

Note that *anynonarray* and *anyenum* do not represent separate type variables; they are the same type as *anyelement*, just with an additional constraint. For example, declaring a function as `myfunc(anyelement, anyenum)` is equivalent to declaring it as `myfunc(anyenum, anyenum)`: both actual arguments must be the same *enum* type.

A variadic function (one taking a variable number of arguments) is polymorphic when its last parameter is declared as VARIADIC *anyarray*. For purposes of argument matching and determining the actual result type, such a function behaves the same as if you had declared the appropriate number of *anynonarray* parameters.

For more information about polymorphic types, see the Postgres documentation about *Polymorphic Arguments and Return Types*. 


Character Set Support

The character set support in Greenplum Database allows you to store text in a variety of character sets, including single-byte character sets such as the ISO 8859 series and multiple-byte character sets such as EUC (Extended Unix Code), UTF-8, and Mule internal code. All supported character sets can be used transparently by clients, but a few are not supported for use within the server (that is, as a server-side encoding). The default character set is selected while initializing your Greenplum Database array using `gpinitsystem`. It can be overridden when you create a database, so you can have multiple databases each with a different character set.

Table 234: Greenplum Database Character Sets

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Language</th>
<th>Server?</th>
<th>Bytes/Char</th>
<th>Aliases</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIG5</td>
<td>Big Five</td>
<td>Traditional Chinese</td>
<td>No</td>
<td>1-2</td>
<td>WIN950, Windows950</td>
</tr>
<tr>
<td>EUC_CN</td>
<td>Extended UNIX Code-CN</td>
<td>Simplified Chinese</td>
<td>Yes</td>
<td>1-3</td>
<td></td>
</tr>
<tr>
<td>EUC_TW</td>
<td>Extended UNIX Code-TW</td>
<td>Traditional Chinese, Taiwanese</td>
<td>Yes</td>
<td>1-3</td>
<td></td>
</tr>
<tr>
<td>GB18030</td>
<td>National Standard</td>
<td>Chinese</td>
<td>No</td>
<td>1-2</td>
<td></td>
</tr>
<tr>
<td>GBK</td>
<td>Extended National Standard</td>
<td>Simplified Chinese</td>
<td>No</td>
<td>1-2</td>
<td>WIN936, Windows936</td>
</tr>
<tr>
<td>ISO_8859_5</td>
<td>ISO 8859-5, ECMA 113</td>
<td>Latin/Cyrillic</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>ISO_8859_6</td>
<td>ISO 8859-6, ECMA 114</td>
<td>Latin/Arabic</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>ISO_8859_7</td>
<td>ISO 8859-7, ECMA 118</td>
<td>Latin/Greek</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>ISO_8859_8</td>
<td>ISO 8859-8, ECMA 121</td>
<td>Latin/Hebrew</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>JOHAB</td>
<td>JOHA</td>
<td>Korean (Hangul)</td>
<td>Yes</td>
<td>1-3</td>
<td></td>
</tr>
<tr>
<td>KOI8</td>
<td>KOI8-R(U)</td>
<td>Cyrillic</td>
<td>Yes</td>
<td>1</td>
<td>KOI8R</td>
</tr>
<tr>
<td>LATIN1</td>
<td>ISO 8859-1, ECMA 94</td>
<td>Western European</td>
<td>Yes</td>
<td>1</td>
<td>ISO88591</td>
</tr>
</tbody>
</table>

Not all APIs support all the listed character sets. For example, the JDBC driver does not support MULE_INTERNAL, LATIN6, LATIN8, and LATIN10.
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Language</th>
<th>Server?</th>
<th>Bytes/Char</th>
<th>Aliases</th>
</tr>
</thead>
<tbody>
<tr>
<td>LATIN2</td>
<td>ISO 8859-2, ECMA 94</td>
<td>Central European</td>
<td>Yes</td>
<td>1</td>
<td>ISO88592</td>
</tr>
<tr>
<td>LATIN3</td>
<td>ISO 8859-3, ECMA 94</td>
<td>South European</td>
<td>Yes</td>
<td>1</td>
<td>ISO88593</td>
</tr>
<tr>
<td>LATIN4</td>
<td>ISO 8859-4, ECMA 94</td>
<td>North European</td>
<td>Yes</td>
<td>1</td>
<td>ISO88594</td>
</tr>
<tr>
<td>LATIN5</td>
<td>ISO 8859-9, ECMA 128</td>
<td>Turkish</td>
<td>Yes</td>
<td>1</td>
<td>ISO88599</td>
</tr>
<tr>
<td>LATIN6</td>
<td>ISO 8859-10, ECMA 144</td>
<td>Nordic</td>
<td>Yes</td>
<td>1</td>
<td>ISO885910</td>
</tr>
<tr>
<td>LATIN7</td>
<td>ISO 8859-13</td>
<td>Baltic</td>
<td>Yes</td>
<td>1</td>
<td>ISO885913</td>
</tr>
<tr>
<td>LATIN8</td>
<td>ISO 8859-14</td>
<td>Celtic</td>
<td>Yes</td>
<td>1</td>
<td>ISO885914</td>
</tr>
<tr>
<td>LATIN9</td>
<td>ISO 8859-15</td>
<td>LATIN1 with Euro and accents</td>
<td>Yes</td>
<td>1</td>
<td>ISO885915</td>
</tr>
<tr>
<td>LATIN10</td>
<td>ISO 8859-16, ASRO SR 14111</td>
<td>Romanian</td>
<td>Yes</td>
<td>1</td>
<td>ISO885916</td>
</tr>
<tr>
<td>MULE_INTERNAL</td>
<td>Mule internal code</td>
<td>Multilingual Emacs</td>
<td>Yes</td>
<td>1-4</td>
<td></td>
</tr>
<tr>
<td>SJIS</td>
<td>Shift JIS</td>
<td>Japanese</td>
<td>No</td>
<td>1-2</td>
<td>Mskanji, ShiftJIS, WIN932, Windows932</td>
</tr>
<tr>
<td>SQL_ASCII</td>
<td>unspecified</td>
<td>any</td>
<td>No</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>UHC</td>
<td>Unified Hangul Code</td>
<td>Korean</td>
<td>No</td>
<td>1-2</td>
<td>WIN949, Windows949</td>
</tr>
<tr>
<td>UTF8</td>
<td>Unicode, 8-bit</td>
<td>all</td>
<td>Yes</td>
<td>1-4</td>
<td>Unicode</td>
</tr>
<tr>
<td>WIN866</td>
<td>Windows CP866</td>
<td>Cyrillic</td>
<td>Yes</td>
<td>1</td>
<td>ALT</td>
</tr>
<tr>
<td>WIN874</td>
<td>Windows CP874</td>
<td>Thai</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WIN1250</td>
<td>Windows CP1250</td>
<td>Central European</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WIN1251</td>
<td>Windows CP1251</td>
<td>Cyrillic</td>
<td>Yes</td>
<td>1</td>
<td>WIN</td>
</tr>
<tr>
<td>WIN1252</td>
<td>Windows CP1252</td>
<td>Western European</td>
<td>Yes</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

The SQL_ASCII setting behaves considerably differently from the other settings. Byte values 0-127 are interpreted according to the ASCII standard, while byte values 128-255 are taken as uninterpreted characters. If you are working with any non-ASCII data, it is unwise to use the SQL_ASCII setting as a client encoding. SQL_ASCII is not supported as a server encoding.
### Setting the Character Set

gpinitsystem defines the default character set for a Greenplum Database system by reading the setting of the `ENCODING` parameter in the `gp_init_config` file at initialization time. The default character set is `UNICODE` or `UTF8`.

You can create a database with a different character set besides what is used as the system-wide default. For example:

```sql
=> CREATE DATABASE korean WITH ENCODING 'EUC_KR';
```

**Important**: Although you can specify any encoding you want for a database, it is unwise to choose an encoding that is not what is expected by the locale you have selected. The `LC_COLLATE` and `LC_CTYPE` settings imply a particular encoding, and locale-dependent operations (such as sorting) are likely to misinterpret data that is in an incompatible encoding.

Since these locale settings are frozen by gpinitsystem, the apparent flexibility to use different encodings in different databases is more theoretical than real.

One way to use multiple encodings safely is to set the locale to `C` or `POSIX` during initialization time, thus disabling any real locale awareness.

### Character Set Conversion Between Server and Client

Greenplum Database supports automatic character set conversion between server and client for certain character set combinations. The conversion information is stored in the master `pg_conversion` system catalog table. Greenplum Database comes with some predefined conversions or you can create a new conversion using the SQL command `CREATE CONVERSION`.

#### Table 235: Client/Server Character Set Conversions

<table>
<thead>
<tr>
<th>Server Character Set</th>
<th>Available Client Character Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIG5</td>
<td>not supported as a server encoding</td>
</tr>
<tr>
<td>EUC_CN</td>
<td>EUC_CN, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>EUC_JP</td>
<td>EUC_JP, MULE_INTERNAL, SJIS, UTF8</td>
</tr>
<tr>
<td>EUC_KR</td>
<td>EUC_KR, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>Server Character Set</td>
<td>Available Client Character Sets</td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>EUC_TW</td>
<td>EUC_TW, BIG5, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>GB18030</td>
<td>not supported as a server encoding</td>
</tr>
<tr>
<td>GBK</td>
<td>not supported as a server encoding</td>
</tr>
<tr>
<td>ISO_8859_5</td>
<td>ISO_8859_5, KOI8, MULE_INTERNAL, UTF8, WIN866, WIN1251</td>
</tr>
<tr>
<td>ISO_8859_6</td>
<td>ISO_8859_6, UTF8</td>
</tr>
<tr>
<td>ISO_8859_7</td>
<td>ISO_8859_7, UTF8</td>
</tr>
<tr>
<td>ISO_8859_8</td>
<td>ISO_8859_8, UTF8</td>
</tr>
<tr>
<td>JOHAB</td>
<td>JOHAB, UTF8</td>
</tr>
<tr>
<td>KOI8</td>
<td>KOI8, ISO_8859_5, MULE_INTERNAL, UTF8, WIN866, WIN1251</td>
</tr>
<tr>
<td>LATIN1</td>
<td>LATIN1, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>LATIN2</td>
<td>LATIN2, MULE_INTERNAL, UTF8, WIN1250</td>
</tr>
<tr>
<td>LATIN3</td>
<td>LATIN3, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>LATIN4</td>
<td>LATIN4, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>LATIN5</td>
<td>LATIN5, UTF8</td>
</tr>
<tr>
<td>LATIN6</td>
<td>LATIN6, UTF8</td>
</tr>
<tr>
<td>LATIN7</td>
<td>LATIN7, UTF8</td>
</tr>
<tr>
<td>LATIN8</td>
<td>LATIN8, UTF8</td>
</tr>
<tr>
<td>LATIN9</td>
<td>LATIN9, UTF8</td>
</tr>
<tr>
<td>LATIN10</td>
<td>LATIN10, UTF8</td>
</tr>
<tr>
<td>MULE_INTERNAL</td>
<td>MULE_INTERNAL, BIG5, EUC_CN, EUC_JP, EUC_KR, EUC_TW, ISO_8859_5, KOI8, LATIN1 to LATIN4, SJIS, WIN866, WIN1250, WIN1251</td>
</tr>
<tr>
<td>SJIS</td>
<td>not supported as a server encoding</td>
</tr>
<tr>
<td>SQL_ASCII</td>
<td>not supported as a server encoding</td>
</tr>
<tr>
<td>UHC</td>
<td>not supported as a server encoding</td>
</tr>
<tr>
<td>UTF8</td>
<td>all supported encodings</td>
</tr>
<tr>
<td>WIN866</td>
<td>WIN866</td>
</tr>
<tr>
<td>ISO_8859_5</td>
<td>KOI8, MULE_INTERNAL, UTF8, WIN1251</td>
</tr>
<tr>
<td>WIN874</td>
<td>WIN874, UTF8</td>
</tr>
<tr>
<td>WIN1250</td>
<td>WIN1250, LATIN2, MULE_INTERNAL, UTF8</td>
</tr>
<tr>
<td>WIN1251</td>
<td>WIN1251, ISO_8859_5, KOI8, MULE_INTERNAL, UTF8, WIN866</td>
</tr>
<tr>
<td>WIN1252</td>
<td>WIN1252, UTF8</td>
</tr>
<tr>
<td>WIN1253</td>
<td>WIN1253, UTF8</td>
</tr>
</tbody>
</table>
To enable automatic character set conversion, you have to tell Greenplum Database the character set (encoding) you would like to use in the client. There are several ways to accomplish this:

- Using the `\encoding` command in `psql`, which allows you to change client encoding on the fly.
- Using `SET client_encoding TO`.

To set the client encoding, use the following SQL command:

```
=> SET CLIENT_ENCODING TO 'value';
```

To query the current client encoding:

```
=> SHOW client_encoding;
```

To return to the default encoding:

```
=> RESET client_encoding;
```

- Using the `PGCLIENTENCODING` environment variable. When `PGCLIENTENCODING` is defined in the client's environment, that client encoding is automatically selected when a connection to the server is made. (This can subsequently be overridden using any of the other methods mentioned above.)

- Setting the configuration parameter `client_encoding`. If `client_encoding` is set in the master `postgresql.conf` file, that client encoding is automatically selected when a connection to Greenplum Database is made. (This can subsequently be overridden using any of the other methods mentioned above.)

If the conversion of a particular character is not possible “suppose you chose EUC_JP for the server and LATIN1 for the client, then some Japanese characters do not have a representation in LATIN1 “then an error is reported.

If the client character set is defined as `SQL_ASCII`, encoding conversion is disabled, regardless of the server’s character set. The use of `SQL_ASCII` is unwise unless you are working with all-ASCII data. `SQL_ASCII` is not supported as a server encoding.
Server Configuration Parameters

There are many Greenplum server configuration parameters that affect the behavior of the Greenplum Database system. Many of these configuration parameters have the same names, settings, and behaviors as in a regular PostgreSQL database system.

- Parameter Types and Values describes the parameter data types and values.
- Setting Parameters describes limitations on who can change them and where or when they can be set.
- Parameter Categories organizes parameters by functionality.
- Configuration Parameters lists the parameter descriptions in alphabetic order.

Parameter Types and Values

All parameter names are case-insensitive. Every parameter takes a value of one of four types: Boolean, integer, floating point, or string. Boolean values may be written as ON, OFF, TRUE, FALSE, YES, NO, 1, 0 (all case-insensitive).

Some settings specify a memory size or time value. Each of these has an implicit unit, which is either kilobytes, blocks (typically eight kilobytes), milliseconds, seconds, or minutes. Valid memory size units are kB (kilobytes), MB (megabytes), and GB (gigabytes). Valid time units are ms (milliseconds), s (seconds), min (minutes), h (hours), and d (days). Note that the multiplier for memory units is 1024, not 1000. A valid time expression contains a number and a unit. When specifying a memory or time unit using the SET command, enclose the value in quotes. For example:

```
SET statement_mem TO '200MB';
```

**Note:** There is no space between the value and the unit names.

Setting Parameters

Many of the configuration parameters have limitations on who can change them and where or when they can be set. For example, to change certain parameters, you must be a Greenplum Database superuser. Other parameters require a restart of the system for the changes to take effect. A parameter that is classified as session can be set at the system level (in the `postgresql.conf` file), at the database-level (using `ALTER DATABASE`), at the role-level (using `ALTER ROLE`), or at the session-level (using `SET`). System parameters can only be set in the `postgresql.conf` file.

In Greenplum Database, the master and each segment instance has its own `postgresql.conf` file (located in their respective data directories). Some parameters are considered local parameters, meaning that each segment instance looks to its own `postgresql.conf` file to get the value of that parameter. You must set local parameters on every instance in the system (master and segments). Others parameters are considered master parameters. Master parameters need only be set at the master instance.

This table describes the values in the Settable Classifications column of the table in the description of a server configuration parameter.
**Parameter Categories**

Configuration parameters affect categories of server behaviors, such as resource consumption, query tuning, and authentication. The following topics describe Greenplum configuration parameter categories.

- Connection and Authentication Parameters
- System Resource Consumption Parameters
- GPORCA Parameters
- Query Tuning Parameters
- Error Reporting and Logging Parameters
- System Monitoring Parameters
- Runtime Statistics Collection Parameters
Connection and Authentication Parameters

These parameters control how clients connect and authenticate to Greenplum Database.

Connection Parameters

- `gp_connection_send_timeout`
- `gp_vmem_idle_resource_timeout`
- `listen_addresses`
- `max_connections`
- `max_prepared_transactions`
- `superuser_reserved_connections`
- `tcp_keepalives_count`
- `tcp_keepalives_idle`
- `tcp_keepalives_interval`
- `unix_socket_directory`
- `unix_socket_group`
- `unix_socket_permissions`

Security and Authentication Parameters

- `authentication_timeout`
- `db_user_namespace`
- `krb_caseins_users`
- `krb_server_keyfile`
- `krb_srvname`
- `password_encryption`
- `password_hash_algorithm`
- `ssl`
- `ssl_ciphers`

System Resource Consumption Parameters

These parameters set the limits for system resources consumed by Greenplum Database.

Memory Consumption Parameters

These parameters control system memory usage.

- `gp_vmem_idle_resource_timeout`
- `gp_resource_group_memory_limit` (resource group-based resource management)
- `gp_vmem_protect_limit` (resource queue-based resource management)
- `gp_vmem_protect_segworker_cache_limit`
- `gp_workfile_limit_per_query`
- `gp_workfile_limit_per_segment`
- `max_stack_depth`
- `shared_buffers`
- `temp_buffers`
Free Space Map Parameters

These parameters control the sizing of the free space map, which contains expired rows. Use VACUUM to reclaim the free space map disk space.

max_fsm_pages
max_fsm_relations

OS Resource Parameters

max_files_per_process
shared_preload_libraries

Cost-Based Vacuum Delay Parameters

Warning: Do not use cost-based vacuum delay because it runs asynchronously among the segment instances. The vacuum cost limit and delay is invoked at the segment level without taking into account the state of the entire Greenplum Database array.

You can configure the execution cost of VACUUM and ANALYZE commands to reduce the I/O impact on concurrent database activity. When the accumulated cost of I/O operations reaches the limit, the process performing the operation sleeps for a while, then resets the counter and continues execution

vacuum_cost_delay
vacuum_cost_page_hit
vacuum_cost_page_limit
vacuum_cost_page_miss

Transaction ID Management Parameters

xid_stop_limit
xid_warn_limit

GPORCA Parameters

These parameters control the usage of GPORCA by Greenplum Database. For information about GPORCA, see About GPORCA in the Greenplum Database Administrator Guide.

optimizer
optimizer_analyze_root_partition
optimizer_array_expansion_threshold
optimizer_cte_inlining_bound
optimizer_control
optimizer_enable_associativity
optimizer_enable_master_only_queries
optimizer_force_multistage_agg
optimizer_join_arity_for_associativity_commutativity
optimizer_join_order
optimizer_join_order_threshold
optimizer_mdcache_size
optimizer_metadata_caching
optimizer_parallel_union
optimizer_print_missing_stats
optimizer_print_optimization_stats
Query Tuning Parameters
These parameters control aspects of SQL query processing such as query operators and operator settings and statistics sampling.

Legacy Query Optimizer Operator Control Parameters
The following parameters control the types of plan operations the legacy query optimizer can use. Enable or disable plan operations to force the legacy optimizer to choose a different plan. This is useful for testing and comparing query performance using different plan types.

- enable_bitmapscan
- enable_groupagg
- enable_hashagg
- enable_hashjoin
- enable_indexscan
- enable_mergejoin
- enable_nestloop
- enable_seqscan
- enable_sort
- enable_tidscan
- gp_enable_adaptive_nestloop
- gp_enable_agg_distinct

Legacy Query Optimizer Costing Parameters

Warning: Do not adjust these query costing parameters. They are tuned to reflect Greenplum Database hardware configurations and typical workloads. All of these parameters are related. Changing one without changing the others can have adverse affects on performance.

- cpu_index_tuple_cost
- cpu_operator_cost
- cpu_tuple_cost
- cursor_tuple_fraction
- effective_cache_size
- gp_motion_cost_per_row
- gp_segments_for_planner
- random_page_cost
- seq_page_cost

Database Statistics Sampling Parameters
These parameters adjust the amount of data sampled by an ANALYZE operation. Adjusting these parameters affects statistics collection system-wide. You can configure statistics collection on particular tables and columns by using the ALTER TABLE SET STATISTICS clause.

- default_statistics_target
gp_analyze_relative_error

**Sort Operator Configuration Parameters**

gp_enable_sort_distinct
gp_enable_sort_limit

**Aggregate Operator Configuration Parameters**

gp_enable_agg_distinct
gp_enable_agg_distinct_pruning
gp_enable_multiphase_agg
gp_enable_preunique
gp_enable_groupext_distinct_gather
gp_enable_groupext_distinct_pruning
gp_workfile_compress_algorithm

**Join Operator Configuration Parameters**

join_collapse_limit
gp_adjust_selectivity_for_outerjoins
gp_hashjoin_tuples_per_bucket
gp_statistics_use_fkeys
gp_workfile_compress_algorithm

**Other Legacy Query Optimizer Configuration Parameters**

from_collapse_limit
gp_enable_predicate_propagation
gp_max_plan_size
gp_statistics_pullup_from_child_partition

**Query Plan Execution**

Control the query plan execution.

gp_max_slices

**Error Reporting and Logging Parameters**

These configuration parameters control Greenplum Database logging.

**Log Rotation**

log_rotation_age
log_rotation_size

log_truncate_on_rotation

**When to Log**

client_min_messages

log_min_error_statement
What to Log

dbg_pretty_print
dbg_print_parse
dbg_print_plan
dbg_print_prelim_plan
dbg_print_rewritten
dbg_print_slice_table
log_autostats
log_connections
log_disconnections
log_dispatch_stats
log_duration

System Monitoring Parameters
These configuration parameters control Greenplum Database data collection and notifications related to database monitoring.

SNMP Alerts
The following parameters send SNMP notifications when events occur.

gp_snmp_community
gp_snmp_monitor_address
gp_snmp_use_inform_or_trap

Email Alerts
The following parameters configure the system to send email alerts for fatal error events, such as a segment going down or a server crash and reset.

gp_email_from
gp_email_to
gp_email_smtp_password
gp_email_smtp_userid
gp_email_smtp_server

gp_email_smtp_server

Greenplum Command Center Agent
The following parameters configure the data collection agents that populate the gpperfmon database for Greenplum Command Center.

gp_enable_gpperfmon
gpperfmon_log_alert_level
**Runtime Statistics Collection Parameters**

These parameters control the server statistics collection feature. When statistics collection is enabled, you can access the statistics data using the `pg_stat` and `pg_statio` family of system catalog views.

- `stats_queue_level`
- `track_activities`
- `track_counts`
- `update_process_title`

**Automatic Statistics Collection Parameters**

When automatic statistics collection is enabled, you can run `ANALYZE` automatically in the same transaction as an `INSERT`, `UPDATE`, `DELETE`, `COPY` or `CREATE TABLE...AS SELECT` statement when a certain threshold of rows is affected (`on_change`), or when a newly generated table has no statistics (`on_no_stats`). To enable this feature, set the following server configuration parameters in your Greenplum Database master `postgresql.conf` file and restart Greenplum Database:

- `gp_autostats_mode`
- `gp_autostats_mode_in_functions`
- `gp_autostats_on_change_threshold`
- `log_autostats`

**Warning:** Depending on the specific nature of your database operations, automatic statistics collection can have a negative performance impact. Carefully evaluate whether the default setting of `on_no_stats` is appropriate for your system.

**Client Connection Default Parameters**

These configuration parameters set defaults that are used for client connections.

**Statement Behavior Parameters**

- `check_function_bodies`
- `default_tablespace`
- `default_transaction_isolation`
- `default_transaction_read_only`
- `search_path`
- `statement_timeout`
- `vacuum_freeze_min_age`

**Locale and Formatting Parameters**

- `client_encoding`
- `DateStyle`
- `extra_float_digits`
- `IntervalStyle`
- `lc_collate`
- `lc_cctype`
- `lc_messages`
- `lc_monetary`
- `lc_numeric`
- `lc_time`
- `TimeZone`
Other Client Default Parameters

dynamic_library_path
local_preload_libraries
explain_pretty_print

Lock Management Parameters

These configuration parameters set limits for locks and deadlocks.

deadlock_timeout
max_locks_per_transaction

Resource Management Parameters (Resource Queues)

The following configuration parameters configure the Greenplum Database resource management feature (resource queues), query prioritization, memory utilization and concurrency control.

gp_resqueue_memory_policy
max_resource_portals_per_transaction
gp_resqueue_priority
max_statement_mem
gp_resqueue_priority_cpucores_per_segment
resource_cleanup_gangs_on_wait
gp_resqueue_priority_sweeper_interval
resource_select_only
gp_vmem_idle_resource_timeout
runaway_detector_activation_percent
gp_vmem_protect_limit
statement_mem
gp_vmem_protect_segworker_cache_limit
stats_queue_level
max_resource_queues
vmem_process_interrupt

Resource Management Parameters (Resource Groups)

The following parameters configure the Greenplum Database resource group workload management feature.

gp_resgroup_memory_policy
gp_vmem_idle_resource_timeout
gp_resource_group_cpu_limit
gp_vmem_protect_segworker_cache_limit
gp_resource_group_memory_limit
memory_spill_ratio
gp_resource_manager
vmem_process_interrupt

External Table Parameters

The following parameters configure the external tables feature of Greenplum Database.

gp_external_enable_exec
readable_external_table_timeout
gp_external_max_segs
writable_external_table_bufsize
gp_initial_bad_row_limit
verify_gpfdists_cert
gp_reject_percent_threshold
Database Table Parameters
The following parameter configures default option settings for Greenplum Database tables.

- gp_create_table_random_default_distribution
- gp_default_storage_options
- gp_enable_exchange_default_partition
- gp_enable_segment_copy_checking

Append-Optimized Table Parameters
The following parameters configure the append-optimized tables feature of Greenplum Database.

- max_appendonly_tables
- gp_appendonly_compaction
- gp_appendonly_compaction_threshold
- validate_previous_free_tid

Database and Tablespace/Filespace Parameters
The following parameters configure the maximum number of databases, tablespaces, and filespaces allowed in a system.

- gp_max_tablespaces
- gp_max_filespaces
- gp_max_databases

Past Version Compatibility Parameters
The following parameters provide compatibility with older PostgreSQL and Greenplum Database versions. You do not need to change these parameters in Greenplum Database.

PostgreSQL
- add_missing_from
- array_nulls
- backslash_quote
- escape_string_warning
- regex_flavor
- standard_conforming_strings
- transform_null_equals

Greenplum Database
- gp_ignore_error_table

Greenplum Database Array Configuration Parameters
The parameters in this topic control the configuration of the Greenplum Database array and its components: segments, master, distributed transaction manager, master mirror, and interconnect.
**Interconnect Configuration Parameters**

- `gp_interconnect_fc_method`
- `gp_interconnect_hash_multiplier`
- `gp_interconnect_queue_depth`
- `gp_interconnect_setup_timeout`
- `gp_interconnect_snd_queue_depth`
- `gp_interconnect_type`
- `gp_max_packet_size`

**Note:** Greenplum Database supports only the UDPIFC (default) and TCP interconnect types.

**Dispatch Configuration Parameters**

- `gp_cached_segworkers_threshold`
- `gp_connections_per_thread`
- `gp_enable_direct_dispatch`
- `gp_segment_connect_timeout`
- `gp_set_proc_affinity`

**Fault Operation Parameters**

- `gp_set_read_only`
- `gp_fts_probe_interval`
- `gp_fts_probe_retries`
- `gp_fts_probe_timeout`
- `gp_fts_probe_threadcount`
- `gp_log_fts`

**Distributed Transaction Management Parameters**

- `gp_max_local_distributed_cache`

**Read-Only Parameters**

- `gp_command_count`
- `gp_content`
- `gp_dbid`
- `gp_num_contents_in_cluster`
- `gp_role`
- `gp_session_id`
- `gp_server_version`
- `gp_server_version_num`

**Greenplum Mirroring Parameters for Master and Segments**

These parameters control the configuration of the replication between Greenplum Database primary master and standby master.

- `keep_wal_segments`
- `repl_catchup_within_range`
- `replication_timeout`
- `wal_receiver_status_interval`

This parameter controls validation between Greenplum Database primary segment and standby segment during incremental resynchronization.
Greenplum Database Extension Parameters

The parameters in this topic control the configuration of Greenplum Database extensions.

- `pljava_classpath`
- `pljava_classpath_insecure`
- `pljava_statement_cache_size`
- `pljava_release_lingering_savepoints`
- `pljava_vmoptions`

XML Data Parameters

- `xmlbinary`
- `xmloption`

Configuration Parameters

Descriptions of the Greenplum Database server configuration parameters listed alphabetically.

**add_missing_from**

Automatically adds missing table references to FROM clauses. Present for compatibility with releases of PostgreSQL prior to 8.1, where this behavior was allowed by default.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**application_name**

Sets the application name for a client session. For example, if connecting via `psql`, this will be set to `psql`. Setting an application name allows it to be reported in log messages and statistics views.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td></td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**array_nulls**

This controls whether the array input parser recognizes unquoted NULL as specifying a null array element. By default, this is on, allowing array values containing null values to be entered. Greenplum Database versions before 3.0 did not support null values in arrays, and therefore would treat NULL as specifying a normal array element with the string value 'NULL'.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>master, session, reload</td>
</tr>
<tr>
<td>Value Range</td>
<td>Default</td>
<td>Set Classifications</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>---------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**authentication_timeout**

Maximum time to complete client authentication. This prevents hung clients from occupying a connection indefinitely.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any valid time expression (number and unit)</td>
<td>1min</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**backslash_quote**

This controls whether a quote mark can be represented by `'` in a string literal. The preferred, SQL-standard way to represent a quote mark is by doubling it (``) but PostgreSQL has historically also accepted `'`. However, use of `'` creates security risks because in some client character set encodings, there are multibyte characters in which the last byte is numerically equivalent to ASCII `'`.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>on (allow <code>'</code> always)</td>
<td>safe_encoding</td>
<td>master</td>
</tr>
<tr>
<td>off (reject always)</td>
<td></td>
<td>session</td>
</tr>
<tr>
<td>safe_encoding (allow only if client encoding does not allow ASCII <code>'</code> within a multibyte character)</td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**block_size**

Reports the size of a disk block.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of bytes</td>
<td>32768</td>
<td>read only</td>
</tr>
</tbody>
</table>

**bonjour_name**

Specifies the Bonjour broadcast name. By default, the computer name is used, specified as an empty string. This option is ignored if the server was not compiled with Bonjour support.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td>unset</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>
check_function_bodies

When set to off, disables validation of the function body string during `CREATE FUNCTION`. Disabling validation is occasionally useful to avoid problems such as forward references when restoring function definitions from a dump.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

client_encoding

Sets the client-side encoding (character set). The default is to use the same as the database encoding. See Supported Character Sets in the PostgreSQL documentation.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>character set</td>
<td>UTF8</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

client_min_messages

Controls which message levels are sent to the client. Each level includes all the levels that follow it. The later the level, the fewer messages are sent.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEBUG5</td>
<td>NOTICE</td>
<td>master</td>
</tr>
<tr>
<td>DEBUG4</td>
<td></td>
<td>session</td>
</tr>
<tr>
<td>DEBUG3</td>
<td></td>
<td>reload</td>
</tr>
<tr>
<td>DEBUG2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEBUG1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOTICE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WARNING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERROR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FATAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PANIC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

cpu_index_tuple_cost

For the legacy query optimizer (planner), sets the estimate of the cost of processing each index row during an index scan. This is measured as a fraction of the cost of a sequential page fetch.
**Value Range** | **Default** | **Set Classifications**
---|---|---
floating point | 0.005 | master, session, reload

### cpu_operator_cost
For the legacy query optimizer (planner), sets the estimate of the cost of processing each operator in a WHERE clause. This is measured as a fraction of the cost of a sequential page fetch.

**Value Range** | **Default** | **Set Classifications**
---|---|---
floating point | 0.0025 | master, session, reload

### cpu_tuple_cost
For the legacy query optimizer (planner), sets the estimate of the cost of processing each row during a query. This is measured as a fraction of the cost of a sequential page fetch.

**Value Range** | **Default** | **Set Classifications**
---|---|---
floating point | 0.01 | master, session, reload

### cursor_tuple_fraction
Tells the legacy query optimizer (planner) how many rows are expected to be fetched in a cursor query, thereby allowing the legacy optimizer to use this information to optimize the query plan. The default of 1 means all rows will be fetched.

**Value Range** | **Default** | **Set Classifications**
---|---|---
integer | 1 | master, session, reload

### custom_variable_classes
Specifies one or several class names to be used for custom variables. A custom variable is a variable not normally known to the server but used by some add-on modules. Such variables must have names consisting of a class name, a dot, and a variable name.

**Value Range** | **Default** | **Set Classifications**
---|---|---
comma-separated list of class names | unset | local, system, restart
**data_checksums**

Reports whether checksums are enabled for heap data storage in the database system. Checksums for heap data are enabled or disabled when the database system is initialized and cannot be changed.

Heap data pages store heap tables, catalog tables, indexes, and database metadata. Append-optimized storage has built-in checksum support that is unrelated to this parameter.

Greenplum Database uses checksums to prevent loading data corrupted in the file system into memory managed by database processes. When heap data checksums are enabled, Greenplum Database computes and stores checksums on heap data pages when they are written to disk. When a page is retrieved from disk, the checksum is verified. If the verification fails, an error is generated and the page is not permitted to load into managed memory.

If the `ignore_checksum_failure` configuration parameter has been set to on, a failed checksum verification generates a warning, but the page is allowed to be loaded into managed memory. If the page is then updated, it is flushed to disk and replicated to the mirror. This can cause data corruption to propagate to the mirror and prevent a complete recovery. Because of the potential for data loss, the `ignore_checksum_failure` parameter should only be enabled when needed to recover data. See `ignore_checksum_failure` for more information.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>read only</td>
</tr>
</tbody>
</table>

**DateStyle**

Sets the display format for date and time values, as well as the rules for interpreting ambiguous date input values. This variable contains two independent components: the output format specification and the input/output specification for year/month/day ordering.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>&lt;format&gt;, &lt;date style&gt;</code></td>
<td>ISO, MDY</td>
<td>master session reload</td>
</tr>
<tr>
<td>where:</td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>&lt;format&gt;</code> is ISO, Postgres, SQL, or German</td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>&lt;date style&gt;</code> is DMY, MDY, or YMD</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**db_user_namespace**

This enables per-database user names. If on, you should create users as `username@dbname`. To create ordinary global users, simply append @ when specifying the user name in the client.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>local system restart</td>
</tr>
</tbody>
</table>
**deadlock_timeout**

The time to wait on a lock before checking to see if there is a deadlock condition. On a heavily loaded server you might want to raise this value. Ideally the setting should exceed your typical transaction time, so as to improve the odds that a lock will be released before the waiter decides to check for deadlock.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any valid time expression (number and unit)</td>
<td>1s</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**debug_assertions**

Turns on various assertion checks.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**debug_pretty_print**

Indents debug output to produce a more readable but much longer output format. `client_min_messages` or `log_min_messages` must be DEBUG1 or lower.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**debug_print_parse**

For each executed query, prints the resulting parse tree. `client_min_messages` or `log_min_messages` must be DEBUG1 or lower.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**debug_print_plan**

For each executed query, prints the Greenplum parallel query execution plan. `client_min_messages` or `log_min_messages` must be DEBUG1 or lower.
### debug_print_prelim_plan

For each executed query, prints the preliminary query plan. `client_min_messages` or `log_min_messages` must be DEBUG1 or lower.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

### debug_print_rewritten

For each executed query, prints the query rewriter output. `client_min_messages` or `log_min_messages` must be DEBUG1 or lower.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

### debug_print_slice_table

For each executed query, prints the Greenplum query slice plan. `client_min_messages` or `log_min_messages` must be DEBUG1 or lower.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

### default_statistics_target

Sets the default statistics sampling target (the number of values that are stored in the list of common values) for table columns that have not had a column-specific target set via `ALTER TABLE SET STATISTICS`. Larger values may improve the quality of the legacy query optimizer (planner) estimates.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>0 &gt; Integer &gt; 10000</code></td>
<td>100</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>
**default_tablespace**

The default tablespace in which to create objects (tables and indexes) when a `CREATE` command does not explicitly specify a tablespace.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>name of a tablespace</td>
<td>unset</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**default_transaction_isolation**

Controls the default isolation level of each new transaction.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>read committed</td>
<td>read committed</td>
<td>master</td>
</tr>
<tr>
<td>read uncommitted</td>
<td></td>
<td>session</td>
</tr>
<tr>
<td>serializable</td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**default_transaction_read_only**

Controls the default read-only status of each new transaction. A read-only SQL transaction cannot alter non-temporary tables.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**dynamic_library_path**

If a dynamically loadable module needs to be opened and the file name specified in the `CREATE FUNCTION` or `LOAD` command does not have a directory component (i.e. the name does not contain a slash), the system will search this path for the required file. The compiled-in PostgreSQL package library directory is substituted for `$libdir`. This is where the modules provided by the standard PostgreSQL distribution are installed.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>a list of absolute directory paths separated by colons</td>
<td><code>$libdir</code></td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**effective_cache_size**

Sets the assumption about the effective size of the disk cache that is available to a single query for the legacy query optimizer (planner). This is factored into estimates of the cost of using an index; a higher value makes it more likely index scans will be used, a lower value makes it more likely sequential scans...
will be used. This parameter has no effect on the size of shared memory allocated by a Greenplum server instance, nor does it reserve kernel disk cache; it is used only for estimation purposes.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>floating point</td>
<td>512MB</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**enable_bitmapscan**

Enables or disables the use of bitmap-scan plan types by the legacy query optimizer (planner). Note that this is different than a Bitmap Index Scan. A Bitmap Scan means that indexes will be dynamically converted to bitmaps in memory when appropriate, giving faster index performance on complex queries against very large tables. It is used when there are multiple predicates on different indexed columns. Each bitmap per column can be compared to create a final list of selected tuples.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**enable_groupagg**

Enables or disables the use of group aggregation plan types by the legacy query optimizer (planner).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**enable_hashagg**

Enables or disables the use of hash aggregation plan types by the legacy query optimizer (planner).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**enable_hashjoin**

Enables or disables the use of hash-join plan types by the legacy query optimizer (planner).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>
enable_indexscan

Enables or disables the use of index-scan plan types by the legacy query optimizer (planner).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

enable_mergejoin

Enables or disables the use of merge-join plan types by the legacy query optimizer (planner). Merge join is based on the idea of sorting the left- and right-hand tables into order and then scanning them in parallel. So, both data types must be capable of being fully ordered, and the join operator must be one that can only succeed for pairs of values that fall at the ‘same place’ in the sort order. In practice this means that the join operator must behave like equality.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

enable_nestloop

Enables or disables the use of nested-loop join plans by the legacy query optimizer (planner). It's not possible to suppress nested-loop joins entirely, but turning this variable off discourages the legacy optimizer from using one if there are other methods available.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

enable_seqscan

Enables or disables the use of sequential scan plan types by the legacy query optimizer (planner). It's not possible to suppress sequential scans entirely, but turning this variable off discourages the legacy optimizer from using one if there are other methods available.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>
**enable_sort**

Enables or disables the use of explicit sort steps by the legacy query optimizer (planner). It's not possible to suppress explicit sorts entirely, but turning this variable off discourages the legacy optimizer from using one if there are other methods available.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**enable_tidscan**

Enables or disables the use of tuple identifier (TID) scan plan types by the legacy query optimizer (planner).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**escape_string_warning**

When on, a warning is issued if a backslash (\) appears in an ordinary string literal (‘...’ syntax). Escape string syntax (E‘...’) should be used for escapes, because in future versions, ordinary strings will have the SQL standard-conforming behavior of treating backslashes literally.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**explain_pretty_print**

Determines whether EXPLAIN VERBOSE uses the indented or non-indented format for displaying detailed query-tree dumps.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**extra_float_digits**

Adjusts the number of digits displayed for floating-point values, including float4, float8, and geometric data types. The parameter value is added to the standard number of digits. The value can be set as high as 2, to include partially-significant digits; this is especially useful for dumping float data that needs to be restored exactly. Or it can be set negative to suppress unwanted digits.
### filerep_mirrorvalidation_during_resync

The default setting `false` improves Greenplum Database performance during incremental resynchronization of segment mirrors. Setting the value to `true` enables checking for the existence of files for all relations on the segment mirror during incremental resynchronization. Checking for files degrades performance of the incremental resynchronization process but provides a minimal check of database objects.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>false</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

### fromCollapseLimit

The legacy query optimizer (planner) will merge sub-queries into upper queries if the resulting FROM list would have no more than this many items. Smaller values reduce planning time but may yield inferior query plans.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-n</td>
<td>20</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

### gp_adjust_selectivity_for_outerjoins

Enables the selectivity of NULL tests over outer joins.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

### gp_analyze_relative_error

Sets the estimated acceptable error in the cardinality of the table * a value of 0.5 is supposed to be equivalent to an acceptable error of 50% (this is the default value used in PostgreSQL). If the statistics collected during `ANALYZE` are not producing good estimates of cardinality for a particular table attribute, decreasing the relative error fraction (accepting less error) tells the system to sample more rows.
### gp_appendonly_compaction

Enables compacting segment files during `VACUUM` commands. When disabled, `VACUUM` only truncates the segment files to the EOF value, as is the current behavior. The administrator may want to disable compaction in high I/O load situations or low space situations.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>floating point &lt; 1.0</td>
<td>0.25</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

### gp_appendonly_compaction_threshold

Specifies the threshold ratio (as a percentage) of hidden rows to total rows that triggers compaction of the segment file when `VACUUM` is run without the `FULL` option (a lazy vacuum). If the ratio of hidden rows in a segment file on a segment is less than this threshold, the segment file is not compacted, and a log message is issued.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer (%)</td>
<td>10</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

### gp_autostats_mode

Specifies the mode for triggering automatic statistics collection with `ANALYZE`. The `on_no_stats` option triggers statistics collection for `CREATE TABLE AS SELECT`, `INSERT`, or `COPY` operations on any table that has no existing statistics.

The `on_change` option triggers statistics collection only when the number of rows affected exceeds the threshold defined by `gp_autostats_on_change_threshold`. Operations that can trigger automatic statistics collection with `on_change` are:

- `CREATE TABLE AS SELECT`
- `UPDATE`
- `DELETE`
- `INSERT`
- `COPY`

Default is `on_no_stats`.

**Note:** For partitioned tables, automatic statistics collection is not triggered if data is inserted from the top-level parent table of a partitioned table.

Automatic statistics collection is triggered if data is inserted directly in a leaf table (where the data is stored) of the partitioned table. Statistics are collected only on the leaf table.
### gp_autostats_mode_in_functions

Specifies the mode for triggering automatic statistics collection with `ANALYZE` for statements in procedural language functions. The `none` option disables statistics collection. The `on_no_stats` option triggers statistics collection for `CREATE TABLE AS SELECT`, `INSERT`, or `COPY` operations that are executed in functions on any table that has no existing statistics.

The `on_change` option triggers statistics collection only when the number of rows affected exceeds the threshold defined by `gp_autostats_on_change_threshold`. Operations in functions that can trigger automatic statistics collection with `on_change` are:

- `CREATE TABLE AS SELECT`
- `UPDATE`
- `DELETE`
- `INSERT`
- `COPY`

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>on_no_stats</td>
<td>master</td>
</tr>
<tr>
<td>on_change</td>
<td></td>
<td>session</td>
</tr>
<tr>
<td>on_no_stats</td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

### gp_autostats_on_change_threshold

Specifies the threshold for automatic statistics collection when `gp_autostats_mode` is set to `on_change`. When a triggering table operation affects a number of rows exceeding this threshold, `ANALYZE` is added and statistics are collected for the table.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>2147483647</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

### gp_backup_directIO

Direct I/O allows Greenplum Database to bypass the buffering of memory within the file system cache for backup. When Direct I/O is used for a file, data is transferred directly from the disk to the application buffer, without the use of the file buffer cache.

Direct I/O is supported only on Red Hat Enterprise Linux, CentOS, and SUSE.
**gp_backup_directIO_read_chunk_mb**

Sets the chunk size in MB when Direct I/O is enabled with `gp_backup_directIO`. The default chunk size is 20MB.

The default value is the optimal setting. Decreasing it will increase the backup time and increasing it will result in little change to backup time.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-200</td>
<td>20 MB</td>
<td>local, session, reload</td>
</tr>
</tbody>
</table>

**gp_cached_segworkers_threshold**

When a user starts a session with Greenplum Database and issues a query, the system creates groups or 'gangs' of worker processes on each segment to do the work. After the work is done, the segment worker processes are destroyed except for a cached number which is set by this parameter. A lower setting conserves system resources on the segment hosts, but a higher setting may improve performance for power-users that want to issue many complex queries in a row.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt; 0</td>
<td>5</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**gp_command_count**

Shows how many commands the master has received from the client. Note that a single SQL command might actually involve more than one command internally, so the counter may increment by more than one for a single query. This counter also is shared by all of the segment processes working on the command.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt; 0</td>
<td>1</td>
<td>read only</td>
</tr>
</tbody>
</table>

**gp_connection_send_timeout**

Timeout for sending data to unresponsive Greenplum Database user clients during query processing. A value of 0 disables the timeout, Greenplum Database waits indefinitely for a client. When the timeout is reached, the query is cancelled with this message:

```plaintext
Could not send data to client: Connection timed out.
```
**gp_connections_per_thread**

Controls the number of asynchronous threads (worker threads) that a Greenplum Database query dispatcher (QD) generates when dispatching work to query executor processes on segment instances when processing SQL queries. The value sets the number of primary segment instances that a worker thread connects to when processing a query. For example, when the value is 2 and there are 64 segment instances, a QD generates 32 worker threads to dispatch a query plan work. Each thread is assigned to two segments.

For the default value, 0, a query dispatcher generates two types of threads: a main thread that manages the dispatch of query plan work, and an interconnect thread. The main thread also acts as a worker thread.

For a value greater than 0, a QD generates three types of threads: a main thread, one or more worker threads, and an interconnect thread. When the value is equal to or greater than the number of segment instances, a QD generates three threads: a main thread, a single worker thread, and an interconnect thread.

The value does not need to be changed from the default unless there are known throughput performance issues.

This parameter is master only and changing it requires a server restart.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of seconds</td>
<td>3600 (1 hour)</td>
<td>master system reload</td>
</tr>
</tbody>
</table>

**gp_content**

The local content id if a segment.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt;= 0</td>
<td>0</td>
<td>master restart</td>
</tr>
</tbody>
</table>

**gp_create_table_random_default_distribution**

Controls table creation when a Greenplum Database table is created with a `CREATE TABLE` or `CREATE TABLE AS` command that does not contain a `DISTRIBUTED BY` clause.

For `CREATE TABLE`, if the value of the parameter is `off` (the default), and the table creation command does not contain a `DISTRIBUTED BY` clause, Greenplum Database chooses the table distribution key based on the command. If the `LIKE` or `INHERITS` clause is specified in table creation command, the created table uses the same distribution key as the source or parent table.

If the value of the parameter is set to `on`, Greenplum Database follows these rules to create a table when the `DISTRIBUTED BY` clause is not specified:

- If `PRIMARY KEY` or `UNIQUE` columns are not specified, the distribution of the table is random (`DISTRIBUTED RANDOMLY`). Table distribution is random even if the table creation command contains the `LIKE` or `INHERITS` clause.
• If PRIMARY KEY or UNIQUE columns are specified, a DISTRIBUTED BY clause must also be specified. If a DISTRIBUTED BY clause is not specified as part of the table creation command, the command fails.

For a CREATE TABLE AS command that does not contain a distribution clause:
• If the legacy query optimizer creates the table, and the value of the parameter is off, the table distribution policy is determined based on the command.
• If the legacy query optimizer creates the table, and the value of the parameter is on, the table distribution policy is random.
• If GPORCA creates the table, the table distribution policy is random. The parameter value has no affect.

For information about the legacy query optimizer and GPORCA, see "Querying Data" in the Greenplum Database Administrator Guide.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>boolean</td>
<td>off</td>
<td>master, system, reload</td>
</tr>
</tbody>
</table>

**gp_dbid**

The local content dbid if a segment.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td></td>
<td>read only</td>
</tr>
</tbody>
</table>

**gp_debug_linger**

Number of seconds for a Greenplum process to linger after a fatal internal error.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any valid time expression (number and unit)</td>
<td>0</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**gp_default_storage_options**

Set the default values for the following table storage options when a table is created with the CREATE TABLE command.

• APPENDONLY
• BLOCKSIZE
• CHECKSUM
• COMPRESSTYPE
• COMPRESSLEVEL
• ORIENTATION

Specify multiple storage option values as a comma separated list.

You can set the storage options with this parameter instead of specifying the table storage options in the WITH of the CREATE TABLE command. The table storage options that are specified with the CREATE TABLE command override the values specified by this parameter.
Not all combinations of storage option values are valid. If the specified storage options are not valid, an error is returned. See the CREATE TABLE command for information about table storage options.

The defaults can be set for a database and user. If the server configuration parameter is set at different levels, this the order of precedence, from highest to lowest, of the table storage values when a user logs into a database and creates a table:

1. The values specified in a CREATE TABLE command with the WITH clause or ENCODING clause
2. The value of gp_default_storage_options that set for the user with the ALTER ROLE...SET command
3. The value of gp_default_storage_options that is set for the database with the ALTER DATABASE...SET command
4. The value of gp_default_storage_options that is set for the Greenplum Database system with the gpconfig utility

The parameter value is not cumulative. For example, if the parameter specifies the APPENDONLY and COMPRESSTYPE options for a database and a user logs in and sets the parameter to specify the value for the ORIENTATION option, the APPENDONLY, and COMPRESSTYPE values set at the database level are ignored.

This example ALTER DATABASE command sets the default ORIENTATION and COMPRESSTYPE table storage options for the database mystest.

```
ALTER DATABASE mytest SET gp_default_storage_options = 'orientation=column, compresstype=rle_type'
```

To create an append-optimized table in the mytest database with column-oriented table and RLE compression. The user needs to specify only APPENDONLY=TRUE in the WITH clause.

This example gpconfig utility command sets the default storage option for a Greenplum Database system. If you set the defaults for multiple table storage options, the value must be enclosed in single quotes.

```
gpconfig -c 'gp_default_storage_options' -v 'appendonly=true, orientation=column'
```

This example gpconfig utility command shows the value of the parameter. The parameter value must be consistent across the Greenplum Database master and all segments.

```
gpconfig -s 'gp_default_storage_options'
```

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications ¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPENDONLY= TRUE</td>
<td>APPENDONLY=FALSE</td>
<td>master session reload</td>
</tr>
<tr>
<td>APPENDONLY= FALSE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLOCKSIZE= integer between 8192 and 2097152</td>
<td>BLOCKSIZE=32768</td>
<td></td>
</tr>
<tr>
<td>CHECKSUM= TRUE</td>
<td>CHECKSUM=TRUE</td>
<td></td>
</tr>
<tr>
<td>CHECKSUM= FALSE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMPRESSTYPE= ZLIB</td>
<td>COMPRESSTYPE=none</td>
<td></td>
</tr>
<tr>
<td>COMPRESSTYPE= QUICKLZ</td>
<td>COMPRESSLEVEL=0</td>
<td></td>
</tr>
<tr>
<td>COMPRESSTYPE= RLE_TYPE</td>
<td>ORIENTATION=ROW</td>
<td></td>
</tr>
<tr>
<td>ORIENTATION= NONE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORIENTATION= ROW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORIENTATION= COLUMN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMPRESSLEVEL= integer between 0 and 19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: ¹The set classification when the parameter is set at the system level with the gpconfig utility.
**gp_dynamic_partition_pruning**
Enables plans that can dynamically eliminate the scanning of partitions.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>on/off</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**gp_email_from**
The email address used to send email alerts, in the format of:

'username@example.com'

or

'Name <username@example.com>'

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td></td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
<tr>
<td></td>
<td></td>
<td>superuser</td>
</tr>
</tbody>
</table>

**gp_email_smtp_password**
The password/passphrase used to authenticate with the SMTP server.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td></td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
<tr>
<td></td>
<td></td>
<td>superuser</td>
</tr>
</tbody>
</table>

**gp_email_smtp_server**
The fully qualified domain name or IP address and port of the SMTP server to use to send the email alerts. Must be in the format of:

smtp_servername.domain.com:port
### gp_email_smtp_userid

The user id used to authenticate with the SMTP server.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td></td>
<td>master, system, reload, superuser</td>
</tr>
</tbody>
</table>

### gp_email_to

A semi-colon (:) separated list of email addresses to receive email alert messages to in the format of:

'username@example.com'

or

'Name <username@example.com>'

If this parameter is not set, then email alerts are disabled.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td></td>
<td>master, system, reload, superuser</td>
</tr>
</tbody>
</table>

### gp_enable_adaptive_nestloop

Enables the use a new type of join node called "Adaptive Nestloop" at query execution time by the legacy query optimizer (planner). This causes the legacy optimizer to favor a hash-join over a nested-loop join if the number of rows on the outer side of the join exceeds a precalculated threshold. This parameter improves performance of index operations, which previously favored slower nested-loop joins.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>
**gp_enable_agg_distinct**
Enables or disables two-phase aggregation to compute a single distinct-qualified aggregate. This applies only to subqueries that include a single distinct-qualified aggregate function.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**gp_enable_agg_distinct_pruning**
Enables or disables three-phase aggregation and join to compute distinct-qualified aggregates. This applies only to subqueries that include one or more distinct-qualified aggregate functions.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**gp_enable_direct_dispatch**
Enables or disables the dispatching of targeted query plans for queries that access data on a single segment. When on, queries that target rows on a single segment will only have their query plan dispatched to that segment (rather than to all segments). This significantly reduces the response time of qualifying queries as there is no interconnect setup involved. Direct dispatch does require more CPU utilization on the master.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master, system, restart</td>
</tr>
</tbody>
</table>

**gp_enable_exchange_default_partition**
Controls availability of the `EXCHANGE DEFAULT PARTITION` clause for `ALTER TABLE`. The default value for the parameter is `off`. The clause is not available and Greenplum Database returns an error if the clause is specified in an `ALTER TABLE` command.

If the value is `on`, Greenplum Database returns a warning stating that exchanging the default partition might result in incorrect results due to invalid data in the default partition.

**Warning:** Before you exchange the default partition, you must ensure the data in the table to be exchanged, the new default partition, is valid for the default partition. For example, the data in the new default partition must not contain data that would be valid in other leaf child partitions of the partitioned table. Otherwise, queries against the partitioned table with the exchanged default partition that are executed by GPORCA might return incorrect results.
**Value Range** | **Default** | **Set Classifications**
--- | --- | ---
Boolean | off | master session reload

**gp_enable_fallback_plan**

Allows use of disabled plan types when a query would not be feasible without them.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master session reload</td>
</tr>
</tbody>
</table>

**gp_enable_fast_sri**

When set to **on**, the legacy query optimizer (planner) plans single row inserts so that they are sent directly to the correct segment instance (no motion operation required). This significantly improves performance of single-row-insert statements.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master session reload</td>
</tr>
</tbody>
</table>

**gp_enable_gpperfmon**

Enables or disables the data collection agents that populate the **gpperfmon** database for Greenplum Command Center.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>local system restart</td>
</tr>
</tbody>
</table>

**gp_enable_groupext_distinct_gather**

Enables or disables gathering data to a single node to compute distinct-qualified aggregates on grouping extension queries. When this parameter and **gp_enable_groupext_distinct_pruning** are both enabled, the legacy query optimizer (planner) uses the cheaper plan.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master session reload</td>
</tr>
</tbody>
</table>
**gp_enable_groupext_distinct_pruning**

Enables or disables three-phase aggregation and join to compute distinct-qualified aggregates on grouping extension queries. Usually, enabling this parameter generates a cheaper query plan that the legacy query optimizer (planner) will use in preference to existing plan.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**gp_enable_multiphase_agg**

Enables or disables the use of two or three-stage parallel aggregation plans legacy query optimizer (planner). This approach applies to any subquery with aggregation. If gp_enable_multiphase_agg is off, then gp_enable_agg_distinct and gp_enable_agg_distinct_pruning are disabled.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**gp_enable_predicate_propagation**

When enabled, the legacy query optimizer (planner) applies query predicates to both table expressions in cases where the tables are joined on their distribution key column(s). Filtering both tables prior to doing the join (when possible) is more efficient.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**gp_enable_preunique**

Enables two-phase duplicate removal for SELECT DISTINCT queries (not SELECT COUNT(DISTINCT)). When enabled, it adds an extra SORT DISTINCT set of plan nodes before motioning. In cases where the distinct operation greatly reduces the number of rows, this extra SORT DISTINCT is much cheaper than the cost of sending the rows across the Interconnect.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>
**gp_enable_relsize_collection**

Enables the legacy query optimizer (planner) to use the estimated size of a table (pg_relation_size function) if there are no statistics for the table. By default, the planner uses a default value to estimate the number of rows if statistics are not available. The default behavior improves query optimization time and reduces resource queue usage in heavy workloads, but can lead to suboptimal plans.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**gp_enable_sequential_window_plans**

If on, enables non-parallel (sequential) query plans for queries containing window function calls. If off, evaluates compatible window functions in parallel and rejoins the results. This is an experimental parameter.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**gp_enable_segment_copy_checking**

Controls whether the distribution policy for a table (from the table DISTRIBUTED clause) is checked when data is copied into the table with the COPY FROM...ON SEGMENT command. The default is true, check the policy when copying data into the table. An error is returned in these situations.

- For a table that is not a partitioned table, an error is returned if the row of data violates the distribution policy for a segment instance.
- For a partitioned table, an error is returned if either of the following is true.
  - If the distribution policy of the child leaf partitioned table is the same as the root table and the row of data violates the distribution policy for a segment instance.
  - If the distribution policy of the child leaf partitioned table is not the same as the root table.

If the value is false, the distribution policy is not checked. The data added to the table might violate the table distribution policy for the segment instance. Manual redistribution of table data might be required. See the ALTER TABLE clause WITH REORGANIZE.

The parameter can be set for a database system or a session. The parameter cannot be set for a specific database.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>true</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>
**gp_enable_sort_distinct**
Enable duplicates to be removed while sorting.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master session reload</td>
</tr>
</tbody>
</table>

**gp_enable_sort_limit**
Enable LIMIT operation to be performed while sorting. Sorts more efficiently when the plan requires the first limit_number of rows at most.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master session reload</td>
</tr>
</tbody>
</table>

**gp_external_enable_exec**
Enables or disables the use of external tables that execute OS commands or scripts on the segment hosts (CREATE EXTERNAL TABLE EXECUTE syntax). Must be enabled if using the Command Center or MapReduce features.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master system restart</td>
</tr>
</tbody>
</table>

**gp_external_max_segs**
Sets the number of segments that will scan external table data during an external table operation, the purpose being not to overload the system with scanning data and take away resources from other concurrent operations. This only applies to external tables that use the gpfdist:// protocol to access external table data.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>64</td>
<td>master session reload</td>
</tr>
</tbody>
</table>

**gp_filerep_tcp_keepalives_count**
How many keepalives may be lost before the connection is considered dead. A value of 0 uses the system default. If TCP_KEEPCNT is not supported, this parameter must be 0.
Use this parameter for all connections that are between a primary and mirror segment. Use `tcp_keepalives_count` for settings that are not between a primary and mirror segment.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of lost keepalives</td>
<td>2</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**gp_filerep_tcp_keepalives_idle**

Number of seconds between sending keepalives on an otherwise idle connection. A value of 0 uses the system default. If TCP_KEEPIDLE is not supported, this parameter must be 0.

Use this parameter for all connections that are between a primary and mirror segment. Use `tcp_keepalives_idle` for settings that are not between a primary and mirror segment.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of seconds</td>
<td>1 min</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**gp_filerep_tcp_keepalives_interval**

How many seconds to wait for a response to a keepalive before retransmitting. A value of 0 uses the system default. If TCP_KEEPINTVL is not supported, this parameter must be 0.

Use this parameter for all connections that are between a primary and mirror segment. Use `tcp_keepalives_interval` for settings that are not between a primary and mirror segment.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of seconds</td>
<td>30 sec</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**gp_fts_probe_interval**

Specifies the polling interval for the fault detection process (`ftsprobe`). The `ftsprobe` process will take approximately this amount of time to detect a segment failure.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 3600 seconds</td>
<td>1 min</td>
<td>master, system, restart</td>
</tr>
</tbody>
</table>

**gp_fts_probe_retries**

Specifies the number of times the fault detection process (`ftsprobe`) attempts to connect to a segment before reporting segment failure.
## gp_fts_probe_threadcount

Specifies the number of `ftsprobe` threads to create. This parameter should be set to a value equal to or greater than the number of segments per host.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 128</td>
<td>16</td>
<td>master, system, restart</td>
</tr>
</tbody>
</table>

## gp_fts_probe_timeout

Specifies the allowed timeout for the fault detection process (`ftsprobe`) to establish a connection to a segment before declaring it down.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 3600 seconds</td>
<td>20 secs</td>
<td>master, system, restart</td>
</tr>
</tbody>
</table>

## gp_log_fts

Controls the amount of detail the fault detection process (`ftsprobe`) writes to the log file.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF</td>
<td>TERSE</td>
<td>master, system, restart</td>
</tr>
<tr>
<td>TERSE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VERBOSE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEBUG</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## gp_log_interconnect

Controls the amount of information that is written to the log file about communication between Greenplum Database segment instance worker processes. The default value is `terse`. The log information is written to both the master and segment instance logs.

Increasing the amount of logging could affect performance and increase disk space usage.
### `gp_log_gang`

Controls the amount of information that is written to the log file about query worker process creation and query management. The default value is **OFF**, do not log information.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>off</td>
<td>terse</td>
<td>master</td>
</tr>
<tr>
<td>terse</td>
<td>terse</td>
<td>session</td>
</tr>
<tr>
<td>verbose</td>
<td>terse</td>
<td>reload</td>
</tr>
<tr>
<td>debug</td>
<td>master</td>
<td></td>
</tr>
</tbody>
</table>

### `gp_gpperfmon_send_interval`

Sets the frequency that the Greenplum Database server processes send query execution updates to the data collection agent processes used to populate the `gpperfmon` database for Command Center. Query operations executed during this interval are sent through UDP to the segment monitor agents. If you find that an excessive number of UDP packets are dropped during long-running, complex queries, you may consider increasing this value.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any valid time expression (number and unit)</td>
<td>1sec</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

### `gpperfmon_log_alert_level`

Controls which message levels are written to the gpperfmon log. Each level includes all the levels that follow it. The later the level, the fewer messages are sent to the log.

**Note:** If the `gpperfmon` database is installed and is monitoring the database, the default value is **warning**.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>none</td>
<td>local</td>
</tr>
<tr>
<td>warning</td>
<td></td>
<td>system</td>
</tr>
<tr>
<td>error</td>
<td></td>
<td>restart</td>
</tr>
<tr>
<td>fatal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>panic</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**gp_hadoop_home**
Specifies the installation directory for the Greenplum Database `gphdfs` Hadoop target.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid directory name</td>
<td>Value of <code>HADOOP_HOME</code></td>
<td>local, session, reload</td>
</tr>
</tbody>
</table>

**gp_hadoop_target_version**
The installed version of the Greenplum Database `gphdfs` Hadoop target.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>cdh, hadoop, hdp, mpr</td>
<td>hadoop</td>
<td>local, session, reload</td>
</tr>
</tbody>
</table>

**gp_hashjoin_tuples_per_bucket**
Sets the target density of the hash table used by HashJoin operations. A smaller value will tend to produce larger hash tables, which can increase join performance.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>5</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**gp_idf_deduplicate**
Changes the strategy to compute and process MEDIAN, and PERCENTILE_DISC.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>auto, none, force</td>
<td>auto</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**gp_ignore_error_table**
Controls Greenplum Database behavior when the `INTO ERROR TABLE` clause is specified in a `CREATE EXTERNAL TABLE` or `COPY` command. The `INTO ERROR TABLE` clause was removed in Greenplum Database 5.

The default value is `false`, Greenplum Database returns an error if the `INTO ERROR TABLE` clause is specified in a command.
If the value is `true`, Greenplum Database ignores the clause, issues a warning, and executes the command and logs information about data rows with formatting errors. In Greenplum Database 5.x, you access the error log information with built-in SQL functions. See the `CREATE EXTERNAL TABLE` or `COPY` command.

You can set this value to `true` to avoid the Greenplum Database 5 error when you run applications that execute `CREATE EXTERNAL TABLE` or `COPY` commands that include the Greenplum Database 4.3.x INTO ERROR TABLE clause.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>false</td>
<td>master system reload</td>
</tr>
</tbody>
</table>

**gp_initial_bad_row_limit**

For the parameter value $n$, Greenplum Database stops processing input rows when you import data with the `COPY` command or from an external table if the first $n$ rows processed contain formatting errors. If a valid row is processed within the first $n$ rows, Greenplum Database continues processing input rows.

Setting the value to 0 disables this limit.

The `SEGMENT REJECT LIMIT` clause can also be specified for the `COPY` command or the external table definition to limit the number of rejected rows.

`INT_MAX` is the largest value that can be stored as an integer on your system.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer 0 - INT_MAX</td>
<td>1000</td>
<td>master session reload</td>
</tr>
</tbody>
</table>

**gp_interconnect_debug_retry_interval**

Specifies the interval, in seconds, to log Greenplum Database interconnect debugging messages when the server configuration parameter `gp_log_interconnect` is set to `DEBUG`. The default is 10 seconds.

The log messages contain information about the interconnect communication between Greenplum Database segment instance worker processes. The information can be helpful when debugging network issues between segment instances.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 &lt;= Integer &lt; 4096</td>
<td>10</td>
<td>master session reload</td>
</tr>
</tbody>
</table>

**gp_interconnect_fc_method**

Specifies the flow control method used for the default Greenplum Database UDPIFC interconnect.

For capacity based flow control, senders do not send packets when receivers do not have the capacity.

Loss based flow control is based on capacity based flow control, and also tunes the sending speed according to packet losses.
<table>
<thead>
<tr>
<th>gp_interconnect_hash_multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sets the size of the hash table used by the Greenplum Database to track interconnect connections with the default UDPIFC interconnect. This number is multiplied by the number of segments to determine the number of buckets in the hash table. Increasing the value may increase interconnect performance for complex multi-slice queries (while consuming slightly more memory on the segment hosts).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-25</td>
<td>2</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>gp_interconnect_queue_depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sets the amount of data per-peer to be queued by the Greenplum Database interconnect on receivers (when data is received but no space is available to receive it the data will be dropped, and the transmitter will need to resend it) for the default UDPIFC interconnect. Increasing the depth from its default value will cause the system to use more memory, but may increase performance. It is reasonable to set this value between 1 and 10. Queries with data skew potentially perform better with an increased queue depth. Increasing this may radically increase the amount of memory used by the system.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2048</td>
<td>4</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>gp_interconnect_setup_timeout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specifies the amount of time to wait for the Greenplum Database interconnect to complete setup before it times out.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any valid time expression (number and unit)</td>
<td>2 hours</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>gp_interconnect_snd_queue_depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sets the amount of data per-peer to be queued by the default UDPIFC interconnect on senders. Increasing the depth from its default value will cause the system to use more memory, but may increase performance. Reasonable values for this parameter are between 1 and 4. Increasing the value might radically increase the amount of memory used by the system.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any valid time expression (number and unit)</td>
<td>2 hours</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>
gp_interconnect_type

Sets the networking protocol used for Greenplum Database interconnect traffic. UDPIFC specifies using UDP with flow control for interconnect traffic, and is the only value supported.

UDPIFC (the default) specifies using UDP with flow control for interconnect traffic. Specify the interconnect flow control method with `gp_interconnect_fc_method`.

With TCP as the interconnect protocol, Greenplum Database has an upper limit of 1000 segment instances - less than that if the query workload involves complex, multi-slice queries.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDPIFC</td>
<td>UDPIFC</td>
<td>local</td>
</tr>
<tr>
<td>TCP</td>
<td>UDPIFC</td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

gp_log_format

Specifies the format of the server log files. If using `gp_toolkit` administrative schema, the log files must be in CSV format.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>csv</td>
<td>csv</td>
<td>local</td>
</tr>
<tr>
<td>text</td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

gp_max_csv_line_length

The maximum length of a line in a CSV formatted file that will be imported into the system. The default is 1MB (1048576 bytes). Maximum allowed is 4MB (4194184 bytes). The default may need to be increased if using the `gp_toolkit` administrative schema to read Greenplum Database log files.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of bytes</td>
<td>1048576</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

gp_max_databases

The maximum number of databases allowed in a Greenplum Database system.
**gp_max_filespaces**

The maximum number of filespaces allowed in a Greenplum Database system.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>16</td>
<td>master, system, restart</td>
</tr>
</tbody>
</table>

**gp_max_local_distributed_cache**

Sets the maximum number of distributed transaction log entries to cache in the backend process memory of a segment instance.

The log entries contain information about the state of rows that are being accessed by an SQL statement. The information is used to determine which rows are visible to an SQL transaction when executing multiple simultaneous SQL statements in an MVCC environment. Caching distributed transaction log entries locally improves transaction processing speed by improving performance of the row visibility determination process.

The default value is optimal for a wide variety of SQL processing environments.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>1024</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**gp_max_packet_size**

Sets the tuple-serialization chunk size for the Greenplum Database interconnect.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>512-65536</td>
<td>8192</td>
<td>master, system, restart</td>
</tr>
</tbody>
</table>

**gp_max_plan_size**

Specifies the total maximum uncompressed size of a query execution plan multiplied by the number of Motion operators (slices) in the plan. If the size of the query plan exceeds the value, the query is cancelled and an error is returned. A value of 0 means that the size of the plan is not monitored.

You can specify a value in kB, MB, or GB. The default unit is kB. For example, a value of 200 is 200kB. A value of 1GB is the same as 1024MB or 1048576kB.
### gp_max_slices

Specifies the maximum number of slices (portions of a query plan that are executed on segment instances) that can be generated by a query. If the query generates more than the specified number of slices, Greenplum Database returns an error and does not execute the query. The default value is 0, no maximum value.

Executing a query that generates a large number of slices might affect Greenplum Database performance. For example, a query that contains `UNION` or `UNION ALL` operators over several complex views can generate a large number of slices. You can run `EXPLAIN ANALYZE` on the query to view slice statistics for the query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>0</td>
<td>master, superuser, session</td>
</tr>
</tbody>
</table>

### gp_max_tablespaces

The maximum number of tablespaces allowed in a Greenplum Database system.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>16</td>
<td>master, system, restart</td>
</tr>
</tbody>
</table>

### gp_motion_cost_per_row

Sets the legacy query optimizer (planner) cost estimate for a Motion operator to transfer a row from one segment to another, measured as a fraction of the cost of a sequential page fetch. If 0, then the value used is two times the value of `cpu_tuple_cost`.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>floating point</td>
<td>0</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

### gp_num_contents_in_cluster

The number of primary segments in the Greenplum Database system.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>-</td>
<td>read only</td>
</tr>
</tbody>
</table>
**gp_recursive_cte_prototype**

Controls the availability of the experimental keyword `RECURSIVE` in the `WITH` clause of a `SELECT [ INTO]` command. The keyword allows a subquery in the `WITH` clause of a `SELECT [ INTO]` command to reference itself. The default value is `false`, the keyword is not allowed in the `WITH` clause a `SELECT [ INTO]` command.

**Warning:** The `RECURSIVE` keyword is an experimental feature and is not intended for use in a production environment. Experimental features are subject to change without notice in future releases.

For information about the experimental keyword `RECURSIVE`, see the `SELECT` command.

The parameter can be set for a database system, an individual database, or a session or query.

**Note:** This parameter will be removed if the `RECURSIVE` keyword is promoted from experimental or if the keyword is removed from Greenplum Database.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>false</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**gp_reject_percent_threshold**

For single row error handling on COPY and external table SELECTs, sets the number of rows processed before SEGMENT REJECT LIMIT \( n \) PERCENT starts calculating.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-( n )</td>
<td>300</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**gp_reraise_signal**

If enabled, will attempt to dump core if a fatal server error occurs.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**gp_resgroup_memory_policy**

**Note:** The `gp_resgroup_memory_policy` server configuration parameter is enforced only when resource group-based resource management is active.

Used by a resource group to manage memory allocation to query operators.

When set to `auto`, Greenplum Database uses resource group memory limits to distribute memory across query operators, allocating a fixed size of memory to non-memory-intensive operators and the rest to memory-intensive operators.
When you specify `eager_free`, Greenplum Database distributes memory among operators more optimally by re-allocating memory released by operators that have completed their processing to operators in a later query stage.

### `gp_resource_group_cpu_limit`

**Note:** The `gp_resource_group_cpu_limit` server configuration parameter is enforced only when resource group-based resource management is active.

Identifies the maximum percentage of system CPU resources to allocate to resource groups on each Greenplum Database segment node.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 - 1.0</td>
<td>0.9</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

### `gp_resource_group_memory_limit`

**Note:** The `gp_resource_group_memory_limit` server configuration parameter is enforced only when resource group-based resource management is active.

Identifies the maximum percentage of system memory resources to allocate to resource groups on each Greenplum Database segment node.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 - 1.0</td>
<td>0.7</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**Note:** When resource group-based resource management is active, the memory allotted to a segment host is equally shared by active primary segments. Greenplum Database assigns memory to primary segments when the segment takes the primary role. The initial memory allotment to a primary segment does not change, even in a failover situation. This may result in a segment host utilizing more memory than the `gp_resource_group_memory_limit` setting permits.

For example, suppose your Greenplum Database cluster is utilizing the default `gp_resource_group_memory_limit` of 0.7 and a segment host named `seghost1` has 4 primary segments and 4 mirror segments. Greenplum Database assigns each primary segment on `seghost1` (0.7 / 4 = 0.175%) of overall system memory. If failover occurs and two mirrors on `seghost1` fail over to become primary segments, each of the original 4 primaries retain their memory allotment of 0.175, and the two new primary segments are each allotted (0.7 / 6 = 0.116%) of system memory. `seghost1`'s overall memory allocation in this scenario is
0.7 + (0.116 * 2) = 0.932%

which is above the percentage configured in the \texttt{gp_resource_group_memory_limit} setting.

gp\_resource\_manager

Identifies the resource management scheme currently enabled in the Greenplum Database cluster. The default scheme is to use resource queues.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>group</td>
<td>queue</td>
<td>local</td>
</tr>
<tr>
<td>queue</td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>


gp\_resqueue\_memory\_policy

\textbf{Note:} The \texttt{gp_resqueue_memory_policy} server configuration parameter is enforced only when resource queue-based resource management is active.

Enables Greenplum memory management features. The distribution algorithm \texttt{eager_free} takes advantage of the fact that not all operators execute at the same time (in Greenplum Database 4.2 and later). The query plan is divided into stages and Greenplum Database eagerly frees memory allocated to a previous stage at the end of that stage’s execution, then allocates the eagerly freed memory to the new stage.

When set to \texttt{none}, memory management is the same as in Greenplum Database releases prior to 4.1.

When set to \texttt{auto}, query memory usage is controlled by \texttt{statement_mem} and resource queue memory limits.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>none, auto, eager_free</td>
<td>eager_free</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart/reload</td>
</tr>
</tbody>
</table>


gp\_resqueue\_priority

\textbf{Note:} The \texttt{gp_resqueue_priority} server configuration parameter is enforced only when resource queue-based resource management is active.

Enables or disables query prioritization. When this parameter is disabled, existing priority settings are not evaluated at query run time.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>


gp\_resqueue\_priority\_cpucores\_per\_segment

\textbf{Note:} The \texttt{gp_resqueue_priority_cpucores_per_segment} server configuration parameter is enforced only when resource queue-based resource management is active.
Specifies the number of CPU units allocated per segment instance. For example, if a Greenplum Database cluster has 10-core segment hosts that are configured with four segments, set the value for the segment instances to 2.5. For the master instance, the value would be 10. A master host typically has only the master instance running on it, so the value for the master should reflect the usage of all available CPU cores.

Incorrect settings can result in CPU under-utilization or query prioritization not working as designed.

The default values for the Greenplum Data Computing Appliance V2 are 4 for segments and 25 for the master.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 - 512.0</td>
<td>4</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**gp_resqueue_priority_sweeper_interval**

*Note:* The `gp_resqueue_priority_sweeper_interval` server configuration parameter is enforced only when resource queue-based resource management is active.

Specifies the interval at which the sweeper process evaluates current CPU usage. When a new statement becomes active, its priority is evaluated and its CPU share determined when the next interval is reached.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 - 15000 ms</td>
<td>1000</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**gp_role**

The role of this server process "set to dispatch for the master and execute for a segment."

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>dispatch</td>
<td></td>
<td>read only</td>
</tr>
<tr>
<td>execute</td>
<td></td>
<td></td>
</tr>
<tr>
<td>utility</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**gp_safefswritesize**

Specifies a minimum size for safe write operations to append-optimized tables in a non-mature file system. When a number of bytes greater than zero is specified, the append-optimized writer adds padding data up to that number in order to prevent data corruption due to file system errors. Each non-mature file system has a known safe write size that must be specified here when using Greenplum Database with that type of file system. This is commonly set to a multiple of the extent size of the file system; for example, Linux ext3 is 4096 bytes, so a value of 32768 is commonly used.
### gp_segment_connect_timeout

Time that the Greenplum interconnect will try to connect to a segment instance over the network before timing out. Controls the network connection timeout between master and primary segments, and primary to mirror segment replication processes.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any valid time expression (number and unit)</td>
<td>10min</td>
<td>local, system, reload</td>
</tr>
</tbody>
</table>

### gp_segments_for_planner

Sets the number of primary segment instances for the legacy query optimizer (planner) to assume in its cost and size estimates. If 0, then the value used is the actual number of primary segments. This variable affects the legacy optimizer's estimates of the number of rows handled by each sending and receiving process in Motion operators.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-n</td>
<td>0</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

### gp_server_version

Reports the version number of the server as a string. A version modifier argument might be appended to the numeric portion of the version string, example: 5.0.0 beta.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>String. Examples: 5.0.0</td>
<td>n/a</td>
<td>read only</td>
</tr>
</tbody>
</table>

### gp_server_version_num

Reports the version number of the server as an integer. The number is guaranteed to always be increasing for each version and can be used for numeric comparisons. The major version is represented as is, the minor and patch versions are zero-padded to always be double digit wide.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mmmp where M is the major version, mm is the minor version zero-padded and pp is the patch version zero-padded. Example: 50000</td>
<td>n/a</td>
<td>read only</td>
</tr>
</tbody>
</table>
**gp_session_id**
A system assigned ID number for a client session. Starts counting from 1 when the master instance is first started.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-n</td>
<td>14</td>
<td>read only</td>
</tr>
</tbody>
</table>

**gp_set_proc_affinity**
If enabled, when a Greenplum server process (postmaster) is started it will bind to a CPU.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**gp_set_read_only**
Set to on to disable writes to the database. Any in progress transactions must finish before read-only mode takes affect.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**gp_snmp_community**
Set to the community name you specified for your environment.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNMP community name</td>
<td>public</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**gp_snmp_monitor_address**
The hostname:port of your network monitor application. Typically, the port number is 162. If there are multiple monitor addresses, separate them with a comma.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>hostname:port</td>
<td></td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>
**gp_snmp_use_inform_or_trap**

Trap notifications are SNMP messages sent from one application to another (for example, between Greenplum Database and a network monitoring application). These messages are unacknowledged by the monitoring application, but generate less network overhead.

Inform notifications are the same as trap messages, except that the application sends an acknowledgement to the application that generated the alert.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>inform</td>
<td>trap</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**gp_statistics_pullup_from_child_partition**

Enables the use of statistics from child tables when planning queries on the parent table by the legacy query optimizer (planner).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**gp_statistics_use_fkeys**

When enabled, allows the legacy query optimizer (planner) to use foreign key information stored in the system catalog to optimize joins between foreign keys and primary keys.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**gp_vmem_idle_resource_timeout**

If a database session is idle for longer than the time specified, the session will free system resources (such as shared memory), but remain connected to the database. This allows more concurrent connections to the database at one time.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any valid time</td>
<td>18s</td>
<td>master</td>
</tr>
<tr>
<td>expression (number</td>
<td></td>
<td>system</td>
</tr>
<tr>
<td>and unit)</td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>
**gp_vmem_protect_limit**

*Note:* The `gp_vmem_protect_limit` server configuration parameter is enforced only when resource queue-based resource management is active.

Sets the amount of memory (in number of MBs) that all postgres processes of an active segment instance can consume. If a query causes this limit to be exceeded, memory will not be allocated and the query will fail. Note that this is a local parameter and must be set for every segment in the system (primary and mirrors). When setting the parameter value, specify only the numeric value. For example, to specify 4096MB, use the value 4096. Do not add the units MB to the value.

To prevent over-allocation of memory, these calculations can estimate a safe `gp_vmem_protect_limit` value.

First calculate the value `gp_vmem`. This is the Greenplum Database memory available on a host

\[
gp_vmem = \frac{(SWAP + RAM) - (7.5GB + 0.05 \times RAM))}{1.7}
\]

where `SWAP` is the host swap space and `RAM` is the RAM on the host in GB.

Next, calculate the `max_acting_primary_segments`. This is the maximum number of primary segments that can be running on a host when mirror segments are activated due to a failure. With mirrors arranged in a 4-host block with 8 primary segments per host, for example, a single segment host failure would activate two or three mirror segments on each remaining host in the failed host's block. The `max_acting_primary_segments` value for this configuration is 11 (8 primary segments plus 3 mirrors activated on failure).

This is the calculation for `gp_vmem_protect_limit`. The value should be converted to MB.

\[
gp_vmem_protect_limit = \frac{gp_vmem}{acting\_primary\_segments}
\]

For scenarios where a large number of workfiles are generated, this is the calculation for `gp_vmem` that accounts for the workfiles.

\[
gp_vmem = \frac{(SWAP + RAM) - (7.5GB + 0.05 \times RAM - (300KB \times total\_\#\_workfiles)))}{1.7}
\]

For information about monitoring and managing workfile usage, see the Greenplum Database Administrator Guide.

Based on the `gp_vmem` value you can calculate the value for the `vm.overcommit_ratio` operating system kernel parameter. This parameter is set when you configure each Greenplum Database host.

\[
vm.overcommit\_ratio = \frac{RAM - (0.026 \times gp_vmem)}{RAM}
\]

*Note:* The default value for the kernel parameter `vm.overcommit\_ratio` in Red Hat Enterprise Linux is 50.

For information about the kernel parameter, see the Greenplum Database Installation Guide.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>8192</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>
**gp_vmem_protect_segworker_cache_limit**

If a query executor process consumes more than this configured amount, then the process will not be cached for use in subsequent queries after the process completes. Systems with lots of connections or idle processes may want to reduce this number to free more memory on the segments. Note that this is a local parameter and must be set for every segment.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of megabytes</td>
<td>500</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**gp_workfile_checksumming**

Adds a checksum value to each block of a work file (or spill file) used by HashAgg and HashJoin query operators. This adds an additional safeguard from faulty OS disk drivers writing corrupted blocks to disk. When a checksum operation fails, the query will cancel and rollback rather than potentially writing bad data to disk.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**gp_workfile_compress_algorithm**

When a hash aggregation or hash join operation spills to disk during query processing, specifies the compression algorithm to use on the spill files. If using zlib, the zlib library must be installed on all hosts in the Greenplum Database cluster.

If your Greenplum Database installation uses serial ATA (SATA) disk drives, setting the value of this parameter to `zlib` might help to avoid overloading the disk subsystem with I/O operations.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>none</td>
<td>master, session, reload</td>
</tr>
<tr>
<td>zlib</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**gp_workfile_limit_files_per_query**

Sets the maximum number of temporary spill files (also known as workfiles) allowed per query per segment. Spill files are created when executing a query that requires more memory than it is allocated. The current query is terminated when the limit is exceeded.

Set the value to 0 (zero) to allow an unlimited number of spill files. master session reload
gp_workfile_limit_per_query
Sets the maximum disk size an individual query is allowed to use for creating temporary spill files at each segment. The default value is 0, which means a limit is not enforced.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>kilobytes</td>
<td>0</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

gp_workfile_limit_per_segment
Sets the maximum total disk size that all running queries are allowed to use for creating temporary spill files at each segment. The default value is 0, which means a limit is not enforced.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>kilobytes</td>
<td>0</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

gpperfmon_port
Sets the port on which all data collection agents (for Command Center) communicate with the master.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>8888</td>
<td>master, system, restart</td>
</tr>
</tbody>
</table>

ignore_checksum_failure
Only has effect if data_checksums is enabled.

Greenplum Database uses checksums to prevent loading data that has been corrupted in the file system into memory managed by database processes.

By default, when a checksum verify error occurs when reading a heap data page, Greenplum Database generates an error and prevents the page from being loaded into managed memory. When ignore_checksum_failure is set to on and a checksum verify failure occurs, Greenplum Database generates a warning, and allows the page to be read into managed memory. If the page is then updated it is saved to disk and replicated to the mirror. If the page header is corrupt an error is reported even if this option is enabled.

Warning: Setting ignore_checksum_failure to on may propagate or hide data corruption or lead to other serious problems. However, if a checksum failure has already been detected and the
page header is uncorrupted, setting `ignore_checksum_failure` to on may allow you to bypass
the error and recover undamaged tuples that may still be present in the table.

The default setting is off, and it can only be changed by a superuser.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**integer_datetimes**

Reports whether PostgreSQL was built with support for 64-bit-integer dates and times.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>read only</td>
</tr>
</tbody>
</table>

**IntervalStyle**

Sets the display format for interval values. The value `sql_standard` produces output matching SQL standard interval literals. The value `postgres` produces output matching PostgreSQL releases prior to 8.4 when the `DateStyle` parameter was set to ISO.

The value `postgres_verbose` produces output matching Greenplum releases prior to 3.3 when the `DateStyle` parameter was set to non-ISO output.

The value `iso_8601` will produce output matching the time interval format with designators defined in section 4.4.3.2 of ISO 8601. See the PostgreSQL 8.4 documentation for more information.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>postgres</td>
<td>postgres</td>
<td>master, session, reload</td>
</tr>
<tr>
<td>postgres_verbose</td>
<td>postgres</td>
<td>master, session, reload</td>
</tr>
<tr>
<td>sql_standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iso_8601</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**joinCollapseLimit**

The legacy query optimizer (planner) will rewrite explicit inner JOIN constructs into lists of FROM items whenever a list of no more than this many items in total would result. By default, this variable is set the same as `fromCollapseLimit`, which is appropriate for most uses. Setting it to 1 prevents any reordering of inner JOINs. Setting this variable to a value between 1 and `fromCollapseLimit` might be useful to trade off planning time against the quality of the chosen plan (higher values produce better plans).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-n</td>
<td>20</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>
**keep_wal_segments**

For Greenplum Database master mirroring, sets the maximum number of processed WAL segment files that are saved by the active Greenplum Database master if a checkpoint operation occurs.

The segment files are used to synchronize the active master on the standby master.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>5</td>
<td>master, system, reload, superuser</td>
</tr>
</tbody>
</table>

**krb_caseins_users**

Sets whether Kerberos user names should be treated case-insensitively. The default is case sensitive (off).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master, system, restart</td>
</tr>
</tbody>
</table>

**krb_server_keyfile**

Sets the location of the Kerberos server key file.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>path and file name</td>
<td>unset</td>
<td>master, system, restart</td>
</tr>
</tbody>
</table>

**krb_srvname**

Sets the Kerberos service name.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>service name</td>
<td>postgres</td>
<td>master, system, restart</td>
</tr>
</tbody>
</table>

**lc_collate**

Reports the locale in which sorting of textual data is done. The value is determined when the Greenplum Database array is initialized.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;system dependent&gt;</td>
<td></td>
<td>read only</td>
</tr>
</tbody>
</table>
**lc_ctype**
Reports the locale that determines character classifications. The value is determined when the Greenplum Database array is initialized.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;system dependent&gt;</td>
<td></td>
<td>read only</td>
</tr>
</tbody>
</table>

**lc_messages**
Sets the language in which messages are displayed. The locales available depends on what was installed with your operating system - use `locale -a` to list available locales. The default value is inherited from the execution environment of the server. On some systems, this locale category does not exist. Setting this variable will still work, but there will be no effect. Also, there is a chance that no translated messages for the desired language exist. In that case you will continue to see the English messages.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;system dependent&gt;</td>
<td></td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**lc_monetary**
Sets the locale to use for formatting monetary amounts, for example with the `to_char` family of functions. The locales available depends on what was installed with your operating system - use `locale -a` to list available locales. The default value is inherited from the execution environment of the server.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;system dependent&gt;</td>
<td></td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**lc_numeric**
Sets the locale to use for formatting numbers, for example with the `to_char` family of functions. The locales available depends on what was installed with your operating system - use `locale -a` to list available locales. The default value is inherited from the execution environment of the server.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;system dependent&gt;</td>
<td></td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**lc_time**
This parameter currently does nothing, but may in the future.
### listen_addresses

Specifies the TCP/IP address(es) on which the server is to listen for connections from client applications - a comma-separated list of host names and/or numeric IP addresses. The special entry * corresponds to all available IP interfaces. If the list is empty, only UNIX-domain sockets can connect.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;system dependent&gt;</td>
<td></td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

### local_preload_libraries

Comma separated list of shared library files to preload at the start of a client session.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>localhost, host names, IP addresses, * (all available IP interfaces)</td>
<td>*</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

### log_autostats

Logs information about automatic `ANALYZE` operations related to `gp_autostats_mode` and `gp_autostats_on_change_threshold`.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
<tr>
<td></td>
<td></td>
<td>superuser</td>
</tr>
</tbody>
</table>

### log_connections

This outputs a line to the server log detailing each successful connection. Some client programs, like `psql`, attempt to connect twice while determining if a password is required, so duplicate "connection received" messages do not always indicate a problem.
### log_disconnections

This outputs a line in the server log at termination of a client session, and includes the duration of the session.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

### log_dispatch_stats

When set to "on," this parameter adds a log message with verbose information about the dispatch of the statement.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

### log_duration

Causes the duration of every completed statement which satisfies log_statement to be logged.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master, session, reload, superuser</td>
</tr>
</tbody>
</table>

### log_error_verbosity

Controls the amount of detail written in the server log for each message that is logged.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>TERSE</td>
<td>DEFAULT</td>
<td>master, session, reload, superuser</td>
</tr>
<tr>
<td>DEFAULT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VERBOSE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**log_executor_stats**

For each query, write performance statistics of the query executor to the server log. This is a crude profiling instrument. Cannot be enabled together with `log_statement_stats`.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>local system restart</td>
</tr>
</tbody>
</table>

**log_hostname**

By default, connection log messages only show the IP address of the connecting host. Turning on this option causes logging of the IP address and host name of the Greenplum Database master. Note that depending on your host name resolution setup this might impose a non-negligible performance penalty.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master system restart</td>
</tr>
</tbody>
</table>

**log_min_duration_statement**

Logs the statement and its duration on a single log line if its duration is greater than or equal to the specified number of milliseconds. Setting this to 0 will print all statements and their durations. -1 disables the feature. For example, if you set it to 250 then all SQL statements that run 250ms or longer will be logged. Enabling this option can be useful in tracking down unoptimized queries in your applications.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of milliseconds, 0, -1</td>
<td>-1</td>
<td>master session reload superuser</td>
</tr>
</tbody>
</table>

**log_min_error_statement**

Controls whether or not the SQL statement that causes an error condition will also be recorded in the server log. All SQL statements that cause an error of the specified level or higher are logged. The default is PANIC (effectively turning this feature off for normal use). Enabling this option can be helpful in tracking down the source of any errors that appear in the server log.
<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEBUG5</td>
<td>ERROR</td>
<td>master</td>
</tr>
<tr>
<td>DEBUG4</td>
<td></td>
<td>session</td>
</tr>
<tr>
<td>DEBUG3</td>
<td></td>
<td>reload</td>
</tr>
<tr>
<td>DEBUG2</td>
<td></td>
<td>superuser</td>
</tr>
<tr>
<td>DEBUG1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INFO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOTICE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WARNING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERROR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FATAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PANIC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### log_min_messages

Controls which message levels are written to the server log. Each level includes all the levels that follow it. The later the level, the fewer messages are sent to the log.

If the Greenplum Database PL/Container extension is installed. This parameter also controls the PL/Container log level. For information about the extension, see [Greenplum PL/Container Language Extension](#).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEBUG5</td>
<td>WARNING</td>
<td>master</td>
</tr>
<tr>
<td>DEBUG4</td>
<td></td>
<td>session</td>
</tr>
<tr>
<td>DEBUG3</td>
<td></td>
<td>reload</td>
</tr>
<tr>
<td>DEBUG2</td>
<td></td>
<td>superuser</td>
</tr>
<tr>
<td>DEBUG1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INFO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOTICE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WARNING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERROR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FATAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PANIC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### log_parser_stats

For each query, write performance statistics of the query parser to the server log. This is a crude profiling instrument. Cannot be enabled together with `log_statement_stats`.
### log_planner_stats

For each query, write performance statistics of the legacy query optimizer (planner) to the server log. This is a crude profiling instrument. Cannot be enabled together with `log_statement_stats`.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
<tr>
<td></td>
<td></td>
<td>superuser</td>
</tr>
</tbody>
</table>

### log_rotation_age

Determines the maximum lifetime of an individual log file. After this time has elapsed, a new log file will be created. Set to zero to disable time-based creation of new log files.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any valid time expression (number and unit)</td>
<td>1d</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

### log_rotation_size

Determines the maximum size of an individual log file. After this many kilobytes have been emitted into a log file, a new log file will be created. Set to zero to disable size-based creation of new log files.

The maximum value is INT_MAX/1024. If an invalid value is specified, the default value is used. INT_MAX is the largest value that can be stored as an integer on your system.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of kilobytes</td>
<td>0</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

### log_statement

Controls which SQL statements are logged. DDL logs all data definition commands like CREATE, ALTER, and DROP commands. MOD logs all DDL statements, plus INSERT, UPDATE, DELETE, TRUNCATE, and COPY FROM. PREPARE and EXPLAIN ANALYZE statements are also logged if their contained command is of an appropriate type.
<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>ALL</td>
<td>master</td>
</tr>
<tr>
<td>DDL</td>
<td>ALL</td>
<td>session</td>
</tr>
<tr>
<td>MOD</td>
<td>ALL</td>
<td>reload</td>
</tr>
<tr>
<td>ALL</td>
<td>ALL</td>
<td>superuser</td>
</tr>
</tbody>
</table>

**log_statement_stats**

For each query, write total performance statistics of the query parser, planner, and executor to the server log. This is a crude profiling instrument.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
<tr>
<td></td>
<td></td>
<td>superuser</td>
</tr>
</tbody>
</table>

**log_temp_files**

Controls logging of temporary file names and sizes. Temporary files can be created for sorts, hashes, temporary query results and spill files. A log entry is made in `pg_log` for each temporary file when it is deleted. Depending on the source of the temporary files, the log entry could be created on either the master and/or segments. A `log_temp_files` value of zero logs all temporary file information, while positive values log only files whose size is greater than or equal to the specified number of kilobytes. The default setting is `-1`, which disables logging. Only superusers can change this setting.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integer</td>
<td>-1</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**log_timezone**

Sets the time zone used for timestamps written in the log. Unlike `TimeZone`, this value is system-wide, so that all sessions will report timestamps consistently. The default is `unknown`, which means to use whatever the system environment specifies as the time zone.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td>unknown</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**log_truncate_on_rotation**

Truncates (overwrites), rather than appends to, any existing log file of the same name. Truncation will occur only when a new file is being opened due to time-based rotation. For example, using this setting in
combination with a log_filename such as gpseg#-%H.log would result in generating twenty-four hourly log files and then cyclically overwriting them. When off, pre-existing files will be appended to in all cases.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**max_appendonly_tables**

Sets the maximum number of concurrent transactions that can write to or update append-optimized tables. Transactions that exceed the maximum return an error.

Operations that are counted are INSERT, UPDATE, COPY, and VACUUM operations. The limit is only for in-progress transactions. Once a transaction ends (either aborted or committed), it is no longer counted against this limit.

For operations against a partitioned table, each subpartition (child table) that is an append-optimized table and is changed counts as a single table towards the maximum. For example, a partitioned table p_tbl is defined with three subpartitions that are append-optimized tables p_tbl_ao1, p_tbl_ao2, and p_tbl_ao3. An INSERT or UPDATE command against the partitioned table p_tbl that changes append-optimized tables p_tbl_ao1 and p_tbl_ao2 is counted as two transactions.

Increasing the limit allocates more shared memory on the master host at server start.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt; 0</td>
<td>10000</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**max_connections**

The maximum number of concurrent connections to the database server. In a Greenplum Database system, user client connections go through the Greenplum master instance only. Segment instances should allow 5-10 times the amount as the master. When you increase this parameter, **max_prepared_transactions** must be increased as well. For more information about limiting concurrent connections, see "Configuring Client Authentication" in the *Greenplum Database Administrator Guide*.

Increasing this parameter might cause Greenplum Database to request more shared memory. See **shared_buffers** for information about Greenplum server instance shared memory buffers. If this value is increased, **shared_buffers** and the kernel parameter **SHMMAX** might also need to be increased. Also, parameters that depend on shared memory such as **max_fsm_pages** might need to be changed.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-n</td>
<td>250 on master</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td>750 on segments</td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**max_files_per_process**

Sets the maximum number of simultaneously open files allowed to each server subprocess. If the kernel is enforcing a safe per-process limit, you don't need to worry about this setting. Some platforms such as BSD, the kernel will allow individual processes to open many more files than the system can really support.
max_fsm_pages

Sets the maximum number of disk pages for which free space will be tracked in the shared free-space map. Six bytes of shared memory are consumed for each page slot. If this value is increased, shared_buffers and the kernel parameter SHMMAX might also need to be increased. Also, parameters that depend on shared memory such as max_connections might need to be changed.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt; 16 * max_fsm_relations</td>
<td>200000</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

max_fsm_relations

Sets the maximum number of relations for which free space will be tracked in the shared memory free-space map. Should be set to a value larger than the total number of:

```
tables + indexes + system tables
```

It costs about 60 bytes of memory for each relation per segment instance. It is better to allow some room for overhead and set too high rather than too low.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>1000</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

max_function_args

Reports the maximum number of function arguments.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>100</td>
<td>read only</td>
</tr>
</tbody>
</table>

max_identifier_length

Reports the maximum identifier length.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>63</td>
<td>read only</td>
</tr>
</tbody>
</table>

max_index_keys

Reports the maximum number of index keys.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>63</td>
<td>read only</td>
</tr>
</tbody>
</table>
### max_locks_per_transaction
The shared lock table is created with room to describe locks on `max_locks_per_transaction` * `(max_connections + max_prepared_transactions)` objects, so no more than this many distinct objects can be locked at any one time. This is not a hard limit on the number of locks taken by any one transaction, but rather a maximum average value. You might need to raise this value if you have clients that touch many different tables in a single transaction.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>32</td>
<td>read only</td>
</tr>
</tbody>
</table>

### max_prepared_transactions
Sets the maximum number of transactions that can be in the prepared state simultaneously. Greenplum uses prepared transactions internally to ensure data integrity across the segments. This value must be at least as large as the value of `max_connections` on the master. Segment instances should be set to the same value as the master.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>128</td>
<td>local system restart</td>
</tr>
</tbody>
</table>

### max_resource_portals_per_transaction
Note: The `max_resource_portals_per_transaction` server configuration parameter is enforced only when resource queue-based resource management is active.

Sets the maximum number of simultaneously open user-declared cursors allowed per transaction. Note that an open cursor will hold an active query slot in a resource queue. Used for resource management.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>64</td>
<td>master system restart</td>
</tr>
</tbody>
</table>

### max_resource_queues
Note: The `max_resource_queues` server configuration parameter is enforced only when resource queue-based resource management is active.

Sets the maximum number of resource queues that can be created in a Greenplum Database system. Note that resource queues are system-wide (as are roles) so they apply to all databases in the system.
### max_stack_depth

Specifies the maximum safe depth of the server's execution stack. The ideal setting for this parameter is the actual stack size limit enforced by the kernel (as set by `ulimit -s` or local equivalent), less a safety margin of a megabyte or so. Setting the parameter higher than the actual kernel limit will mean that a runaway recursive function can crash an individual backend process.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>9</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

### max_statement_mem

**Note:** The `max_statement_mem` server configuration parameter is enforced only when resource queue-based resource management is active.

Sets the maximum memory limit for a query. Helps avoid out-of-memory errors on a segment host during query processing as a result of setting `statement_mem` too high. When `gp_resqueue_memory_policy=auto,statement_mem` and resource queue memory limits control query memory usage. Taking into account the configuration of a single segment host, calculate this setting as follows:

\[(\text{seghost_physical_memory}) / (\text{average_number_concurrent_queries})\]

When changing both `max_statement_mem` and `statement_mem`, `max_statement_mem` must be changed first, or listed first in the `postgresql.conf` file.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of kilobytes</td>
<td>2MB</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

### memory_spill_ratio

**Note:** The `memory_spill_ratio` server configuration parameter is enforced only when resource group-based resource management is active.

Sets the memory usage threshold for memory-intensive operators in a transaction. When a transaction reaches this threshold, it spills to disk.

The default `memory_spill_ratio` is the value defined for the resource group assigned to the currently active role. You can set `memory_spill_ratio` at the session level to selectively set this limit on a per-query basis. For example, if you have a specific query that spills to disk and requires more memory, you may choose to set a larger `memory_spill_ratio` to increase the initial memory allocation.
When you set `memory_spill_ratio` at the session level, Greenplum Database does not perform semantic validation on the new value until you next perform a query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 100</td>
<td>20</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**optimizer**

Enables or disables GPORCA when running SQL queries. The default is `on`. If you disable GPORCA, Greenplum Database uses only the legacy query optimizer.

GPORCA co-exists with the legacy query optimizer. With GPORCA enabled, Greenplum Database uses GPORCA to generate an execution plan for a query when possible. If GPORCA cannot be used, then the legacy query optimizer is used.

The `optimizer` parameter can be set for a database system, an individual database, or a session or query.

For information about the legacy query optimizer and GPORCA, see [*Querying Data* in the Greenplum Database Administrator Guide](#).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td><code>on</code></td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**optimizer_analyze_root_partition**

For a partitioned table, collects statistics for the root partition when the `ANALYZE` command is run on the table. GPORCA uses the root partition statistics when generating a query plan. The legacy query optimizer does not use these statistics. If you set the value of the server configuration parameter `optimizer` to `on`, set the value of this parameter to `on` and run the command `ANALYZE` or `ANALYZE_ROOTPARTITION` on partitioned tables to ensure the proper statistics have been collected.

For information about the legacy query optimizer and GPORCA, see [*Querying Data* in the Greenplum Database Administrator Guide](#).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td><code>off</code></td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**optimizer_array_expansion_threshold**

When GPORCA is enabled (the default) and is processing a query that contains a predicate with a constant array, the `optimizer_array_expansion_threshold` parameter limits the optimization process based on the number of constants in the array. If the array in the query predicate contains more than the number elements specified by parameter, GPORCA disables the transformation of the predicate into its disjunctive normal form during query optimization.

The default value is 25.
For example, when GPORCA is executing a query that contains an `IN` clause with more than 25 elements, GPORCA does not transform the predicate into its disjunctive normal form during query optimization to reduce optimization time and consume less memory. The difference in query processing can be seen in the filter condition for the `IN` clause of the query `EXPLAIN` plan.

Changing the value of this parameter changes the trade-off between a shorter optimization time and lower memory consumption, and the potential benefits from constraint derivation during query optimization, for example conflict detection and partition elimination.

The parameter can be set for a database system, an individual database, or a session or query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integer &gt; 0</td>
<td>25</td>
<td>master session</td>
</tr>
</tbody>
</table>

**optimizer_control**

Controls whether the server configuration parameter `optimizer` can be changed with `SET`, the `RESET` command, or the Greenplum Database utility `gpconfig`. If the `optimizer_control` parameter value is `on`, users can set the `optimizer` parameter. If the `optimizer_control` parameter value is `off`, the `optimizer` parameter cannot be changed.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master system restart superuser</td>
</tr>
</tbody>
</table>

**optimizer_cte_inlining_bound**

When GPORCA is enabled (the default), this parameter controls the amount of inlining performed for common table expression (CTE) queries (queries that contain a `WHERE` clause). The default value, 0, disables inlining.

The parameter can be set for a database system, an individual database, or a session or query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decimal &gt;= 0</td>
<td>0</td>
<td>master session</td>
</tr>
</tbody>
</table>

**optimizer_enable_associativity**

When GPORCA is enabled (the default), this parameter controls whether the join associativity transform is enabled during query optimization. The transform analyzes join orders. For the default value `off`, only the GPORCA dynamic programming algorithm for analyzing join orders is enabled. The join associativity transform largely duplicates the functionality of the newer dynamic programming algorithm.

If the value is `on`, GPORCA can use the associativity transform during query optimization.

The parameter can be set for a database system, an individual database, or a session or query.
For information about GPORCA, see *About GPORCA* in the *Greenplum Database Administrator Guide*.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**optimizer_enable_master_only_queries**

When GPORCA is enabled (the default), this parameter allows GPORCA to execute catalog queries that run only on the Greenplum Database master. For the default value *off*, only the legacy query optimizer can execute catalog queries that run only on the Greenplum Database master.

The parameter can be set for a database system, an individual database, or a session or query.

*Note:* Enabling this parameter decreases performance of short running catalog queries. To avoid this issue, set this parameter only for a session or a query.

For information about GPORCA, see *About GPORCA* in the *Greenplum Database Administrator Guide*.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>true</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**optimizer_force_multistage_agg**

For the default settings, GPORCA is enabled and this parameter is *true*, GPORCA chooses a 3 stage aggregate plan for scalar distinct qualified aggregate when such a plan alternative is generated. When the value is *false*, GPORCA makes a cost based choice rather than a heuristic choice.

The parameter can be set for a database system, an individual database, or a session or query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>true</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**optimizer_force_three_stage_scalar_dqa**

For the default settings, GPORCA is enabled and this parameter is *true*, GPORCA chooses a plan with multistage aggregates when such a plan alternative is generated. When the value is *false*, GPORCA makes a cost based choice rather than a heuristic choice.

The parameter can be set for a database system, an individual database, or a session, or query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>true</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>
### optimizer_join_arity_for_associativity_commutativity

The value is an optimization hint to limit the number of join associativity and join commutativity transformations explored during query optimization. The limit controls the alternative plans that GPORCA considers during query optimization. For example, the default value of 18 is an optimization hint for GPORCA to stop exploring join associativity and join commutativity transformations when an n-ary join operator has more than 18 children during optimization.

For a query with a large number of joins, specifying a lower value improves query performance by limiting the number of alternate query plans that GPORCA evaluates. However, setting the value too low might cause GPORCA to generate a query plan that performs sub-optimally.

This parameter has no effect when the `optimizer_join_order` parameter is set to `query` or `greedy`.

This parameter can be set for a database system or a session.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt; 0</td>
<td>18</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

### optimizer_join_order

When GPORCA is enabled, this parameter sets the optimization level for join ordering during query optimization by specifying which types of join ordering alternatives to evaluate.

- **query** - Uses the join order specified in the query.
- **greedy** - Evaluates the join order specified in the query and alternatives based on minimum cardinalities of the relations in the joins.
- **exhaustive** - Applies transformation rules to find and evaluate all join ordering alternatives.

The default value is `exhaustive`. Setting this parameter to `query` or `greedy` can generate a suboptimal query plan. However, if the administrator is confident that a satisfactory plan is generated with the `query` or `greedy` setting, query optimization time can be improved by setting the parameter to the lower optimization level.

Setting this parameter to `query` or `greedy` overrides the `optimizer_join_order_threshold` and `optimizer_join_arity_for_associativity_commutativity` parameters.

This parameter can be set for an individual database, a session, or a query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>query</td>
<td>exhaustive</td>
<td>master</td>
</tr>
<tr>
<td>greedy</td>
<td>exhaustive</td>
<td>session</td>
</tr>
<tr>
<td>exhaustive</td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

### optimizer_join_order_threshold

When GPORCA is enabled (the default), this parameter sets the maximum number of join children for which GPORCA will use the dynamic programming-based join ordering algorithm. You can set this value for a single query or for an entire session.

This parameter has no effect when the `optimizer_join_query` parameter is set to `query` or `greedy`. 
**optimizer_mdcache_size**

Sets the maximum amount of memory on the Greenplum Database master that GPORCA uses to cache query metadata (optimization data) during query optimization. The memory limit is session based. GPORCA caches query metadata during query optimization with the default settings: GPORCA is enabled and `optimizer_metadata_caching` is on.

The default value is 16384 (16MB). This is an optimal value that has been determined through performance analysis.

You can specify a value in KB, MB, or GB. The default unit is KB. For example, a value of 16384 is 16384KB. A value of 1GB is the same as 1024MB or 1048576KB. If the value is 0, the size of the cache is not limited.

This parameter can be set for a database system, an individual database, or a session or query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integer &gt;= 0</td>
<td>16384</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**optimizer_metadata_caching**

When GPORCA is enabled (the default), this parameter specifies whether GPORCA caches query metadata (optimization data) in memory on the Greenplum Database master during query optimization. The default for this parameter is on, enable caching. The cache is session based. When a session ends, the cache is released. If the amount of query metadata exceeds the cache size, then old, unused metadata is evicted from the cache.

If the value is off, GPORCA does not cache metadata during query optimization.

This parameter can be set for a database system, an individual database, or a session or query.

The server configuration parameter `optimizer_mdcache_size` controls the size of the query metadata cache.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**optimizer_minidump**

GPORCA generates minidump files to describe the optimization context for a given query. The information in the file is not in a format that can be easily used for debugging or troubleshooting. The minidump file is located under the master data directory and uses the following naming format:

`Minidump_date_time.mdp`
The minidump file contains this query related information:

- Catalog objects including data types, tables, operators, and statistics required by GPORCA
- An internal representation (DXL) of the query
- An internal representation (DXL) of the plan produced by GPORCA
- System configuration information passed to GPORCA such as server configuration parameters, cost and statistics configuration, and number of segments
- A stack trace of errors generated while optimizing the query

Setting this parameter to **ALWAYS** generates a minidump for all queries. Set this parameter to **ONERROR** to minimize total optimization time.

For information about GPORCA, see *About GPORCA* in the *Greenplum Database Administrator Guide*.

### optimizer_nestloop_factor

When GPORCA is enabled (the default), this parameter controls the nested loop join cost factor to apply to during query optimization. The default value, 1, specifies the default sort cost factor. The value is a ratio of increase or decrease from the default factor. For example, a value of 2.0 sets the cost factor at twice the default, and a value of 0.5 sets the factor at half the default.

The parameter can be set for a database system, an individual database, or a session or query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decimal &gt; 0</td>
<td>1</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

### optimizer_parallel_union

When GPORCA is enabled (the default), `optimizer_parallel_union` controls the amount of parallelization that occurs for queries that contain a `UNION` or `UNION ALL` clause.

When the value is **off**, the default, GPORCA generates a query plan where each child of an `APPEND(UNION)` operator is in the same slice as the `APPEND` operator. During query execution, the children are executed in a sequential manner.

When the value is **on**, GPORCA generates a query plan where a redistribution motion node is under an `APPEND(UNION)` operator. During query execution, the children and the parent `APPEND` operator are on different slices, allowing the children of the `APPEND(UNION)` operator to execute in parallel on segment instances.

The parameter can be set for a database system, an individual database, or a session or query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>
**optimizer_print_missing_stats**

When GPORCA is enabled (the default), this parameter controls the display of table column information about columns with missing statistics for a query. The default value is `true`, display the column information to the client. When the value is `false`, the information is not sent to the client.

The information is displayed during query execution, or with the `EXPLAIN` or `EXPLAIN ANALYZE` commands.

The parameter can be set for a database system, an individual database, or a session.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>true</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**optimizer_print_optimization_stats**

When GPORCA is enabled (the default), this parameter enables logging of GPORCA query optimization statistics for various optimization stages for a query. The default value is `off`, do not log optimization statistics. To log the optimization statistics, this parameter must be set to `on` and the parameter `client_min_messages` must be set to `log`.

- `set optimizer_print_optimization_stats = on;`
- `set client_min_messages = 'log';`

The information is logged during query execution, or with the `EXPLAIN` or `EXPLAIN ANALYZE` commands.

This parameter can be set for a database system, an individual database, or a session or query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**optimizer_sort_factor**

When GPORCA is enabled (the default), `optimizer_sort_factor` controls the cost factor to apply to sorting operations during query optimization. The default value `1` specifies the default sort cost factor. The value is a ratio of increase or decrease from the default factor. For example, a value of `2.0` sets the cost factor at twice the default, and a value of `0.5` sets the factor at half the default.

The parameter can be set for a database system, an individual database, or a session or query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decimal &gt; 0</td>
<td>1</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**password_encryption**

When a password is specified in `CREATE USER` or `ALTER USER` without writing either `ENCRYPTED` or `UNENCRYPTED`, this option determines whether the password is to be encrypted.
password_hash_algorithm

Specifies the cryptographic hash algorithm that is used when storing an encrypted Greenplum Database user password. The default algorithm is MD5.

For information about setting the password hash algorithm to protect user passwords, see "Protecting Passwords in Greenplum Database" in the Greenplum Database Administrator Guide.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
<tr>
<td>MD5</td>
<td>MD5</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
<tr>
<td>SHA-256</td>
<td></td>
<td>superuser</td>
</tr>
</tbody>
</table>

pgstat_track_activity_query_size

Sets the maximum length limit for the query text stored in current_query column of the system catalog view pg_stat_activity. The minimum length is 1024 characters.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>1024</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

pljava_classpath

A colon (:) separated list of jar files or directories containing jar files needed for PL/Java functions. The full path to the jar file or directory must be specified, except the path can be omitted for jar files in the $GPHOME/lib/postgresql/java directory. The jar files must be installed in the same locations on all Greenplum hosts and readable by the gpadmin user.

The pljava_classpath parameter is used to assemble the PL/Java classpath at the beginning of each user session. Jar files added after a session has started are not available to that session.

If the full path to a jar file is specified in pljava_classpath it is added to the PL/Java classpath. When a directory is specified, any jar files the directory contains are added to the PL/Java classpath. The search does not descend into subdirectories of the specified directories. If the name of a jar file is included in pljava_classpath with no path, the jar file must be in the $GPHOME/lib/postgresql/java directory.

Note: Performance can be affected if there are many directories to search or a large number of jar files.

If pljava_classpath_insecure is false, setting the pljava_classpath parameter requires superuser privilege. Setting the classpath in SQL code will fail when the code is executed by a user without superuser privilege. The pljava_classpath parameter must have been set previously by a superuser
or in the `postgresql.conf` file. Changing the classpath in the `postgresql.conf` file requires a reload (`gpstop -u`).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td></td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
<tr>
<td></td>
<td></td>
<td>superuser</td>
</tr>
</tbody>
</table>

**pljava_classpath_insecure**

Controls whether the server configuration parameter `pljava_classpath` can be set by a user without Greenplum Database superuser privileges. When `true`, `pljava_classpath` can be set by a regular user. Otherwise, `pljava_classpath` can be set only by a database superuser. The default is `false`.

**Warning**: Enabling this parameter exposes a security risk by giving non-administrator database users the ability to run unauthorized Java methods.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>false</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
<tr>
<td></td>
<td></td>
<td>superuser</td>
</tr>
</tbody>
</table>

**pljava_statement_cache_size**

Sets the size in KB of the JRE MRU (Most Recently Used) cache for prepared statements.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of kilobytes</td>
<td>10</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
<tr>
<td></td>
<td></td>
<td>superuser</td>
</tr>
</tbody>
</table>

**pljava_release_lingering_savepoints**

If true, lingering savepoints used in PL/Java functions will be released on function exit. If false, savepoints will be rolled back.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>true</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
<tr>
<td></td>
<td></td>
<td>superuser</td>
</tr>
</tbody>
</table>
**pljava_vmoptions**

Defines the startup options for the Java VM. The default value is an empty string ("").

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td></td>
<td>master</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td></td>
<td>system</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td></td>
<td>superuser</td>
</tr>
</tbody>
</table>

**port**

The database listener port for a Greenplum instance. The master and each segment has its own port. Port numbers for the Greenplum system must also be changed in the `gp_segment_configuration` catalog. You must shut down your Greenplum Database system before changing port numbers.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>any valid port number</td>
<td>5432</td>
<td>local</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>any valid port number</td>
<td></td>
<td>system</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>any valid port number</td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**random_page_cost**

Sets the estimate of the cost of a nonsequentially fetched disk page for the legacy query optimizer (planner). This is measured as a multiple of the cost of a sequential page fetch. A higher value makes it more likely a sequential scan will be used, a lower value makes it more likely an index scan will be used.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>floating point</td>
<td>100</td>
<td>master</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>floating point</td>
<td></td>
<td>session</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>floating point</td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**readable_external_table_timeout**

When an SQL query reads from an external table, the parameter value specifies the amount of time in seconds that Greenplum Database waits before cancelling the query when data stops being returned from the external table.

The default value of 0, specifies no time out. Greenplum Database does not cancel the query.

If queries that use gpfdist run a long time and then return the error "intermittent network connectivity issues", you can specify a value for `readable_external_table_timeout`. If no data is returned by gpfdist for the specified length of time, Greenplum Database cancels the query.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt;= 0</td>
<td>0</td>
<td>master</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt;= 0</td>
<td></td>
<td>system</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt;= 0</td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>
repl_catchup_within_range

For Greenplum Database master mirroring, controls updates to the active master. If the number of WAL segment files that have not been processed by the `walsender` exceeds this value, Greenplum Database updates the active master.

If the number of segment files does not exceed the value, Greenplum Database blocks updates to the to allow the `walsender` process the files. If all WAL segments have been processed, the active master is updated.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 64</td>
<td>1</td>
<td>master system reload superuser</td>
</tr>
</tbody>
</table>

replication_timeout

For Greenplum Database master mirroring, sets the maximum time in milliseconds that the `walsender` process on the active master waits for a status message from the `walreceiver` process on the standby master. If a message is not received, the `walsender` logs an error message.

The `wal_receiver_status_interval` controls the interval between `walreceiver` status messages.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - INT_MAX</td>
<td>60000 ms (60 seconds)</td>
<td>master system reload superuser</td>
</tr>
</tbody>
</table>

regex_flavor

The 'extended' setting may be useful for exact backwards compatibility with pre-7.4 releases of PostgreSQL.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>advanced</td>
<td>advanced</td>
<td>master session reload</td>
</tr>
<tr>
<td>extended</td>
<td></td>
<td></td>
</tr>
<tr>
<td>basic</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

resource_cleanup_gangs_on_wait

Note: The `resource_cleanup_gangs_on_wait` server configuration parameter is enforced only when resource queue-based resource management is active.

If a statement is submitted through a resource queue, clean up any idle query executor worker processes before taking a lock on the resource queue.
### Value Range | Default | Set Classifications
--- | --- | ---
Boolean | on | master, system, restart

**resource_select_only**

**Note:** The resource_select_only server configuration parameter is enforced only when resource queue-based resource management is active.

Sets the types of queries managed by resource queues. If set to on, then SELECT, SELECT INTO, CREATE TABLE AS SELECT, and DECLARE CURSOR commands are evaluated. If set to off INSERT, UPDATE, and DELETE commands will be evaluated as well.

### Value Range | Default | Set Classifications
--- | --- | ---
Boolean | off | master, system, restart

**runaway_detector_activation_percent**

**Note:** The runaway_detector_activation_percent server configuration parameter is enforced only when resource queue-based resource management is active.

Sets the percentage of Greenplum Database vmem memory that triggers the termination of queries. If the percentage of vmem memory that is utilized for a Greenplum Database segment exceeds the specified value, Greenplum Database terminates queries based on memory usage, starting with the query consuming the largest amount of memory. Queries are terminated until the percentage of utilized vmem is below the specified percentage.

Specify the maximum vmem value for active Greenplum Database segment instances with the server configuration parameter `gp_vmem_protect_limit`.

For example, if vmem memory is set to 10GB, and the value of runaway_detector_activation_percent is 90 (90%), Greenplum Database starts terminating queries when the utilized vmem memory exceeds 9 GB.

A value of 0 disables the automatic termination of queries based on percentage of vmem that is utilized.

### Value Range | Default | Set Classifications
--- | --- | ---
percentage (integer) | 90 | local, system, restart

**search_path**

Specifies the order in which schemas are searched when an object is referenced by a simple name with no schema component. When there are objects of identical names in different schemas, the one found first in the search path is used. The system catalog schema, `pg_catalog`, is always searched, whether it is mentioned in the path or not. When objects are created without specifying a particular target schema, they will be placed in the first schema listed in the search path. The current effective value of the search path can be examined via the SQL function `current_schemas()`. `current_schemas()` shows how the requests appearing in search_path were resolved.
### seq_page_cost

For the legacy query optimizer (planner), sets the estimate of the cost of a disk page fetch that is part of a series of sequential fetches.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>floating point</td>
<td>1</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

### server_encoding

Reports the database encoding (character set). It is determined when the Greenplum Database array is initialized. Ordinarily, clients need only be concerned with the value of `client_encoding`.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;system dependent&gt;</td>
<td>UTF8</td>
<td>read only</td>
</tr>
</tbody>
</table>

### server_version

Reports the version of PostgreSQL that this release of Greenplum Database is based on.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td>8.3.23</td>
<td>read only</td>
</tr>
</tbody>
</table>

### server_version_num

Reports the version of PostgreSQL that this release of Greenplum Database is based on as an integer.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>80323</td>
<td>read only</td>
</tr>
</tbody>
</table>

### shared_buffers

Sets the amount of memory a Greenplum Database segment instance uses for shared memory buffers. This setting must be at least 128KB and at least 16KB times `max_connections`.

Each Greenplum Database segment instance calculates and attempts to allocate certain amount of shared memory based on the segment configuration. The value of `shared_buffers` is significant portion of this shared memory calculation, but is not all it. When setting `shared_buffers`, the values for the operating system parameters `SHMMAX` or `SHMALL` might also need to be adjusted.

The operating system parameter `SHMMAX` specifies maximum size of a single shared memory allocation. The value of `SHMMAX` must be greater than this value:

```
shared_buffers + other_seg_shmem
```
The value of `other_seg_shmem` is the portion the Greenplum Database shared memory calculation that is not accounted for by the `shared_buffers` value. The `other_seg_shmem` value will vary based on the segment configuration.

With the default Greenplum Database parameter values, the value for `other_seg_shmem` is approximately 111MB for Greenplum Database segments and approximately 79MB for the Greenplum Database master.

The operating system parameter `SHMALL` specifies the maximum amount of shared memory on the host. The value of `SHMALL` must be greater than this value:

```
(num_instances_per_host * ( shared_buffers + other_seg_shmem ))
+ other_app_shared_mem
```

The value of `other_app_shared_mem` is the amount of shared memory that is used by other applications and processes on the host.

When shared memory allocation errors occur, possible ways to resolve shared memory allocation issues are to increase `SHMMAX` or `SHMALL`, or decrease `shared_buffers` or `max_connections`.

See the *Greenplum Database Installation Guide* for information about the Greenplum Database values for the parameters `SHMMAX` and `SHMALL`.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt; 16K * max_connections</td>
<td>125MB</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**shared_preload_libraries**

A comma-separated list of shared libraries that are to be preloaded at server start. PostgreSQL procedural language libraries can be preloaded in this way, typically by using the syntax `$libdir/plXXX` where `XXX` is `pgsql`, `perl`, `tcl`, or `python`. By preloading a shared library, the library startup time is avoided when the library is first used. If a specified library is not found, the server will fail to start.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**ssl**

Enables SSL connections.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master, system, restart</td>
</tr>
</tbody>
</table>

**ssl_ciphers**

Specifies a list of SSL ciphers that are allowed to be used on secure connections. See the openssl manual page for a list of supported ciphers.
### standard_conforming_strings

Determines whether ordinary string literals ("...") treat backslashes literally, as specified in the SQL standard. The default value is on. Turn this parameter off to treat backslashes in string literals as escape characters instead of literal backslashes. Applications may check this parameter to determine how string literals are processed. The presence of this parameter can also be taken as an indication that the escape string syntax (E'...') is supported.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

### statement_mem

**Note:** The `statement_mem` server configuration parameter is enforced only when resource queue-based resource management is active.

Allocates segment host memory per query. The amount of memory allocated with this parameter cannot exceed `max_statement_mem` or the memory limit on the resource queue through which the query was submitted. When `gp_resqueue_memory_policy = auto, statement_mem` and resource queue memory limits control query memory usage.

If additional memory is required for a query, temporary spill files on disk are used.

This calculation can be used to estimate a reasonable value for a wide variety of situations.

\[
\frac{(gp\_vmem\_protect\_limitGB \times .9)}{\text{max\_expected\_concurrent\_queries}}
\]

With the `gp\_vmem\_protect\_limit` set to 8192MB (8GB) and assuming a maximum of 40 concurrent queries with a 10% buffer

\[
\frac{(8GB \times .9)}{40} = .18GB = 184MB
\]

When changing both `max_statement_mem` and `statement_mem`, `max_statement_mem` must be changed first, or listed first in the `postgresql.conf` file.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of kilobytes</td>
<td>128MB</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

### statement_timeout

Abort any statement that takes over the specified number of milliseconds. 0 turns off the limitation.
<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of milliseconds</td>
<td>0</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**stats_queue_level**

*Note:* The `stats_queue_level` server configuration parameter is enforced only when resource queue-based resource management is active.

Collects resource queue statistics on database activity.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**superuser_reserved_connections**

Determines the number of connection slots that are reserved for Greenplum Database superusers.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &lt; <code>max_connections</code></td>
<td>3</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**tcp_keepalives_count**

How many keepalives may be lost before the connection is considered dead. A value of 0 uses the system default. If TCP_KEEPCNT is not supported, this parameter must be 0.

Use this parameter for all connections that are not between a primary and mirror segment. Use `gp_filerep_tcp_keepalives_count` for settings that are between a primary and mirror segment.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of lost keepalives</td>
<td>0</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**tcp_keepalives_idle**

Number of seconds between sending keepalives on an otherwise idle connection. A value of 0 uses the system default. If TCP_KEEPIDLE is not supported, this parameter must be 0.

Use this parameter for all connections that are not between a primary and mirror segment. Use `gp_filerep_tcp_keepalives_idle` for settings that are between a primary and mirror segment.
### tcp_keepalives_interval

How many seconds to wait for a response to a keepalive before retransmitting. A value of 0 uses the system default. If TCP_KEEPINTVL is not supported, this parameter must be 0.

Use this parameter for all connections that are not between a primary and mirror segment. Use gp_filerep_tcp_keepalives_interval for settings that are between a primary and mirror segment.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of seconds</td>
<td>0</td>
<td>local system restart</td>
</tr>
</tbody>
</table>

### temp_buffers

Sets the maximum number of temporary buffers used by each database session. These are session-local buffers used only for access to temporary tables. The setting can be changed within individual sessions, but only up until the first use of temporary tables within a session. The cost of setting a large value in sessions that do not actually need a lot of temporary buffers is only a buffer descriptor, or about 64 bytes, per increment. However if a buffer is actually used, an additional 8192 bytes will be consumed.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer</td>
<td>1024</td>
<td>master session reload</td>
</tr>
</tbody>
</table>

### TimeZone

Sets the time zone for displaying and interpreting time stamps. The default is to use whatever the system environment specifies as the time zone. See Date/Time Keywords in the PostgreSQL documentation.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>time zone abbreviation</td>
<td></td>
<td>local restart</td>
</tr>
</tbody>
</table>

### timezone_abbreviations

Sets the collection of time zone abbreviations that will be accepted by the server for date time input. The default is Default, which is a collection that works in most of the world. Australia and India, and other collections can be defined for a particular installation. Possible values are names of configuration files stored in $GPHOME/share/postgresql/timezonesets/.

To configure Greenplum Database to use a custom collection of timezones, copy the file that contains the timezone definitions to the directory $GPHOME/share/postgresql/timezonesets/ on the Greenplum Database master and segment hosts. Then set value of the server configuration parameter.
timezone_abbreviations to the file. For example, to use a file custom that contains the default timezones and the WIB (Waktu Indonesia Barat) timezone.

1. Copy the file Default from the directory `$GPHOME/share/postgresql/timezonesets/` the file custom. Add the WIB timezone information from the file Asia.txt to the custom.
2. Copy the file custom to the directory `$GPHOME/share/postgresql/timezonesets/` on the Greenplum Database master and segment hosts.
3. Set value of the server configuration parameter timezone_abbreviations to custom.
4. Reload the server configuration file (`gpstop -u`).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td>Default</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**track_activities**

Enables the collection of statistics on the currently executing command of each session, along with the time at which that command began execution. When enabled, this information is not visible to all users, only to superusers and the user owning the session. This data can be accessed via the `pg_stat_activity` system view.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**track_counts**

Enables the collection of row and block level statistics on database activity. If enabled, the data that is produced can be accessed via the `pg_stat` and `pg_statio` family of system views.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

**transaction_isolation**

Sets the current transaction's isolation level.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>read committed serializable</td>
<td>read committed</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

**transaction_read_only**

Sets the current transaction's read-only status.
<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**transform_null_equals**

When on, expressions of the form \( \text{expr} = \text{NULL} \) (or \( \text{NULL} = \text{expr} \)) are treated as \( \text{expr IS NULL} \), that is, they return true if \( \text{expr} \) evaluates to the null value, and false otherwise. The correct SQL-spec-compliant behavior of \( \text{expr} = \text{NULL} \) is to always return null (unknown).

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

**unix_socket_directory**

Specifies the directory of the UNIX-domain socket on which the server is to listen for connections from client applications.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>directory path</td>
<td>unset</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**unix_socket_group**

Sets the owning group of the UNIX-domain socket. By default this is an empty string, which uses the default group for the current user.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIX group name</td>
<td>unset</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

**unix_socket_permissions**

Sets the access permissions of the UNIX-domain socket. UNIX-domain sockets use the usual UNIX file system permission set. Note that for a UNIX-domain socket, only write permission matters.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>numeric UNIX file permission mode (as accepted by the chmod or umask commands)</td>
<td>511</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>
**update_process_title**

Enables updating of the process title every time a new SQL command is received by the server. The process title is typically viewed by the `ps` command.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>on</td>
<td>local system restart</td>
</tr>
</tbody>
</table>

**vacuum_cost_delay**

The length of time that the process will sleep when the cost limit has been exceeded. 0 disables the cost-based vacuum delay feature.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>milliseconds &lt; 0 (in multiples of 10)</td>
<td>0</td>
<td>local system restart</td>
</tr>
</tbody>
</table>

**vacuum_cost_limit**

The accumulated cost that will cause the vacuuming process to sleep.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt; 0</td>
<td>200</td>
<td>local system restart</td>
</tr>
</tbody>
</table>

**vacuum_cost_page_dirty**

The estimated cost charged when vacuum modifies a block that was previously clean. It represents the extra I/O required to flush the dirty block out to disk again.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt; 0</td>
<td>20</td>
<td>local system restart</td>
</tr>
</tbody>
</table>

**vacuum_cost_page_hit**

The estimated cost for vacuuming a buffer found in the shared buffer cache. It represents the cost to lock the buffer pool, lookup the shared hash table and scan the content of the page.
### vacuum_cost_page_miss

The estimated cost for vacuuming a buffer that has to be read from disk. This represents the effort to lock the buffer pool, lookup the shared hash table, read the desired block in from the disk and scan its content.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer &gt; 0</td>
<td>1</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

### vacuum_freeze_min_age

Specifies the cutoff age (in transactions) that VACUUM should use to decide whether to replace transaction IDs with FrozenXID while scanning a table.

For information about VACUUM and transaction ID management, see "Managing Data" in the Greenplum Database Administrator Guide and the PostgreSQL documentation.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer 0-1000000000000</td>
<td>100000000</td>
<td>local, system, restart</td>
</tr>
</tbody>
</table>

### validate_previous_free_tid

Enables a test that validates the free tuple ID (TID) list. The list is maintained and used by Greenplum Database. Greenplum Database determines the validity of the free TID list by ensuring the previous free TID of the current free tuple is a valid free tuple. The default value is true, enable the test.

If Greenplum Database detects a corruption in the free TID list, the free TID list is rebuilt, a warning is logged, and a warning is returned by queries for which the check failed. Greenplum Database attempts to execute the queries.

**Note:** If a warning is returned, please contact Pivotal Support.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>true</td>
<td>master, session, reload</td>
</tr>
</tbody>
</table>

### verify_gpfdists_cert

When a Greenplum Database external table is defined with the gpfdists protocol to use SSL security, this parameter controls whether SSL certificate authentication is enabled. The default is true, SSL.
authentication is enabled when Greenplum Database communicates with the gpfdist utility to either read data from or write data to an external data source.

The value false disables SSL certificate authentication. These SSL exceptions are ignored:

- The self-signed SSL certificate that is used by gpfdist is not trusted by Greenplum Database.
- The host name contained in the SSL certificate does not match the host name that is running gpfdist.

You can set the value to false to disable authentication when testing the communication between the Greenplum Database external table and the gpfdist utility that is serving the external data.

**Warning:** Disabling SSL certificate authentication exposes a security risk by not validating the gpfdist's SSL certificate.

For information about the gpfdist protocol, see gpfdists:// Protocol. For information about running the gpfdist utility, see gpfdist.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>true</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

### vmem_process_interrupt

Enables checking for interrupts before reserving vmem memory for a query during Greenplum Database query execution. Before reserving further vmem for a query, check if the current session for the query has a pending query cancellation or other pending interrupts. This ensures more responsive interrupt processing, including query cancellation requests. The default is off.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>off</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

### wal_receiver_status_interval

For Greenplum Database master mirroring, sets the interval in seconds between walreceiver process status messages that are sent to the active master. Under heavy loads, the time might be longer.

The value of replication_timeout controls the time that the walsender process waits for a walreceiver message.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer 0- INT_MAX/1000</td>
<td>10 sec</td>
<td>master</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
<tr>
<td></td>
<td></td>
<td>superuser</td>
</tr>
</tbody>
</table>

### writable_external_table_bufsize

Size of the buffer (in KB) that Greenplum Database uses for network communication, such as the gpfdist utility and external web tables (that use http). Greenplum Database stores data in the buffer before writing the data out. For information about gpfdist, see the Greenplum Database Utility Guide.
### xid_stop_limit

The number of transaction IDs prior to the ID where transaction ID wraparound occurs. When this limit is reached, Greenplum Database stops creating new transactions to avoid data loss due to transaction ID wraparound.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer 32 - 131072 (32KB - 128MB)</td>
<td>64</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

### xid_warn_limit

The number of transaction IDs prior to the limit specified by `xid_stop_limit`. When Greenplum Database reaches this limit, it issues a warning to perform a VACUUM operation to avoid data loss due to transaction ID wraparound.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>integer 10000000 - 2000000000</td>
<td>1000000000</td>
<td>local</td>
</tr>
<tr>
<td></td>
<td></td>
<td>system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>restart</td>
</tr>
</tbody>
</table>

### xmlbinary

Specifies how binary values are encoded in XML data. For example, when `bytea` values are converted to XML. The binary data can be converted to either base64 encoding or hexadecimal encoding. The default is base64.

The parameter can be set for a database system, an individual database, or a session.

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>base64</td>
<td>base64</td>
<td>master</td>
</tr>
<tr>
<td>hex</td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>

### xmloption

Specifies whether XML data is to be considered as an XML document (`document`) or XML content fragment (`content`) for operations that perform implicit parsing and serialization. The default is `content`.

This parameter affects the validation performed by `xml_is_well_formed()`. If the value is `document`, the function checks for a well-formed XML document. If the value is `content`, the function checks for a well-formed XML content fragment.
**Note:** An XML document that contains a document type declaration (DTD) is not considered a valid XML content fragment. If `xmloption` set to `content`, XML that contains a DTD is not considered valid XML.

To cast a character string that contains a DTD to the `xml` data type, use the `xmlparse` function with the `document` keyword, or change the `xmloption` value to `document`.

The parameter can be set for a database system, an individual database, or a session. The SQL command to set this option for a session is also available in Greenplum Database.

```
SET XML OPTION { DOCUMENT | CONTENT }
```

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Default</th>
<th>Set Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>document</td>
<td>content</td>
<td>master</td>
</tr>
<tr>
<td>content</td>
<td></td>
<td>session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reload</td>
</tr>
</tbody>
</table>
Summary of Built-in Functions

Greenplum Database supports built-in functions and operators including analytic functions and window functions that can be used in window expressions. For information about using built-in Greenplum Database functions see, "Using Functions and Operators" in the Greenplum Database Administrator Guide.

- Greenplum Database Function Types
- Built-in Functions and Operators
- JSON Functions and Operators
- Window Functions
- Advanced Aggregate Functions

Greenplum Database Function Types

Greenplum Database evaluates functions and operators used in SQL expressions. Some functions and operators are only allowed to execute on the master since they could lead to inconsistencies in Greenplum Database segment instances. This table describes the Greenplum Database Function Types.

Table 237: Functions in Greenplum Database

<table>
<thead>
<tr>
<th>Function Type</th>
<th>Greenplum Support</th>
<th>Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMMUTABLE</td>
<td>Yes</td>
<td>Relies only on information directly in its argument list. Given the same argument values, always returns the same result.</td>
<td></td>
</tr>
<tr>
<td>STABLE</td>
<td>Yes, in most cases</td>
<td>Within a single table scan, returns the same result for same argument values, but results change across SQL statements.</td>
<td>Results depend on database lookups or parameter values. current_timestamp family of functions is STABLE; values do not change within an execution.</td>
</tr>
<tr>
<td>VOLATILE</td>
<td>Restricted</td>
<td>Function values can change within a single table scan. For example: random(),timeofday().</td>
<td>Any function with side effects is volatile, even if its result is predictable. For example: setval().</td>
</tr>
</tbody>
</table>

In Greenplum Database, data is divided up across segments — each segment is a distinct PostgreSQL database. To prevent inconsistent or unexpected results, do not execute functions classified as VOLATILE at the segment level if they contain SQL commands or modify the database in any way. For example, functions such as `setval()` are not allowed to execute on distributed data in Greenplum Database because they can cause inconsistent data between segment instances.

To ensure data consistency, you can safely use VOLATILE and STABLE functions in statements that are evaluated on and run from the master. For example, the following statements run on the master (statements without a FROM clause):

```sql
SELECT setval('myseq', 201);
SELECT foo();
```
If a statement has a `FROM` clause containing a distributed table and the function in the `FROM` clause returns a set of rows, the statement can run on the segments:

```sql
SELECT * from foo();
```

Greenplum Database does not support functions that return a table reference (`rangeFuncs`) or functions that use the `refCursor` datatype.

### Built-in Functions and Operators

The following table lists the categories of built-in functions and operators supported by PostgreSQL. All functions and operators are supported in Greenplum Database as in PostgreSQL with the exception of `STABLE` and `VOLATILE` functions, which are subject to the restrictions noted in Greenplum Database Function Types. See the Functions and Operators section of the PostgreSQL documentation for more information about these built-in functions and operators.

**Table 238: Built-in functions and operators**

<table>
<thead>
<tr>
<th>Operator/Function Category</th>
<th>VOLATILE Functions</th>
<th>STABLE Functions</th>
<th>Restrictions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Logical Operators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Comparison Operators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mathematical Functions and Operators</strong></td>
<td>random, setseed</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>String Functions and Operators</strong></td>
<td>All built-in conversion functions, convert, pg_client_encoding</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Binary String Functions and Operators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bit String Functions and Operators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pattern Matching</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Data Type Formatting Functions</strong></td>
<td>to_char, to_timestamp</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Date/Time Functions and Operators</strong></td>
<td>timeofday, age, current_date, current_time, current_timestamp, localtime, localtimestamp, now</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Enum Support Functions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Geometric Functions and Operators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operator/Function Category</td>
<td>VOLATILE Functions</td>
<td>STABLE Functions</td>
<td>Restrictions</td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------------------</td>
<td>-----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Network Address Functions and Operators</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sequence Manipulation Functions</td>
<td>nextval()</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditional Expressions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Array Functions and Operators</td>
<td></td>
<td>All array functions</td>
<td></td>
</tr>
<tr>
<td>Aggregate Functions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subquery Expressions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row and Array Comparisons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set Returning Functions</td>
<td>generate_series</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Information Functions</td>
<td></td>
<td>All session information functions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>All access privilege inquiry functions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>All schema visibility inquiry functions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>All system catalog information functions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>All comment information functions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>All transaction ids and snapshots</td>
<td></td>
</tr>
<tr>
<td>System Administration Functions</td>
<td>set_config</td>
<td>current_setting</td>
<td><strong>Note:</strong> The function pg_column_size displays bytes required to store the value, possibly with TOAST compression.</td>
</tr>
<tr>
<td></td>
<td>pg_cancel_backend</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pg_reload_conf</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pg_rotate_logfile</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pg_start_backup</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pg_stop_backup</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pg_size_pretty</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pg_ls_dir</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pg_read_file</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pg_stat_file</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operator/Function Category</td>
<td>VOLATILE Functions</td>
<td>STABLE Functions</td>
<td>Restrictions</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-------------------</td>
<td>-----------------</td>
<td>--------------</td>
</tr>
<tr>
<td><strong>XML Functions and function-like expressions</strong></td>
<td>cursor_to_xml(cursor refcursor, count int, nulls boolean, tableforest boolean, targetns text)</td>
<td>database_to_xml(nulls boolean, tableforest boolean, targetns text)</td>
<td></td>
</tr>
<tr>
<td>Operator/Function Category</td>
<td>VOLATILE Functions</td>
<td>STABLE Functions</td>
<td>Restrictions</td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------------------</td>
<td>------------------</td>
<td>--------------</td>
</tr>
<tr>
<td></td>
<td>table_to_xml_and_xmlschema(tbl regclass, nulls boolean, tableforest boolean, targetns text)</td>
<td>xmlagg(xml)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xmlconcat(xml[, ...])</td>
<td>xmlconcat(xml[, ...])</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xmlelement(name name [, xmlattributes(value [AS attname] [, ...])] [, content, ...])</td>
<td>xmlexists(text, xml)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xmlforest(content [AS name] [, ...])</td>
<td>xml_is_well_formed(text)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xml_is_well_formed_document(text)</td>
<td>xml_is_well_formed_content(text)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xmlparse ( { DOCUMENT</td>
<td>CONTENT } value)</td>
<td>xpath(text, xml)</td>
</tr>
<tr>
<td></td>
<td>xpath(text, xml, text[])</td>
<td>xpath_exists(text, xml)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xpath_exists(text, xml, text[])</td>
<td>xmlpi(name target [, content])</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xmlroot(xml, version text</td>
<td>no value [, standalone yes</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>xmlserialize ( { DOCUMENT</td>
<td>CONTENT } value AS type )</td>
<td>xml(text)</td>
</tr>
<tr>
<td></td>
<td>text(xml)</td>
<td>xmlcomment(xml)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>xmlconcat2(xml, xml)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### JSON Functions and Operators

Built-in functions and operators that create and manipulate JSON data.

- **JSON Operators**
- **JSON Creation Functions**
- **JSON Processing Functions**

**Note:** For JSON values, all key/value pairs are kept even if a JSON object contains duplicate key/value pairs. The processing functions consider the last value as the operative one.
**JSON Operators**

This table describes the operators that are available for use with the `json` data type.

**Table 239: json Operators**

<table>
<thead>
<tr>
<th>Operator</th>
<th>Right Operand Type</th>
<th>Description</th>
<th>Example</th>
<th>Example Result</th>
</tr>
</thead>
</table>
| `->`     | int                | Get JSON array element (indexed from zero). | '[["a":"foo"],
{"b":"bar"},
{"c":"baz"}]::json->2' | "c":"baz" |
| `->`     | text               | Get JSON object field by key. | '{"a":
{"b":"foo"}}::json->'a' | "b":"foo" |
| `>>>`    | int                | Get JSON array element as text. | '[1,2,3]::json->>>2' | 3 |
| `>>>`    | text               | Get JSON object field as text. | '{"a":1,"b":2}::json->>'b' | 2 |
| `#>`     | text[]             | Get JSON object at specified path. | '{"a":{"b":{"c":"foo"}}}::json#>{a,b} | "c": "foo" |
| `#>>`    | text[]             | Get JSON object at specified path as text. | '{"a":[1,2,3],"b":[4,5,6]}::json#>>'{a,2}' | 3 |

**JSON Creation Functions**

This table describes the functions that create `json` values.

**Table 240: JSON Creation Functions**

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Example</th>
<th>Example Result</th>
</tr>
</thead>
</table>
| `array_to_json(anyarray [, pretty_bool])` | Returns the array as a JSON array. A Greenplum Database multidimensional array becomes a JSON array of arrays. Line feeds are added between dimension 1 elements if `pretty_bool` is true. | `array_to_json('{{1,5},
{99,100}}'::int[])` | `[[1,5],[99,100]]` |
| `row_to_json(record [, pretty_bool])` | Returns the row as a JSON object. Line feeds are added between level 1 elements if `pretty_bool` is true. | `row_to_json(row(1,'foo'))` | `{"f1":1,"f2":"foo"}` |
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JSON Processing Functions
This table describes the functions that process json values.
Table 241: JSON Processing Functions
Function

Return Type

Description

Example

json_
each(json)

setof key
text, value
json

Expands the
outermost JSON
object into a set of
key/value pairs.

select *
key | value
from json_
-----+------| "foo"
each('{"a":"foo", a
b
| "bar"
"b":"bar"}')

setof key
text, value
jsonb

Example Result

json_each_
text(json)

setof key
text, value
text

Expands the
outermost JSON
object into a set
of key/value pairs.
The returned
values are of type
text.

select * from
key | value
json_each_
-----+------| foo
text('{"a":"foo", a
b
| bar
"b":"bar"}')

json_extract_
path(from_json
json, VARIADIC
path_elems
text[])

json

Returns the JSON
value specified to
by path_elems.
Equivalent to #>
operator.

json_extract_
{"f5":99,"f6":"foo"}
path('{"f2":
{"f3":1},"f4":
{"f5":99,"f6":"foo"}}','f4')

json_
extract_path_
text(from_json
json, VARIADIC
path_elems
text[])

text

Returns the JSON
value specified to
by path_elems
as text. Equivalent
to #>> operator.

json_extract_
foo
path_text('{"f2":
{"f3":1},"f4":
{"f5":99,"f6":"foo"}}','f4',
'f6')

json_object_
keys(json)

setof text

Returns set
of keys in the
outermost JSON
object.

json_object_
json_object_
keys('{"f1":"abc","f2":
keys
-----------------{"f3":"a",
f1
"f4":"b"}}')
f2

json_populate_
record(base
anyelement,
from_json
json)

anyelement

Expands the
object in from_
json to a row
whose columns
match the record
type defined by
base. See Note.

select * from
a | b
json_populate_
---+--1 | 2
record(null::myrowtype,
'{"a":1,"b":2}')

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### Function

<table>
<thead>
<tr>
<th>Function</th>
<th>Return Type</th>
<th>Description</th>
<th>Example</th>
<th>Example Result</th>
</tr>
</thead>
</table>
| json_populate_recordset   | setof anyelement | Expands the outermost array of objects in from_ | select * from json_populate_recordset(null::myrowtype, '[["a":1,"b":2], ["a":3,"b":4]]') | a | b  
|                           |             | json to a set of rows whose columns match the record type defined by base. See Note. |                           | 1 | 2  
|                           |             |                                                                             |                           | 3 | 4  |
| json_array_elements(json) | setof json  | Expands a JSON array to a set of JSON values.                                | select * from json_array_elements('[1,true,[2,false]]')                  | value         
|                           |             |                                                                             |                           | 1  
|                           |             |                                                                             |                           | true          
|                           |             |                                                                             |                           | [2,false]     |

**Note:** Many of these functions and operators convert Unicode escapes in JSON strings to regular characters. The functions throw an error for characters that cannot be represented in the database encoding.

For `json_populate_record` and `json_populate_recordset`, type coercion from JSON is best effort and might not result in desired values for some types. JSON keys are matched to identical column names in the target row type. JSON fields that do not appear in the target row type are omitted from the output, and target columns that do not match any JSON field return `NULL`.

### Window Functions

The following built-in window functions are Greenplum extensions to the PostgreSQL database. All window functions are immutable. For more information about window functions, see "Window Expressions" in the Greenplum Database Administrator Guide.

**Table 242: Window functions**

<table>
<thead>
<tr>
<th>Function</th>
<th>Return Type</th>
<th>Full Syntax</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cume_dist()</td>
<td>double precision</td>
<td>CUME_DIST() OVER ( [PARTITION BY expr ] ORDER BY expr )</td>
<td>Calculates the cumulative distribution of a value in a group of values. Rows with equal values always evaluate to the same cumulative distribution value.</td>
</tr>
<tr>
<td>dense_rank()</td>
<td>bigint</td>
<td>DENSE_RANK () OVER ( [PARTITION BY expr ] ORDER BY expr )</td>
<td>Computes the rank of a row in an ordered group of rows without skipping rank values. Rows with equal values are given the same rank value.</td>
</tr>
<tr>
<td>first_value(expr)</td>
<td>same as input expr type</td>
<td>FIRST_VALUE(expr) OVER ( [PARTITION BY expr ] ORDER BY expr [ROWS</td>
<td>RANGE frame_expr ] )</td>
</tr>
<tr>
<td>Function</td>
<td>Return Type</td>
<td>Full Syntax</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------</td>
<td>----------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><code>lag(expr [,offset] [,default])</code></td>
<td>same as input expr type</td>
<td><code>LAG(expr [, offset] [, default]) OVER ( [PARTITION BY expr] ORDER BY expr )</code></td>
<td>Provides access to more than one row of the same table without doing a self join. Given a series of rows returned from a query and a position of the cursor, LAG provides access to a row at a given physical offset prior to that position. The default offset is 1. default sets the value that is returned if the offset goes beyond the scope of the window. If default is not specified, the default value is null.</td>
</tr>
<tr>
<td><code>last_value(expr)</code></td>
<td>same as input expr type</td>
<td>`LAST_VALUE(expr) OVER ( [PARTITION BY expr] ORDER BY expr [ROWS</td>
<td>RANGE frame_expr] )`</td>
</tr>
<tr>
<td><code>lead(expr [,offset] [,default])</code></td>
<td>same as input expr type</td>
<td><code>LEAD(expr [,offset] [,exprdefault]) OVER ( [PARTITION BY expr] ORDER BY expr )</code></td>
<td>Provides access to more than one row of the same table without doing a self join. Given a series of rows returned from a query and a position of the cursor, lead provides access to a row at a given physical offset after that position. If offset is not specified, the default offset is 1. default sets the value that is returned if the offset goes beyond the scope of the window. If default is not specified, the default value is null.</td>
</tr>
<tr>
<td><code>ntile(expr)</code></td>
<td>bigint</td>
<td><code>NTILE(expr) OVER ( [PARTITION BY expr] ORDER BY expr )</code></td>
<td>Divides an ordered data set into a number of buckets (as defined by expr) and assigns a bucket number to each row.</td>
</tr>
<tr>
<td><code>percent_rank()</code></td>
<td>double precision</td>
<td><code>PERCENT_RANK () OVER ( [PARTITION BY expr] ORDER BY expr )</code></td>
<td>Calculates the rank of a hypothetical row R minus 1, divided by 1 less than the number of rows being evaluated (within a window partition).</td>
</tr>
<tr>
<td>Function</td>
<td>Return Type</td>
<td>Full Syntax</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>rank()</td>
<td>bigint</td>
<td>RANK () OVER ( [PARTITION BY expr] ORDER BY expr )</td>
<td>Calculates the rank of a row in an ordered group of values. Rows with equal values for the ranking criteria receive the same rank. The number of tied rows are added to the rank number to calculate the next rank value. Ranks may not be consecutive numbers in this case.</td>
</tr>
<tr>
<td>row_number()</td>
<td>bigint</td>
<td>ROW_NUMBER () OVER ( [PARTITION BY expr] ORDER BY expr )</td>
<td>Assigns a unique number to each row to which it is applied (either each row in a window partition or each row of the query).</td>
</tr>
</tbody>
</table>

### Advanced Aggregate Functions

The following built-in advanced analytic functions are Greenplum extensions of the PostgreSQL database. Analytic functions are immutable.

**Note:** The Greenplum MADlib Extension for Analytics provides additional advanced functions to perform statistical analysis and machine learning with Greenplum Database data. See Greenplum MADlib Extension for Analytics.

#### Table 243: Advanced Aggregate Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Return Type</th>
<th>Full Syntax</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEDIAN (expr)</td>
<td>timestamp, timestamptz, interval, float</td>
<td>MEDIAN (expression)</td>
<td>Can take a two-dimensional array as input. Treats such arrays as matrices.</td>
</tr>
<tr>
<td>Example:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SELECT department_id, MEDIAN(salary) FROM employees GROUP BY department_id;</td>
<td></td>
</tr>
<tr>
<td>PERCENTILE_CONT (expr) WITHIN GROUP (ORDER BY expr [DESC/ASC])</td>
<td>timestamp, timestamptz, interval, float</td>
<td>PERCENTILE_CONT(percentage) WITHIN GROUP (ORDER BY expression)</td>
<td>Performs an inverse distribution function that assumes a continuous distribution model. It takes a percentile value and a sort specification and returns the same datatype as the numeric datatype of the argument. This returned value is a computed result after performing linear interpolation. Null are ignored in this calculation.</td>
</tr>
<tr>
<td>Example:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SELECT department_id, PERCENTILE_CONT (0.5) WITHIN GROUP (ORDER BY salary DESC) &quot;Median_cont&quot; FROM employees GROUP BY department_id;</td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td>Return Type</td>
<td>Full Syntax</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>PERCENTILE_DISC(expr)</td>
<td>timestamp</td>
<td>PERCENTILE_DISC(percentage) WITHIN GROUP (ORDER BY expression)</td>
<td>Performs an inverse distribution function that assumes a discrete distribution model. It takes a percentile value and a sort specification. This returned value is an element from the set. Null are ignored in this calculation.</td>
</tr>
<tr>
<td></td>
<td>timestamp</td>
<td>SELECT department_id, PERCENTILE_DISC (0.5) WITHIN GROUP (ORDER BY salary DESC) &quot;Median_desc&quot; FROM employees GROUP BY department_id;</td>
<td>Example:</td>
</tr>
<tr>
<td></td>
<td>interval</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>float</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sum(array[])</td>
<td>bigint[]</td>
<td>sum(array[[1,2],[3,4]])</td>
<td>Performs matrix summation. Can take as input a two-dimensional array that is treated as a matrix.</td>
</tr>
<tr>
<td></td>
<td>float[]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pivot_sum(label[], label, expr)</td>
<td>int[], bigint[], float[]</td>
<td>pivot_sum( array['A1','A2'], attr, value)</td>
<td>A pivot aggregation using sum to resolve duplicate entries.</td>
</tr>
<tr>
<td>unnest(array[])</td>
<td>set of anyelement</td>
<td>unnest( array['one', 'row', 'per', 'item'])</td>
<td>Transforms a one dimensional array into rows. Returns a set of anyelement, a polymorphic pseudotype in PostgreSQL.</td>
</tr>
</tbody>
</table>
Greenplum MapReduce Specification

This specification describes the document format and schema for defining Greenplum MapReduce jobs. MapReduce is a programming model developed by Google for processing and generating large data sets on an array of commodity servers. Greenplum MapReduce allows programmers who are familiar with the MapReduce model to write map and reduce functions and submit them to the Greenplum Database parallel engine for processing.

To enable Greenplum to process MapReduce functions, define the functions in a document, then pass the document to the Greenplum MapReduce program, `gpmapreduce`, for execution by the Greenplum Database parallel engine. The Greenplum Database system distributes the input data, executes the program across a set of machines, handles machine failures, and manages the required inter-machine communication.

See the Greenplum Database Utility Guide for information about `gpmapreduce`.

### Greenplum MapReduce Document Format

This section explains some basics of the Greenplum MapReduce document format to help you get started creating your own Greenplum MapReduce documents. Greenplum uses the YAML 1.1 document format and then implements its own schema for defining the various steps of a MapReduce job.

All Greenplum MapReduce files must first declare the version of the YAML specification they are using. After that, three dashes (---) denote the start of a document, and three dots (...) indicate the end of a document without starting a new one. Comment lines are prefixed with a pound symbol (#). It is possible to declare multiple Greenplum MapReduce documents in the same file:

```
---
# Begin Document 1
# ...
---
# Begin Document 2
# ...
```

Within a Greenplum MapReduce document, there are three basic types of data structures or nodes: scalars, sequences and mappings.

A scalar is a basic string of text indented by a space. If you have a scalar input that spans multiple lines, a preceding pipe (|) denotes a literal style, where all line breaks are significant. Alternatively, a preceding angle bracket (> ) folds a single line break to a space for subsequent lines that have the same indentation level. If a string contains characters that have reserved meaning, the string must be quoted or the special character must be escaped with a backslash (\).

```
# Read each new line literally
somedkey: |  this value contains two lines
          and each line is read literally
# Treat each new line as a space
anotherkey: >
            this value contains two lines
            but is treated as one continuous line
# This quoted string contains a special character
ThirdKey: "This is a string: not a mapping"
```

A sequence is a list with each entry in the list on its own line denoted by a dash and a space (- ). Alternatively, you can specify an inline sequence as a comma-separated list within square brackets.
A sequence provides a set of data and gives it an order. When you load a list into the Greenplum MapReduce program, the order is kept.

```
# list sequence
- this
- is
- a list
- with
- five scalar values
# inline sequence
[this, is, a list, with, five scalar values]
```

A mapping is used to pair up data values with identifiers called keys. Mappings use a colon and space (:) for each key: value pair, or can also be specified inline as a comma-separated list within curly braces. The key is used as an index for retrieving data from a mapping.

```
# a mapping of items
title: War and Peace
author: Leo Tolstoy
date: 1865
# same mapping written inline
{title: War and Peace, author: Leo Tolstoy, date: 1865}
```

Keys are used to associate meta information with each node and specify the expected node type (scalar, sequence or mapping). See Greenplum MapReduce Document Schema for the keys expected by the Greenplum MapReduce program.

The Greenplum MapReduce program processes the nodes of a document in order and uses indentation (spaces) to determine the document hierarchy and the relationships of the nodes to one another. The use of white space is significant. White space should not be used simply for formatting purposes, and tabs should not be used at all.

**Greenplum MapReduce Document Schema**

Greenplum MapReduce uses the YAML document framework and implements its own YAML schema. The basic structure of a Greenplum MapReduce document is:

```
---
VERSION: 1.0.0.2
DATABASE: dbname
USER: db_username
HOST: master_hostname
PORT: master_port

DEFINE:
  - INPUT:
    NAME: input_name
    FILE:
      - hostname:/path/to/file
    GPFDIST:
      - hostname:port/file_pattern
    TABLE: table_name
    QUERY: SELECT statement
    EXEC: command_string
    COLUMNS:
      - field_name data_type
    FORMAT: TEXT | CSV
    DELIMITER: delimiter_character
    ESCAPE: escape_character
```
NULL: null_string
QUOTE: csv_quote_character
ERROR_LIMIT: integer
ENCODING: database_encoding

- OUTPUT:
  - NAME: output_name
  - FILE: file_path_on_client
  - TABLE: table_name
  - KEYS:
    - column_name
  - MODE: REPLACE | APPEND

- MAP:
  - NAME: function_name
  - FUNCTION: function_definition
  - LANGUAGE: perl | python | c
  - LIBRARY: /path/filename.so
  - PARAMETERS:
    - nametype
  - RETURNS:
    - nametype
  - OPTIMIZE: STRICT IMMUTABLE
  - MODE: SINGLE | MULTI

- TRANSITION | CONSOLIDATE | FINALIZE:
  - NAME: function_name
  - FUNCTION: function_definition
  - LANGUAGE: perl | python | c
  - LIBRARY: /path/filename.so
  - PARAMETERS:
    - nametype
  - RETURNS:
    - nametype
  - OPTIMIZE: STRICT IMMUTABLE
  - MODE: SINGLE | MULTI

- REDUCE:
  - NAME: reduce_job_name
  - TRANSITION: transition_function_name
  - CONSOLIDATE: consolidate_function_name
  - FINALIZE: finalize_function_name
  - INITIALIZE: value
  - KEYS:
    - key_name

- TASK:
  - NAME: task_name
  - SOURCE: input_name
  - MAP: map_function_name
  - REDUCE: reduce_function_name
  - EXECUTE

- RUN:
  - SOURCE: input_or_task_name
  - TARGET: output_name
  - MAP: map_function_name
  - REDUCE: reduce_function_name...
VERSION

Required. The version of the Greenplum MapReduce YAML specification. Current versions are 1.0.0.1.

DATABASE

Optional. Specifies which database in Greenplum to connect to. If not specified, defaults to the default database or $PGDATABASE if set.

USER

Optional. Specifies which database role to use to connect. If not specified, defaults to the current user or $PGUSER if set. You must be a Greenplum superuser to run functions written in untrusted Python and Perl. Regular database users can run functions written in trusted Perl. You also must be a database superuser to run MapReduce jobs that contain FILE, GPFDIST and EXEC input types.

HOST

Optional. Specifies Greenplum master host name. If not specified, defaults to localhost or $PGHOST if set.

PORT

Optional. Specifies Greenplum master port. If not specified, defaults to 5432 or $PGPORT if set.

DEFINE

Required. A sequence of definitions for this MapReduce document. The DEFINE section must have at least one INPUT definition.

INPUT

Required. Defines the input data. Every MapReduce document must have at least one input defined. Multiple input definitions are allowed in a document, but each input definition can specify only one of these access types: a file, a gpfdist file distribution program, a table in the database, an SQL command, or an operating system command. See the Greenplum Database Utility Guide for information about gpfdist.

NAME

A name for this input. Names must be unique with regards to the names of other objects in this MapReduce job (such as map function, task, reduce function and output names). Also, names cannot conflict with existing objects in the database (such as tables, functions or views).

FILE

A sequence of one or more input files in the format: seghostname:/path/to/ filename. You must be a Greenplum Database superuser to run MapReduce jobs with FILE input. The file must reside on a Greenplum segment host.

GPFDIST

A sequence of one or more running gpfdist file distribution programs in the format: hostname[:port]/file_pattern. You must be a Greenplum Database superuser to run MapReduce jobs with GPFDIST input, unless the server configuration parameter Server Configuration Parameters is set to on.

TABLE

The name of an existing table in the database.

QUERY

A SQL SELECT command to run within the database.

EXEC

An operating system command to run on the Greenplum segment hosts. The command is run by all segment instances in the system by default. For example, if you have four
segment instances per segment host, the command will be run four times on each host. You must be a Greenplum Database superuser to run MapReduce jobs with EXEC input and the server configuration parameter Server Configuration Parameters is set to on.

**COLUMNS**

Optional. Columns are specified as: `column_name [data_type]`. If not specified, the default is `value text`. The **DELIMITER** character is what separates two data value fields (columns). A row is determined by a line feed character (0x0a).

**FORMAT**

Optional. Specifies the format of the data - either delimited text (TEXT) or comma separated values (CSV) format. If the data format is not specified, defaults to TEXT.

**DELIMITER**

Optional for FILE, GPFDIST and EXEC inputs. Specifies a single character that separates data values. The default is a tab character in TEXT mode, a comma in CSV mode. The delimiter character must only appear between any two data value fields. Do not place a delimiter at the beginning or end of a row.

**ESCAPE**

Optional for FILE, GPFDIST and EXEC inputs. Specifies the single character that is used for C escape sequences (such as \n, \t, \100, and so on) and for escaping data characters that might otherwise be taken as row or column delimiters. Make sure to choose an escape character that is not used anywhere in your actual column data. The default escape character is a \ (backslash) for text-formatted files and a " (double quote) for csv-formatted files, however it is possible to specify another character to represent an escape. It is also possible to disable escaping by specifying the value 'OFF' as the escape value. This is very useful for data such as text-formatted web log data that has many embedded backslashes that are not intended to be escapes.

**NULL**

Optional for FILE, GPFDIST and EXEC inputs. Specifies the string that represents a null value. The default is \n in TEXT format, and an empty value with no quotations in CSV format. You might prefer an empty string even in TEXT mode for cases where you do not want to distinguish nulls from empty strings. Any input data item that matches this string will be considered a null value.

**QUOTE**

Optional for FILE, GPFDIST and EXEC inputs. Specifies the quotation character for CSV formatted files. The default is a double quote ("). In CSV formatted files, data value fields must be enclosed in double quotes if they contain any commas or embedded new lines. Fields that contain double quote characters must be surrounded by double quotes, and the embedded double quotes must each be represented by a pair of consecutive double quotes. It is important to always open and close quotes correctly in order for data rows to be parsed correctly.

**ERRORLIMIT**

If the input rows have format errors they will be discarded provided that the error limit count is not reached on any Greenplum segment instance during input processing. If the error limit is not reached, all good rows will be processed and any error rows discarded.

**ENCODING**

Character set encoding to use for the data. Specify a string constant (such as 'SQL_ASCII'), an integer encoding number, or DEFAULT to use the default client encoding. See Character Set Support for more information.

**OUTPUT**
Optional. Defines where to output the formatted data of this MapReduce job. If output is not defined, the default is \texttt{STDOUT} (standard output of the client). You can send output to a file on the client host or to an existing table in the database.

**NAME**

A name for this output. The default output name is \texttt{STDOUT}. Names must be unique with regards to the names of other objects in this MapReduce job (such as map function, task, reduce function and input names). Also, names cannot conflict with existing objects in the database (such as tables, functions or views).

**FILE**

Specifies a file location on the MapReduce client machine to output data in the format: /path/to/filename.

**TABLE**

Specifies the name of a table in the database to output data. If this table does not exist prior to running the MapReduce job, it will be created using the distribution policy specified with \texttt{KEYS}.

**KEYS**

Optional for \texttt{TABLE} output. Specifies the column(s) to use as the Greenplum Database distribution key. If the \texttt{EXECUTE} task contains a \texttt{REDUCE} definition, then the \texttt{REDUCE} keys will be used as the table distribution key by default. Otherwise, the first column of the table will be used as the distribution key.

**MODE**

Optional for \texttt{TABLE} output. If not specified, the default is to create the table if it does not already exist, but error out if it does exist. Declaring \texttt{APPEND} adds output data to an existing table (provided the table schema matches the output format) without removing any existing data. Declaring \texttt{REPLACE} will drop the table if it exists and then recreate it. Both \texttt{APPEND} and \texttt{REPLACE} will create a new table if one does not exist.

**MAP**

Required. Each \texttt{MAP} function takes data structured in \((\text{key}, \text{value})\) pairs, processes each pair, and generates zero or more output \((\text{key}, \text{value})\) pairs. The Greenplum MapReduce framework then collects all pairs with the same key from all output lists and groups them together. This output is then passed to the \texttt{REDUCE} task, which is comprised of \texttt{TRANSITION | CONSOLIDATE | FINALIZE} functions. There is one predefined \texttt{MAP} function named \texttt{IDENTITY} that returns \((\text{key}, \text{value})\) pairs unchanged. Although \((\text{key}, \text{value})\) are the default parameters, you can specify other prototypes as needed.

**TRANSITION | CONSOLIDATE | FINALIZE**

\texttt{TRANSITION}, \texttt{CONSOLIDATE} and \texttt{FINALIZE} are all component pieces of \texttt{REDUCE}. A \texttt{TRANSITION} function is required. \texttt{CONSOLIDATE} and \texttt{FINALIZE} functions are optional. By default, all take \texttt{state} as the first of their input \texttt{PARAMETERS}, but other prototypes can be defined as well.

A \texttt{TRANSITION} function iterates through each value of a given key and accumulates values in a \texttt{state} variable. When the transition function is called on the first value of a key, the \texttt{state} is set to the value specified by \texttt{INITIALIZE} of a \texttt{REDUCE} job (or the default state value for the data type). A transition takes two arguments as input; the current state of the key reduction, and the next value, which then produces a new \texttt{state}.

If a \texttt{CONSOLIDATE} function is specified, \texttt{TRANSITION} processing is performed at the segment-level before redistributing the keys across the Greenplum interconnect for final aggregation (two-phase aggregation). Only the resulting \texttt{state} value for a given key is redistributed, resulting in lower interconnect traffic and greater parallelism. \texttt{CONSOLIDATE} is handled like a \texttt{TRANSITION}, except that instead of \((\text{state} + \text{value}) \Rightarrow \text{state}\), it is \((\text{state} + \text{state}) \Rightarrow \text{state}\).
If a **FINALIZE** function is specified, it takes the final **state** produced by **CONSOLIDATE** (if present) or **TRANSITION** and does any final processing before emitting the final result. **TRANSITION** and **CONSOLIDATE** functions cannot return a set of values. If you need a **REDUCE** job to return a set, then a **FINALIZE** is necessary to transform the final state into a set of output values.

**NAME**

Required. A name for the function. Names must be unique with regards to the names of other objects in this MapReduce job (such as function, task, input and output names). You can also specify the name of a function built-in to Greenplum Database. If using a built-in function, do not supply **LANGUAGE** or a **FUNCTION** body.

**FUNCTION**

Optional. Specifies the full body of the function using the specified **LANGUAGE**. If **FUNCTION** is not specified, then a built-in database function corresponding to **NAME** is used.

**LANGUAGE**

Required when **FUNCTION** is used. Specifies the implementation language used to interpret the function. This release has language support for perl, python, and C. If calling a built-in database function, **LANGUAGE** should not be specified.

**LIBRARY**

Required when **LANGUAGE** is C (not allowed for other language functions). To use this attribute, **VERSION** must be 1.0.0.2. The specified library file must be installed prior to running the MapReduce job, and it must exist in the same file system location on all Greenplum hosts (master and segments).

**PARAMETERS**

Optional. Function input parameters. The default type is **text**.

- **MAP** default - key **text**, value **text**
- **TRANSITION** default - state **text**, value **text**
- **CONSOLIDATE** default - state1 **text**, state2 **text** (must have exactly two input parameters of the same data type)
- **FINALIZE** default - state **text** (single parameter only)

**RETURNS**

Optional. The default return type is **text**.

- **MAP** default - key **text**, value **text**
- **TRANSITION** default - state **text** (single return value only)
- **CONSOLIDATE** default - state **text** (single return value only)
- **FINALIZE** default - value **text**

**OPTIMIZE**

Optional optimization parameters for the function:

- **STRICK** - function is not affected by NULL values
- **IMMUTABLE** - function will always return the same value for a given input

**MODE**

Optional. Specifies the number of rows returned by the function.

- **MULTI** - returns 0 or more rows per input record. The return value of the function must be an array of rows to return, or the function must be written as an iterator using `yield`
in Python or return_next in Perl. MULTI is the default mode for MAP and FINALIZE functions.

SINGLE - returns exactly one row per input record. SINGLE is the only mode supported for TRANSITION and CONSOLIDATE functions. When used with MAP and FINALIZE functions, SINGLE mode can provide modest performance improvement.

REDUCE

Required. A REDUCE definition names the TRANSITION | CONSOLIDATE | FINALIZE functions that comprise the reduction of (key, value) pairs to the final result set. There are also several predefined REDUCE jobs you can execute, which all operate over a column named value:

IDENTITY - returns (key, value) pairs unchanged
SUM - calculates the sum of numeric data
AVG - calculates the average of numeric data
COUNT - calculates the count of input data
MIN - calculates minimum value of numeric data
MAX - calculates maximum value of numeric data

NAME

Required. The name of this REDUCE job. Names must be unique with regards to the names of other objects in this MapReduce job (function, task, input and output names). Also, names cannot conflict with existing objects in the database (such as tables, functions or views).

TRANSITION

Required. The name of the TRANSITION function.

CONSOLIDATE

Optional. The name of the CONSOLIDATE function.

FINALIZE

Optional. The name of the FINALIZE function.

INITIALIZE

Optional for text and float data types. Required for all other data types. The default value for text is ''. The default value for float is 0.0. Sets the initial state value of the TRANSITION function.

KEYS

Optional. Defaults to [key, *]. When using a multi-column reduce it may be necessary to specify which columns are key columns and which columns are value columns. By default, any input columns that are not passed to the TRANSITION function are key columns, and a column named key is always a key column even if it is passed to the TRANSITION function. The special indicator * indicates all columns not passed to the TRANSITION function. If this indicator is not present in the list of keys then any unmatched columns are discarded.

TASK

Optional. A TASK defines a complete end-to-end INPUT/MAP/REDUCE stage within a Greenplum MapReduce job pipeline. It is similar to EXECUTE except it is not immediately executed. A task object can be called as INPUT to further processing stages.

NAME

Required. The name of this task. Names must be unique with regards to the names of other objects in this MapReduce job (such as map function, reduce function, input and
output names). Also, names cannot conflict with existing objects in the database (such as tables, functions or views).

**SOURCE**

The name of an INPUT or another TASK.

**MAP**

Optional. The name of a MAP function. If not specified, defaults to IDENTITY.

**REDUCE**

Optional. The name of a REDUCE function. If not specified, defaults to IDENTITY.

**EXECUTE**

Required. EXECUTE defines the final INPUT/MAP/REDUCE stage within a Greenplum MapReduce job pipeline.

**RUN**

**SOURCE**

Required. The name of an INPUT or TASK.

**TARGET**

Optional. The name of an OUTPUT. The default output is STDOUT.

**MAP**

Optional. The name of a MAP function. If not specified, defaults to IDENTITY.

**REDUCE**

Optional. The name of a REDUCE function. Defaults to IDENTITY.

### Example Greenplum MapReduce Document

```yaml
---
VERSION:1.0.0.1
---

# This example MapReduce job processes documents and looks for keywords in them.
# It takes two database tables as input:
#   - documents (doc_id integer, url text, data text)
#   - keywords (keyword_id integer, keyword text)
# The documents data is searched for occurrences of keywords and returns results of
# url, data and keyword (a keyword can be multiple words, such as "high performance # computing")

%YAML 1.1

# Connect to Greenplum Database using this database and role
DATABASE:webdata
USER:jsmith

# Begin definition section
DEFINE:

  # Declare the input, which selects all columns and rows from the
  # 'documents' and 'keywords' tables.
  - INPUT:
    NAME:doc
    TABLE:documents
  - INPUT:
    NAME:kw
    TABLE:keywords

# Define the map functions to extract terms from documents and keyword
# This example simply splits on white space, but it would be possible
```
# to make use of a python library like nltk (the natural language toolkit)
# to perform more complex tokenization and word stemming.
- MAP:
  NAME:doc_map
  LANGUAGE:python
  FUNCTION:
      i = 0          # the index of a word within the document
  terms = {}# a hash of terms and their indexes within the document

  # Lower-case and split the text string on space
  for term in data.lower().split():
      i = i + 1# increment i (the index)

      # Check for the term in the terms list:
      # if stem word already exists, append the i value to the array
      # corresponding to the term. This counts multiple occurrences of the
      # word.
      # If stem word does not exist, add it to the dictionary with
      # position i.
      # For example:
      # data: "a computer is a machine that manipulates data"
      # "a"   [1, 4]
      # "computer" [2]
      # "machine" [3]
      # ...
      if term in terms:
          terms[term] += ','+str(i)
      else:
          terms[term] = str(i)

  # Return multiple lines for each document. Each line consists of
  # the doc_id, a term and the positions in the data where the term appeared.
  # For example:
  # (doc_id => 100, term => "a", [1,4]
  # (doc_id => 100, term => "computer", [2]
  # ...
  for term in terms:
      yield([doc_id, term, terms[term]])

  OPTIMIZE:STRICT IMMUTABLE
  PARAMETERS:
      - doc_id integer
      - data text

  RETURNS:
      - doc_id integer
      - term text
      - positions text

# The map function for keywords is almost identical to the one for
documents
# but it also counts the number of terms in the keyword.
- MAP:
  NAME:kw_map
  LANGUAGE:python
  FUNCTION:
      i = 0
  terms = {}# a hash of terms and their indexes within the document

  # Lower-case and split the text string on space
  for term in keyword.lower().split():
      i = i + 1# increment i (the index)

      # Check for the term in the terms list:
      # if stem word already exists, append the i value to the array
      # corresponding to the term. This counts multiple occurrences of the
      # word.
      # If stem word does not exist, add it to the dictionary with
      # position i.
      # For example:
      # data: "a computer is a machine that manipulates data"
      # "a"   [1, 4]
      # "computer" [2]
      # "machine" [3]
      # ...
      if term in terms:
          terms[term] += ','+str(i)
      else:
          terms[term] = str(i)
```python
# output 4 values including i (the total count for term in terms):
yield([keyword_id, i, term, terms[term]])
    OPTIMIZE:STRICT IMMUTABLE
PARAMETERS:
- keyword_id integer
- keyword text
RETURNS:
- keyword_id integer
- nterms integer
- term text
- positions text

# A TASK is an object that defines an entire INPUT/MAP/REDUCE stage
# within a Greenplum MapReduce pipeline. It is like EXECUTION, but it is
# executed only when called as input to other processing stages.
# Identify a task called 'doc_prep' which takes in the 'doc' INPUT defined
# earlier
# and runs the 'doc_map' MAP function which returns doc_id, term,
# [term_position]
- TASK:
  NAME:doc_prep
  SOURCE:doc
  MAP:doc_map

# Identify a task called 'kw_prep' which takes in the 'kw' INPUT defined
# earlier
# and runs the kw_map MAP function which returns kw_id, term,
# [term_position]
- TASK:
  NAME:kw_prep
  SOURCE:kw
  MAP:kw_map

# One advantage of Greenplum MapReduce is that MapReduce tasks can be
# used as input to SQL operations and SQL can be used to process a MapReduce
task.
# This INPUT defines a SQL query that joins the output of the 'doc_prep'
# TASK to that of the 'kw_prep' TASK. Matching terms are output to the
# 'candidate'
# list (any keyword that shares at least one term with the document).
- INPUT:
  NAME: term_join
  QUERY: |
    SELECT doc.doc_id, kw.keyword_id, kw.term, kw.nterms,
        doc.positions as doc_positions,
        kw.positions as kw_positions
    FROM doc_prep doc INNER JOIN kw_prep kw ON (doc.term = kw.term)

# A TASK is an object that defines an entire INPUT/MAP/REDUCE stage
# within a Greenplum MapReduce pipeline. It is like EXECUTION, but it is
# executed only when called as input to other processing stages.
# Identify a task called 'doc_prep' which takes in the 'doc' INPUT defined
# earlier
# and runs the 'doc_map' MAP function which returns doc_id, term,
# [term_position]
- TASK:
  NAME:doc_prep
  SOURCE:doc
  MAP:doc_map

# Identify a task called 'kw_prep' which takes in the 'kw' INPUT defined
# earlier
# and runs the kw_map MAP function which returns kw_id, term,
# [term_position]
- TASK:
  NAME:kw_prep
  SOURCE:kw
  MAP:kw_map

# A TASK is an object that defines an entire INPUT/MAP/REDUCE stage
# within a Greenplum MapReduce pipeline. It is like EXECUTION, but it is
# executed only when called as input to other processing stages.
# Identify a task called 'doc_prep' which takes in the 'doc' INPUT defined
# earlier
# and runs the 'doc_map' MAP function which returns doc_id, term,
# [term_position]
- TASK:
  NAME:doc_prep
  SOURCE:doc
  MAP:doc_map

# Identify a task called 'kw_prep' which takes in the 'kw' INPUT defined
# earlier
# and runs the kw_map MAP function which returns kw_id, term,
# [term_position]
- TASK:
  NAME:kw_prep
  SOURCE:kw
  MAP:kw_map

# A TASK is an object that defines an entire INPUT/MAP/REDUCE stage
# within a Greenplum MapReduce pipeline. It is like EXECUTION, but it is
# executed only when called as input to other processing stages.
# Identify a task called 'doc_prep' which takes in the 'doc' INPUT defined
# earlier
# and runs the 'doc_map' MAP function which returns doc_id, term,
# [term_position]
- TASK:
  NAME:doc_prep
  SOURCE:doc
  MAP:doc_map

# Identify a task called 'kw_prep' which takes in the 'kw' INPUT defined
# earlier
# and runs the kw_map MAP function which returns kw_id, term,
# [term_position]
- TASK:
  NAME:kw_prep
  SOURCE:kw
  MAP:kw_map

# One advantage of Greenplum MapReduce is that MapReduce tasks can be
# used as input to SQL operations and SQL can be used to process a MapReduce
task.
# This INPUT defines a SQL query that joins the output of the 'doc_prep'
# TASK to that of the 'kw_prep' TASK. Matching terms are output to the
# 'candidate'
# list (any keyword that shares at least one term with the document).
- INPUT:
  NAME: term_join
  QUERY: |
    SELECT doc.doc_id, kw.keyword_id, kw.term, kw.nterms,
        doc.positions as doc_positions,
        kw.positions as kw_positions
    FROM doc_prep doc INNER JOIN kw_prep kw ON (doc.term = kw.term)

# In Greenplum MapReduce, a REDUCE function is comprised of one or more
# functions.
# A REDUCE has an initial 'state' variable defined for each grouping key.
# that is
# A TRANSITION function adjusts the state for every value in a key grouping.
# If present, an optional CONSOLIDATE function combines multiple
# 'state' variables. This allows the TRANSITION function to be executed
# locally at
# the segment-level and only redistribute the accumulated 'state' over
# the network. If present, an optional FINALIZE function can be used to
# perform
# final computation on a state and emit one or more rows of output from the
# state.
# # This REDUCE function is called 'term_reducer' with a TRANSITION function
called 'term_transition' and a FINALIZE function called 'term_finalizer'
```
- **REDUCE:**
  NAME: term_reducer
  TRANSITION: termransition
  FINALIZE: term_finalizer

- **TRANSITION:**
  NAME: term_transition
  LANGUAGE: python
  PARAMETERS:
  - state text
  - term text
  - nterms integer
  - doc_positions text
  - kw_positions text
  FUNCTION:

  ```
  # 'state' has an initial value of '' and is a colon delimited set
  # of keyword positions. keyword positions are comma delimited sets
  # of integers. For example, '1,3,2:4:'
  # If there is an existing state, split it into the set of keyword
  # positions
  # otherwise construct a set of 'nterms' keyword positions - all empty
  if state:
    kw_split = state.split(':')
  else:
    kw_split = []
    for i in range(0, nterms):
      kw_split.append('')

  # 'kw_positions' is a comma delimited field of integers indicating
  # position a single term occurs within a given keyword.
  # Splitting based on ',' converts the string into a python list.
  # add doc_positions for the current term
  for kw_p in kw_positions.split(', '):
    kw_split[int(kw_p) - 1] = doc_positions

  # This section takes each element in the 'kw_split' array and
  # strings
  # them together placing a ':' in between each element from the
  # array.
  # For example: for the keyword "computer software computer hardware",
  # the 'kw_split' array matched up to the document data of
  # "in the business of computer software software engineers"
  # would look like: ['5', '6,7', '5', '']
  # and the outstate would look like: 5:6,7:5:
  outstate = kw_split[0]
  for s in kw_split[1:]:
    outstate = outstate + ':' + s
  return outstate
  ```

- **FINALIZE:**
  NAME: term_finalizer
  LANGUAGE: python
  RETURNS:
  - count integer
  MODE: MULTI
  FUNCTION:
  ```
  if not state:
    return 0
  kw_split = state.split(':')
  ```

  # This function does the following:
# 1) Splits 'kw_split' on ':'
#    for example, 1,5,7:2,8 creates '1,5,7' and '2,8'
# 2) For each group of positions in 'kw_split', splits the set on ',',
#    to create ['1', '5', '7'] from Set 0: 1,5,7 and
#    eventually ['2', '8'] from Set 1: 2,8
# 3) Checks for empty strings
# 4) Adjusts the split sets by subtracting the position of the set
#    in the 'kw_split' array
#    ['1', '5', '7'] - 0 from each element = ['1', '5', '7']
#    ['2', '8'] - 1 from each element = ['1', '7']
# 5) Resulting arrays after subtracting the offset in step 4 are
#    intersected and their overlapping values kept:
#    ['1', '5', '7'].intersect['1', '7'] = [1, 7]
# 6) Determines the length of the intersection, which is the number of
#    times that an entire keyword (with all its pieces) matches in the
#    document data.
previous = None
for i in range(0, len(kw_split)):
    isplit = kw_split[i].split(',')
    if any(map(lambda(x): x == '', isplit)):
        return 0
    adjusted = set(map(lambda(x): int(x) - i, isplit))
    if (previous):
        previous = adjusted.intersection(previous)
    else:
        previous = adjusted

# return the final count
if previous:
    return len(previous)

# Define the 'term_match' task which is then executed as part
# of the 'final_output' query. It takes the INPUT 'term_join' defined
# earlier and uses the REDUCE function 'term_reducer' defined earlier
- TASK:
NAME:term_match
SOURCE:term_join
REDUCE:term_reducer
- INPUT:
NAME:final_output
QUERY:
    SELECT doc.*, kw.*, tm.count
FROM documents doc, keywords kw, term_match tm
WHERE doc.doc_id = tm.doc_id
AND kw.keyword_id = tm.keyword_id
AND tm.count > 0

# Execute this MapReduce job and send output to STDOUT
EXECUTE:
- RUN:
SOURCE:final_output
TARGET:STDOUT

Flow Diagram for MapReduce Example
The following diagram shows the job flow of the MapReduce job defined in the example:
Greenplum Database PL/pgSQL is a loadable procedural language that is installed and registered by default with Greenplum Database. You can create user-defined functions using SQL statements, functions, and operators.

With PL/pgSQL you can group a block of computation and a series of SQL queries inside the database server, thus having the power of a procedural language and the ease of use of SQL. Also, with PL/pgSQL you can use all the data types, operators and functions of Greenplum Database SQL.

The PL/pgSQL language is a subset of Oracle PL/SQL. Greenplum Database PL/pgSQL is based on Postgres PL/pgSQL. The Postgres PL/pgSQL documentation is at https://www.postgresql.org/docs/8.3/static/plpgsql.html

When using PL/pgSQL functions, function attributes affect how Greenplum Database creates query plans. You can specify the attribute IMMUTABLE, STABLE, or VOLATILE as part of the LANGUAGE clause to classify the type of function. For information about the creating functions and function attributes, see the CREATE FUNCTION command in the Greenplum Database Reference Guide.

You can run PL/SQL code blocks as anonymous code blocks. See the DO command in the Greenplum Database Reference Guide.

Greenplum Database SQL Limitations

When using Greenplum Database PL/pgSQL, limitations include

- Triggers are not supported
- Cursors are forward moving only (not scrollable)
- Updatable cursors (UPDATE...WHERE CURRENT OF and DELETE...WHERE CURRENT OF) are not supported.

For information about Greenplum Database SQL conformance, see Summary of Greenplum Features in the Greenplum Database Reference Guide.

The PL/pgSQL Language

PL/pgSQL is a block-structured language. The complete text of a function definition must be a block. A block is defined as:

```
[ label ]
[ DECLARE
  declarations ]
BEGIN
  statements
END [ label ];
```
Each declaration and each statement within a block is terminated by a semicolon (;). A block that appears within another block must have a semicolon after END, as shown in the previous block. The END that concludes a function body does not require a semicolon.

**Important:** Do not confuse the use of the BEGIN and END keywords for grouping statements in PL/pgSQL with the database commands for transaction control. The PL/pgSQL BEGIN and END keywords are only for grouping; they do not start or end a transaction. Functions are always executed within a transaction established by an outer query — they cannot start or commit that transaction, since there would be no context for them to execute in. However, a PL/pgSQL block that contains an EXCEPTION clause effectively forms a subtransaction that can be rolled back without affecting the outer transaction. For more about the EXCEPTION clause, see the post the Postgres documentation on error trapping at [https://www.postgresql.org/docs/8.3/static/plpgsql-control-structures.html#PLPGSQL-ERROR-TRAPPING](https://www.postgresql.org/docs/8.3/static/plpgsql-control-structures.html#PLPGSQL-ERROR-TRAPPING).

All key words and identifiers can be written in mixed upper and lower case. Identifiers are implicitly converted to lowercase unless enclosed in double-quotes (" ).

You can add comments in PL/pgSQL in the following ways:

- A double dash (--) starts a comment that extends to the end of the line.
- A /* starts a block comment that extends to the next occurrence of */.

Block comments cannot be nested, but double dash comments can be enclosed into a block comment and a double dash can hide the block comment delimiters /* and */.

Any statement in the statement section of a block can be a subblock. Subblocks can be used for logical grouping or to localize variables to a small group of statements.

The variables declared in the declarations section preceding a block are initialized to their default values every time the block is entered, not only once per function call. For example declares the variable quantity several times:

```sql
CREATE FUNCTION testfunc() RETURNS integer AS $$
DECLARE
  quantity integer := 30;
BEGIN
  RAISE NOTICE 'Quantity here is %', quantity;
  -- Quantity here is 30
  quantity := 50;
  --
  -- Create a subblock
  --
  DECLARE
    quantity integer := 80;
  BEGIN
    RAISE NOTICE 'Quantity here is %', quantity;
    -- Quantity here is 80
  END;
  RAISE NOTICE 'Quantity here is %', quantity;
  -- Quantity here is 50
  RETURN quantity;
END;
$$ LANGUAGE plpgsql;
```

**Executing SQL Commands**

You can execute SQL commands with PL/pgSQL statements such as EXECUTE, PERFORM, and SELECT ... INTO. For information about the PL/pgSQL statements, see [https://www.postgresql.org/docs/8.3/static/plpgsql-statements.html](https://www.postgresql.org/docs/8.3/static/plpgsql-statements.html).

**Note:** The PL/pgSQL statement SELECT INTO is not supported in the EXECUTE statement.
**PL/pgSQL Plan Caching**

A PL/pgSQL function’s volatility classification has implications on how Greenplum Database caches plans that reference the function. Refer to Function Volatility and Plan Caching in the Greenplum Database Administrator Guide for information on plan caching considerations for Greenplum Database function volatility categories.

When a PL/pgSQL function executes for the first time in a database session, the PL/pgSQL interpreter parses the function’s SQL expressions and commands. The interpreter creates a prepared execution plan as each expression and SQL command is first executed in the function. The PL/pgSQL interpreter reuses the execution plan for a specific expression and SQL command for the life of the database connection. While this reuse substantially reduces the total amount of time required to parse and generate plans, errors in a specific expression or command cannot be detected until run time when that part of the function is executed.

Greenplum Database will automatically re-plan a saved query plan if there is any schema change to any relation used in the query, or if any user-defined function used in the query is redefined. This makes the re-use of a prepared plan transparent in most cases.

The SQL commands that you use in a PL/pgSQL function must refer to the same tables and columns on every execution. You cannot use a parameter as the name of a table or a column in an SQL command.

PL/pgSQL caches a separate query plan for each combination of actual argument types in which you invoke a polymorphic function to ensure that data type differences do not cause unexpected failures.

Refer to the PostgreSQL Plan Caching documentation for a detailed discussion of plan caching considerations in the PL/pgSQL language.

**PL/pgSQL Examples**

The following are examples of PL/pgSQL user-defined functions.

**Example: Aliases for Function Parameters**

Parameters passed to functions are named with identifiers such as $1, $2. Optionally, aliases can be declared for $n parameter names for increased readability. Either the alias or the numeric identifier can then be used to refer to the parameter value.

There are two ways to create an alias. The preferred way is to give a name to the parameter in the CREATE FUNCTION command, for example:

```sql
CREATE FUNCTION sales_tax(subtotal real) RETURNS real AS $$
BEGIN
    RETURN subtotal * 0.06;
END;
$$ LANGUAGE plpgsql;
```

You can also explicitly declare an alias, using the declaration syntax:

```sql
name ALIAS FOR $n;
```

This example, creates the same function with the DECLARE syntax.

```sql
CREATE FUNCTION sales_tax(real) RETURNS real AS $$
DECLARE
    subtotal ALIAS FOR $1;
BEGIN
    RETURN subtotal * 0.06;
END;
$$ LANGUAGE plpgsql;
```
Example: Using the Data Type of a Table Column

When declaring a variable, you can use %TYPE to specify the data type of a variable or table column. This is the syntax for declaring a variable with the data type of a table column:

```sql
name table.column_name%TYPE;
```

You can use this to declare variables that will hold database values. For example, if you have a column named `user_id` in your `users` table. To declare the variable `my_userid` with the same data type as the `users.user_id` column:

```sql
my_userid users.user_id%TYPE;
```

%TYPE is particularly valuable in polymorphic functions, since the data types needed for internal variables may change from one call to the next. Appropriate variables can be created by applying %TYPE to the function’s arguments or result placeholders.

Example: Composite Type Based on a Table Row

The following syntax declares a composite variable based on table row:

```sql
name table_name%ROWTYPE;
```

Such a row variable can hold a whole row of a SELECT or FOR query result, so long as that query column set matches the declared type of the variable. The individual fields of the row value are accessed using the usual dot notation, for example `rowvar.column`.

Parameters to a function can be composite types (complete table rows). In that case, the corresponding identifier $n will be a row variable, and fields can be selected from it, for example `$1.user_id`.

Only the user-defined columns of a table row are accessible in a row-type variable, not the OID or other system columns. The fields of the row type inherit the table’s field size or precision for data types such as `char(n)`.

The next example function uses a row variable composite type. Before creating the function, create the table that is used by the function with this command.

```sql
CREATE TABLE table1 (  
  f1 text,  
  f2 numeric,  
  f3 integer  
) distributed by (f1);
```

This INSERT command adds data to the table.

```sql
INSERT INTO table1 values  
  ('test1', 14.1, 3),  
  ('test2', 52.5, 2),  
  ('test3', 32.22, 6),  
  ('test4', 12.1, 4);
```

This function uses a variable and ROWTYPE composite variable based on `table1`.

```sql
CREATE OR REPLACE FUNCTION t1_calc( name text) RETURNS integer AS $$
DECLARE  
  tl_row table1%ROWTYPE;
$$
```
calc_int table1.f3%TYPE;
BEGIN
  SELECT * INTO t1_row FROM table1 WHERE table1.f1 = $1;
  calc_int = (t1_row.f2 * t1_row.f3)::integer;
  RETURN calc_int;
END;
$$ LANGUAGE plpgsql VOLATILE;

Note: The previous function is classified as a VOLATILE function because function values could change within a single table scan.

The following SELECT command uses the function.

select t1_calc( 'test1' );

Note: The example PL/pgSQL function uses SELECT with the INTO clause. It is different from the SQL command SELECT INTO. If you want to create a table from a SELECT result inside a PL/pgSQL function, use the SQL command CREATE TABLE AS.

Example: Using a Variable Number of Arguments

You can declare a PL/pgSQL function to accept variable numbers of arguments, as long as all of the optional arguments are of the same data type. You must mark the last argument of the function as VARIADIC and declare the argument using an array type. You can refer to a function that includes VARIADIC arguments as a variadic function.

For example, this variadic function returns the minimum value of a variable array of numerics:

```
CREATE FUNCTION mleast (VARIADIC numeric[])
  RETURNS numeric AS $$
DECLARE minval numeric;
BEGIN
  SELECT min($1[i]) FROM generate_subscripts( $1, 1) g(i) INTO minval;
  RETURN minval;
END;
$$ LANGUAGE plpgsql;
CREATE FUNCTION

SELECT mleast(10, -1, 5, 4.4);
mleast
--------
-1
(1 row)
```

Effectively, all of the actual arguments at or beyond the VARIADIC position are gathered up into a one-dimensional array.

You can pass an already-constructed array into a variadic function. This is particularly useful when you want to pass arrays between variadic functions. Specify VARIADIC in the function call as follows:

```
SELECT mleast(VARIADIC ARRAY[10, -1, 5, 4.4]);
```

This prevents PL/pgSQL from expanding the function's variadic parameter into its element type.

Example: Using Default Argument Values

You can declare PL/pgSQL functions with default values for some or all input arguments. The default values are inserted whenever the function is called with fewer than the declared number of arguments. Because arguments can only be omitted from the end of the actual argument list, you must provide default values for all arguments after an argument defined with a default value.
For example:

```sql
CREATE FUNCTION use_default_args(a int, b int DEFAULT 2, c int DEFAULT 3)
RETURNS int AS $$
DECLARE
  sum int;
BEGIN
  sum := $1 + $2 + $3;
  RETURN sum;
END;
$$ LANGUAGE plpgsql;

SELECT use_default_args(10, 20, 30);
use_default_args
------------------
60
(1 row)

SELECT use_default_args(10, 20);
use_default_args
------------------
33
(1 row)

SELECT use_default_args(10);
use_default_args
------------------
15
(1 row)
```

You can also use the `=` sign in place of the keyword `DEFAULT`.

### Example: Using Polymorphic Data Types

PL/pgSQL supports the polymorphic `anyelement`, `anyarray`, `anyenum`, and `anynonarray` types. Using these types, you can create a single PL/pgSQL function that operates on multiple data types. Refer to Greenplum Database Data Types for additional information on polymorphic type support in Greenplum Database.

A special parameter named `$0` is created when the return type of a PL/pgSQL function is declared as a polymorphic type. The data type of `$0` identifies the return type of the function as deduced from the actual input types.

In this example, you create a polymorphic function that returns the sum of two values:

```sql
CREATE FUNCTION add_two_values(v1 anyelement, v2 anyelement)
RETURNS anyelement AS $$
DECLARE
  sum ALIAS FOR $0;
BEGIN
  sum := v1 + v2;
  RETURN sum;
END;
$$ LANGUAGE plpgsql;

Execute `add_two_values()` providing integer input values:

```
SELECT add_two_values(1, 2);
add_two_values
--------------
3
(1 row)
```
The return type of `add_two_values()` is integer, the type of the input arguments. Now execute `add_two_values()` providing float input values:

```
SELECT add_two_values (1.1, 2.2);
```

```
<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>add_two_values</td>
</tr>
<tr>
<td>--------------</td>
</tr>
<tr>
<td>3.3</td>
</tr>
</tbody>
</table>

(1 row)
```

The return type of `add_two_values()` in this case is float.

You can also specify `VARIADIC` arguments in polymorphic functions.

**Example: Anonymous Block**

This example executes the function in the previous example as an anonymous block with the `DO` command. In the example, the anonymous block retrieves the input value from a temporary table.

```
CREATE TEMP TABLE list AS VALUES ('test1') DISTRIBUTED RANDOMLY;
DO $$
DECLARE
  t1_row   table1%ROWTYPE;
  calc_int table1.f3%TYPE;
BEGIN
  SELECT * INTO t1_row FROM table1, list WHERE table1.f1 = list.column1 ;
  calc_int = (t1_row.f2 * t1_row.f3)::integer ;
  RAISE NOTICE 'calculated value is %', calc_int ;
END $$ LANGUAGE plpgsql ;
```

**References**

The Postgres documentation about PL/pgSQL is at [https://www.postgresql.org/docs/8.3/static/plpgsql.html](https://www.postgresql.org/docs/8.3/static/plpgsql.html)

Also, see the `CREATE FUNCTION` command in the *Greenplum Database Reference Guide*.

For a summary of built-in Greenplum Database functions, see *Summary of Built-in Functions* in the *Greenplum Database Reference Guide*. For information about using Greenplum Database functions see "Querying Data" in the *Greenplum Database Administrator Guide*

For information about porting Oracle functions, see [https://www.postgresql.org/docs/8.3/static/plpgsql-porting.html](https://www.postgresql.org/docs/8.3/static/plpgsql-porting.html). For information about installing and using the Oracle compatibility functions with Greenplum Database, see "Oracle Compatibility Functions" in the *Greenplum Database Utility Guide*. 
Greenplum PostGIS Extension

This chapter contains the following information:

• About PostGIS
• Greenplum PostGIS Extension
• Enabling and Removing PostGIS Support
• Usage
• PostGIS Extension Support and Limitations
• PostGIS Support Scripts

About PostGIS

PostGIS is a spatial database extension for PostgreSQL that allows GIS (Geographic Information Systems) objects to be stored in the database. The Greenplum Database PostGIS extension includes support for GiST-based R-Tree spatial indexes and functions for analysis and processing of GIS objects.

The Greenplum Database PostGIS extension supports the optional PostGIS raster data type and most PostGIS Raster functions. With the PostGIS Raster objects, PostGIS geometry data type offers a single set of overlay SQL functions (such as ST_Intersects) operating seamlessly on vector and raster geospatial data. PostGIS Raster uses the GDAL (Geospatial Data Abstraction Library) translator library for raster geospatial data formats that presents a single raster abstract data model to a calling application.

For information about Greenplum Database PostGIS extension support, see PostGIS Extension Support and Limitations.

For information about PostGIS, see http://postgis.refractions.net/

For information about GDAL, see http://www.gdal.org.

Greenplum PostGIS Extension

The Greenplum Database PostGIS extension package is available from Pivotal Network. You can install the package using the Greenplum Package Manager (gppkg). For details, see gppkg in the Greenplum Database Utility Guide.

Greenplum Database supports the PostGIS extension with these component versions.

• PostGIS 2.1.5
• Proj 4.8.0
• Geos 3.4.2
• GDAL 1.11.1
• Json 0.12
• Expat 2.1.0

For the information about supported extension packages and software versions see the Greenplum Database Release Notes.

Major enhancements and changes in PostGIS 2.1.5 from 2.0.3 include new PostGIS Raster functions. For a list of new and enhanced functions in PostGIS 2.1, see the PostGIS documentation PostGIS Functions new or enhanced in 2.1.

For a list of breaking changes in PostGIS 2.1, see PostGIS functions breaking changes in 2.1.

For a comprehensive list of PostGIS changes in PostGIS 2.1.5 and earlier, see PostGIS 2.1 Appendix A Release 2.1.5.
Greenplum Database PostGIS Limitations

The Greenplum Database PostGIS extension does not support the following features:

- Topology
- A small number of user defined functions and aggregates
- PostGIS long transaction support
- Geometry and geography type modifier

For information about Greenplum Database PostGIS support, see PostGIS Extension Support and Limitations.

Enabling and Removing PostGIS Support

The Greenplum Database PostGIS extension contains the postgis_manager.sh script that installs or removes both the PostGIS and PostGIS Raster features in a database. After the PostGIS extension package is installed, the script is in $GPHOME/share/postgresql/contrib/postgis-2.1/. The postgis_manager.sh script runs SQL scripts that install or remove PostGIS and PostGIS Raster from a database.

For information about the PostGIS and PostGIS Raster SQL scripts, and required PostGIS Raster environment variables, see PostGIS Support Scripts.

Enabling PostGIS Support

Run the postgis_manager.sh script specifying the database and with the install option to install PostGIS and PostGIS Raster. This example installs PostGIS and PostGIS Raster objects in the database mydatabase.

```
postgis_manager.sh mydatabase install
```

The script runs all the PostGIS SQL scripts that enable PostGIS in a database: install/postgis.sql, install/rtpostgis.sql install/spatial_ref_sys.sql, install/postgis_comments.sql, and install/raster_comments.sql.

The postGIS package installation adds these lines to the greenplum_path.sh file for PostGIS Raster support.

```
export GDAL_DATA=$GPHOME/share/gdal
export POSTGIS_ENABLE_OUTDB_RASTERS=0
export POSTGIS_GDAL_ENABLED_DRIVERS=DISABLE_ALL
```

Enabling GDAL Raster Drivers

PostGIS uses GDAL raster drivers when processing raster data with commands such as ST_AsJPEG(). As the default, PostGIS disables all raster drivers. You enable raster drivers by setting the value of the POSTGIS_GDAL_ENABLED_DRIVERS environment variable in the greenplum_path.sh file on all Greenplum Database hosts.

To see the list of supported GDAL raster drivers for a Greenplum Database system, run the raster2pgsql utility with the -G option on the Greenplum Database master.

```
raster2pgsql -G
```

The command lists the driver long format name. The GDAL Raster Formats table at http://www.gdal.org/formats_list.html lists the long format names and the corresponding codes that you specify as the value of
the environment variable. For example, the code for the long name Portable Network Graphics is PNG. This example export line enables four GDAL raster drivers.

```bash
export POSTGIS_GDAL_ENABLED_DRIVERS="GTiff PNG JPEG GIF"
```

The `gpstop -r` command restarts the Greenplum Database system to use the updated settings in the `greenplum_path.sh` file.

After you have updated the `greenplum_path.sh` file on all hosts, and have restarted the Greenplum Database system, you can display the enabled raster drivers with the `ST_GDALDrivers()` function. This `SELECT` command lists the enabled raster drivers.

```sql
SELECT short_name, long_name FROM ST_GDALDrivers();
```

### Removing PostGIS Support

Run the `postgis_manager.sh` script specifying the database and with the `uninstall` option to remove PostGIS and PostGIS Raster. This example removes PostGIS and PostGIS Raster support from the database `mydatabase`.

```bash
postgis_manager.sh mydatabase uninstall
```

The script runs both the PostGIS SQL scripts that remove PostGIS and PostGIS Raster from a database: `uninstall_rtpostgis.sql` and `uninstall_postgis.sql`.

The `postgis_manager.sh` script does not remove these PostGIS Raster environment variables the `greenplum_path.sh` file: `GDAL_DATA`, `POSTGIS_ENABLE_OUTDB_RASTERS`, `POSTGIS_GDAL_ENABLED_DRIVERS`. The environment variables are removed when you uninstall the PostGIS extension package with the `gppkg` utility.

### Usage

The following example SQL statements create non-OpenGIS tables and geometries.

```sql
CREATE TABLE geom_test ( gid int4, geom geometry, name varchar(25) );
INSERT INTO geom_test ( gid, geom, name )
VALUES ( 1, 'POLYGON((0 0 0,0 5 0,5 5 0,5 0 0,0 0 0))', '3D Square' );
INSERT INTO geom_test ( gid, geom, name )
VALUES ( 2, 'LINESTRING(1 1 1,5 5 5,7 7 5)', '3D Line' );
INSERT INTO geom_test ( gid, geom, name )
VALUES ( 3, 'MULTIPOINT(3 4, 8 9)', '2D Aggregate Point' );
SELECT * from geom_test WHERE geom && Box3D(ST_GeomFromEWKT('LINESTRING(2 2 0, 3 3 0)'));
```

The following example SQL statements create a table and add a geometry column to the table with a SRID integer value that references an entry in the `SPATIAL_REF_SYS` table. The `INSERT` statements add two geopoints to the table.

```sql
CREATE TABLE geotest (id INT4, name VARCHAR(32) );
SELECT AddGeometryColumn('geotest','geopoint', 4326,'POINT',2);
INSERT INTO geotest (id, name, geopoint)
VALUES (1, 'Olympia', ST_GeometryFromText('POINT(-122.90 46.97)', 4326));
INSERT INTO geotest (id, name, geopoint)
VALUES (2, 'Renton', ST_GeometryFromText('POINT(-122.22 47.50)', 4326));
SELECT name,ST_AsText(geopoint) FROM geotest;
```
Spatial Indexes

PostgreSQL provides support for GiST spatial indexing. The GiST scheme offers indexing even on large objects. It uses a system of lossy indexing in which smaller objects act as proxies for larger ones in the index. In the PostGIS indexing system, all objects use their bounding boxes as proxies in the index.

Building a Spatial Index

You can build a GiST index as follows:

```
CREATE INDEX indexname
  ON tablename
  USING GIST ( geometryfield );
```

PostGIS Extension Support and Limitations

This section describes Greenplum PostGIS extension feature support and limitations.

- Supported PostGIS Data Types
- Supported PostGIS Index
- Supported PostGIS Raster Data Types
- PostGIS Extension Limitations

The Greenplum Database PostGIS extension does not support the following features:

- Topology
- Some Raster Functions

Supported PostGIS Data Types

Greenplum Database PostGIS extension supports these PostGIS data types:

- box2d
- box3d
- geometry
- geography

For a list of PostGIS data types, operators, and functions, see the PostGIS reference documentation.

Supported PostGIS Raster Data Types

Greenplum Database PostGIS supports these PostGIS Raster data types.

- geomval
- addbandarg
- rastbandarg
- raster
- reclassarg
- summarystats
- unionarg


For a list of PostGIS Raster data types, operators, and functions, see the PostGIS Raster reference documentation.
Supported PostGIS Index

Greenplum Database PostGIS extension supports the GiST (Generalized Search Tree) index.

PostGIS Extension Limitations

This section lists the Greenplum Database PostGIS extension limitations for user-defined functions (UDFs), data types, and aggregates.

- Data types and functions related to PostGIS topology functionality, such as TopoGeometry, are not supported by Greenplum Database.
- Functions that perform ANALYZE operations for user-defined data types are not supported. For example, the ST_Estimated_Extent function is not supported. The function requires table column statistics for user defined data types that are not available with Greenplum Database.
- These PostGIS aggregates are not supported by Greenplum Database:
  - ST_MemCollect
  - ST_MakeLine

On a Greenplum Database with multiple segments, the aggregate might return different answers if it is called several times repeatedly.

- Greenplum Database does not support PostGIS long transactions.

  PostGIS relies on triggers and the PostGIS table public.authorization_table for long transaction support. When PostGIS attempts to acquire locks for long transactions, Greenplum Database reports errors citing that the function cannot access the relation, authorization_table.

- Greenplum Database does not support type modifiers for user defined types.

  The work around is to use the AddGeometryColumn function for PostGIS geometry. For example, a table with PostGIS geometry cannot be created with the following SQL command:

  ```sql
  CREATE TABLE geometries(id INTEGER, geom geometry(LINESTRING));
  ```

  Use the AddGeometryColumn function to add PostGIS geometry to a table. For example, these following SQL statements create a table and add PostGIS geometry to the table:

  ```sql
  CREATE TABLE geometries(id INTEGER);
  SELECT AddGeometryColumn('public', 'geometries', 'geom', 0, 'LINESTRING', 2);
  ```

PostGIS Support Scripts

After installing the PostGIS extension package, you enable PostGIS support for each database that requires its use. To enable or remove PostGIS support in your database, you can run SQL scripts that are supplied with the PostGIS package in $GPHOME/share/postgresql/contrib/postgis-2.1/.

- Scripts that Enable PostGIS and PostGIS Raster Support
- Scripts that Remove PostGIS and PostGIS Raster Support

Instead of running the scripts individually, you can use the postgis_manager.sh script to run SQL scripts that enable or remove PostGIS support. See Enabling and Removing PostGIS Support.

You can run the PostGIS SQL scripts individually to enable or remove PostGIS support. For example, these commands run the SQL scripts postgis.sql, rtpostgis.sql, and spatial_ref_sys.sql in the database mydatabase.

  ```bash
  psql -d mydatabase -f $GPHOME/share/postgresql/contrib/postgis-2.1/install/postgis.sql
  psql -d mydatabase -f
  ```
After running the scripts, the database is enabled with both PostGIS and PostGIS Raster.

Scripts that Enable PostGIS and PostGIS Raster Support

These scripts enable PostGIS, and the optional PostGIS Raster in a database.

- install/postgis.sql - Load the PostGIS objects and function definitions.
- install/rtpostgis.sql - Load the PostGIS raster object and function definitions.

**Note:** If you are installing PostGIS Raster, PostGIS objects must be installed before PostGIS Raster. PostGIS Raster depends on PostGIS objects. Greenplum Database returns an error if rtpostgis.sql is run before postgis.sql.

These SQL scripts add data and comments to a PostGIS enabled database.

- install/spatial_ref_sys.sql - Populate the spatial_ref_sys table with a complete set of EPSG coordinate system definition identifiers. With the definition identifiers you can perform ST_Transform() operations on geometries.

  **Note:** If you have overridden standard entries and want to use those overrides, do not load the spatial_ref_sys.sql file when creating the new database.

- install/postgis_comments.sql - Add comments to the PostGIS functions.
- install/raster_comments.sql - Add comments to the PostGIS Raster functions.

You can view comments with the psql meta-command \dd function_name or from any tool that can show Greenplum Database function comments.

PostGIS Raster Environment Variables

The postGIS package installation adds these lines to the greenplum_path.sh file for PostGIS Raster support.

```bash
export GDAL_DATA=$GPHOME/share/gdal
export POSTGIS_ENABLE_OUTDB_RASTERS=0
export POSTGIS_GDAL_ENABLED_DRIVERS=DISABLE_ALL
```

**GDAL_DATA** specifies the location of GDAL utilities and support files used by the GDAL library. For example, the directory contains EPSG support files such as gcs.csv and pcs.csv (so called dictionaries, mostly in CSV format). The GDAL library requires the support files to properly evaluate EPSG codes.

**POSTGIS_GDAL_ENABLED_DRIVERS** sets the enabled GDAL drivers in the PostGIS environment.

**POSTGIS_ENABLE_OUTDB_RASTERS** is a boolean configuration option to enable access to out of database raster bands.

Scripts that Remove PostGIS and PostGIS Raster Support

To remove PostGIS support from a database, run SQL scripts that are supplied with the PostGIS extension package in $GPHOME/share/postgresql/contrib/postgis-2.1/

**Note:** If you installed PostGIS Raster, you must uninstall PostGIS Raster before you uninstall the PostGIS objects. PostGIS Raster depends on PostGIS objects. Greenplum Database returns an error if PostGIS objects are removed before PostGIS Raster.

These scripts remove PostGIS and PostGIS Raster objects from a database.

- uninstall/uninstall_rtpostgis.sql - Removes the PostGIS Raster object and function definitions.
• `uninstall/uninstall_postgis.sql` - Removes the PostGIS objects and function definitions.

After PostGIS support has been removed from all databases in the Greenplum Database system, you can remove the PostGIS extension package. For example, this `gppkg` command removes the PostGIS extension package.

```
 gppkg -r postgis-ossv2.1.5_pv2.1_gpdb5.0
```

Restart Greenplum Database after removing the package.

```
 gpstop -r
```

Ensure that these lines for PostGIS Raster support are removed from the `greenplum_path.sh` file.

```
export GDAL_DATA=$GPHOME/share/gdal
export POSTGIS_ENABLE_OUTDB_RASTERS=0
export POSTGIS_GDAL_ENABLED_DRIVERS=DISABLE_ALL
```
Greenplum Database PL/R Language Extension

This chapter contains the following information:

- About Greenplum Database PL/R
- Installing PL/R
- Uninstalling PL/R
- Enabling PL/R Language Support
- Examples
- Downloading and Installing R Packages
- Displaying R Library Information
- References

About Greenplum Database PL/R

PL/R is a procedural language. With the Greenplum Database PL/R extension you can write database functions in the R programming language and use R packages that contain R functions and data sets. For information about supported PL/R versions, see the Greenplum Database Release Notes.

Installing PL/R

The PL/R extension is available as a package. Download the package from Pivotal Network and install it with the Greenplum Package Manager (gppkg).

The gppkg utility installs Greenplum Database extensions, along with any dependencies, on all hosts across a cluster. It also automatically installs extensions on new hosts in the case of system expansion and segment recovery.

For information about gppkg, see the Greenplum Database Utility Guide.

Installing the Extension Package

Before you install the PL/R extension, make sure that your Greenplum Database is running, you have sourced greenplum_path.sh, and that the $MASTER_DATA_DIRECTORY and $GPHOME variables are set.

1. Download the PL/R extension package from Pivotal Network.
2. Copy the PL/R package to the Greenplum Database master host.
3. Install the software extension package by running the gppkg command. This example installs the PL/R extension on a Linux system:

   ```bash
   $ gppkg -i plr-2.3.1-gp5-rhel6-x86_64.gppkg
   ```

4. Restart the database.

   ```bash
   $ gpstop -r
   ```

5. Source the file $GPHOME/greenplum_path.sh.

The extension and the R environment is installed in this directory:

```
$GPHOME/ext/R-3.3.3/
```

Note: The version of some shared libraries installed with the operating system might not be compatible with the Greenplum Database PL/R extension.
If a shared library is not compatible, edit the file $GPHOME/greenplum_path.sh in all Greenplum Database master and segment hosts and set environment variable LD_LIBRARY_PATH to specify the location that is installed with the PL/R extension.

```bash
export LD_LIBRARY_PATH=
    $GPHOME/ext/R-3.3.3/lib:$LD_LIBRARY_PATH
```

### Uninstalling PL/R

- **Remove PL/R Support for a Database**
- **Uninstall the Extension Package**

When you remove PL/R language support from a database, the PL/R routines that you created in the database will no longer work.

**Remove PL/R Support for a Database**

For a database that no longer requires the PL/R language, remove support for PL/R with the SQL command `DROP LANGUAGE` or the Greenplum Database `droplang` utility. Because PL/R is an untrusted language, only superusers can remove support for the PL/R language from a database. For example, running this command as the gpadmin user removes support for PL/R from the database named `testdb`:

```bash
$ droplang plr -d testdb
```

**Uninstall the Extension Package**

If no databases have PL/R as a registered language, uninstall the Greenplum PL/R extension with the `gppkg` utility. This example uninstalls PL/R package version 2.3.1

```bash
$ gppkg -r plr-2.3.1
```

You can run the `gppkg` utility with the options `-q --all` to list the installed extensions and their versions. Restart the database.

```bash
$ gpstop -r
```

### Enabling PL/R Language Support

For each database that requires its use, register the PL/R language with the SQL command `CREATE LANGUAGE` or the utility `createlang`. Because PL/R is an untrusted language, only superusers can register PL/R with a database. For example, running this command as the gpadmin system user registers the language with the database named `testdb`:

```bash
$ createlang plr -d testdb
```

PL/R is registered as an untrusted language.

### Examples

The following are simple PL/R examples.

#### Example 1: Using PL/R for single row operators

This function generates an array of numbers with a normal distribution using the R function `rnorm()`.

```sql
CREATE OR REPLACE FUNCTION r_norm(n integer, mean float8, std_dev float8) RETURNS float8[ ] AS
```

```sql
    CREATE OR REPLACE FUNCTION r_norm(n integer, mean float8, std_dev float8) RETURNS float8[ ] AS
```

```sql
    CREATE OR REPLACE FUNCTION r_norm(n integer, mean float8, std_dev float8) RETURNS float8[ ] AS
```

```sql
    CREATE OR REPLACE FUNCTION r_norm(n integer, mean float8, std_dev float8) RETURNS float8[ ] AS
```
The following CREATE TABLE command uses the `r_norm` function to populate the table. The `r_norm` function creates an array of 10 numbers.

```sql
CREATE TABLE test_norm_var
AS SELECT id, r_norm(10,0,1) as x
FROM (SELECT generate_series(1,30:: bigint) AS ID) foo
DISTRIBUTED BY (id);
```

### Example 2: Returning PL/R data.frames in Tabular Form

Assuming your PL/R function returns an R `data.frame` as its output, unless you want to use arrays of arrays, some work is required to see your `data.frame` from PL/R as a simple SQL table:

- Create a TYPE in a Greenplum database with the same dimensions as your R `data.frame`:

  ```sql
  CREATE TYPE t1 AS ...
  ```

- Use this TYPE when defining your PL/R function

  ```sql
  ... RETURNS SET OF t1 AS ...
  ```

Sample SQL for this is given in the next example.

### Example 3: Hierarchical Regression using PL/R

The SQL below defines a TYPE and runs hierarchical regression using PL/R:

```sql
--Create TYPE to store model results
DROP TYPE IF EXISTS wj_model_results CASCADE;
CREATE TYPE wj_model_results AS (
    cs text, coefext float, ci_95_lower float, ci_95_upper float,
    ci_90_lower, float, ci_90_upper float, ci_80_lower,
    float, ci_80_upper float);

--Create PL/R function to run model in R
DROP FUNCTION wj.plr.RE(response float [], cs text [])
RETURNS SETOF wj_model_results AS
$$
library(arm)
y<- log(response)
cs<- cs
d_temp<- data.frame(y,cs)
m0 <- lmer (y ~ 1 + (1 | cs), data=d_temp)
ns_unique<- sort(unique(cs))
n_cs_unique<- length(cs_unique)
temp_m0<- data.frame(matrix(0,n_cs_unique, 7))
for (i in 1:n_cs_unique){temp_m0[i,]<-
    c(exp(coef(m0)$cs[i,1] + c(0,-1.96,1.96,-1.65,1.65
    -1.28,1.28)*se.ranef(m0)$cs[i]))}
names(temp_m0)<- c("Coefest", "CI_95_Lower",
    "CI_95_Upper", "CI_90_Lower", "CI_90_Upper",
    "CI_80_Lower", "CI_80_Upper")
temp_m0_v2<- data.frames(cs_unique, temp_m0)
return(temp_m0_v2)
$$
LANGUAGE 'plr';
```
--Run modeling plr function and store model results in a table
DROP TABLE IF EXISTS wj_model_results_roi;
CREATE TABLE wj_model_results_roi AS SELECT * 
FROM wj.plr_RE((SELECT wj.droi2_array), 
(SELECT cs FROM wj.droi2_array));

Downloading and Installing R Packages

R packages are modules that contain R functions and data sets. You can install R packages to extend R and PL/R functionality in Greenplum Database.

Greenplum Database provides a collection of data science-related R libraries that can be used with the Greenplum Database PL/R language. You can download these libraries in .gppkg format from Pivotal Network. For information about the libraries, see R Data Science Library Package.

Note: If you expand Greenplum Database and add segment hosts, you must install the R packages in the R installation of the new hosts.

1. For an R package, identify all dependent R packages and each package web URL. The information can be found by selecting the given package from the following navigation page:
   http://cran.r-project.org/web/packages/available_packages_by_name.html
   As an example, the page for the R package arm indicates that the package requires the following R libraries: Matrix, lattice, Ime4, R2WinBUGS, coda, abind, foreign, and MASS.
   You can also try installing the package with R CMD INSTALL command to determine the dependent packages.
   For the R installation included with the Greenplum Database PL/R extension, the required R packages are installed with the PL/R extension. However, the Matrix package requires a newer version.

2. From the command line, use the wget utility to download the .tar.gz files for the arm package to the Greenplum Database master host:
   wget http://cran.r-project.org/src/contrib/Archive/arm/arm_1.5-03.tar.gz
   wget http://cran.r-project.org/src/contrib/Archive/Matrix/Matrix_0.9996875-1.tar.gz

3. Use the gpscp utility and the hosts_all file to copy the .tar.gz files to the same directory on all nodes of the Greenplum Database cluster. The hosts_all file contains a list of all the Greenplum Database segment hosts. You might require root access to do this.
   gpscp -f hosts_all Matrix_0.9996875-1.tar.gz =:/home/gpadmin
   gpscp -f /hosts_all arm_1.5-03.tar.gz =:/home/gpadmin

4. Use the gpssh utility in interactive mode to log into each Greenplum Database segment host (gpssh -f all_hosts). Install the packages from the command prompt using the R CMD INSTALL command. Note that this may require root access. For example, this R install command installs the packages for the arm package.
   $R_HOME/bin/R CMD INSTALL Matrix_0.9996875-1.tar.gz arm_1.5-03.tar.gz
5. Ensure that the package is installed in the $R_HOME/library directory on all the segments (the gpssh can be use to install the package). For example, this gpssh command list the contents of the R library directory.

```
gpssh -s -f all_hosts "ls $R_HOME/library"
```

The gpssh option -s sources the greenplum_path.sh file before running commands on the remote hosts.

6. Test if the R package can be loaded.

This function performs a simple test to if an R package can be loaded:

```sql
CREATE OR REPLACE FUNCTION R_test_require(fname text)
RETURNS boolean AS
$BODY$
    return(require(fname, character.only = T))
$BODY$
LANGUAGE 'plr';
```

This SQL command checks if the R package arm can be loaded:

```
SELECT R_test_require('arm');
```

Displaying R Library Information

You can use the R command line to display information about the installed libraries and functions on the Greenplum Database host. You can also add and remove libraries from the R installation. To start the R command line on the host, log into the host as the gadmin user and run the script R from the directory $GPHOME/ext/R-3.3.3/bin.

This R function lists the available R packages from the R command line:

```r
> library()
```

Display the documentation for a particular R package

```r
> library(help="package_name")
> help(package="package_name")
```

Display the help file for an R function:

```r
> help("function_name")
> ?function_name
```

To see what packages are installed, use the R command installed.packages(). This will return a matrix with a row for each package that has been installed. Below, we look at the first 5 rows of this matrix.

```r
> installed.packages()
```

Any package that does not appear in the installed packages matrix must be installed and loaded before its functions can be used.

An R package can be installed with install.packages():

```r
> install.packages("package_name")
> install.packages("mypkg", dependencies = TRUE, type="source")
```
Load a package from the R command line.

```r
> library("package_name")
```

An R package can be removed with `remove.packages`

```r
> remove.packages("package_name")
```

You can use the R command `-e` option to run functions from the command line. For example, this command displays help on the R package MASS.

```r
$ R -e 'help("MASS")'
```

**References**

- [http://www.r-project.org/](http://www.r-project.org/) - The R Project home page
- [https://cran.r-project.org/web/packages/PivotalR/](https://cran.r-project.org/web/packages/PivotalR/) - The home page for PivotalR, a package that provides an R interface to operate on Greenplum Database tables and views that is similar to the R `data.frame`. PivotalR also supports using the machine learning package `MADlib` directly from R.

R documentation is installed with the Greenplum R package:

```bash
$GPHOME/ext/R-3.3.3/doc
```

**R Functions and Arguments**


**Passing Data Values in R**


**Aggregate Functions in R**

Greenplum PL/Python Language Extension

This section contains an overview of the Greenplum Database PL/Python Language.

- About Greenplum PL/Python
- Enabling and Removing PL/Python support
- Developing Functions with PL/Python
- Installing Python Modules
- Examples
- References

About Greenplum PL/Python

PL/Python is a loadable procedural language. With the Greenplum Database PL/Python extension, you can write a Greenplum Database user-defined functions in Python that take advantage of Python features and modules to quickly build robust database applications.

You can run PL/Python code blocks as anonymous code blocks. See the `DO` command in the Greenplum Database Reference Guide.

The Greenplum Database PL/Python extension is installed by default with Greenplum Database. Greenplum Database installs a version of Python and PL/Python. This is location of the Python installation that Greenplum Database uses:

```
$GPHOME/ext/python/
```

Greenplum Database PL/Python Limitations

- Greenplum Database does not support PL/Python triggers.
- PL/Python is available only as a Greenplum Database untrusted language.
- Updatable cursors (`UPDATE...WHERE CURRENT OF` and `DELETE...WHERE CURRENT OF`) are not supported.

Enabling and Removing PL/Python support

The PL/Python language is installed with Greenplum Database. To create and run a PL/Python user-defined function (UDF) in a database, you must register the PL/Python language with the database.

Enabling PL/Python Support

For each database that requires its use, register the PL/Python language with the SQL command `CREATE LANGUAGE` or the Greenplum Database utility `createlang`. Because PL/Python is an untrusted language, only superusers can register PL/Python with a database. For example, running this command as the `gpadmin` system user registers PL/Python with the database named `testdb`:

```
$ createlang plpythonu -d testdb
```

PL/Python is registered as an untrusted language.

Removing PL/Python Support

For a database that no longer requires the PL/Python language, remove support for PL/Python with the SQL command `DROP LANGUAGE` or the Greenplum Database `droplang` utility. Because PL/Python is an untrusted language, only superusers can remove support for the PL/Python language from a database.
For example, running this command as the `gpadmin` system user removes support for PL/Python from the database named `testdb`:

```
$ droplang plpythonu -d testdb
```

When you remove support for PL/Python, the PL/Python user-defined functions that you created in the database will no longer work.

### Developing Functions with PL/Python

The body of a PL/Python user-defined function is a Python script. When the function is called, its arguments are passed as elements of the array `args[]`. Named arguments are also passed as ordinary variables to the Python script. The result is returned from the PL/Python function with `return` statement, or `yield` statement in case of a result-set statement.

### Arrays and Lists

You pass SQL array values into PL/Python functions with a Python list. Similarly, PL/Python functions return SQL array values as a Python list. In the typical PL/Python usage pattern, you will specify an array with `[]`.

The following example creates a PL/Python function that returns an array of integers:

```sql
CREATE FUNCTION return_py_int_array()
RETURNS int[]
AS $$
return [1, 11, 21, 31]
$$ LANGUAGE plpythonu;

SELECT return_py_int_array();
```

```
return_py_int_array
---------------------
{1,11,21,31}
(1 row)
```

PL/Python treats multi-dimensional arrays as lists of lists. You pass a multi-dimensional array to a PL/Python function using nested Python lists. When a PL/Python function returns a multi-dimensional array, the inner lists at each level must all be of the same size.

The following example creates a PL/Python function that takes a multi-dimensional array of integers as input. The function displays the type of the provided argument, and returns the multi-dimensional array:

```sql
CREATE FUNCTION return_multidim_py_array(x int4[])
RETURNS int4[]
AS $$
plpy.info(x, type(x))
return x
$$ LANGUAGE plpythonu;

SELECT * FROM return_multidim_py_array(ARRAY[[1,2,3], [4,5,6]]);  
INFO:  ([1, 2, 3], [4, 5, 6], <type 'list'>)  
CONTEXT:  PL/Python function "return_multidim_py_type"  
return_multidim_py_array
--------------------------
{{1,2,3},{4,5,6}}
(1 row)
```

PL/Python also accepts other Python sequences, such as tuples, as function arguments for backwards compatibility with Greenplum versions where multi-dimensional arrays were not supported. In such cases,
the Python sequences are always treated as one-dimensional arrays because they are ambiguous with composite types.

**Composite Types**

You pass composite-type arguments to a PL/Python function using Python mappings. The element names of the mapping are the attribute names of the composite types. If an attribute has the null value, its mapping value is `None`.

You can return a composite type result as a sequence type (tuple or list). You must specify a composite type as a tuple, rather than a list, when it is used in a multi-dimensional array. You cannot return an array of composite types as a list because it would be ambiguous to determine whether the list represents a composite type or another array dimension. In the typical usage pattern, you will specify composite type tuples with `()`.

In the following example, you create a composite type and a PL/Python function that returns an array of the composite type:

```sql
CREATE TYPE type_record AS (
    first text,
    second int4
);

CREATE FUNCTION composite_type_as_list()
    RETURNS type_record[]
AS $$
    return [([('first', 1), ('second', 1)], [('first', 2), ('second', 2)],
        [('first', 3), ('second', 3)]);
$$ LANGUAGE plpythonu;

SELECT * FROM composite_type_as_list();
```

Refer to the PostgreSQL Arrays, Lists documentation for additional information on PL/Python handling of arrays and composite types.

**Executing and Preparing SQL Queries**

The PL/Python `plpy` module provides two Python functions to execute an SQL query and prepare an execution plan for a query, `plpy.execute` and `plpy.prepare`. Preparing the execution plan for a query is useful if you run the query from multiple Python functions.

PL/Python also supports the `plpy.subtransaction()` function to help manage `plpy.execute` calls in an explicit subtransaction. See Explicit Subtransactions in the PostgreSQL documentation for additional information about `plpy.subtransaction()`.

**plpy.execute**

Calling `plpy.execute` with a query string and an optional limit argument causes the query to be run and the result to be returned in a Python result object. The result object emulates a list or dictionary object. The rows returned in the result object can be accessed by row number and column name. The result set row numbering starts with 0 (zero). The result object can be modified. The result object has these additional methods:

- `nrows` that returns the number of rows returned by the query.
- `status` which is the `SPI_execute()` return value.
For example, this Python statement in a PL/Python user-defined function executes a query.

```python
rv = plpy.execute("SELECT * FROM my_table", 5)
```

The `plpy.execute` function returns up to 5 rows from `my_table`. The result set is stored in the `rv` object. If `my_table` has a column `my_column`, it would be accessed as:

```python
my_col_data = rv[i]["my_column"]
```

Since the function returns a maximum of 5 rows, the index `i` can be an integer between 0 and 4.

**plpy.prepare**

The function `plpy.prepare` prepares the execution plan for a query. It is called with a query string and a list of parameter types, if you have parameter references in the query. For example, this statement can be in a PL/Python user-defined function:

```python
plan = plpy.prepare("SELECT last_name FROM my_users WHERE first_name = $1", [ "text" ])
```

The string `text` is the data type of the variable that is passed for the variable `$1`. After preparing a statement, you use the function `plpy.execute` to run it:

```python
rv = plpy.execute(plan, [ "Fred" ], 5)
```

The third argument is the limit for the number of rows returned and is optional.

When you prepare an execution plan using the PL/Python module the plan is automatically saved. See the Postgres Server Programming Interface (SPI) documentation for information about the execution plans [https://www.postgresql.org/docs/8.3/static/spi.html](https://www.postgresql.org/docs/8.3/static/spi.html).

To make effective use of saved plans across function calls you use one of the Python persistent storage dictionaries SD or GD.

The global dictionary SD is available to store data between function calls. This variable is private static data. The global dictionary GD is public data, available to all Python functions within a session. Use GD with care.

Each function gets its own execution environment in the Python interpreter, so that global data and function arguments from `myfunc` are not available to `myfunc2`. The exception is the data in the GD dictionary, as mentioned previously.

This example uses the SD dictionary:

```python
CREATE FUNCTION usesavedplan() RETURNS trigger AS $$
if SD.has_key("plan"):
    plan = SD["plan"]
else:
    plan = plpy.prepare("SELECT 1")
SD["plan"] = plan
# rest of function
$$ LANGUAGE plpythonu;
```

**Handling Python Errors and Messages**

The Python module `plpy` implements these functions to manage errors and messages:

- `plpy.debug`
- `plpy.log`
• plpy.info
• plpy.notice
• plpy.warning
• plpy.error
• plpy.fatal
• plpy.debug

The message functions plpy.error and plpy.fatal raise a Python exception which, if uncaught, propagates out to the calling query, causing the current transaction or subtransaction to be aborted. The functions raise plpy.ERROR(msg) and raise plpy.FATAL(msg) are equivalent to calling plpy.error and plpy.fatal, respectively. The other message functions only generate messages of different priority levels.

Whether messages of a particular priority are reported to the client, written to the server log, or both is controlled by the Greenplum Database server configuration parameters log_min_messages and client_min_messages. For information about the parameters see the Greenplum Database Reference Guide.

Using the dictionary GD To Improve PL/Python Performance

In terms of performance, importing a Python module is an expensive operation and can affect performance. If you are importing the same module frequently, you can use Python global variables to load the module on the first invocation and not require importing the module on subsequent calls. The following PL/Python function uses the GD persistent storage dictionary to avoid importing a module if it has already been imported and is in the GD.

```sql
psql=#
CREATE FUNCTION pytest() returns text as $$
if 'mymodule' not in GD:
    import mymodule
    GD['mymodule'] = mymodule
return GD['mymodule'].sumd([1,2,3])$$;
```

Installing Python Modules

When you install a Python module on Greenplum Database, the Greenplum Database Python environment must have the module added to it across all segment hosts and mirror hosts in the cluster. When expanding Greenplum Database, you must add the Python modules to the new segment hosts. You can use the Greenplum Database utilities gpssh and gpscp run commands on Greenplum Database hosts and copy files to the hosts. For information about the utilities, see the Greenplum Database Utility Guide.

As part of the Greenplum Database installation, the gpadmin user environment is configured to use Python that is installed with Greenplum Database.

To check the Python environment, you can use the which command:

```bash
which python
```

The command returns the location of the Python installation. The Python installed with Greenplum Database is in the Greenplum Database ext/python directory.

```
/path_to_greenplum-db/ext/python/bin/python
```

When running shell commands on remote hosts with gpssh, you can specify the -s option. When the option is specified, gpssh sources the greenplum_path.sh file before running commands on the remote
hosts. For example, this command should display the Python installed with Greenplum Database on each host.

```
gpssh -f gpdb_hosts which python
```

If it does not, you can add the `-s` to source `greenplum_path.sh` on the remote hosts before running the command.

```
gpssh -s -f gpdb_hosts which python
```

To display the list of currently installed Python modules, run this command.

```
python -c "help('modules')"
```

Run `gpssh` in interactive mode to display Python modules on remote hosts. This example starts `gpssh` in interactive mode and lists the Python modules on the Greenplum Database host `sdw1`.

```
$ gpssh -s -h sdw1
  => python -c "help('modules')"
  ...  
  => exit

$  
```

Greenplum Database provides a collection of data science-related Python libraries that can be used with the Greenplum Database PL/Python language. You can download these libraries in `.gppkg` format from Pivotal Network. For information about the libraries, see Python Data Science Module Package.

These sections describe installing and testing Python modules:

- Installing Python `pip`
- Installing Python Packages with `pip`
- Building and Installing Python Modules Locally
- Testing Installed Python Modules

## Installing Python `pip`

The Python utility `pip` installs Python packages that contain Python modules and other resource files from versioned archive files.

Run this command to install `pip`.

```
python -m ensurepip --default-pip
```

The command runs the `ensurepip` module to bootstrap (install and configure) the `pip` utility from the local Python installation.

You can run this command to ensure the `pip`, `setuptools` and `wheel` projects are current. Current Python projects ensure that you can install Python packages from source distributions or pre-built distributions (wheels).

```
python -m pip install --upgrade pip setuptools wheel
```

You can use `gpssh` to run the commands on the Greenplum Database hosts. This example runs `gpssh` in interactive mode to install `pip` on the hosts listed in the file `gpdb_hosts`.

```
$ gpssh -s -f gpdb_hosts
  => python -m ensurepip --default-pip
  [centos6-mdw1] Ignoring indexes: https://pypi.python.org/simple
  [centos6-mdw1] Collecting setuptools
  [centos6-mdw1] Collecting pip
```
The => is the inactive prompt for gpssh. The utility displays the output from each host. The exit command exits from gpssh interactive mode.

This gpssh command runs a single command on all hosts listed in the file gpdb_hosts.

gpssh -s -f gpdb_hosts python -m pip install --upgrade pip setuptools wheel

The utility displays the output from each host.

For more information about installing Python packages, see https://packaging.python.org/tutorials/installing-packages/.

**Installing Python Packages with pip**

After installing pip, you can install Python packages. This command installs the numpy and scipy packages.

```
python -m pip install --user numpy scipy
```

The --user option attempts to avoid conflicts when installing Python packages.

You can use gpssh to run the command on the Greenplum Database hosts.

For information about these and other Python packages, see References.

**Building and Installing Python Modules Locally**

If you are building a Python module, you must ensure that the build creates the correct executable. For example on a Linux system, the build should create a 64-bit executable.

Before building a Python module to be installed, ensure that the appropriate software to build the module is installed and properly configured. The build environment is required only on the host where you build the module.

You can use the Greenplum Database utilities gpssh and gpscp to run commands on Greenplum Database hosts and to copy files to the hosts.

**Testing Installed Python Modules**

You can create a simple PL/Python user-defined function (UDF) to validate that Python a module is available in the Greenplum Database. This example tests the NumPy module.

This PL/Python UDF imports the NumPy module. The function returns SUCCESS if the module is imported, and FAILURE if an import error occurs.

```
CREATE OR REPLACE FUNCTION plpy_test(x int)
returns text
as $$
    try:
        from numpy import *
        return 'SUCCESS'
    except ImportError, e:
```

Create a table that contains data on each Greenplum Database segment instance. Depending on the size of your Greenplum Database installation, you might need to generate more data to ensure data is distributed to all segment instances.

```
CREATE TABLE DIST AS (SELECT x FROM generate_series(1,50) x ) DISTRIBUTED RANDOMLY ;
```

This `SELECT` command runs the UDF on the segment hosts where data is stored in the primary segment instances.

```
SELECT gp_segment_id, plpy_test(x) AS status
FROM dist
GROUP BY gp_segment_id, status
ORDER BY gp_segment_id, status;
```

The `SELECT` command returns `SUCCESS` if the UDF imported the Python module on the Greenplum Database segment instance. If the `SELECT` command returns `FAILURE`, you can find the segment host of the segment instance host. The Greenplum Database system table `gp_segment_configuration` contains information about mirroring and segment configuration. This command returns the host name for a segment ID.

```
SELECT hostname, content AS seg_ID FROM gp_segment_configuration
  WHERE content = seg_id ;
```

If `FAILURE` is returned, these are some possible causes:

- A problem accessing required libraries. For the NumPy example, a Greenplum Database might have a problem accessing the OpenBLAS libraries or the Python libraries on a segment host.

  Make sure you get no errors when running command on the segment host as the `gpadmin` user. This `gpssh` command tests importing the numpy module on the segment host `mdw1`.

  ```
  gpssh -s -h mdw1 python -c "import numpy"
  ```

- If the Python `import` command does not return an error, environment variables might not be configured in the Greenplum Database environment. For example, the Greenplum Database might not have been restarted after installing the Python Package on the host system.

**Examples**

This PL/Python UDF returns the maximum of two integers:

```
CREATE FUNCTION pymax (a integer, b integer)
  RETURNS integer AS $$
    if (a is None) or (b is None):
      return None
    if a > b:
      return a
    return b
$$ LANGUAGE plpythonu;
```

You can use the `STRICT` property to perform the null handling instead of using the two conditional statements.

```
CREATE FUNCTION pymax (a integer, b integer)
  RETURNS integer AS $$
```

```
return 'FAILURE'
$$ language plpythonu;
```
You can run the user-defined function `pymax` with `SELECT` command. This example runs the UDF and shows the output.

```
SELECT ( pymax(123, 43));
column1  
---------
   123
(1 row)
```

This example that returns data from an SQL query that is run against a table. These two commands create a simple table and add data to the table.

```
CREATE TABLE sales (id int, year int, qtr int, day int, region text)
   DISTRIBUTED BY (id) ;
INSERT INTO sales VALUES
  (1, 2014, 1, 1, 'usa'),
  (2, 2002, 2, 2, 'europe'),
  (3, 2014, 3, 3, 'asia'),
  (4, 2014, 4, 4, 'usa'),
  (5, 2014, 1, 5, 'europe'),
  (6, 2014, 2, 6, 'asia'),
  (7, 2002, 3, 7, 'usa') ;
```

This PL/Python UDF executes a `SELECT` command that returns 5 rows from the table. The Python function returns the `region` value from the row specified by the input value. In the Python function, the row numbering starts from 0. Valid input for the function is an integer between 0 and 4.

```
CREATE OR REPLACE FUNCTION mypytest(a integer)
RETURNS text
AS $$
rv = plpy.execute("SELECT * FROM sales ORDER BY id", 5)
region = rv[a]["region"]
return region
$$ language plpythonu;
```

Running this `SELECT` statement returns the `region` column value from the third row of the result set.

```
SELECT mypytest(2) ;
```

This command deletes the UDF from the database.

```
DROP FUNCTION mypytest(integer) ;
```

This example executes the PL/Python function in the previous example as an anonymous block with the `DO` command. In the example, the anonymous block retrieves the input value from a temporary table.

```
CREATE TEMP TABLE mytemp AS VALUES (2) DISTRIBUTED RANDOMLY;
DO $$
  temprow = plpy.execute("SELECT * FROM mytemp", 1)
  myval = temprow[0]["column1"]
  rv = plpy.execute("SELECT * FROM sales ORDER BY id", 5)
  region = rv[myval]["region"]
  plpy.notice("region is %s" % region)
$$ language plpythonu;
```
References

Technical References

For information about the Python language, see https://www.python.org/.

For information about PL/Python see the PostgreSQL documentation at https://www.postgresql.org/docs/8.3/static/plpython.html.

For information about Python Package Index (PyPI), see https://pypi.python.org/pypi.

These are some Python modules that can be installed:

- SciPy library provides user-friendly and efficient numerical routines such as routines for numerical integration and optimization. The SciPy site includes other similar Python libraries http://www.scipy.org/index.html.
- Natural Language Toolkit (nltk) is a platform for building Python programs to work with human language data. http://www.nltk.org/. For information about installing the toolkit see http://www.nltk.org/install.html.
Greenplum PL/Container Language Extension

This section includes the following information about PL/Container 1.1 and later:

- About the PL/Container Language Extension
- About PL/Container Resource Management
- PL/Container Docker Images
- Installing the PL/Container Language Extension
- Upgrading from PL/Container 1.0
- Upgrading from PL/Container 1.1
- Uninstalling PL/Container
- Using PL/Container Functions
- About PL/Container Running PL/Python
- About PL/Container Running PL/R
- Configuring PL/Container
- Installing Docker
- References

**Note:** The extension PL/Container 1.1 and later is installed by `gppkg` as a Greenplum Database extension, while the extension PL/Container 1.0 is installed as a Greenplum Database language. To upgrade to PL/Container 1.1 or later from PL/Container 1.0, you uninstall the old version and install the new version. See Upgrading from PL/Container 1.0.

**Warning:** PL/Container is compatible with Greenplum Database 5.2.0 and later. PL/Container has not been tested for compatibility with Greenplum Database 5.1.0 or 5.0.0.

### About the PL/Container Language Extension

The Greenplum Database PL/Container language extension (PL/Container) is an interface that allows Greenplum Database to interact with a Docker container to execute a user-defined function (UDF) in the container. Docker containers ensure the user code cannot access the file system of the source host. Also, containers are started without network access or with limited network access and cannot connect back to Greenplum Database or open any other external connections. For information about available UDF languages, see PL/Container Docker Images.

Generally speaking, a Docker container is a Linux process that runs in a managed way by using Linux kernel features such as cgroups, namespaces and union file systems. A Docker image is the basis of a container. A Docker container is a running instance of a Docker image. When you start a Docker container you specify a Docker image. A Docker image is the collection of root filesystem changes and execution parameters that are used when you run a Docker container on the host system. An image does not have state and never changes. For information about Docker, see the Docker web site [https://www.docker.com/](https://www.docker.com/).

Greenplum Database starts a container only on the first call to a function in that container. For example, consider a query that selects table data using all available segments, and applies a transformation to the data using a PL/Container function. In this case, Greenplum Database would start the Docker container only once on each segment, and then contact the running container to obtain the results.

After starting a full cycle of a query execution, the executor sends a call to the container. The container might respond with an SPI - SQL query executed by the container to get some data back from the database, returning the result to the query executor.

The container shuts down when the connection to it is closed. This occurs when you close the Greenplum Database session that started the container. A container running in standby mode has almost no consumption of CPU resources as it is waiting on the socket. PL/Container memory consumption depends on the amount of data you cache in global dictionaries.
**Warning:** PL/Container is not supported when Greenplum Database is run within a Docker container.

The PL/Container language extension is available as an open source module. For information about the module, see the README file in the GitHub repository at [https://github.com/greenplum-db/plcontainer](https://github.com/greenplum-db/plcontainer).

### About PL/Container Resource Management

Greenplum Database runs PL/Container user-defined functions in Docker containers. The Docker containers and the Greenplum Database server share CPU and memory resources on the same hosts. In the default case, Greenplum Database is unaware of the resources consumed by running PL/Container instances. In PL/Container version 1.2 and later, you can use Greenplum Database resource groups to control overall CPU and memory resource usage for running PL/Container instances, as described in the following section.

PL/Container manages resource usage at two levels - the container level and the runtime level. You can control container-level CPU and memory resources with the `memory_mb` and `cpu_share` settings that you configure for the PL/Container runtime. `memory_mb` governs the memory resources available to each container instance. The `cpu_share` setting identifies the relative weighting of a container's CPU usage compared to other containers. Refer to [PL/Container Configuration File](#) for PL/Container configuration information.

You cannot by default restrict the number of executing PL/Container container instances, nor can you restrict the total amount of memory or CPU resources that they consume.

### Using Resource Groups to Manage PL/Container Resources

In PL/Container version 1.2.0 and later, you can use Greenplum Database resource groups to manage and limit the total CPU and memory resources of containers in PL/Container runtimes. For more information about enabling, configuring, and using Greenplum Database resource groups, refer to [Using Resource Groups](#) in the [Greenplum Database Administrator Guide](#).

**Note:** If you do not explicitly configure resource groups for a PL/Container runtime, its container instances are limited only by system resources. The containers may consume resources at the expense of the Greenplum Database server.

Resource groups for external components such as PL/Container use Linux control groups (cgroups) to manage component-level use of memory and CPU resources. When you manage PL/Container resources with resource groups, you configure both a memory limit and a CPU limit that Greenplum Database applies to all container instances that share the same PL/Container runtime configuration.

When you create a resource group to manage the resources of a PL/Container runtime, you must specify `MEMORY_AUDITOR=cgroup` and `CONCURRENCY=0` in addition to the required CPU and memory limits. For example, the following command creates a resource group named `plpy_run1_rg` for a PL/Container runtime:

```sql
CREATE RESOURCE GROUP plpy_run1_rg WITH (MEMORY_AUDITOR=cgroup,
CONCURRENCY=0,
CPU_RATE_LIMIT=10, MEMORY_LIMIT=10);
```

PL/Container does not use the `MEMORY_SHARED_QUOTA` and `MEMORY_SPILL_RATIO` resource group memory limits. Refer to the [CREATE RESOURCE GROUP](#) reference page for detailed information about this SQL command.

You can create one or more resource groups to manage your running PL/Container instances. After you create a resource group for PL/Container, you assign the resource group to one or more PL/Container runtimes. You make this assignment using the `groupid` of the resource group. You can determine the
You assign a resource group to a PL/Container runtime configuration by specifying the `-s resource_group_id=rg_groupid` option to the `plcontainer runtime-add` (new runtime) or `plcontainer runtime-replace` (existing runtime) commands. For example, to assign the `plpy_run1_rg` resource group to a new PL/Container runtime named `python_run1`:

```
plcontainer runtime-add -r python_run1 -i pivotaldata/plcontainer_python_shared:devel -l python -s resource_group_id=16391
```

You can also assign a resource group to a PL/Container runtime using the `plcontainer runtime-edit` command. For information about the `plcontainer` command, see The `plcontainer` Utility.

After you assign a resource group to a PL/Container runtime, all container instances that share the same runtime configuration are subject to the memory limit and the CPU limit that you configured for the group. If you decrease the memory limit of a PL/Container resource group, queries executing in running containers in the group may fail with an out of memory error. If you drop a PL/Container resource group while there are running container instances, Greenplum Database kills the running containers.

### Configuring Resource Groups for PL/Container

To use Greenplum Database resource groups to manage PL/Container resources, you must explicitly configure both resource groups and PL/Container.

**Note:** PL/Container version 1.2 utilizes the new resource group capabilities introduced in Greenplum Database version 5.8.0. If you downgrade to a Greenplum Database system that uses PL/Container version 1.1. or earlier, you must use `plcontainer runtime-edit` to remove any `resource_group_id` settings from your PL/Container runtime configuration.

**Procedure**

Perform the following procedure to configure PL/Container to use Greenplum Database resource groups for CPU and memory resource management:

1. If you have not already configured and enabled resource groups in your Greenplum Database deployment, configure cgroups and enable Greenplum Database resource groups as described in Using Resource Groups in the Greenplum Database Administrator Guide.

   **Note:** If you have previously configured and enabled resource groups in your deployment, ensure that the Greenplum Database resource group `gpdb.conf` cgroups configuration file includes a `memory { }` block as described in the previous link.

2. Analyze the resource usage of your Greenplum Database deployment. Determine the percentage of resource group CPU and memory resources that you want to allocate to PL/Container Docker containers.

3. Determine how you want to distribute the total PL/Container CPU and memory resources that you identified in the step above among the PL/Container runtimes. Identify:

   - The number of PL/Container resource group(s) that you require.
   - The percentage of memory and CPU resources to allocate to each resource group.
   - The resource-group-to-PL/Container-runtime assignment(s).
4. Create the PL/Container resource groups that you identified in the step above. For example, suppose that you choose to allocate 25% of both memory and CPU Greenplum Database resources to PL/Container. If you further split these resources among 2 resource groups 60/40, the following SQL commands create the resource groups:

```
CREATE RESOURCE GROUP plr_run1_rg WITH (MEMORY_AUDITOR=cgroup,
CONCURRENCY=0,
CPU_RATE_LIMIT=15, MEMORY_LIMIT=15);
CREATE RESOURCE GROUP plpy_run1_rg WITH (MEMORY_AUDITOR=cgroup,
CONCURRENCY=0,
CPU_RATE_LIMIT=10, MEMORY_LIMIT=10);
```

5. Find and note the groupid associated with each resource group that you created. For example:

```
SELECT groupname, groupid FROM gp_toolkit.gp_resgroup_config
WHERE groupname IN ('plpy_run1_rg', 'plr_run1_rg');
```

```
groupname    |  groupid
-------------+----------
plpy_run1_rg |   16391
plr_run1_rg  |   16393
(1 row)
```

6. Assign each resource group that you created to the desired PL/Container runtime configuration. If you have not yet created the runtime configuration, use the `plcontainer runtime-add` command. If the runtime already exists, use the `plcontainer runtime-replace` or `plcontainer runtime-edit` command to add the resource group assignment to the runtime configuration. For example:

```
plcontainer runtime-add -r python_run1 -i pivotaldata/plcontainer_python_shared:devel -l python -s resource_group_id=16391
plcontainer runtime-replace -r r_run1 -i pivotaldata/plcontainer_r_shared:devel -l r -s resource_group_id=16393
```

For information about the `plcontainer` command, see The `plcontainer` Utility.

**PL/Container Docker Images**

A PL/Python image and a PL/R image are available from the Greenplum Database product download site of Pivotal Network at https://network.pivotal.io/.

- **PL/Container for Python** - Docker image with Python 2.7.12 installed.
  
  The Python Data Science Module is also installed. The module contains a set python libraries related to data science. For information about the module, see Python Data Science Module Package.

- **PL/Container for R** - A Docker image with container with R-3.3.3 installed.

  The R Data Science package is also installed. The package contains a set of R libraries related to data science. For information about the module, see R Data Science Library Package.

The Docker image tag represents the PL/Container release version (for example, 1.0.0). For example, the full Docker image name for the PL/Container for Python Docker image is similar to `pivotaldata/plc_python_shared:1.0.0`. This is the name that is referred to in the default PL/Container configuration. Also, You can create custom Docker images, install the image and add the image to the PL/Container configuration.

**Prerequisites**

Ensure your Greenplum Database system meets the following prerequisites:

- PL/Container is supported on Pivotal Greenplum Database 5.2.x on Red Hat Enterprise Linux (RHEL) 7.x or 6.6+ (or later) and CentOS 7.x or 6.6+ (or later).
• These are Docker host operating system prerequisites.

RHEL or CentOS 7.x - Minimum supported Linux OS kernel version is 3.10. RHEL 7.x and CentOS 7.x use this kernel version.

RHEL or CentOS 6.6+ - Minimum supported Linux OS kernel version 2.6.32-431

You can check your kernel version with the command `uname -r`

**Note:** The Red Hat provided, maintained, and supported version of Docker is only available on RHEL 7. Red Hat does not recommend running any version of Docker on any RHEL 6 releases. Docker feature developments are tied to RHEL7.x infrastructure components for kernel, devicemapper (thin provisioning, direct lvm), sVirt and systemd.

• Docker is installed on Greenplum Database hosts (master, primary and all standby hosts)

  • For RHEL or CentOS 7.x - Docker 17.05
  • RHEL or CentOS 6.6+ - Docker 1.7

  See [Installing Docker](#).

• On each Greenplum Database host the `gpadmin` user should be part of the `docker` group for the user to be able to manage Docker images and containers.

## Installing the PL/Container Language Extension

To use PL/Container, install the PL/Container language extension, install Docker images, and configure PL/Container to use the images.

1. Ensure the Greenplum Database hosts meet the prerequisites, see [Prerequisites](#).
2. Install the PL/Container extension, see [Installing the PL/Container Language Extension Package](#).

   If you are upgrading from PL/Container 1.0, see [Upgrading from PL/Container 1.0](#).

3. Install Docker images and configure PL/Container, see [Installing PL/Container Docker Images](#).

### Installing the PL/Container Language Extension Package

Install the PL/Container language extension with the Greenplum Database `gppkg` utility.

1. Copy the PL/Container language extension package to the Greenplum Database master host as the `gpadmin` user.
2. Make sure Greenplum Database is up and running. If not, bring it up with this command.

   ```bash
gpstart -a
   ```
3. Run the package installation command.

   ```bash
gppkg -i plcontainer-1.1.0-rhel7-x86_64.gppkg
   ```
4. Source the file `$GPHOME/greenplum_path.sh`.

   ```bash
   source $GPHOME/greenplum_path.sh
   ```
5. Restart Greenplum Database.

   ```bash
gpstop -ra
   ```
6. Enable PL/Container for specific databases by running this command.

   **a.** For PL/Container 1.1 and later, log into the database as a Greenplum Database superuser (`gpadmin`) and run this command.

   ```sql
   CREATE EXTENSION plcontainer;
   ```
The command registers PL/Container and creates PL/Container-specific functions and views.
b. For PL/Container 1.0, run this command.

```sql
psql -d your_database -f $GPHOME/share/postgresql/plcontainer/plcontainer_install.sql
```

The SQL script registers the language `plcontainer` in the database and creates PL/Container-specific functions and views.

After installing PL/Container, you can manage Docker images and manage the PL/Container configuration with the Greenplum Database `plcontainer` utility.

## Upgrading from PL/Container 1.0

To upgrade to version 1.1 or higher, uninstall version 1.0 and install the new version. The `gppkg` utility installs PL/Container version 1.1 and later as a Greenplum Database extension, while PL/Container 1.0 is installed as a Greenplum Database language. The Docker images and the PL/Container configuration do not change when upgrading PL/Container, only the PL/Container extension installation changes.

As part of the upgrade process, you must drop PL/Container from all databases that are configured with PL/Container.

**Important:** Dropping PL/Container from a database drops all PL/Container UDFs from the database, including user-created PL/Container UDFs. If the UDFs are required, ensure you can re-create the UDFs before dropping PL/Container. This `SELECT` command lists the names of and body of PL/Container UDFs in a database.

```sql
SELECT proname, prosrc FROM pg_proc WHERE prolang = (SELECT oid FROM pg_language WHERE lanname = 'plcontainer');
```

For information about the catalog tables, `pg_proc` and `pg_language`, see [System Tables](#).

These steps upgrade from PL/Container 1.0 to PL/Container 1.1 or later in a database. The steps save the PL/Container 1.0 configuration and restore the configuration for use with PL/Container 1.1 or later.

1. Save the PL/Container configuration. This example saves the configuration to `plcontainer10-backup.xml` in the local directory.

   ```shell
   plcontainer runtime-backup -f plcontainer10-backup.xml
   ```

2. Remove any `setting` elements that contain the `use_container_network` attribute from the configuration file. For example, this `setting` element must be removed from the configuration file.

   ```xml
   <setting use_container_network="yes"/>
   ```

3. Run the `plcontainer_uninstall.sql` script as the `gpadmin` user for each database that is configured with PL/Container. For example, this command drops the `plcontainer` language in the `mytest` database.

   ```sql
   psql -d mytest -f $GPHOME/share/postgresql/plcontainer/plcontainer_uninstall.sql
   ```

   The script drops the `plcontainer` language with the `CASCADE` clause that drops PL/Container-specific functions and views in the database.

4. Use the Greenplum Database `gppkg` utility with the `-r` option to uninstall the PL/Container language extension. This example uninstalls the PL/Container language extension on a Linux system.

   ```bash
   $ gppkg -r plcontainer-1.0.0
   ```
5. Run the package installation command. This example installs the PL/Container 1.1 language extension on a Linux system.

```bash
gppkg -i plcontainer-1.1.0-rhel7-x86_64.gppkg
```

6. Source the file `$GPHOME/greenplum_path.sh`.

```bash
source $GPHOME/greenplum_path.sh
```

7. Update the PL/Container configuration. This command restores the saved configuration.

```bash
plcontainer runtime-restore -f plcontainer10-backup.xml
```

8. Restart Greenplum Database.

```bash
gpstop -ra
```

9. Register the new PL/Container extension as an extension for each database that uses PL/Container UDFs. This `psql` command runs a `CREATE EXTENSION` command to register PL/Container in the database `mytest`.

```bash
psql -d mytest -c 'CREATE EXTENSION plcontainer;'
```

The command registers PL/Container as an extension and creates PL/Container-specific functions and views.

After upgrading PL/Container for a database, re-install any user-created PL/Container UDFs that are required.

### Upgrading from PL/Container 1.1

To upgrade from PL/Container version 1.1 or higher, you save the current configuration, upgrade PL/Container, and then restore the configuration after upgrade. There is no need to update the Docker images when you upgrade PL/Container.

**Note:** Before you perform this upgrade procedure, ensure that you have migrated your PL/Container 1.1 package from your previous Greenplum Database installation to your new Greenplum Database installation. Refer to the `gppkg` command for package installation and migration information.

Perform the following procedure to upgrade from PL/Container 1.1 to PL/Container version 1.2 or later.

1. Save the PL/Container configuration. For example, to save the configuration to a file named `plcontainer110-backup.xml` in the local directory:

   ```bash
   $ plcontainer runtime-backup -f plcontainer110-backup.xml
   ```

2. Use the Greenplum Database `gppkg` utility with the `-u` option to update the PL/Container language extension. For example, the following command updates the PL/Container language extension to version 1.2 on a Linux system:

   ```bash
   $ gppkg -u plcontainer-1.2.0-rhel7-x86_64.gppkg
   ```


   ```bash
   $ source $GPHOME/greenplum_path.sh
   ```

4. Restore the PL/Container configuration. For example, this command restores the PL/Container configuration that you saved in a previous step:

   ```bash
   $ plcontainer runtime-restore -f plcontainer110-backup.xml
   ```
5. Restart Greenplum Database.

```
$ gpstop -ra
```

6. You do not need to re-register the PL/Container extension in the databases in which you previously created the extension. Do register the PL/Container extension in each new database that will run PL/Container UDFs. For example, the following command registers PL/Container in a database named mytest:

```
$ psql -d mytest -c 'CREATE EXTENSION plcontainer;'
```

The command also creates PL/Container-specific functions and views.

**Note:** PL/Container version 1.2 utilizes the new resource group capabilities introduced in Greenplum Database version 5.8.0. If you downgrade to a Greenplum Database system that uses PL/Container version 1.1 or earlier, you must use `plcontainer runtime-edit` to remove any resource_group_id settings from your PL/Container runtime configuration.

---

### Installing PL/Container Docker Images

The PL/Container language extension includes the `plcontainer` utility that installs Docker images on the Greenplum Database hosts and adds configuration information to the PL/Container configuration file. The configuration information allows PL/Container to create Docker containers with the Docker images. For information about `plcontainer`, see *The plcontainer Utility*.

Download the `tar.gz` file that contains the Docker images from Pivotal Network.

- `plcontainer-python-images-1.0.0.tar.gz`
- `plcontainer-r-images-1.0.0.tar.gz`

Install the Docker images on the Greenplum Database hosts. This example uses the `plcontainer` utility to install a Docker image for Python and to update the PL/Container configuration. The example assumes the Docker image to be installed is in a file in `/home/gpadmin`.

This `plcontainer` command installs the Docker image for PL/Python from a Docker image file.

```
plcontainer image-add -f /home/gpadmin/plcontainer-python-images-1.0.0.tar.gz
```

The utility displays progress information as it installs the Docker image on the Greenplum Database hosts.

Use the `plcontainer image-list` command to display the installed Docker images on the local host.

This command adds information to the PL/Container configuration file so that PL/Container can access the Docker image to create a Docker container.

```
plcontainer runtime-add -r plc_py -i pivotaldata/plcontainer_python_shared:devel -l python
```

The utility displays progress information as it updates the PL/Container configuration file on the Greenplum Database instances.

You can view the PL/Container configuration information with the `plcontainer runtime-show -r plc_py` command. You can view the PL/Container configuration XML file with the `plcontainer runtime-edit` command.

---

### Uninstalling PL/Container

To uninstall PL/Container, remove Docker containers and images, and then remove the PL/Container support from Greenplum Database.
When you remove support for PL/Container, the `plcontainer` user-defined functions that you created in the database will no longer work.

**Uninstall Docker Containers and Images**

On the Greenplum Database hosts, uninstall the Docker containers and images that are no longer required.

The `plcontainer image-list` command lists the Docker images that are installed on the local Greenplum Database host.

The `plcontainer image-delete` command deletes a specified Docker image from all Greenplum Database hosts.

Some Docker containers might exist on a host if the containers were not managed by PL/Container. You might need to remove the containers with Docker commands. These `docker` commands manage Docker containers and images on a local host.

- The command `docker ps -a` lists all containers on a host. The command `docker stop` stops a container.
- The command `docker images` lists the images on a host.
- The command `docker rmi` removes images.
- The command `docker rm` removes containers.

**Remove PL/Container Support for a Database**

For a database that no longer requires PL/Container, remove support for PL/Container.

**PL/Container 1.1 and Later**

For PL/Container 1.1 and later, drop the extension from the database. This `psql` command runs a `DROP EXTENSION` command to remove PL/Container in the database `mytest`.

```
psql -d mytest -c 'DROP EXTENSION plcontainer cascade;'
```

The command drops the `plcontainer` extension and drops PL/Container-specific functions and views from the database.

**PL/Container 1.0**

Run the `plcontainer_uninstall.sql` script as the `gpadmin` user. For example, this command removes the `plcontainer` language in the `mytest` database.

```
psql -d mytest -f $GPHOME/share/postgresql/plcontainer/plcontainer_uninstall.sql
```

The script drops the `plcontainer` language with `CASCADE` to drop PL/Container-specific functions and views from the database.

**Uninstalling PL/Container Language Extension**

If no databases have `plcontainer` as a registered language, uninstall the Greenplum Database PL/Container language extension with the `gppkg` utility.

1. Use the Greenplum Database `gppkg` utility with the `-r` option to uninstall the PL/Container language extension. This example uninstalls the PL/Container language extension on a Linux system:

```
$ gppkg -r plcontainer-1.1.0
```
You can run the `gppkg` utility with the options `-q --all` to list the installed extensions and their versions.

2. **Reload** `greenplum_path.sh`.

   ```bash
   $ source $GPHOME/greenplum_path.sh
   $$
   
3. **Restart the database.**

   ```bash
   $ gpstop -ra
   $$
   
---

**Using PL/Container Functions**

When you enable PL/Container in a database of a Greenplum Database system, the language `plcontainer` is registered in the database. You can create and run user-defined functions in the procedural languages supported by the PL/Container Docker images when you specify `plcontainer` as a language in a UDF definition.

A UDF definition that uses PL/Container must have the these items.

- The first line of the UDF must be `# container: ID`
- The `LANGUAGE` attribute must be `plcontainer`

The `ID` is the name that PL/Container uses to identify a Docker image. When Greenplum Database executes a UDF on a host, the Docker image on the host is used to start a Docker container that runs the UDF. In the XML configuration file `plcontainer_configuration.xml`, there is a `runtime` XML element that contains a corresponding `id` XML element that specifies the Docker container startup information. See [Configuring PL/Container](#) for information about how PL/Container maps the `ID` to a Docker image. See [Examples](#) for example UDF definitions.

The PL/Container configuration file is read only on the first invocation of a PL/Container function in each Greenplum Database session that runs PL/Container functions. You can force the configuration file to be re-read by performing a `SELECT` command on the view `plcontainer_refresh_config` during the session. For example, this `SELECT` command forces the configuration file to be read.

```sql
SELECT * FROM plcontainer_refresh_config;
```

Running the command executes a PL/Container function that updates the configuration on the master and segment instances and returns the status of the refresh.

<table>
<thead>
<tr>
<th>gp_segment_id</th>
<th>plcontainer_refresh_local_config</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ok</td>
</tr>
<tr>
<td>0</td>
<td>ok</td>
</tr>
<tr>
<td>-1</td>
<td>ok</td>
</tr>
</tbody>
</table>

(3 rows)

Also, you can show all the configurations in the session by performing a `SELECT` command on the view `plcontainer_show_config`. For example, this `SELECT` command returns the PL/Container configurations.

```sql
SELECT * FROM plcontainer_show_config;
```

Running the command executes a PL/Container function that displays configuration information from the master and segment instances. This is an example of the start and end of the view output.

```
INFO:  plcontainer: Container 'plc_py_test' configuration
INFO:  plcontainer:     image = 'pivotaldata/plcontainer_python_shared:devel'
INFO:  plcontainer:     memory_mb = '1024'
```
The PL/Container function `plcontainer_containers_summary()` displays information about the currently running Docker containers.

```
SELECT * FROM plcontainer_containers_summary();
```

If a normal (non-superuser) Greenplum Database user runs the function, the function displays information only for containers created by the user. If a Greenplum Database superuser runs the function, information for all containers created by Greenplum Database users is displayed. This is sample output when 2 containers are running.

```
SEGMENT_ID | CONTAINER_ID |
----------- |--------------
           |              
```

Examples

The values in the `# container` lines of the examples, `plc_python_shared` and `plc_r_shared`, are the `id` XML elements defined in the `plcontainer_config.xml` file. The `id` element is mapped to the `image` element that specifies the Docker image to be started. If you configured PL/Container with a different ID, change the value of the `# container` line. For information about configuring PL/Container and viewing the configuration settings, see Configuring PL/Container.
This is an example of PL/Python function that runs using the `plc_python_shared` container:

```
CREATE OR REPLACE FUNCTION pylog100() RETURNS double precision AS $$
# container: plc_python_shared
import math
return math.log10(100)
$$ LANGUAGE plcontainer;
```

This is an example of a similar function using the `plc_r_shared` container:

```
CREATE OR REPLACE FUNCTION rlog100() RETURNS text AS $$
# container: plc_r_shared
return(log10(100))
$$ LANGUAGE plcontainer;
```

If the `# container` line in a UDF specifies an ID that is not in the PL/Container configuration file, Greenplum Database returns an error when you try to execute the UDF.

### About PL/Container Running PL/Python

In the Python language container, the module `plpy` is implemented. The module contains these methods:

- `plpy.execute(stmt)` - Executes the query string `stmt` and returns query result in a list of dictionary objects. To be able to access the result fields ensure your query returns named fields.
- `plpy.prepare(stmt[, argtypes])` - Prepares the execution plan for a query. It is called with a query string and a list of parameter types, if you have parameter references in the query.
- `plpy.execute(plan[, argtypes])` - Executes a prepared plan.
- `plpy.debug(msg)` - Sends a DEBUG2 message to the Greenplum Database log.
- `plpy.log(msg)` - Sends a LOG message to the Greenplum Database log.
- `plpy.info(msg)` - Sends an INFO message to the Greenplum Database log.
- `plpy.notice(msg)` - Sends a NOTICE message to the Greenplum Database log.
- `plpy.warning(msg)` - Sends a WARNING message to the Greenplum Database log.
- `plpy.error(msg)` - Sends an ERROR message to the Greenplum Database log. An ERROR message raised in Greenplum Database causes the query execution process to stop and the transaction to rollback.
- `plpy.fatal(msg)` - Sends a FATAL message to the Greenplum Database log. A FATAL message causes Greenplum Database session to be closed and transaction to be rolled back.
- `plpy.subtransaction()` - Manages `plpy.execute` calls in an explicit subtransaction. See `Explicit Subtransactions` in the PostgreSQL documentation for additional information about `plpy.subtransaction()`.

PL/Container does not support this Greenplum Database PL/Python feature:

- Multi-dimensional arrays.

Also, the Python module has two global dictionary objects that retain the data between function calls. They are named GD and SD. GD is used to share the data between all the function running within the same container, while SD is used for sharing the data between multiple calls of each separate function. Be aware that accessing the data is possible only within the same session, when the container process lives on a segment or master. Be aware that for idle sessions Greenplum Database terminates segment processes, which means the related containers would be shut down and the data from GD and SD lost.

For information about PL/Python, see [Greenplum PL/Python Language Extension](https://www.postgresql.org/docs/8.4/static/plpython-database.htm).

**About PL/Container Running PL/R**

In the R language container, the module `pg.spi` is implemented. The module contains these methods:

- **pg.spi.exec(stmt)** - Executes the query string `stmt` and returns query result in R data.frame. To be able to access the result fields make sure your query returns named fields.
- **pg.spi.prepare(stmt[, argtypes])** - Prepares the execution plan for a query. It is called with a query string and a list of parameter types if you have parameter references in the query.
- **pg.spi.execp(plan[, argtypes])** - Execute a prepared plan.
- **pg.spi.debug(msg)** - Sends a DEBUG2 message to the Greenplum Database log.
- **pg.spi.log(msg)** - Sends a LOG message to the Greenplum Database log.
- **pg.spi.info(msg)** - Sends an INFO message to the Greenplum Database log.
- **pg.spi.notice(msg)** - Sends a NOTICE message to the Greenplum Database log.
- **pg.spi.warning(msg)** - Sends a WARNING message to the Greenplum Database log.
- **pg.spi.error(msg)** - Sends an ERROR message to the Greenplum Database log. An ERROR message raised in Greenplum Database causes the query execution process to stop and the transaction to rollback.
- **pg.spi.fatal(msg)** - Sends a FATAL message to the Greenplum Database log. A FATAL message causes Greenplum Database session to be closed and transaction to be rolled back.

PL/Container does not support this PL/R feature:

- Multi-dimensional arrays.

For information about PL/R, see [Greenplum PL/R Language Extension](#).


**Configuring PL/Container**

The Greenplum Database utility `plcontainer` manages the PL/Container configuration files in a Greenplum Database system. The utility ensures that the configuration files are consistent across the Greenplum Database master and segment instances.

**Warning:** Modifying the configuration files on the segment instances without using the utility might create different, incompatible configurations on different Greenplum Database segments that could cause unexpected behavior.

Configuration changes that are made with the utility are applied to the XML files on all Greenplum Database segments. However, PL/Container configurations of currently running sessions use the configuration that existed during session start up. To update the PL/Container configuration in a running session, execute this command in the session.

```
SELECT * FROM plcontainer_refresh_config;
```

Running the command executes a PL/Container function that updates the session configuration on the master and segment instances.

**The plcontainer Utility**

The `plcontainer` utility installs Docker images and manages the PL/Container configuration. The utility consists of two sets of commands.

- **image-** commands manage Docker images on the Greenplum Database system hosts.
- **runtime-** commands manage the PL/Container configuration file on the Greenplum Database instances. You can add Docker image information to the PL/Container configuration file including the image name, location, and shared folder information. You can also edit the configuration file.
To configure PL/Container to use a Docker image, you install the Docker image on all the Greenplum Database hosts and then add configuration information to the PL/Container configuration.

PL/Container configuration values, such as image names, runtime IDs, and parameter values and names are case sensitive.

**plcontainer Syntax**

```
plcontainer [command] [-h | --help] [--verbose]
```

Where `command` is one of the following.

- `image-add` `{--file} image_file | {-u | --URL} image_URL`
- `image-delete {-i | --image} image_name`
- `image-list`
- `runtime-add {-r | --runtime} runtime_id {-i | --image} image_name {-v | --volume} shared_volume ... {-s | --setting} param=value ...`
- `runtime-replace {-r | --runtime} runtime_id {-i | --image} image_name {-v | --volume} shared_volume ... {-s | --setting} param=value ...`
- `runtime-show {-r | --runtime} runtime_id`
- `runtime-delete {-r | --runtime} runtime_id`
- `runtime-edit {-e | --editor} editor`
- `runtime-backup {-f | --file} config_file`
- `runtime-restore {-f | --file} config_file`
- `runtime-verify`

**plcontainer Commands and Options**

**image-add** `location`

Install a Docker image on the Greenplum Database hosts. Specify either the location of the Docker image file on the host or the URL to the Docker image. These are the supported location options.

- `{--file} image_file` Specify the tar archive file on the host that contains the Docker image. This example points to an image file in the gpadmin home directory `/home/gpadmin/test_image.tar.gz`
- `{--URL} image_URL` Specify the URL of the Docker repository and image. This example URL points to a local Docker repository `192.168.0.1:5000/images/mytest_plc_r:devel`

After installing the Docker image, use the `runtime-add` command to configure PL/Container to use the Docker image.

**image-delete** `{--image} image_name`

Remove an installed Docker image from all Greenplum Database hosts. Specify the full Docker image name including the tag for example `pivotaldata/plcontainer_python_shared:1.0.0`

**image-list**

List the Docker images installed on the host. The command list only the images on the local host, not remote hosts. The command lists all installed Docker images, including images installed with Docker commands.

**runtime-add options**
Add configuration information to the PL/Container configuration file on all Greenplum Database hosts. If the specified runtime_id exists, the utility returns an error and the configuration information is not added.

For information about PL/Container configuration, see PL/Container Configuration File.

These are the supported options:

{-i | --image} docker-image
Required. Specify the full Docker image name, including the tag, that is installed on the Greenplum Database hosts. For example pivotaldata/plcontainer_python:1.0.0.

The utility returns a warning if the specified Docker image is not installed.

The plcontainer image-list command displays installed image information including the name and tag (the Repository and Tag columns).

{-l | --language} python | r
Required. Specify the PL/Container language type, supported values are python (PL/Python) and r (PL/R). When adding configuration information for a new runtime, the utility adds a startup command to the configuration based on the language you specify.

Startup command for the Python language.

```
/clientdir/pyclient.sh
```

Startup command for the R language.

```
/clientdir/rclient.sh
```

{-r | --runtime} runtime_id
Required. Add the runtime ID. When adding a runtime element in the PL/Container configuration file, this is the value of the id element in the PL/Container configuration file. Maximum length is 63 Bytes.

You specify the name in the Greenplum Database UDF on the # container line. See Examples.

{-s | --setting} param=value
Optional. Specify a setting to add to the runtime configuration information. You can specify this option multiple times. The setting applies to the runtime configuration specified by the runtime_id. The parameter is the XML attribute of the settings element in the PL/Container configuration file. These are valid parameters.

- cpu_share - Set the CPU limit for each container in the runtime configuration. The default value is 1024. The value is a relative weighting of CPU usage compared to other containers.
- memory_mb - Set the memory limit for each container in the runtime configuration. The default value is 1024. The value is an integer that specifies the amount of memory in MB.
- resource_group_id - Assign the specified resource group to the runtime configuration. The resource group limits the total CPU and memory resource usage for all containers that share this runtime configuration. You must specify the groupid of the resource group. For information about managing PL/Container resources, see About PL/Container Resource Management.
- use_container_logging - Enable or disable Docker logging for the container. The value is either yes (enable logging) or no (disable logging, the default).
The Greenplum Database server configuration parameter `log_min_messages` controls the log level. The default log level is `warning`. For information about PL/Container log information, see Notes.

```bash
{-v | --volume} shared-volume
```

Optional. Specify a Docker volume to bind mount. You can specify this option multiple times to define multiple volumes.

The format for a shared volume: `host-dir:container-dir:[rw|ro]`. The information is stored as attributes in the `shared_directory` element of the `runtime` element in the PL/Container configuration file.

- `host-dir` - absolute path to a directory on the host system. The Greenplum Database administrator user (gpadmin) must have appropriate access to the directory.
- `container-dir` - absolute path to a directory in the Docker container.
- `[rw|ro]` - read-write or read-only access to the host directory from the container.

When adding configuration information for a new runtime, the utility adds this read-only shared volume information.

```bash
greenplum-home/bin/plcontainer_clients:/clientdir:ro
```

If needed, you can specify other shared directories. The utility returns an error if the specified `container-dir` is the same as the one that is added by the utility, or if you specify multiple shared volumes with the same `container-dir`.

**Warning:** Allowing read-write access to a host directory requires special considerations.

- When specifying read-write access to host directory, ensure that the specified host directory has the correct permissions.
- When running PL/Container user-defined functions, multiple concurrent Docker containers that are running on a host could change data in the host directory. Ensure that the functions support multiple concurrent access to the data in the host directory.

```bash
runtime-backup {-f | --file} config_file
```

Copies the PL/Container configuration file to the specified file on the local host.

```bash
runtime-delete {-r | --runtime} runtime_id
```

Removes runtime configuration information in the PL/Container configuration file on all Greenplum Database instances. The utility returns a message if the specified `runtime_id` does not exist in the file.

```bash
runtime-edit [{-e | --editor} editor]
```

Edit the XML file `plcontainer_configuration.xml` with the specified editor. The default editor is `vi`.

Saving the file updates the configuration file on all Greenplum Database hosts. If errors exist in the updated file, the utility returns an error and does not update the file.

```bash
runtime-replace options
```

Replaces runtime configuration information in the PL/Container configuration file on all Greenplum Database instances. If the `runtime_id` does not exist, the information is added to the configuration file. The utility adds a startup command and shared directory to the configuration.

See `runtime-add` for command options and information added to the configuration.

```bash
runtime-restore {-f | --file} config_file
```
Replaces information in the PL/Container configuration file
plcontainer_configuration.xml on all Greenplum Database instances with the
information from the specified file on the local host.

runtime-show [{-r | --runtime} runtime_id]
Displays formatted PL/Container runtime configuration information. If a runtime_id is not
specified, the configuration for all runtime IDs are displayed.

runtime-verify
Checks the PL/Container configuration information on the Greenplum Database instances
with the configuration information on the master. If the utility finds inconsistencies, you are
prompted to replace the remote copy with the local copy. The utility also performs XML
validation.

-h | --help
Display help text. If specified without a command, displays help for all plcontainer
commands. If specified with a command, displays help for the command.

--verbose
Enable verbose logging for the command.

Examples
These are examples of common commands to manage PL/Container:

• Install a Docker image on all Greenplum Database hosts. This example loads a Docker image from
a file. The utility displays progress information on the command line as the utility installs the Docker
image on all the hosts.

    plcontainer image-add -f plc_newr.tar.gz

After installing the Docker image, you add or update a runtime entry in the PL/Container configuration
file to give PL/Container access to the Docker image to start Docker containers.

• Add a container entry to the PL/Container configuration file. This example adds configuration
information for a PL/R runtime, and specifies a shared volume and settings for memory and logging.

    plcontainer runtime-add -r runtime2 -i test_image2:0.1 -l r \
    -v /host_dir2/shared2:/container_dir2/shared2:ro \ 
    -s memory_mb=512 -s use_container_logging=yes

The utility displays progress information on the command line as it adds the runtime configuration to the
configuration file and distributes the updated configuration to all instances.

• Show specific runtime with given runtime id in configuration file

    plcontainer runtime-show -r plc_python_shared

The utility displays the configuration information similar to this output.

    PL/Container Runtime Configuration:
    -------------------------------
    Runtime ID: plc_python_shared
    Linked Docker Image: test1:latest
    Runtime Setting(s):
    Shared Directory:
    ---- Shared Directory From HOST '/usr/local/greenplum-db/bin/
    plcontainer_clients' to Container '/clientdir', access mode is 'ro'
    ---- Shared Directory From HOST '/home/gpadmin/share/' to Container '/
    opt/share', access mode is 'rw'
• Edit the configuration in an interactive editor of your choice. This example edits the configuration file with the vim editor.

```bash
plcontainer runtime-edit -e vim
```

When you save the file, the utility displays progress information on the command line as it distributes the file to the Greenplum Database hosts.

• Save the current PL/Container configuration to a file. This example saves the file to the local file /home/gpadmin/saved_plc_config.xml

```bash
plcontainer runtime-backup -f /home/gpadmin/saved_plc_config.xml
```

• Overwrite PL/Container configuration file with an XML file. This example replaces the information in the configuration file with the information from the file in the /home/gpadmin directory.

```bash
plcontainer runtime-restore -f /home/gpadmin/new_plcontainer_configuration.xml
```

The utility displays progress information on the command line as it distributes the updated file to the Greenplum Database instances.

### PL/Container Configuration File

PL/Container maintains a configuration file `plcontainer_configuration.xml` in the data directory of all Greenplum Database segments. The PL/Container configuration file is an XML file. In the XML file, the root element `configuration` contains one or more `runtime` elements. You specify the id of the `runtime` element in the `# container:` line of a PL/Container function definition.

In an XML file, names, such as element and attribute names, and values are case sensitive.

This is an example file.

```xml
<?xml version="1.0" ?>
<configuration>
    <runtime>
        <id>plc_python_example1</id>
        <image>pivotaldata/plcontainer_python_with_clients:0.1</image>
        <command>./pyclient</command>
    </runtime>
    <runtime>
        <id>plc_python_example2</id>
        <image>pivotaldata/plcontainer_python_without_clients:0.1</image>
        <command>/clientdir/pyclient.sh</command>
        <shared_directory access="ro" container="/clientdir" host="/usr/local/greenplum-db/bin/plcontainer_clients"/>
        <setting memory_mb="512"/>
        <setting use_container_logging="yes"/>
        <setting cpu_share="1024"/>
        <setting resource_group_id="16391"/>
    </runtime>
    <runtime>
        <id>plc_r_example</id>
        <image>pivotaldata/plcontainer_r_without_clients:0.2</image>
        <command>/clientdir/rclient.sh</command>
        <shared_directory access="ro" container="/clientdir" host="/usr/local/greenplum-db/bin/plcontainer_clients"/>
        <setting use_container_logging="yes"/>
    </runtime>
</configuration>
```
These are the XML elements and attributes in a PL/Container configuration file.

configuration
   Root element for the XML file.

runtime
   One element for each specific container available in the system. These are child elements of the configuration element.

   id
   Required. The value is used to reference a Docker container from a PL/Container user-defined function. The id value must be unique in the configuration. The id must start with a character or digit (a-z, A-Z, or 0-9) and can contain characters, digits, or the characters _ (underscore), . (period), or - (dash). Maximum length is 63 Bytes.

   The id specifies which Docker image to use when PL/Container creates a Docker container to execute a user-defined function.

image
   Required. The value is the full Docker image name, including image tag. The same way you specify them for starting this container in Docker. Configuration allows to have many container objects referencing the same image name, this way in Docker they would be represented by identical containers.

   For example, you might have two runtime elements, with different id elements, plc_python_128 and plc_python_256, both referencing the Docker image pivotaldata/plcontainer_python:1.0.0. The first runtime specifies a 128MB RAM limit and the second one specifies a 256MB limit that is specified by the memory_mb attribute of a setting element.

command
   Required. The value is the command to be run inside of container to start the client process inside in the container. When creating a runtime element, the plcontainer utility adds a command element based on the language (the -l option).

   command element for the python language.
   
   <command>/clientdir/pyclient.sh</command>

   command element for the R language.
   
   <command>/clientdir/rclient.sh</command>

   You should modify the value only if you build a custom container and want to implement some additional initialization logic before the container starts.

   Note: This element cannot be set with the plcontainer utility. You can update the configuration file with the plcontainer runtime-edit command.

shared_directory
   Optional. This element specifies a shared Docker shared volume for a container with access information. Multiple shared_directory elements are allowed. Each shared_directory element specifies a single shared volume. XML attributes for the shared_directory element:
     • host - a directory location on the host system.
     • container - a directory location inside of container.
• access - access level to the host directory, which can be either ro (read-only) or rw (read-write).

When creating a runtime element, the plcontainer utility adds a shared_directory element.

```xml
<shared_directory access="ro" container="/clientdir" host="/usr/local/greenplum-db/bin/plcontainer_clients"/>
```

For each runtime element, the container attribute of the shared_directory elements must be unique. For example, a runtime element cannot have two shared_directory elements with attribute container="/clientdir".

**Warning:** Allowing read-write access to a host directory requires special consideration.

- When specifying read-write access to host directory, ensure that the specified host directory has the correct permissions.
- When running PL/Container user-defined functions, multiple concurrent Docker containers that are running on a host could change data in the host directory. Ensure that the functions support multiple concurrent access to the data in the host directory.

**settings**

Optional. This element specifies Docker container configuration information. Each setting element contains one attribute. The element attribute specifies logging, memory, or networking information. For example, this element enables logging.

```xml
<setting use_container_logging="yes"/>
```

These are the valid attributes.

**cpu_share**

Optional. Specify the CPU usage for each PL/Container container in the runtime. The value of the element is a positive integer. The default value is 1024. The value is a relative weighting of CPU usage compared to other containers.

For example, a container with a cpu_share of 2048 is allocated double the CPU slice time compared with container with the default value of 1024.

**memory_mb="size"**

Optional. The value specifies the amount of memory, in MB, that each container is allowed to use. Each container starts with this amount of RAM and twice the amount of swap space. The container memory consumption is limited by the host system cgroups configuration, which means in case of memory overcommit, the container is terminated by the system.

**resource_group_id="rg_groupid"**

Optional. The value specifies the groupid of the resource group to assign to the PL/Container runtime. The resource group limits the total CPU and memory resource usage for all running containers that share this runtime configuration. You must specify the groupid of the resource group. If you do not assign a resource group to a PL/Container runtime configuration, its container instances are limited only by system resources. For information about managing PL/Container resources, see About PL/Container Resource Management.

**use_container_logging="{yes | no}"**

Optional. Enables or disables Docker logging for the container. The attribute value yes enables logging. The attribute value no disables logging (the default).
The Greenplum Database server configuration parameter `log_min_messages` controls the PL/Container log level. The default log level is `warning`. For information about PL/Container log information, see Notes.

By default, the PL/Container log information is sent to a system service. On Red Hat 7 or CentOS 7 systems, the log information is sent to the `journald` service. On Red Hat 6 or CentOS 6 systems, the log is sent to the `syslogd` service.

### Updating the PL/Container Configuration

You can add a runtime element to the PL/Container configuration file with the `plcontainer runtime-add` command. The command options specify information such as the runtime ID, Docker image, and language. You can use the `plcontainer runtime-replace` command to update an existing runtime element. The utility updates the configuration file on the master and all segment instances.

The PL/Container configuration file can contain multiple runtime elements that reference the same Docker image specified by the XML element `image`. In the example configuration file, the runtime elements contain `id` elements named `plc_python_128` and `plc_python_256`, both referencing the Docker container `pivotaldata/plcontainer_python:1.0.0`. The first runtime element is defined with a 128MB RAM limit and the second one with a 256MB RAM limit.

```xml
<configuration>
  <runtime>
    <id>plc_python_128</id>
    <image>pivotaldata/plcontainer_python:1.0.0</image>
    <command>./client</command>
    <shared_directory access="ro" container="/clientdir" host="/usr/local/gpdb/bin/plcontainer_clients"/>
    <setting memory_mb="128"/>
  </runtime>
  <runtime>
    <id>plc_python_256</id>
    <image>pivotaldata/plcontainer_python:1.0.0</image>
    <command>./client</command>
    <shared_directory access="ro" container="/clientdir" host="/usr/local/gpdb/bin/plcontainer_clients"/>
    <setting memory_mb="256"/>
    <setting resource_group_id="16391"/>
  </runtime>
<configuration>
```

### Notes

- PL/Container maintains the configuration file `plcontainer_configuration.xml` in the data directory of all Greenplum Database segment instances: master, standby master, primary, and mirror. This query lists the Greenplum Database system data directories:

```sql
SELECT g.hostname, fe.fselocation as directory
FROM pg_filespace AS f, pg_filespace_entry AS fe,
gp_segment_configuration AS g
WHERE f.oid = fe.fsefsoid AND g.dbid = fe.fsedbid
AND f.fsname = 'pg_system';
```

A sample PL/Container configuration file is in `$GPHOME/share/postgresql/plcontainer`.

- When Greenplum Database executes a PL/Container UDF, Query Executer (QE) processes start Docker containers and reuse them as needed. After a certain amount of idle time, a QE process quits and destroys its Docker containers. You can control the amount of idle time with the Greenplum Database server configuration parameter `gp_vmem_idle_resource_timeout`. Controlling the idle
time might help with Docker container reuse and avoid the overhead of creating and starting a Docker container.

**Warning:** Changing `gp_vmem_idle_resource_timeout` value, might affect performance due to resource issues. The parameter also controls the freeing of Greenplum Database resources other than Docker containers.

- If a PL/Container Docker container exceeds the maximum allowed memory, it is terminated and an out of memory warning is displayed. On Red Hat 6 or CentOS 6 systems that are configured with Docker version 1.7.1, the out of memory warning is also displayed if the PL/Container Docker container main program (PID 1) is terminated.

- In some cases, when PL/Container is running in a high concurrency environment, the Docker daemon hangs with log entries that indicate a memory shortage. This can happen even when the system seems to have adequate free memory.

The issue seems to be triggered by a combination of two factors, the aggressive virtual memory requirement of the Go language (`golang`) runtime that is used by PL/Container, and the Greenplum Database Linux server kernel parameter setting for `overcommit_memory`. The parameter is set to 2 which does not allow memory overcommit.

A workaround that might help is to increase the amount of swap space and increase the Linux server kernel parameter `overcommit_ratio`. If the issue still occurs after the changes, there might be memory shortage. You should check free memory on the system and add more RAM if needed. You can also decrease the cluster load.

- PL/Container does not limit the Docker base device size, the size of the Docker container. In some cases, the Docker daemon controls the base device size. For example, if the Docker storage driver is `devicemapper`, the Docker daemon `--storage-opt` option flag `dm.basesize` controls the base device size. The default base device size for `devicemapper` is 10GB. The Docker command `docker info` displays Docker system information including the storage driver. The base device size is displayed in Docker 1.12 and later. For information about Docker storage drivers, see the Docker information `Daemon storage-driver`.

When setting the Docker base device size, the size must be set on all Greenplum Database hosts.

- When PL/Container logging is enabled, you can set the log level with the Greenplum Database server configuration parameter `log_min_messages`. The default log level is `warning`. The parameter controls the PL/Container log level and also controls the Greenplum Database log level.

  - PL/Container logging is enabled or disabled for each runtime ID with the setting attribute `use_container_logging`. The default is no logging.

  - The PL/Container log information is the information from the UDF that is run in the Docker container. By default, the PL/Container log information is sent to a system service. On Red Hat 7 or CentOS 7 systems, the log information is sent to the `journald` service. On Red Hat 6 or CentOS 6 systems, the log information is sent to the `syslogd` service. The PL/Container log information is sent to the log file of the host were the Docker container runs.

  - The Greenplum Database log information is sent to log file on the Greenplum Database master.

When testing or troubleshooting a PL/Container UDF, you can change the Greenplum Database log level with the `SET` command. You can set the parameter in the session before you run your PL/Container UDF. This example sets the log level to `debug1`.

```
SET log_min_messages='debug1' ;
```

**Note:** The parameter `log_min_messages` controls both the Greenplum Database and PL/Container logging, increasing the log level might affect Greenplum Database performance even if a PL/Container UDF is not running.
Installing Docker

To use PL/Container, Docker must be installed on all Greenplum Database host systems. The these instructions show how to set up the Docker service on CentOS 6 and CentOS 7. Installing on RHEL 6 or RHEL 7 is a similar process.

Before performing the Docker installation ensure these requirements are met.

- The CentOS extras repository is accessible.
- The user has sudo privileges or is root.

See also the Docker site installation instructions for CentOS [https://docs.docker.com/engine/installation/linux/centos/](https://docs.docker.com/engine/installation/linux/centos/). For a list of Docker commands, see the Docker engine Run Reference [https://docs.docker.com/engine/reference/run/](https://docs.docker.com/engine/reference/run/).

## Installing Docker on CentOS 7

These steps install the docker package and start the docker service as a user with sudo privileges.

1. Install dependencies required for Docker
   
   ```bash
   sudo yum install -y yum-utils device-mapper-persistent-data lvm2
   ```

2. Add the Docker repo
   
   ```bash
   sudo yum-config-manager --add-repo https://download.docker.com/linux/centos/docker-ce.repo
   ```

3. Update yum cache
   
   ```bash
   sudo yum makecache fast
   ```

4. Install Docker
   
   ```bash
   sudo yum -y install docker-ce
   ```

5. Start Docker daemon.
   
   ```bash
   sudo systemctl start docker
   ```

6. To give access to the Docker daemon and docker commands, assign the Greenplum Database administrator (gpadmin) to the group `docker`.
   
   ```bash
   sudo usermod -aG docker gpadmin
   ```

7. Exit the session and login again to update the privileges.

8. Run a Docker command to test the Docker installation. This command lists the currently running Docker containers.
   
   ```bash
   docker ps
   ```

   This command configures Docker to start when the host system starts.

   ```bash
   sudo systemctl start docker.service
   ```

After you have installed Docker on all Greenplum Database hosts, restart the Greenplum Database system to give Greenplum Database access to Docker.

```bash
gpstop -ra
```
## Installing Docker on CentOS 6

These steps install the Docker package and start the docker service as a user with sudo privileges.

1. **Install EPEL package**
   
   ```bash
   sudo yum -y install epel-release
   ```

2. **Install Docker**
   
   ```bash
   sudo yum -y install docker-io
   ```

3. **Create a docker group**
   
   ```bash
   sudo groupadd docker
   ```

4. **Start Docker**
   
   ```bash
   sudo service docker start
   ```

5. **To give access to the Docker daemon and docker commands, assign the Greenplum Database administrator (gpadmin) to the group docker.**
   
   ```bash
   sudo usermod -aG docker gpadmin
   ```

6. **Exit the session and login again to update the privileges.**

7. **Run a Docker command to test the Docker installation. This command lists the currently running Docker containers.**
   
   ```bash
   docker ps
   ```

This command configures Docker to start when the host system starts.

```bash
sudo chkconfig docker on
```

After you have installed Docker on all Greenplum Database hosts, restart the Greenplum Database system to give Greenplum Database access to Docker.

```bash
gpstop -ra
```

### References

- Docker home page [https://www.docker.com/](https://www.docker.com/)
- Docker command line interface [https://docs.docker.com/engine/reference/commandline/cli/](https://docs.docker.com/engine/reference/commandline/cli/)
- Dockerfile reference [https://docs.docker.com/engine/reference/builder/](https://docs.docker.com/engine/reference/builder/)
- Installing Docker on Linux systems [https://docs.docker.com/engine/installation/linux/centos/](https://docs.docker.com/engine/installation/linux/centos/)
- Control and configure Docker with systemd [https://docs.docker.com/engine/admin/systemd/](https://docs.docker.com/engine/admin/systemd/)
Greenplum PL/Java Language Extension

This section contains an overview of the Greenplum Database PL/Java language.

- About PL/Java
- About Greenplum Database PL/Java
- Installing PL/Java
- Uninstalling PL/Java
- Enabling PL/Java and Installing JAR Files
- Writing PL/Java functions
- Using JDBC
- Exception Handling
- Savepoints
- Logging
- Security
- Some PL/Java Issues and Solutions
- Example
- References

About PL/Java

With the Greenplum Database PL/Java extension, you can write Java methods using your favorite Java IDE and install the JAR files that contain those methods into Greenplum Database.

Greenplum Database PL/Java package is based on the open source PL/Java 1.4.0. Greenplum Database PL/Java provides the following features.

- Ability to execute PL/Java functions with Java 1.7 or higher.
- Ability to specify Java runtime.
- Standardized utilities (modeled after the SQL 2003 proposal) to install and maintain Java code in the database.
- Standardized mappings of parameters and result. Complex types as well as sets are supported.
- An embedded, high performance, JDBC driver utilizing the internal Greenplum Database SPI routines.
- Metadata support for the JDBC driver. Both DatabaseMetaData and ResultSetMetaData are included.
- The ability to return a ResultSet from a query as an alternative to building a ResultSet row by row.
- Full support for savepoints and exception handling.
- The ability to use IN, INOUT, and OUT parameters.
- Two separate Greenplum Database languages:
  - pljava, TRUSTED PL/Java language
  - pljavau, UNTRUSTED PL/Java language
- Transaction and Savepoint listeners enabling code execution when a transaction or savepoint is committed or rolled back.
- Integration with GNU GCJ on selected platforms.

A function in SQL will appoint a static method in a Java class. In order for the function to execute, the appointed class must available on the class path specified by the Greenplum Database sever configuration parameter pljava_classpath. The PL/Java extension adds a set of functions that helps installing and maintaining the java classes. Classes are stored in normal Java archives, JAR files. A JAR file can optionally contain a deployment descriptor that in turn contains SQL commands to be executed when the JAR is deployed or undeployed. The functions are modeled after the standards proposed for SQL 2003.
PL/Java implements a standardized way of passing parameters and return values. Complex types and sets are passed using the standard JDBC ResultSet class.

A JDBC driver is included in PL/Java. This driver calls Greenplum Database internal SPI routines. The driver is essential since it is common for functions to make calls back to the database to fetch data. When PL/Java functions fetch data, they must use the same transactional boundaries that are used by the main function that entered PL/Java execution context.

PL/Java is optimized for performance. The Java virtual machine executes within the same process as the backend to minimize call overhead. PL/Java is designed with the objective to enable the power of Java to the database itself so that database intensive business logic can execute as close to the actual data as possible.

The standard Java Native Interface (JNI) is used when bridging calls between the backend and the Java VM.

About Greenplum Database PL/Java

There are a few key differences between the implementation of PL/Java in standard PostgreSQL and Greenplum Database.

Functions

The following functions are not supported in Greenplum Database. The classpath is handled differently in a distributed Greenplum Database environment than in the PostgreSQL environment.

- `sqlj.install_jar`
- `sqlj.replace_jar`
- `sqlj.remove_jar`
- `sqlj.get_classpath`
- `sqlj.set_classpath`

Greenplum Database uses the `pljava_classpath` server configuration parameter in place of the `sqlj.set_classpath` function.

Server Configuration Parameters

The following server configuration parameters are used by PL/Java in Greenplum Database. These parameters replace the `pljava.*` parameters that are used in the standard PostgreSQL PL/Java implementation:

- `pljava_classpath`

  A colon (:) separated list of the jar files containing the Java classes used in any PL/Java functions. The jar files must be installed in the same locations on all Greenplum Database hosts. With the trusted PL/Java language handler, jar file paths must be relative to the `$GPHOME/lib/postgresql/java/` directory. With the untrusted language handler (javaU language tag), paths may be relative to `$GPHOME/lib/postgresql/java/` or absolute.

  The server configuration parameter `pljava_classpath_insecure` controls whether the server configuration parameter `pljava_classpath` can be set by a user without Greenplum Database superuser privileges. When `pljava_classpath_insecure` is enabled, Greenplum Database developers who are working on PL/Java functions do not have to be database superusers to change `pljava_classpath`.

  **Warning:** Enabling `pljava_classpath_insecure` exposes a security risk by giving non-administrator database users the ability to run unauthorized Java methods.

- `pljava_statement_cache_size`

  Sets the size in KB of the Most Recently Used (MRU) cache for prepared statements.
Greenplum Database Reference Guide

- **pljava_release_lingering_savepoints**
  
  If **TRUE**, lingering savepoints will be released on function exit. If **FALSE**, they will be rolled back.

- **pljava_vmoptions**

  Defines the start up options for the Greenplum Database Java VM.

  See the *Greenplum Database Reference Guide* for information about the Greenplum Database server configuration parameters.

### Installing PL/Java

For Greenplum Database, the PL/Java extension is available as a package. Download the package from the Greenplum Database page on *Pivotal Network* and then install it with the Greenplum Package Manager (gppkg).

The **gppkg** utility installs Greenplum Database extensions, along with any dependencies, on all hosts across a cluster. It also automatically installs extensions on new hosts in the case of system expansion and segment recovery.

For information about **gppkg**, see the *Greenplum Database Utility Guide*.

**Important:** PL/Java requires a Java environment on each Greenplum Database host. Ensure that the same Java environment is at the same location on all hosts: masters and segments.

To install and use PL/Java:

1. Specify the Java version used by PL/Java. Set the environment variables **JAVA_HOME** and **LD_LIBRARY_PATH** in the **greenplum_path.sh**.
2. Install the Greenplum Database PL/Java extension.
3. Enable the language for each database where you intend to use PL/Java.
4. Install user-created JAR files containing Java methods into the same directory on all Greenplum Database hosts.
5. Add the name of the JAR file to the Greenplum Database server configuration parameter **pljava_classpath**. The parameter lists the installed JAR files. For information about the parameter, see the *Greenplum Database Reference Guide*.

### Installing the Greenplum PL/Java Extension

Before you install the PL/Java extension, make sure that your Greenplum database is running, you have sourced **greenplum_path.sh**, and that the **$MASTER_DATA_DIRECTORY** and **$GPHOME** variables are set.

1. Download the PL/Java extension package from the Greenplum Database page on *Pivotal Network* then copy it to the master host.
2. Install the software extension package by running the **gppkg** command. This example installs the PL/Java extension package on a Linux system:

   ```shell
   $ gppkg -i pljava-ossv1.5.0_pv1.4.0-GPDB-version-orca-rhel6-x86_64.gppkg
   ```

3. Ensure the environment variables **JAVA_HOME** and **LD_LIBRARY_PATH** are set properly in **$GPHOME/greenplum_path.sh** on all Greenplum Database hosts.

   - Set the **JAVA_HOME** variable to the directory where your Java Runtime is installed. For example, for Oracle JRE this directory would be /usr/java/latest. For OpenJDK, the directory is /usr/lib/jvm/jre. This example changes the environment variable to use /usr/java/latest.

     ```shell
     JAVA_HOME=/usr/java/latest
     ```

   - Set the **LD_LIBRARY_PATH** to include the directory with Java server runtime libraries. PL/Java depends on libjvm.so and the shared object should be in your **LD_LIBRARY_PATH**. By default,
**Uninstalling PL/Java**

- **Remove PL/Java Support for a Database**
  - **Uninstall the Java JAR files and Software Package**

**Remove PL/Java Support for a Database**

For a database that no longer requires the PL/Java language, remove support for PL/Java. Run the `uninstall.sql` file as the `gpadmin` user. For example, this command disables the PL/Java language in the specified database.

```bash
$ psql -d mydatabase -f $GPHOME/share/postgresql/pljava/uninstall.sql
```

**Uninstall the Java JAR files and Software Package**

If no databases have PL/Java as a registered language, remove the Java JAR files and uninstall the Greenplum PL/Java extension with the `gppkg` utility.

1. Remove the `pljava_classpath` server configuration parameter from the `postgresql.conf` file on all Greenplum Database hosts. For example:

   ```bash
   $ gpconfig -r pljava_classpath
   ```

2. Remove the JAR files from the directories where they were installed on all Greenplum Database hosts. For information about JAR file installation directories, see *Enabling PL/Java and Installing JAR Files*.

3. Use the Greenplum `gppkg` utility with the `-r` option to uninstall the PL/Java extension. This example uninstalls the PL/Java extension on a Linux system:

   ```bash
   $ gppkg -r pljava-ossv1.4.0_pv1.3_gpdbversion
   ``

You can run the `gppkg` utility with the options `-q --all` to list the installed extensions and their versions.

4. **Reload** `greenplum_path.sh`.

   ```bash
   $ source $GPHOME/greenplum_path.sh
   ```
5. Restart the database.

```
$ gpstop -r
```

**Enabling PL/Java and Installing JAR Files**

Perform the following steps as the Greenplum Database administrator `gpadmin`.

1. Enable PL/Java by running the SQL script `$GPHOME/share/postgresql/pljava/install.sql` in the databases that will use PL/Java. For example, this example enables PL/Java on the database `mytestdb`:

```
$ psql -d mytestdb \
    -f $GPHOME/share/postgresql/pljava/install.sql
```

The script `install.sql` registers both the trusted and untrusted PL/Java language.

2. Copy your Java archives (JAR files) to the same directory on all Greenplum Database hosts. This example uses the Greenplum Database `gpscp` utility to copy the file `myclasses.jar` to the directory `$GPHOME/lib/postgresql/java/`:

```
$ gpscp -f gphosts_file myclasses.jar \
        =:/usr/local/greenplum-db/lib/postgresql/java/
```

The file `gphosts_file` contains a list of the Greenplum Database hosts.

3. Set the `pljava_classpath` server configuration parameter in the master `postgresql.conf` file. For this example, the parameter value is a colon (:) separated list of the JAR files. For example:

```
$ gpconfig -c pljava_classpath -v 'examples.jar:myclasses.jar'
```

The file `examples.jar` is installed when you install the PL/Java extension package with the `gppkg` utility.

**Note:** If you install JAR files in a directory other than `$GPHOME/lib/postgresql/java/`, you must specify the absolute path to the JAR file. Each JAR file must be in the same location on all Greenplum Database hosts. For more information about specifying the location of JAR files, see the information about the `pljava_classpath` server configuration parameter in the `Greenplum Database Reference Guide`.

4. Reload the `postgresql.conf` file.

```
$ gpstop -u
```

5. (optional) Greenplum provides an `examples.sql` file containing sample PL/Java functions that you can use for testing. Run the commands in this file to create the test functions (which use the Java classes in `examples.jar`).

```
$ psql -f $GPHOME/share/postgresql/pljava/examples.sql
```

**Writing PL/Java functions**

Information about writing functions with PL/Java.

- **SQL Declaration**
- **Type Mapping**
- **NULL Handling**
- **Complex Types**
- **Returning Complex Types**
- **Returning Complex Types**
• Functions That Return Sets
• Returning a SETOF <scalar type>
• Returning a SETOF <complex type>

SQL Declaration

A Java function is declared with the name of a class and a static method on that class. The class will be resolved using the classpath that has been defined for the schema where the function is declared. If no classpath has been defined for that schema, the public schema is used. If no classpath is found there either, the class is resolved using the system classloader.

The following function can be declared to access the static method `getProperty` on `java.lang.System` class:

```sql
CREATE FUNCTION getsysprop(VARCHAR) RETURNS VARCHAR
AS 'java.lang.System.getProperty'
LANGUAGE java;
```

Run the following command to return the Java `user.home` property:

```sql
SELECT getsysprop('user.home');
```

Type Mapping

Scalar types are mapped in a straight forward way. This table lists the current mappings.

Table 244: PL/Java data type mapping

<table>
<thead>
<tr>
<th>PostgreSQL</th>
<th>Java</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>bool</code></td>
<td>boolean</td>
</tr>
<tr>
<td><code>char</code></td>
<td>byte</td>
</tr>
<tr>
<td><code>int2</code></td>
<td>short</td>
</tr>
<tr>
<td><code>int4</code></td>
<td>int</td>
</tr>
<tr>
<td><code>int8</code></td>
<td>long</td>
</tr>
<tr>
<td><code>varchar</code></td>
<td>java.lang.String</td>
</tr>
<tr>
<td><code>text</code></td>
<td>java.lang.String</td>
</tr>
<tr>
<td><code>bytea</code></td>
<td>byte[ ]</td>
</tr>
<tr>
<td><code>date</code></td>
<td>java.sql.Date</td>
</tr>
<tr>
<td><code>time</code></td>
<td>java.sql.Time (stored value treated as local time)</td>
</tr>
<tr>
<td><code>timetz</code></td>
<td>java.sql.Time</td>
</tr>
<tr>
<td><code>timestamp</code></td>
<td>java.sql.Timestamp (stored value treated as local time)</td>
</tr>
<tr>
<td><code>timestamptz</code></td>
<td>java.sql.Timestamp</td>
</tr>
<tr>
<td>complex</td>
<td>java.sql.ResultSet</td>
</tr>
<tr>
<td>setof complex</td>
<td>java.sql.ResultSet</td>
</tr>
</tbody>
</table>
All other types are mapped to java.lang.String and will utilize the standard `textin/textout` routines registered for respective type.

**NULL Handling**

The scalar types that map to Java primitives can not be passed as NULL values. To pass NULL values, those types can have an alternative mapping. You enable this mapping by explicitly denoting it in the method reference.

```java
CREATE FUNCTION trueIfEvenOrNull(integer)
RETURNS bool
AS 'foo.fee.Fum.trueIfEvenOrNull(java.lang.Integer)'
LANGUAGE java;
```

The Java code would be similar to this:

```java
package foo.fee;
public class Fum {
    static boolean trueIfEvenOrNull(Integer value) {
        return (value == null) ? true : (value.intValue() % 2) == 0;
    }
}
```

The following two statements both yield true:

```sql
SELECT trueIfEvenOrNull(NULL);
SELECT trueIfEvenOrNull(4);
```

In order to return NULL values from a Java method, you use the object type that corresponds to the primitive (for example, you return `java.lang.Integer` instead of `int`). The PL/Java resolve mechanism finds the method regardless. Since Java cannot have different return types for methods with the same name, this does not introduce any ambiguity.

**Complex Types**

A complex type will always be passed as a read-only `java.sql.ResultSet` with exactly one row. The ResultSet is positioned on its row so a call to `next()` should not be made. The values of the complex type are retrieved using the standard getter methods of the ResultSet.

Example:

```sql
CREATE TYPE complexTest
    AS(base integer, incbase integer, ctime timestamptz);
CREATE FUNCTION useComplexTest(complexTest)
    RETURNS VARCHAR
    AS 'foo.fee.Fum.useComplexTest'
    IMmutable LANGUAGE java;
```

In the Java class `Fum`, we add the following static method:

```java
public static String useComplexTest(ResultSet complexTest) throws SQLException {
    int base = complexTest.getInt(1);
    int incbase = complexTest.getInt(2);
    Timestamp ctime = complexTest.getTimestamp(3);
```
Returning Complex Types

Java does not stipulate any way to create a ResultSet. Hence, returning a ResultSet is not an option. The SQL-2003 draft suggests that a complex return value should be handled as an IN/OUT parameter. PL/Java implements a ResultSet that way. If you declare a function that returns a complex type, you will need to use a Java method with boolean return type with a last parameter of type java.sql.ResultSet. The parameter will be initialized to an empty updateable ResultSet that contains exactly one row.

Assume that the `complexTest` type in previous section has been created.

```sql
CREATE FUNCTION createComplexTest(int, int)
RETURNS complexTest
AS 'foo.fee.Fum.createComplexTest'
IMMUTABLE LANGUAGE java;
```

The PL/Java method `resolve` will now find the following method in the `Fum` class:

```java
public static boolean complexReturn(int base, int increment, ResultSet receiver)
throws SQLException
{
    receiver.updateInt(1, base);
    receiver.updateInt(2, base + increment);
    receiver.updateTimestamp(3, new Timestamp(System.currentTimeMillis()));
    return true;
}
```

The return value denotes if the receiver should be considered as a valid tuple (true) or NULL (false).

Functions That Return Sets

When returning result set, you should not build a result set before returning it, because building a large result set would consume a large amount of resources. It is better to produce one row at a time. Incidentally, that is what the Greenplum Database backend expects a function with SETOF return to do. You can return a SETOF a scalar type such as an `int`, `float` or `varchar`, or you can return a SETOF a complex type.

Returning a SETOF <scalar type>

In order to return a set of a scalar type, you need create a Java method that returns something that implements the `java.util.Iterator` interface. Here is an example of a method that returns a SETOF `varchar`:

```sql
CREATE FUNCTION javatest.getSystemProperties()
RETURNS SETOF varchar
AS 'foo.fee.Bar.getNames'
IMMUTABLE LANGUAGE java;
```

This simple Java method returns an iterator:

```java
package foo.fee;
import java.util.Iterator;
```
public class Bar
{
    public static Iterator getNames()
    {
        ArrayList names = new ArrayList();
        names.add("Lisa");
        names.add("Bob");
        names.add("Bill");
        names.add("Sally");
        return names.iterator();
    }
}

Returning a SETOF <complex type>

A method returning a SETOF <complex type> must use either the interface
org.postgresql.pljava.ResultSetProvider or org.postgresql.pljava.ResultSetHandle.
The reason for having two interfaces is that they cater for optimal handling of two distinct use cases. The
former is for cases when you want to dynamically create each row that is to be returned from the SETOF
function. The latter makes is in cases where you want to return the result of an executed query.

Using the ResultSetProvider Interface

This interface has two methods. The boolean assignRowValues(java.sql.ResultSet
tupleBuilder, int rowNumber) and the void close() method. The Greenplum Database query
evaluator will call the assignRowValues repeatedly until it returns false or until the evaluator decides that
it does not need any more rows. Then it calls close.

You can use this interface the following way:

CREATE FUNCTION javatest.listComplexTests(int, int)
    RETURNS SETOF complexTest
    AS 'foo.fee.Fum.listComplexTest'
    IMMUTABLE LANGUAGE java;

The function maps to a static java method that returns an instance that implements the
ResultSetProvider interface.

public class Fum implements ResultSetProvider
{
    private final int m_base;
    private final int m_increment;
    public Fum(int base, int increment)
    {
        m_base = base;
        m_increment = increment;
    }
    public boolean assignRowValues(ResultSet receiver, int
currentRow)
        throws SQLException
    {
        // Stop when we reach 12 rows.
        //
        if(currentRow >= 12)
            return false;
        receiver.updateInt(1, m_base);
        receiver.updateInt(2, m_base + m_increment * currentRow);
        receiver.updateTimestamp(3, new
Timestamp(System.currentTimeMillis()));
        return true;
    }
The `listComplexTests` method is called once. It may return NULL if no results are available or an instance of the `ResultSetProvider`. Here the Java class `Fum` implements this interface so it returns an instance of itself. The method `assignRowValues` will then be called repeatedly until it returns false. At that time, close will be called.

### Using the ResultSetHandle Interface

This interface is similar to the `ResultSetProvider` interface in that it has a `close()` method that will be called at the end. But instead of having the evaluator call a method that builds one row at a time, this method has a method that returns a ResultSet. The query evaluator will iterate over this set and deliver the ResultSet contents, one tuple at a time, to the caller until a call to `next()` returns false or the evaluator decides that no more rows are needed.

Here is an example that executes a query using a statement that it obtained using the default connection. The SQL suitable for the deployment descriptor looks like this:

```sql
CREATE FUNCTION javatest.listSupers()
RETURNS SETOF pg_user
AS 'org.postgresql.pljava.example.Users.listSupers'
LANGUAGE java;
CREATE FUNCTION javatest.listNonSupers()
RETURNS SETOF pg_user
AS 'org.postgresql.pljava.example.Users.listNonSupers'
LANGUAGE java;
```

And in the Java package `org.postgresql.pljava.example` a class `Users` is added:

```java
public class Users implements ResultSetHandle
{
   private final String m_filter;
   private Statement m_statement;
   public Users(String filter)
   {
      m_filter = filter;
   }
   public ResultSet getResultSet()
   throws SQLException
   {
      m_statement =
         DriverManager.getConnection("jdbc:default:connection").createStatement();
      return m_statement.executeQuery("SELECT * FROM pg_user
WHERE " + m_filter);
   }
   public void close()
   throws SQLException
   {
      m_statement.close();
   }
}
```
public static ResultSetHandle listSupers()
{
    return new Users("usesuper = true");
}

public static ResultSetHandle listNonSupers()
{
    return new Users("usesuper = false");
}

Using JDBC

PL/Java contains a JDBC driver that maps to the PostgreSQL SPI functions. A connection that maps to the current transaction can be obtained using the following statement:

```java
Connection conn =
    DriverManager.getConnection("jdbc:default:connection");
```

After obtaining a connection, you can prepare and execute statements similar to other JDBC connections. These are limitations for the PL/Java JDBC driver:

- The transaction cannot be managed in any way. Thus, you cannot use methods on the connection such as:
  - `commit()`
  - `rollback()`
  - `setAutoCommit()`
  - `setTransactionIsolation()`

- Savepoints are available with some restrictions. A savepoint cannot outlive the function in which it was set and it must be rolled back or released by that same function.

- A ResultSet returned from `executeQuery()` are always `FETCH_FORWARD` and `CONCUR_READ_ONLY`.

- Meta-data is only available in PL/Java 1.1 or higher.

- `CallableStatement` (for stored procedures) is not implemented.

- The types `Clob` or `Blob` are not completely implemented, they need more work. The types `byte[]` and `String` can be used for `byte` and `text` respectively.

Exception Handling

You can catch and handle an exception in the Greenplum Database backend just like any other exception. The backend `ErrorData` structure is exposed as a property in a class called `org.postgresql.pljava.ServerException` (derived from `java.sql.SQLException`) and the Java try/catch mechanism is synchronized with the backend mechanism.

**Important:** You will not be able to continue executing backend functions until your function has returned and the error has been propagated when the backend has generated an exception unless you have used a savepoint. When a savepoint is rolled back, the exceptional condition is reset and you can continue your execution.

Savepoints

Greenplum Database savepoints are exposed using the `java.sql.Connection` interface. Two restrictions apply.

- A savepoint must be rolled back or released in the function where it was set.
- A savepoint must not outlive the function where it was set.
Logging

PL/Java uses the standard Java Logger. Hence, you can write things like:

```java
Logger.getAnonymousLogger().info("Time is " + new Date(System.currentTimeMillis()));
```

At present, the logger uses a handler that maps the current state of the Greenplum Database configuration setting `log_min_messages` to a valid Logger level and that outputs all messages using the Greenplum Database backend function `elog()`.

**Note:** The `log_min_messages` setting is read from the database the first time a PL/Java function in a session is executed. On the Java side, the setting does not change after the first PL/Java function execution in a specific session until the Greenplum Database session that is working with PL/Java is restarted.

The following mapping apply between the Logger levels and the Greenplum Database backend levels.

**Table 245: PL/Java Logging Levels**

<table>
<thead>
<tr>
<th>java.util.logging.Level</th>
<th>Greenplum Database Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEVERE ERROR</td>
<td>ERROR</td>
</tr>
<tr>
<td>WARNING</td>
<td>WARNING</td>
</tr>
<tr>
<td>CONFIG</td>
<td>LOG</td>
</tr>
<tr>
<td>INFO</td>
<td>INFO</td>
</tr>
<tr>
<td>FINE</td>
<td>DEBUG1</td>
</tr>
<tr>
<td>FINER</td>
<td>DEBUG2</td>
</tr>
<tr>
<td>FINEST</td>
<td>DEBUG3</td>
</tr>
</tbody>
</table>

Security

- **Installation**
- **Trusted Language**

Installation

Only a database superuser can install PL/Java. The PL/Java utility functions are installed using SECURITY DEFINER so that they execute with the access permissions that where granted to the creator of the functions.

Trusted Language

PL/Java is a trusted language. The trusted PL/Java language has no access to the file system as stipulated by PostgreSQL definition of a trusted language. Any database user can create and access functions in a trusted language.

PL/Java also installs a language handler for the language `javau`. This version is not trusted and only a superuser can create new functions that use it. Any user can call the functions.
Some PL/Java Issues and Solutions

When writing the PL/Java, mapping the JVM into the same process-space as the Greenplum Database backend code, some concerns have been raised regarding multiple threads, exception handling, and memory management. Here are brief descriptions explaining how these issues were resolved.

- **Multi-threading**
- **Exception Handling**
- **Java Garbage Collector Versus palloc() and Stack Allocation**

**Multi-threading**

Java is inherently multi-threaded. The Greenplum Database backend is not. There is nothing stopping a developer from utilizing multiple Threads class in the Java code. Finalizers that call out to the backend might have been spawned from a background Garbage Collection thread. Several third party Java-packages that are likely to be used make use of multiple threads. How can this model coexist with the Greenplum Database backend in the same process?

**Solution**

The solution is simple. PL/Java defines a special object called the `Backend.THREADLOCK`. When PL/Java is initialized, the backend immediately grabs this object's monitor (i.e. it will synchronize on this object). When the backend calls a Java function, the monitor is released and then immediately regained when the call returns. All calls from Java out to backend code are synchronized on the same lock. This ensures that only one thread at a time can call the backend from Java, and only at a time when the backend is awaiting the return of a Java function call.

**Exception Handling**

Java makes frequent use of try/catch/finally blocks. Greenplum Database sometimes use an exception mechanism that calls `longjmp` to transfer control to a known state. Such a jump would normally effectively bypass the JVM.

**Solution**

The backend now allows errors to be caught using the macros `PG_TRY/PG_CATCH/PG_END_TRY` and in the catch block, the error can be examined using the `ErrorData` structure. PL/Java implements a `java.sql.SQLException` subclass called `org.postgresql.pljava.ServerException`. The `ErrorData` can be retrieved and examined from that exception. A catch handler is allowed to issue a rollback to a savepoint. After a successful rollback, execution can continue.

**Java Garbage Collector Versus palloc() and Stack Allocation**

Primitive types are always passed by value. This includes the `String` type (this is a must since Java uses double byte characters). Complex types are often wrapped in Java objects and passed by reference. For example, a Java object can contain a pointer to a palloc'ed or stack allocated memory and use native JNI calls to extract and manipulate data. Such data will become stale once a call has ended. Further attempts to access such data will at best give very unpredictable results but more likely cause a memory fault and a crash.

**Solution**

The PL/Java contains code that ensures that stale pointers are cleared when the MemoryContext or stack where they where allocated goes out of scope. The Java wrapper objects might live on but any attempt to use them will result in a stale native handle exception.
Example

The following simple Java example creates a JAR file that contains a single method and runs the method.

Note: The example requires Java SDK to compile the Java file.

The following method returns a substring.

```java
{  
public static String substring(String text, int beginIndex,  
    int endIndex)  
{  
    return text.substring(beginIndex, endIndex);  
    }  
}
```

Enter the java code in a text file example.class.

Contents of the file manifest.txt:

```plaintext
Manifest-Version: 1.0  
Main-Class: Example  
Specification-Title: "Example"  
Specification-Version: "1.0"  
Created-By: 1.6.0_35-b10-428-11M3811  
Build-Date: 01/20/2013 10:09 AM
```

Compile the java code:

```
javac *.java
```

Create a JAR archive named analytics.jar that contains the class file and the manifest file MANIFEST file in the JAR.

```
jar cfm analytics.jar manifest.txt *.class
```

Upload the jar file to the Greenplum master host.

Run the gpscp utility to copy the jar file to the Greenplum Java directory. Use the -f option to specify the file that contains a list of the master and segment hosts.

```
gpscp -f gphosts_file analytics.jar  
=:/usr/local/greenplum-db/lib/postgresql/java/
```

Use the gpconfig utility to set the Greenplum pljava_classpath server configuration parameter. The parameter lists the installed jar files.

```
gpconfig -c pljava_classpath -v 'analytics.jar'
```

Run the gpstop utility with the -u option to reload the configuration files.

```
gpstop -u
```

From the psql command line, run the following command to show the installed jar files.

```
show pljava_classpath
```
The following SQL commands create a table and define a Java function to test the method in the jar file:

```sql
create table temp (a varchar) distributed randomly;
insert into temp values ('my string');
--Example function
create or replace function java_substring(varchar, int, int)
returns varchar as 'Example.substring' language java;
--Example execution
select java_substring(a, 1, 5) from temp;
```

You can place the contents in a file, `mysample.sql` and run the command from a `psql` command line:

```sql
> \i mysample.sql
```

The output is similar to this:

```sql
java_substring
-----------
y st
(1 row)
```

**References**

The PL/Java Github wiki page - [https://github.com/tada/pljava/wiki](https://github.com/tada/pljava/wiki).

PL/Java 1.4.0 release - [https://github.com/tada/pljava/tree/B1_4](https://github.com/tada/pljava/tree/B1_4).
Greenplum PL/Perl Language Extension

This chapter includes the following information:

- About Greenplum PL/Perl
- Greenplum Database PL/Perl Limitations
- Trusted/Untrusted Language
- Developing Functions with PL/Perl

About Greenplum PL/Perl

With the Greenplum Database PL/Perl extension, you can write user-defined functions in Perl that take advantage of its advanced string manipulation operators and functions. PL/Perl provides both trusted and untrusted variants of the language.

PL/Perl is embedded in your Greenplum Database distribution. Greenplum Database PL/Perl requires Perl to be installed on the system of each database host.

Refer to the PostgreSQL PL/Perl documentation for additional information.

Greenplum Database PL/Perl Limitations

Limitations of the Greenplum Database PL/Perl language include:

- Greenplum Database does not support PL/Perl triggers.
- PL/Perl functions cannot call each other directly.
- SPI is not yet fully implemented.
- If you fetch very large data sets using `spi_exec_query()`, you should be aware that these will all go into memory. You can avoid this problem by using `spi_query()/spi_fetchrow()`. A similar problem occurs if a set-returning function passes a large set of rows back to Greenplum Database via a `return` statement. Use `return_next` for each row returned to avoid this problem.
- When a session ends normally, not due to a fatal error, PL/Perl executes any `END` blocks that you have defined. No other actions are currently performed. (File handles are not automatically flushed and objects are not automatically destroyed.)

Trusted/Untrusted Language

PL/Perl includes trusted and untrusted language variants.

The PL/Perl trusted language is named `plperl`. The trusted PL/Perl language restricts file system operations, as well as `require`, `use`, and other statements that could potentially interact with the operating system or database server process. With these restrictions in place, any Greenplum Database user can create and execute functions in the trusted `plperl` language.

The PL/Perl untrusted language is named `plperlu`. You cannot restrict the operation of functions you create with the `plperlu` untrusted language. Only database superusers have privileges to create untrusted PL/Perl user-defined functions. And only database superusers and other database users that are explicitly granted the permissions can execute untrusted PL/Perl user-defined functions.

PL/Perl has limitations with respect to communication between interpreters and the number of interpreters running in a single process. Refer to the PostgreSQL Trusted and Untrusted PL/Perl documentation for additional information.
Enabling and Removing PL/Perl Support

You must register the PL/Perl language with a database before you can create and execute a PL/Perl user-defined function within that database. To remove PL/Perl support, you must explicitly remove the extension from each database in which it was registered. You must be a database superuser or owner to register or remove trusted languages in Greenplum databases.

Note: Only database superusers may register or remove support for the untrusted PL/Perl language plperlu.

Before you enable or remove PL/Perl support in a database, ensure that:

• Your Greenplum Database is running.
• You have sourced greenplum_path.sh.
• You have set the $MASTER_DATA_DIRECTORY and $GPHOME environment variables.

Enabling PL/Perl Support

For each database in which you want to enable PL/Perl, register the language using the SQL CREATE LANGUAGE command or the Greenplum Database createlang utility. For example, run the following command as the gpadmin user to register the trusted PL/Perl language for the database named testdb:

$ createlang plperl -d testdb

Removing PL/Perl Support

To remove support for PL/Perl from a database, run the SQL DROP LANGUAGE command or the Greenplum Database droplang utility. For example, run the following command as the gpadmin user to remove support for the trusted PL/Perl language from the database named testdb:

$ psql -d testdb
psql (8.3.23)
Type "help" for help.

```
testdb=# DROP LANGUAGE plperl;
```

The default DROP LANGUAGE behavior is RESTRICT; the command fails if any existing objects (such as functions) depend on the language. Specify the CASCADE clause to also drop all dependent objects, including functions that you created with PL/Perl.

Developing Functions with PL/Perl

You define a PL/Perl function using the standard SQL CREATE FUNCTION syntax. The body of a PL/Perl user-defined function is ordinary Perl code. The PL/Perl interpreter wraps this code inside a Perl subroutine.

You can also create an anonymous code block with PL/Perl. An anonymous code block, called with the SQL DO command, receives no arguments, and whatever value it might return is discarded. Otherwise, a PL/Perl anonymous code block behaves just like a function. Only database superusers create an anonymous code block with the untrusted plperlu language.

The syntax of the CREATE FUNCTION command requires that you write the PL/Perl function body as a string constant. While it is more convenient to use dollar-quoting, you can choose to use escape string syntax (\E'\E') provided that you double any single quote marks and backslashes used in the body of the function.
PL/Perl arguments and results are handled as they are in Perl. Arguments you pass in to a PL/Perl function are accessed via the @_ array. You return a result value with the return statement, or as the last expression evaluated in the function. A PL/Perl function cannot directly return a non-scalar type because you call it in a scalar context. You can return non-scalar types such as arrays, records, and sets in a PL/Perl function by returning a reference.

PL/Perl treats null argument values as "undefined". Adding the STRICT keyword to the LANGUAGE subclause instructs Greenplum Database to immediately return null when any of the input arguments are null. When created as STRICT, the function itself need not perform null checks.

The following PL/Perl function utilizes the STRICT keyword to return the greater of two integers, or null if any of the inputs are null:

```perl
CREATE FUNCTION perl_max (integer, integer) RETURNS integer AS $$
   if ($_[0] > $_[1]) { return $_[0]; }
   return $_[1];
$$ LANGUAGE plperl STRICT;
SELECT perl_max( 1, 3 );
perl_max
---------
   3
(1 row)
SELECT perl_max( 1, null );
perl_max
---------
(1 row)
```

PL/Perl considers anything in a function argument that is not a reference to be a string, the standard Greenplum Database external text representation. The argument values supplied to a PL/Perl function are simply the input arguments converted to text form (just as if they had been displayed by a SELECT statement). In cases where the function argument is not an ordinary numeric or text type, you must convert the Greenplum Database type to a form that is more usable by Perl. Conversely, the return and return_next statements accept any string that is an acceptable input format for the function's declared return type.

Refer to the PostgreSQL PL/Perl Functions and Arguments documentation for additional information, including composite type and result set manipulation.

**Built-in PL/Perl Functions**

PL/Perl includes built-in functions to access the database, including those to prepare and perform queries and manipulate query results. The language also includes utility functions for error logging and string manipulation.

The following example creates a simple table with an integer and a text column. It creates a PL/Perl user-defined function that takes an input string argument and invokes the spi_exec_query() built-in function to select all columns and rows of the table. The function returns all rows in the query results where the v column includes the function input string.

```sql
CREATE TABLE test (    
   i int,    
   v varchar
);
INSERT INTO test (i, v) VALUES (1, 'first line');
INSERT INTO test (i, v) VALUES (2, 'line2');
INSERT INTO test (i, v) VALUES (3, '3rd line');
```
INSERT INTO test (i, v) VALUES (4, 'different');

CREATE OR REPLACE FUNCTION return_match(varchar) RETURNS SETOF test AS $$
# store the input argument
$ss = $_[0];

# run the query
my $rv = spi_exec_query('select i, v from test;');

# retrieve the query status
my $status = $rv->{status};

# retrieve the number of rows returned in the query
my $nrows = $rv->{processed};

# loop through all rows, comparing column v value with input argument
foreach my $rn (0 .. $nrows - 1) {
  my $row = $rv->{rows}[$rn];
  my $textstr = $row->{v};
  if( index($textstr, $ss) != -1 ) {
    # match! return the row.
    return_next($row);
  }
}

return undef;
$$ LANGUAGE plperl;

SELECT return_match( 'iff' );

Refer to the PostgreSQL PL/Perl Built-in Functions documentation for a detailed discussion of available functions.

Global Values in PL/Perl

You can use the global hash map %_SHARED to share data, including code references, between PL/Perl function calls for the lifetime of the current session.

The following example uses %_SHARED to share data between the user-defined set_var() and get_var() PL/Perl functions:

CREATE OR REPLACE FUNCTION set_var(name text, val text) RETURNS text AS $$
if ($_SHARED{$_[0]} = $_[1]) {
  return 'ok';
} else {
  return "cannot set shared variable $_[0] to $_[1]";
}
$$ LANGUAGE plperl;

CREATE OR REPLACE FUNCTION get_var(name text) RETURNS text AS $$
return $_SHARED{$_[0]};
$$ LANGUAGE plperl;

SELECT set_var('key1', 'value1');

set_var
---------
ok
(1 row)
SELECT get_var('key1');

get_var
--------
value1
(1 row)

For security reasons, PL/Perl creates a separate Perl interpreter for each role. This prevents accidental or malicious interference by one user with the behavior of another user's PL/Perl functions. Each such interpreter retains its own value of the %_SHARED variable and other global state. Two PL/Perl functions share the same value of %_SHARED if and only if they are executed by the same SQL role.

There are situations where you must take explicit steps to ensure that PL/Perl functions can share data in %_SHARED. For example, if an application executes under multiple SQL roles (via SECURITY DEFINER functions, use of SET ROLE, etc.) in a single session, make sure that functions that need to communicate are owned by the same user, and mark these functions as SECURITY DEFINER.

Notes

Additional considerations when developing PL/Perl functions:

- PL/Perl internally utilizes the UTF-8 encoding. It converts any arguments provided in other encodings to UTF-8, and converts return values from UTF-8 back to the original encoding.
- Nesting named PL/Perl subroutines retains the same dangers as in Perl.
- Only the untrusted PL/Perl language variant supports module import. Use plperlu with care.
- Any module that you use in a plperlu function must be available from the same location on all Greenplum Database hosts.
Greenplum MADlib Extension for Analytics

This chapter includes the following information:

- About MADlib
- Installing MADlib
- Upgrading MADlib
- Uninstalling MADlib
- Examples
- References

About MADlib

MADlib is an open-source library for scalable in-database analytics. With the Greenplum Database MADlib extension, you can use MADlib functionality in a Greenplum Database.

MADlib provides data-parallel implementations of mathematical, statistical and machine-learning methods for structured and unstructured data. It provides an suite of SQL-based algorithms for machine learning, data mining and statistics that run at scale within a database engine, with no need for transferring data between Greenplum Database and other tools.

MADlib requires the m4 macro processor version 1.4.13 or later.

MADlib can be used with PivotalR, an R package that enables users to interact with data resident in Greenplum Database using the R client. See About MADlib, R, and PivotalR.

Note: When using MADlib 1.11 and earlier, set the server configuration parameter optimizer_control to on (the default). If the parameter is set to off, these MADlib functions do not work: decision tree, random forest, LDA, k-Means, PMML export for decision tree, PMML export for random forest. The installation checks for these functions also fail.

The parameter optimizer_control controls whether the server configuration parameter optimizer can be changed. The parameter optimizer controls whether the GPORCA optimizer is enabled when running SQL queries. Some MADlib installation checks and functions change the value of optimizer to improve performance. If optimizer_control is set to off, the value of optimizer cannot be changed and the function fails.

Installing MADlib

To install MADlib on Greenplum Database, you first install a compatible Greenplum MADlib package and then install the MADlib function libraries on all databases that will use MADlib.

The gppkg utility installs Greenplum Database extensions, along with any dependencies, on all hosts across a cluster. It also automatically installs extensions on new hosts in the case of system expansion segment recovery.

Installing the Greenplum Database MADlib Package

Before you install the MADlib package, make sure that your Greenplum database is running, you have sourced greenplum_path.sh, and that the $MASTER_DATA_DIRECTORY and $GPHOME variables are set.

1. Download the MADlib extension package from Pivotal Network.
2. Copy the MADlib package to the Greenplum Database master host.
3. Install the software package by running the `gppkg` command. This example installs the MADlib 1.11 package on a Linux system:

```bash
$ gppkg -i madlib-ossvl.11_pvl.9.8_gpdb<version>-rhel6-x86_64.gppkg
```

### Adding MADlib Functions to a Database

After installing the MADlib package, run the `madpack` command to add MADlib functions to Greenplum Database. `madpack` is in `$GPHOME/madlib/bin`.

```bash
$ madpack [-s `schema_name`] -p `greenplum` -c `user`@`host:port`/`database` install
```

For example, this command creates MADlib functions in the Greenplum database `testdb` running on server `mdw` on port 5432. The `madpack` command logs in as the user `gpadmin` and prompts for password. The target schema is `madlib`.

```bash
$ madpack -s madlib -p greenplum -c gpadmin@mdw:5432/testdb install
```

After installing the functions, The Greenplum Database `gpadmin` superuser role should grant all privileges on the target schema (in the example `madlib`) to users who will be accessing MADlib functions. Users without access to the functions will get the error `ERROR: permission denied for schema MADlib`.

The `madpack` `install-check` option runs test using Madlib modules to check the MADlib installation:

```bash
$ madpack -s madlib -p greenplum -c gpadmin@mdw:5432/testdb install-check
```

**Note:** The command `madpack` `-h` displays information for the utility.

### Upgrading MADlib

You upgrade an installed MADlib package with the Greenplum Database `gppkg` utility and the MADlib `madpack` command.

For information about the upgrade paths that MADlib supports, see the MADlib support and upgrade matrix in the [MADlib FAQ page](#).

#### Upgrading a MADlib Package

To upgrade MADlib, run the `gppkg` utility with the `-u` option. This command upgrades an installed MADlib package to MADlib 1.13.

```bash
gppkg -u madlib-1.13-gp4.3orca-rhel5-x86_64.tar.gz
```

#### Upgrading MADlib Functions

After you upgrade the MADlib package, you run the `madpack` `upgrade` command to upgrade the MADlib functions in Greenplum Database.

**Note:** The upgrade to MADlib 1.13 has a minor issue with some leftover `knn` functions.

Before running the `madpack` command to upgrade to MADlib 1.13, run these `psql` commands as the `gpadmin` user to drop the leftover functions from the databases where MADlib is installed.

```bash
psql db_name -c "DROP FUNCTION IF EXISTS schema.knn(VARCHAR);"
psql db_name -c "DROP FUNCTION IF EXISTS schema.knn();"
```

`db_name` is the name of the database. `schema` is the name of the MADlib schema.

See the [MADlib Installation Guide](#).
The `madpack upgrade` command upgrades the MADlib functions in the database schema. This example command upgrades the MADlib functions in the schema `madlib` of the Greenplum Database `test`.

```
madpack -s madlib -p greenplum -c gpadmin@mdw:5432/testdb upgrade
```

### Uninstalling MADlib

- **Remove MADlib objects from the database**
- **Uninstall the Greenplum Database MADlib Package**

When you remove MADlib support from a database, routines that you created in the database that use MADlib functionality will no longer work.

#### Remove MADlib objects from the database

Use the `madpack uninstall` command to remove MADlib objects from a Greenplum database. For example, this command removes MADlib objects from the database `testdb`.

```
$ madpack -s madlib -p greenplum -c gpadmin@mdw:5432/testdb uninstall
```

#### Uninstall the Greenplum Database MADlib Package

If no databases use the MADlib functions, use the Greenplum `gppkg` utility with the `-r` option to uninstall the MADlib package. When removing the package you must specify the package and version. This example uninstalls MADlib package version 1.9.

```
$ gppkg -r madlib-ossv1.11_pvl.9.8_gpdb<version>-rhe16-x86_64.gppkg
```

You can run the `gppkg` utility with the options `-q` `--all` to list the installed extensions and their versions.

After you uninstall the package, restart the database.

```
$ gpstop -r
```

### Examples

Following are examples using the Greenplum MADlib extension:

- **Linear Regression**
- **Association Rules**
- **Naive Bayes Classification**

See the MADlib documentation for additional examples.

### Linear Regression

This example runs a linear regression on the table `regr_example`. The dependent variable data are in the `y` column and the independent variable data are in the `x1` and `x2` columns.

The following statements create the `regr_example` table and load some sample data:

```
DROP TABLE IF EXISTS regr_example;
CREATE TABLE regr_example (
    id int,
    y int,
    x1 int,
    x2 int
);
```
**INSERT INTO regr_example VALUES**
(1, 5, 2, 3),
(2, 10, 7, 2),
(3, 6, 4, 1),
(4, 8, 3, 4);

The MADlib `linregr_train()` function produces a regression model from an input table containing training data. The following SELECT statement runs a simple multivariate regression on the `regr_example` table and saves the model in the `regr_example_model` table.

```sql
SELECT madlib.linregr_train (
    'regr_example', -- source table
    'regr_example_model', -- output model table
    'y', -- dependent variable
    'ARRAY[1, x1, x2]' -- independent variables
);
```

Running this query against the `regr_example` table creates the `regr_example_model` table with one row of data:

```
SELECT * FROM regr_example_model;
- [ RECORD 1 ]------------+------------------------
  coef                     |
  {0.111111111111127,1.14814814814815,1.01851851851852}
  r2                       | 0.968612680477111
  std_err                  |
  {1.49587911309236,0.207043331249903,0.346449758034495}
  t_stats                  |
  {0.0742781352708591,5.54544858420156,2.93987366103776}
  p_values                 |
  {0.952799748147436,0.113579771006374,0.208730790695278}
  condition_no             | 22.650203241881
  num_rows_processed       | 4
  num_missing_rows_skipped | 0
  variance_covariance      |
  {(2.23765432098598,-0.257201646090342,-0.437242798353582),
   {-0.257201646090342,0.042866941015057,0.0342935528120456},
   {-0.437242798353582,0.0342935528120457,0.12002743484216}}
```

The model saved in the `regr_example_model` table can be used with the MADlib linear regression prediction function, `madlib.linregr_predict()`, to view the residuals:

```sql
SELECT regr_example.*,
    madlib.linregr_predict ( ARRAY[1, x1, x2], m.coef ) as predict,
    y - madlib.linregr_predict ( ARRAY[1, x1, x2], m.coef ) as residual
FROM regr_example, regr_example_model m;
```

```
id | y  | x1 | x2 |     predict      |      residual
----+----+----+----+------------------+-------------------
 1 |  5 |  2 |  3 | 5.46296296296297 | -0.462962962962971
 3 | 10 |  7 |  2 | 10.1851851851852 | -0.185185185185201
 4 |  8 |  3 |  4 | 7.62962962962964 | 0.370370370370364
```

**Note:** The intercept is computed by setting one of the independent variables to a constant 1, as shown in the preceding example.
Association Rules

This example demonstrates the association rules data mining technique on a transactional data set. Association rule mining is a technique for discovering relationships between variables in a large data set. This example considers items in a store that are commonly purchased together. In addition to market basket analysis, association rules are also used in bioinformatics, web analytics, and other fields.

The example analyzes purchase information for seven transactions that are stored in a table with the MADlib function `madlib assoc_rules`. The function assumes that the data is stored in two columns with a single item and transaction ID per row. Transactions with multiple items consist of multiple rows with one row per item.

These commands create the table.

```sql
DROP TABLE IF EXISTS test_data;
CREATE TABLE test_data (  
  trans_id INT,
  product text
);  
```

This `INSERT` command adds the data to the table.

```sql
INSERT INTO test_data VALUES
  (1, 'beer'),
  (1, 'diapers'),
  (1, 'chips'),
  (2, 'beer'),
  (2, 'diapers'),
  (3, 'beer'),
  (3, 'diapers'),
  (4, 'beer'),
  (4, 'chips'),
  (5, 'beer'),
  (6, 'beer'),
  (6, 'diapers'),
  (6, 'chips'),
  (7, 'beer'),
  (7, 'diapers');  
```

The MADlib function `madlib assoc_rules()` analyzes the data and determines association rules with the following characteristics.

- A support value of at least .40. Support is the ratio of transactions that contain X to all transactions.
- A confidence value of at least .75. Confidence is the ratio of transactions that contain X to transactions that contain Y. One could view this metric as the conditional probability of X given Y.

This `SELECT` command determines association rules, creates the table `assoc_rules`, and adds the statistics to the table.

```sql
SELECT * FROM madlib assoc_rules (  
  .40,  -- support
  .75,  -- confidence
  'trans_id',  -- transaction column
  'product',  -- product purchased column
  'test_data',  -- table name
  'public',  -- schema name
  false);  -- display processing details
```

This is the output of the `SELECT` command. There are two rules that fit the characteristics.

<table>
<thead>
<tr>
<th>output_schema</th>
<th>output_table</th>
<th>total_rules</th>
<th>total_time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
To view the association rules, you can run this `SELECT` command.

```
SELECT pre, post, support FROM assoc_rules
ORDER BY support DESC;
```

This is the output. The `pre` and `post` columns are the itemsets of left and right hand sides of the association rule respectively.

<table>
<thead>
<tr>
<th>pre</th>
<th>post</th>
<th>support</th>
</tr>
</thead>
<tbody>
<tr>
<td>{diapers}</td>
<td>{beer}</td>
<td>0.714285714285714</td>
</tr>
<tr>
<td>{chips}</td>
<td>{beer}</td>
<td>0.428571428571429</td>
</tr>
</tbody>
</table>

Based on the data, beer and diapers are often purchased together. To increase sales, you might consider placing beer and diapers closer together on the shelves.

**Naive Bayes Classification**

Naive Bayes analysis predicts the likelihood of an outcome of a class variable, or category, based on one or more independent variables, or attributes. The class variable is a non-numeric categorial variable, a variable that can have one of a limited number of values or categories. The class variable is represented with integers, each integer representing a category. For example, if the category can be one of "true", "false", or "unknown," the values can be represented with the integers 1, 2, or 3.

The attributes can be of numeric types and non-numeric, categorical, types. The training function has two signatures – one for the case where all attributes are numeric and another for mixed numeric and categorical types. Additional arguments for the latter identify the attributes that should be handled as numeric values. The attributes are submitted to the training function in an array.

The MADlib Naive Bayes training functions produce a features probabilities table and a class priors table, which can be used with the prediction function to provide the probability of a class for the set of attributes.

**Naive Bayes Example 1 - Simple All-numeric Attributes**

In the first example, the class variable is either 1 or 2 and there are three integer attributes.

1. The following commands create the input table and load sample data.

```
DROP TABLE IF EXISTS class_example CASCADE;
CREATE TABLE class_example(
    id int, class int, attributes int[]);
INSERT INTO class_example VALUES
    (1, 1, '{1, 2, 3}'),
    (2, 1, '{1, 4, 3}'),
    (3, 2, '{0, 2, 2}'),
    (4, 1, '{1, 2, 1}'),
    (5, 2, '{1, 2, 2}'),
    (6, 2, '{0, 1, 3}');
```

Actual data in production scenarios is more extensive than this example data and yields better results. Accuracy of classification improves significantly with larger training data sets.

2. Train the model with the `create_nb_prepared_data_tables()` function.

```
SELECT * FROM madlib.create_nb_prepared_data_tables(
    'class_example',  -- name of the training table
    'class',          -- name of the class (dependent) column
);
'attributes',  -- name of the attributes column
3,  -- the number of attributes
'example_feature_probs',  -- name for the feature probabilities output table
'table
'example_priors'  -- name for the class priors output table
);

3. Create a table with data to classify using the model.

```sql
DROP TABLE IF EXISTS class_example_topredict;
CREATE TABLE class_example_topredict (
id int,
attributes int[]);
INSERT INTO class_example_topredict VALUES
(1, '{1, 3, 2}'),
(2, '{4, 2, 2}'),
(3, '{2, 1, 1}');
```

4. Create a classification view using the feature probabilities, class priors, and class_example_topredict tables.

```sql
SELECT madlib.create_nb_probs_view (
'example_feature_probs',  -- feature probabilities output table
'example_priors',  -- class priors output table
'class_example_topredict',  -- table with data to classify
'id',  -- name of the key column
'attributes',  -- name of the attributes column
3,  -- number of attributes
'example_classified'  -- name of the view to create
);
```

5. Display the classification results.

```sql
SELECT * FROM example_classified;
```

<table>
<thead>
<tr>
<th>key</th>
<th>class</th>
<th>nb_prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>0.6</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0.25</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0.75</td>
</tr>
</tbody>
</table>

(6 rows)

**Naive Bayes Example 2 – Weather and Outdoor Sports**

This example calculates the probability that the user will play an outdoor sport, such as golf or tennis, based on weather conditions.

The table `weather_example` contains the example values.

The identification column for the table is `day`, an integer type.

The `play` column holds the dependent variable and has two classifications:

- **0** - No
- **1** - Yes

There are four attributes: `outlook`, `temperature`, humidity, and wind. These are categorical variables. The MADlib `create_nb_classify_view()` function expects the attributes to be provided as an array of `INTEGER`, `NUMERIC`, or `FLOAT8` values, so the attributes for this example are encoded with integers as follows:

- **outlook** may be sunny (1), overcast (2), or rain (3).
- **temperature** may be hot (1), mild (2), or cool (3).
• humidity may be high (1) or normal (2).
• wind may be strong (1) or weak (2).

The following table shows the training data, before encoding the variables.

<table>
<thead>
<tr>
<th>day</th>
<th>play</th>
<th>outlook</th>
<th>temperature</th>
<th>humidity</th>
<th>wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>No</td>
<td>Sunny</td>
<td>Hot</td>
<td>High</td>
<td>Strong</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Rain</td>
<td>Mild</td>
<td>High</td>
<td>Weak</td>
</tr>
<tr>
<td>6</td>
<td>No</td>
<td>Rain</td>
<td>Cool</td>
<td>Normal</td>
<td>Strong</td>
</tr>
<tr>
<td>8</td>
<td>No</td>
<td>Sunny</td>
<td>Cool</td>
<td>Normal</td>
<td>Weak</td>
</tr>
<tr>
<td>10</td>
<td>Yes</td>
<td>Rain</td>
<td>Mild</td>
<td>Normal</td>
<td>Weak</td>
</tr>
<tr>
<td>12</td>
<td>Yes</td>
<td>Overcast</td>
<td>Mild</td>
<td>Normal</td>
<td>Strong</td>
</tr>
<tr>
<td>14</td>
<td>No</td>
<td>Rain</td>
<td>Mild</td>
<td>High</td>
<td>Strong</td>
</tr>
<tr>
<td>1</td>
<td>No</td>
<td>Sunny</td>
<td>Hot</td>
<td>High</td>
<td>Weak</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Overcast</td>
<td>Hot</td>
<td>High</td>
<td>Weak</td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>Rain</td>
<td>Cool</td>
<td>Normal</td>
<td>Weak</td>
</tr>
<tr>
<td>7</td>
<td>Yes</td>
<td>Overcast</td>
<td>Cool</td>
<td>Normal</td>
<td>Strong</td>
</tr>
<tr>
<td>9</td>
<td>Yes</td>
<td>Sunny</td>
<td>Cool</td>
<td>Normal</td>
<td>Weak</td>
</tr>
<tr>
<td>11</td>
<td>Yes</td>
<td>Sunny</td>
<td>Mild</td>
<td>Normal</td>
<td>Strong</td>
</tr>
<tr>
<td>13</td>
<td>Yes</td>
<td>Overcast</td>
<td>Hot</td>
<td>Normal</td>
<td>Weak</td>
</tr>
</tbody>
</table>

(14 rows)

1. Create the training table.

```sql
DROP TABLE IF EXISTS weather_example;
CREATE TABLE weather_example (  
day int,  
play int,  
attrs int[]
);
INSERT INTO weather_example VALUES  
( 2, 0, '{1,1,1,1}'), -- sunny, hot, high, strong  
( 4, 1, '{3,2,1,2}'), -- rain, mild, high, weak  
( 6, 0, '{3,3,2,1}'), -- rain, cool, normal, strong  
( 8, 0, '{1,2,1,2}'), -- sunny, mild, high, weak  
(10, 1, '{3,2,2,2}'), -- rain, mild, normal, weak  
(12, 1, '{2,2,1,1}'), -- etc.  
(14, 0, '{3,2,1,1}'),  
( 1, 0, '{1,1,1,2}'),  
( 3, 1, '{2,1,1,2}'),  
( 5, 1, '{3,3,2,2}'),  
( 7, 1, '{2,3,2,1}'),  
( 9, 1, '{1,3,2,2}'),  
(11, 1, '{1,2,1,1}'),  
(13, 1, '{2,1,2,2}');
```

2. Create the model from the training table.

```sql
SELECT madlib.create_nb_prepared_data_tables (  
  'weather_example', -- training source table  
  'play', -- dependent class column  
  'attrs', -- attributes column  
  4,  
  'weather_probs', -- feature probabilities output table  
  'weather_priors' -- class priors
);
```

3. View the feature probabilities:

```sql
SELECT * FROM weather_probs;
class | attr | value | cnt | attr_cnt
-------+------+-------+-----+----------
4. To classify a group of records with a model, first load the data into a table. In this example, the table `t1` has four rows to classify.

```sql
DROP TABLE IF EXISTS t1;
CREATE TABLE t1 (id integer, attributes integer[]);
insert into t1 values
(1, '{1, 2, 1, 1}'),
(2, '{3, 3, 2, 1}'),
(3, '{2, 1, 2, 2}'),
(4, '{3, 1, 1, 2}');
```

5. Use the MADlib `create_nb_classify_view()` function to classify the rows in the table.

```sql
SELECT madlib.create_nb_classify_view(
    'weather_probs', -- feature probabilities table
    'weather_priors', -- classPriorsName
    't1', -- table containing values to classify
    'id', -- key column
    'attributes', -- attributes column
    4, -- number of attributes
    't1_out' -- output table name
);
```

The result is four rows, one for each record in the `t1` table.

```sql
SELECT * FROM t1_out ORDER BY key;
key | nb_classification
-----+-------------------
1   | {0}
2   | {1}
3   | {1}
4   | {0}
(4 rows)
```

References

MADlib documentation is at http://madlib.apache.org/documentation.html.

PivotalR is a first class R package that enables users to interact with data resident in Greenplum Database and MADLib using an R client.

**About MADlib, R, and PivotalR**

The R language is an open-source language that is used for statistical computing. PivotalR is an R package that enables users to interact with data resident in Greenplum Database using the R client. Using PivotalR requires that MADlib is installed on the Greenplum Database.

PivotalR allows R users to leverage the scalability and performance of in-database analytics without leaving the R command line. The computational work is executed in-database, while the end user benefits from the familiar R interface. Compared with respective native R functions, there is an increase in scalability and a decrease in running time. Furthermore, data movement, which can take hours for very large data sets, is eliminated with PivotalR.

Key features of the PivotalR package:

- Explore and manipulate data in the database with R syntax. SQL translation is performed by PivotalR.
- Use the familiar R syntax for predictive analytics algorithms, for example linear and logistic regression. PivotalR accesses the MADlib in-database analytics function calls.
- Comprehensive documentation package with examples in standard R format accessible from an R client.
- The PivotalR package also supports access to the MADlib functionality.

For information about PivotalR, including supported MADlib functionality, see https://cwiki.apache.org/confluence/display/MADLIB/PivotalR.

The R package for PivotalR can be found at https://cran.r-project.org/web/packages/PivotalR/index.html.
Greenplum Fuzzy String Match Extension

The Greenplum Database Fuzzy String Match extension provides functions to determine similarities and distance between strings based on various algorithms.

- Soundex Functions
- Levenshtein Functions
- Metaphone Functions
- Double Metaphone Functions
- Installing and Uninstalling the Fuzzy String Match Functions

The Greenplum Database installation contains the files required for the functions in this extension module and SQL scripts to define the extension functions in a database and remove the functions from a database.

Warning: The functions soundex, metaphone, dmetaphone, and dmetaphone_alt do not work well with multibyte encodings (such as UTF-8).

The Greenplum Database Fuzzy String Match extension is based on the PostgreSQL fuzzystrmatch module.

Soundex Functions

The Soundex system is a method of matching similar-sounding (similar phonemes) names by converting them to the same code.

Note: Soundex is most useful for English names.

These functions work with Soundex codes:

- soundex(text string1) returns text
- difference(text string1, text string2) returns int

The soundex function converts a string to its Soundex code. Soundex codes consist of four characters.

The difference function converts two strings to their Soundex codes and then reports the number of matching code positions. The result ranges from zero to four, zero being no match and four being an exact match. These are some examples:

```
SELECT soundex('hello world!');
SELECT soundex('Anne'), soundex('Ann'), difference('Anne', 'Ann');
SELECT soundex('Anne'), soundex('Andrew'), difference('Anne', 'Andrew');
SELECT soundex('Anne'), soundex('Margaret'), difference('Anne', 'Margaret');
CREATE TABLE s (nm text);
INSERT INTO s VALUES ('john');
INSERT INTO s VALUES ('joan');
INSERT INTO s VALUES ('wobbly');
INSERT INTO s VALUES ('jack');
SELECT * FROM s WHERE soundex(nm) = soundex('john');
SELECT * FROM s WHERE difference(s.nm, 'john') > 2;
```

For information about the Soundex indexing system see https://www.archives.gov/research/census/soundex.html.
Levenshtein Functions

These functions calculate the Levenshtein distance between two strings:

\[
\text{levenshtein}( \text{text source}, \text{text target}, \text{int ins_cost}, \text{int del_cost}, \text{int sub_cost}) \quad \text{returns int} \\
\text{levenshtein}( \text{text source}, \text{text target}) \quad \text{returns int} \\
\text{levenshtein_less_equal}( \text{text source}, \text{text target}, \text{int ins_cost}, \text{int del_cost}, \text{int sub_cost}, \text{int max_d}) \quad \text{returns int} \\
\text{levenshtein_less_equal}( \text{text source}, \text{text target}, \text{int max_d}) \quad \text{returns int}
\]

Both the source and target parameters can be any non-null string, with a maximum of 255 bytes. The cost parameters ins_cost, del_cost, and sub_cost specify cost of a character insertion, deletion, or substitution, respectively. You can omit the cost parameters, as in the second version of the function; in that case the cost parameters default to 1.

levenshtein_less_equal is an accelerated version of levenshtein function for low values of distance. If actual distance is less or equal then max_d, then levenshtein_less_equal returns an accurate value of the distance. Otherwise, this function returns value which is greater than max_d. Examples:

```
test=# SELECT levenshtein('GUMBO', 'GAMBOL');
levenshtein
-------------
  2
(1 row)
```

```
test=# SELECT levenshtein('GUMBO', 'GAMBOL', 2,1,1);
levenshtein
-------------
  3
(1 row)
```

```
test=# SELECT levenshtein_less_equal('extensive', 'exhaustive',2);
levenshtein_less_equal
------------------------
  3
(1 row)
```

```
test=# SELECT levenshtein_less_equal('extensive', 'exhaustive',4);
levenshtein_less_equal
------------------------
  4
(1 row)
```

For information about the Levenshtein algorithm, see http://www.levenshtein.net/.

Metaphone Functions

Metaphone, like Soundex, is based on the idea of constructing a representative code for an input string. Two strings are then deemed similar if they have the same codes. This function calculates the metaphone code of an input string:

\[
\text{metaphone}( \text{text source}, \text{int max_output_length}) \quad \text{returns text}
\]

The source parameter must be a non-null string with a maximum of 255 characters. The max_output_length parameter sets the maximum length of the output metaphone code; if longer, the output is truncated to this length. Example:

```
test=# SELECT metaphone('GUMBO', 4);
```
For information about the Metaphone algorithm, see https://en.wikipedia.org/wiki/Metaphone.

**Double Metaphone Functions**

The Double Metaphone system computes two "sounds like" strings for a given input string - a "primary" and an "alternate". In most cases they are the same, but for non-English names especially they can be a bit different, depending on pronunciation. These functions compute the primary and alternate codes:

- `dmetaphone(text source) returns text`
- `dmetaphone_alt(text source) returns text`

There is no length limit on the input strings. Example:

```sql
test=# select dmetaphone('gumbo');
dmetaphone
------------
KMP
(1 row)
```

For information about the Double Metaphone algorithm, see https://en.wikipedia.org/wiki/Metaphone#Double_Metaphone.

**Installing and Uninstalling the Fuzzy String Match Functions**

Greenplum Database supplies SQL scripts to install and uninstall the Fuzzy String Match extension functions.

To install the functions in a database, run the following SQL script:

```sql
psql -f $GPHOME/share/postgresql/contrib/fuzzystrmatch.sql
```

To uninstall the functions, run the following SQL script:

```sql
psql -f $GPHOME/share/postgresql/contrib/uninstall_fuzzystrmatch.sql
```

**Note:** When you uninstall the Fuzzy String Match functions from a database, routines that you created in the database that use the functions will no longer work.
Summary of Greenplum Features

This section provides a high-level overview of the system requirements and feature set of Greenplum Database. It contains the following topics:

- Greenplum SQL Standard Conformance
- Greenplum and PostgreSQL Compatibility

Greenplum SQL Standard Conformance

The SQL language was first formally standardized in 1986 by the American National Standards Institute (ANSI) as SQL 1986. Subsequent versions of the SQL standard have been released by ANSI and as International Organization for Standardization (ISO) standards: SQL 1989, SQL 1992, SQL 1999, SQL 2003, SQL 2006, and finally SQL 2008, which is the current SQL standard. The official name of the standard is ISO/IEC 9075-14:2008. In general, each new version adds more features, although occasionally features are deprecated or removed.

It is important to note that there are no commercial database systems that are fully compliant with the SQL standard. Greenplum Database is almost fully compliant with the SQL 1992 standard, with most of the features from SQL 1999. Several features from SQL 2003 have also been implemented (most notably the SQL OLAP features).

This section addresses the important conformance issues of Greenplum Database as they relate to the SQL standards. For a feature-by-feature list of Greenplum's support of the latest SQL standard, see SQL 2008 Optional Feature Compliance.

Core SQL Conformance

In the process of building a parallel, shared-nothing database system and query optimizer, certain common SQL constructs are not currently implemented in Greenplum Database. The following SQL constructs are not supported:

1. Some set returning subqueries in EXISTS or NOT EXISTS clauses that Greenplum's parallel optimizer cannot rewrite into joins.
2. Backwards scrolling cursors, including the use of FETCH PRIOR, FETCH FIRST, FETCH ABOLUTE, and FETCH RELATIVE.
3. In CREATE TABLE statements (on hash-distributed tables): a UNIQUE or PRIMARY KEY clause must include all of (or a superset of) the distribution key columns. Because of this restriction, only one UNIQUE clause or PRIMARY KEY clause is allowed in a CREATE TABLE statement. UNIQUE or PRIMARY KEY clauses are not allowed on randomly-distributed tables.
4. CREATE UNIQUE INDEX statements that do not contain all of (or a superset of) the distribution key columns. CREATE UNIQUE INDEX is not allowed on randomly-distributed tables.
   Note that UNIQUE INDEXES (but not UNIQUE CONSTRAINTS) are enforced on a part basis within a partitioned table. They guarantee the uniqueness of the key within each part or sub-part.
5. VOLATILE or STABLE functions cannot execute on the segments, and so are generally limited to being passed literal values as the arguments to their parameters.
6. Triggers are not supported since they typically rely on the use of VOLATILE functions.
7. Referential integrity constraints (foreign keys) are not enforced in Greenplum Database. Users can declare foreign keys and this information is kept in the system catalog, however.
8. Sequence manipulation functions CURRVAL and LASTVAL.

SQL 1992 Conformance

The following features of SQL 1992 are not supported in Greenplum Database:
1. **NATIONAL CHARACTER (NCHAR) and NATIONAL CHARACTER VARYING (NVARCHAR).** Users can declare the NCHAR and NVARCHAR types, however they are just synonyms for CHAR and VARCHAR in Greenplum Database.

2. **CREATE ASSERTION statement.**

3. **INTERVAL literals are supported in Greenplum Database, but do not conform to the standard.**

4. **GET DIAGNOSTICS statement.**

5. **GRANT INSERT or UPDATE privileges on columns. Privileges can only be granted on tables in Greenplum Database.**

6. **GLOBAL TEMPORARY TABLEs and LOCAL TEMPORARY TABLEs.** Greenplum temporary tables do not conform to the SQL standard, but many commercial database systems have implemented temporary tables in the same way. Greenplum temporary tables are the same as VOLATILE TABLEs in Teradata.

7. **UNIQUE predicate.**

8. **MATCH PARTIAL for referential integrity checks (most likely will not be implemented in Greenplum Database).**

### SQL 1999 Conformance

The following features of SQL 1999 are not supported in Greenplum Database:

1. **Large Object data types:** BLOB, CLOB, NCLOB. However, the BYTEA and TEXT columns can store very large amounts of data in Greenplum Database (hundreds of megabytes).

2. **MODULE (SQL client modules).**

3. **CREATE PROCEDURE (SQL/PSM).** This can be worked around in Greenplum Database by creating a FUNCTION that returns void, and invoking the function as follows:

   ```sql
   SELECT myfunc(args);
   ```

4. The PostgreSQL/Greenplum function definition language (PL/PGSQL) is a subset of Oracle's PL/SQL, rather than being compatible with the SQL/PSM function definition language. Greenplum Database also supports function definitions written in Python, Perl, Java, and R.

5. **BIT and BIT VARYING data types (intentionally omitted).** These were deprecated in SQL 2003, and replaced in SQL 2008.

6. Greenplum supports identifiers up to 63 characters long. The SQL standard requires support for identifiers up to 128 characters long.

7. **Prepared transactions (PREPARE TRANSACTION, COMMIT PREPARED, ROLLBACK PREPARED).** This also means Greenplum does not support XA Transactions (2 phase commit coordination of database transactions with external transactions).

8. **CHARACTER SET option on the definition of CHAR() or VARCHAR() columns.**

9. **Specification of CHARACTERS or OCTETS (BYTES) on the length of a CHAR() or VARCHAR() column.** For example, VARCHAR(15 CHARACTERS) or VARCHAR(15 OCTETS) or VARCHAR(15 BYTES).

10. **CURRENT_SCHEMA function.**

11. **CREATE DISTINCT TYPE statement.**CREATE DOMAIN can be used as a work-around in Greenplum.

12. The **explicit table construct.**

### SQL 2003 Conformance

The following features of SQL 2003 are not supported in Greenplum Database:

1. **MERGE statements.**

2. **IDENTITY columns and the associated GENERATED ALWAYS/GENERATED BY DEFAULT clause.** The SERIAL or BIGSERIAL data types are very similar to INT or BIGINT GENERATED BY DEFAULT AS IDENTITY.

3. **MULTISET modifiers on data types.**

4. **ROW data type.**
5. Greenplum Database syntax for using sequences is non-standard. For example, `nextval('seq')` is used in Greenplum instead of the standard `NEXT VALUE FOR seq`.

6. `GENERATED ALWAYS AS` columns. Views can be used as a work-around.

7. The sample clause (TABLESAMPLE) on SELECT statements. The `random()` function can be used as a work-around to get random samples from tables.

8. The `partitioned join tables` construct (PARTITION BY in a join).

9. `GRANT SELECT` privileges on columns. Privileges can only be granted on tables in Greenplum Database. Views can be used as a work-around.

10. For CREATE TABLE x (LIKE y) statements, Greenplum does not support the [INCLUDING|EXCLUDING] [DEFAULTS|CONSTRAINTS|INDEXES] clauses.

11. Greenplum array data types are almost SQL standard compliant with some exceptions. Generally customers should not encounter any problems using them.

**SQL 2008 Conformance**

The following features of SQL 2008 are not supported in Greenplum Database:

1. `BINARY` and `VARBINARY` data types. `BYTEA` can be used in place of `VARBINARY` in Greenplum Database.

2. `FETCH FIRST` or `FETCH NEXT` clause for SELECT, for example:

   ```sql
   SELECT id, name FROM tab1 ORDER BY id OFFSET 20 ROWS FETCH NEXT 10 ROWS ONLY;
   ```

   Greenplum has `LIMIT` and `LIMIT OFFSET` clauses instead.

3. The `ORDER BY` clause is ignored in views and subqueries unless a `LIMIT` clause is also used. This is intentional, as the Greenplum optimizer cannot determine when it is safe to avoid the sort, causing an unexpected performance impact for such `ORDER BY` clauses. To work around, you can specify a really large `LIMIT`. For example: `SELECT * FROM mytable ORDER BY 1 LIMIT 9999999999`

4. The `row subquery` construct is not supported.

5. `TRUNCATE TABLE` does not accept the `CONTINUE IDENTITY` and `RESTART IDENTITY` clauses.

**Greenplum and PostgreSQL Compatibility**

Greenplum Database is based on PostgreSQL 8.3 with additional features from newer PostgreSQL releases. To support the distributed nature and typical workload of a Greenplum Database system, some SQL commands have been added or modified, and there are a few PostgreSQL features that are not supported. Greenplum has also added features not found in PostgreSQL, such as physical data distribution, parallel query optimization, external tables, resource queues, and enhanced table partitioning. For full SQL syntax and references, see the SQL Command Reference.

**Table 246: SQL Support in Greenplum Database**

<table>
<thead>
<tr>
<th>SQL Command</th>
<th>Supported in Greenplum</th>
<th>Modifications, Limitations, Exceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALTER AGGREGATE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER CONVERSION</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER DATABASE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER DOMAIN</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER EXTENSION</td>
<td>YES</td>
<td>Changes the definition of a Greenplum Database extension - based on PostgreSQL 9.6.</td>
</tr>
<tr>
<td>SQL Command</td>
<td>Supported in Greenplum</td>
<td>Modifications, Limitations, Exceptions</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>ALTER FILESPACE</td>
<td>YES</td>
<td>Greenplum Database parallel tablespace feature - not in PostgreSQL 8.3.</td>
</tr>
<tr>
<td>ALTER FUNCTION</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER GROUP</td>
<td>YES</td>
<td>An alias for ALTER ROLE</td>
</tr>
<tr>
<td>ALTER INDEX</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER LANGUAGE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER OPERATOR</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER OPERATOR CLASS</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER OPERATOR FAMILY</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER PROTOCOL</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER RESOURCE QUEUE</td>
<td>YES</td>
<td>Greenplum Database resource management feature - not in PostgreSQL.</td>
</tr>
<tr>
<td>ALTER ROLE</td>
<td>YES</td>
<td>Greenplum Database Clauses: RESOURCE QUEUE queue_name</td>
</tr>
<tr>
<td>ALTER SCHEMA</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER SEQUENCE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER TABLE</td>
<td>YES</td>
<td>Unsupported Clauses / Options: CLUSTER ON ENABLE/DISABLE TRIGGER</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Greenplum Database Clauses: ADD</td>
</tr>
<tr>
<td>ALTER TABLESPACE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER TRIGGER</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>ALTER TYPE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ALTER USER</td>
<td>YES</td>
<td>An alias for ALTER ROLE</td>
</tr>
<tr>
<td>ALTER VIEW</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ANALYZE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>BEGIN</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>SQL Command</td>
<td>Supported in Greenplum</td>
<td>Modifications, Limitations, Exceptions</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>CHECKPOINT</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>CLOSE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>CLUSTER</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>COMMENT</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>COMMIT</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>COMMIT PREPARED</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>COPY</td>
<td>YES</td>
<td>Modified Clauses:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ESCAPE [ AS ] 'escape'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Greenplum Database Clauses:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[LOG ERRORS] SEGMENT REJECT LIMIT count [ROWS</td>
</tr>
<tr>
<td>CREATE AGGREGATE</td>
<td>YES</td>
<td>Unsupported Clauses / Options:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ , SORTOP = sort_operator ]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Greenplum Database Clauses:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ , PREFUNC = prefunc ]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limitations:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The functions used to implement the aggregate must be IMMUTABLE functions.</td>
</tr>
<tr>
<td>CREATE CAST</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>CREATE CONSTRAINT TRIGGER</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>CREATE CONVERSION</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>CREATE DATABASE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>CREATE DOMAIN</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>CREATE EXTENSION</td>
<td>YES</td>
<td>Loads a new extension into Greenplum Database - based on PostgreSQL 9.6.</td>
</tr>
<tr>
<td>CREATE EXTERNAL TABLE</td>
<td>YES</td>
<td>Greenplum Database parallel ETL feature - not in PostgreSQL 8.3.</td>
</tr>
<tr>
<td>SQL Command</td>
<td>Supported in Greenplum</td>
<td>Modifications, Limitations, Exceptions</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>CREATE FUNCTION</td>
<td>YES</td>
<td><strong>Limitations:</strong> Functions defined as <strong>STABLE</strong> or <strong>VOLATILE</strong> can be executed in Greenplum Database provided that they are executed on the master only. <strong>STABLE</strong> and <strong>VOLATILE</strong> functions cannot be used in statements that execute at the segment level.</td>
</tr>
<tr>
<td>CREATE GROUP</td>
<td>YES</td>
<td>An alias for <strong>CREATE ROLE</strong></td>
</tr>
<tr>
<td>CREATE INDEX</td>
<td>YES</td>
<td><strong>Greenplum Database Clauses:</strong> USING bitmap (bitmap indexes) <strong>Limitations:</strong> <strong>UNIQUE</strong> indexes are allowed only if they contain all of (or a superset of) the Greenplum distribution key columns. On partitioned tables, a unique index is only supported within an individual partition - not across all partitions. <strong>CONCURRENTLY</strong> keyword not supported in Greenplum.</td>
</tr>
<tr>
<td>CREATE LANGUAGE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>CREATE OPERATOR</td>
<td>YES</td>
<td><strong>Limitations:</strong> The function used to implement the operator must be an <strong>IMMUTABLE</strong> function.</td>
</tr>
<tr>
<td>CREATE OPERATOR CLASS</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>CREATE OPERATOR FAMILY</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>CREATE PROTOCOL</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>CREATE RESOURCE QUEUE</td>
<td>YES</td>
<td>Greenplum Database resource management feature - not in PostgreSQL 8.3.</td>
</tr>
<tr>
<td>CREATE ROLE</td>
<td>YES</td>
<td><strong>Greenplum Database Clauses:</strong> RESOURCE QUEUE queue_name</td>
</tr>
<tr>
<td>CREATE RULE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>CREATE SCHEMA</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>SQL Command</td>
<td>Supported in Greenplum</td>
<td>Modifications, Limitations, Exceptions</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>CREATE SEQUENCE</td>
<td>YES</td>
<td><strong>Limitations:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The <code>lastval()</code> and <code>currval()</code> functions are not supported.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The <code>setval()</code> function is only allowed in queries that do not operate on distributed data.</td>
</tr>
<tr>
<td>CREATE TABLE</td>
<td>YES</td>
<td><strong>Unsupported Clauses / Options:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>`[GLOBAL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>REFERENCES</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FOREIGN KEY</td>
</tr>
<tr>
<td></td>
<td></td>
<td>`[DEFERRABLE</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Limited Clauses:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>UNIQUE</code> or <code>PRIMARY KEY</code> constraints are only allowed on hash-distributed tables (<code>DISTRIBUTED BY</code>), and the constraint columns must be the same as or a superset of the distribution key columns of the table and must include all the distribution key columns of the partitioning key.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Greenplum Database Clauses:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>`DISTRIBUTED BY (column, [ ... ] )</td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>DISTRIBUTED RANDOMLY</code></td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>PARTITION BY type (column [, ...]) (partition_specification, [...] )</code></td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>WITH (appendonly=true [,compresslevel=value,blocksize=value] )</code></td>
</tr>
<tr>
<td>CREATE TABLE AS</td>
<td>YES</td>
<td>See <code>CREATE TABLE</code></td>
</tr>
<tr>
<td>CREATE TABLESPACE</td>
<td>NO</td>
<td><strong>Greenplum Database Clauses:</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>FILESPACE filespace_name</code></td>
</tr>
<tr>
<td>CREATE TRIGGER</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>SQL Command</td>
<td>Supported in Greenplum</td>
<td>Modifications, Limitations, Exceptions</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>CREATE TYPE</td>
<td>YES</td>
<td>Limitations:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The functions used to implement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>a new base type must be IMMUTABLE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>functions.</td>
</tr>
<tr>
<td>CREATE USER</td>
<td>YES</td>
<td>An alias for <strong>CREATE ROLE</strong></td>
</tr>
<tr>
<td>CREATE VIEW</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DEALLOCATE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DECLARE</td>
<td>YES</td>
<td>Unsupported Clauses / Options:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SCROLL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FOR UPDATE [ OF column [, ...] ]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limitations:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cursors cannot be backward-scrolled.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Forward scrolling is supported.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PL/pgSQL does not have support for</td>
</tr>
<tr>
<td></td>
<td></td>
<td>updatable cursors.</td>
</tr>
<tr>
<td>DELETE</td>
<td>YES</td>
<td>Unsupported Clauses / Options:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RETURNING</td>
</tr>
<tr>
<td>DISCARD</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>YES</td>
<td>PostgreSQL 9.0 feature</td>
</tr>
<tr>
<td>DROP AGGREGATE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP CAST</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP CONVERSION</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP DATABASE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP DOMAIN</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP EXTENSION</td>
<td>YES</td>
<td>Removes an extension from Greenplum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Database – based on PostgreSQL 9.6.</td>
</tr>
<tr>
<td>DROP EXTERNAL TABLE</td>
<td>YES</td>
<td>Greenplum Database parallel ETL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>feature - not in PostgreSQL 8.3.</td>
</tr>
<tr>
<td>DROP FILESPACE</td>
<td>YES</td>
<td>Greenplum Database parallel tablespace</td>
</tr>
<tr>
<td></td>
<td></td>
<td>feature - not in PostgreSQL 8.3.</td>
</tr>
<tr>
<td>DROP FUNCTION</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP GROUP</td>
<td>YES</td>
<td>An alias for <strong>DROP ROLE</strong></td>
</tr>
<tr>
<td>SQL Command</td>
<td>Supported in Greenplum</td>
<td>Modifications, Limitations, Exceptions</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>DROP INDEX</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP LANGUAGE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP OPERATOR</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP OPERATOR CLASS</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP OPERATOR FAMILY</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP OWNED</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>DROP PROTOCOL</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP RESOURCE QUEUE</td>
<td>YES</td>
<td>Greenplum Database resource management feature - not in PostgreSQL 8.3.</td>
</tr>
<tr>
<td>DROP ROLE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP RULE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP SCHEMA</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP SEQUENCE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP TABLE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP TABLESPACE</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>DROP TRIGGER</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>DROP TYPE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>DROP USER</td>
<td>YES</td>
<td>An alias for DROP ROLE</td>
</tr>
<tr>
<td>DROP VIEW</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>END</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>EXECUTE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>EXPLAIN</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>FETCH</td>
<td>YES</td>
<td>Unsupported Clauses / Options:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LAST</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PRIOR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BACKWARD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BACKWARD ALL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limitations:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cannot fetch rows in a nonsequential fashion; backward scan is not supported.</td>
</tr>
<tr>
<td>GRANT</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>SQL Command</td>
<td>Supported in Greenplum</td>
<td>Modifications, Limitations, Exceptions</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>INSERT</td>
<td>YES</td>
<td>Unsupported Clauses / Options: RETURNING</td>
</tr>
<tr>
<td>LISTEN</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>LOAD</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>LOCK</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>MOVE</td>
<td>YES</td>
<td>See FETCH</td>
</tr>
<tr>
<td>NOTIFY</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>PREPARE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>PREPARE TRANSACTION</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>REASSIGN OWNED</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>REINDEX</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>RELEASE SAVEPOINT</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>RESET</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>REVOKE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ROLLBACK</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>ROLLBACK PREPARED</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>ROLLBACK TO SAVEPOINT</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>SAVEPOINT</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>SELECT</td>
<td>YES</td>
<td>Limitations:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limited use of VOLATILE and STABLE functions in FROM or WHERE clauses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Text search (Tsearch2) is not supported</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FETCH FIRST or FETCH NEXT clauses not supported</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Greenplum Database Clauses (OLAP):</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[GROUP BY grouping_element [, ...]]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[WINDOW window_name AS (window_specification)]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[FILTER (WHERE condition)] applied to an aggregate function in the SELECT list</td>
</tr>
<tr>
<td>SELECT INTO</td>
<td>YES</td>
<td>See SELECT</td>
</tr>
<tr>
<td>SQL Command</td>
<td>Supported in Greenplum</td>
<td>Modifications, Limitations, Exceptions</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>SET</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>SET CONSTRAINTS</td>
<td>NO</td>
<td>In PostgreSQL, this only applies to foreign key constraints, which are currently not enforced in Greenplum Database.</td>
</tr>
<tr>
<td>SET ROLE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>SET SESSION AUTHORIZATION</td>
<td>YES</td>
<td>Deprecated as of PostgreSQL 8.1 - see SET ROLE</td>
</tr>
<tr>
<td>SET TRANSACTION</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>SHOW</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>START TRANSACTION</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>TRUNCATE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>UNLISTEN</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>
| UPDATE                  | YES                    | **Unsupported Clauses:**
|                          |                        | RETURNING
|                          |                        | **Limitations:**
|                          |                        | SET not allowed for Greenplum distribution key columns. |
| VACUUM                  | YES                    | **Limitations:**
|                          |                        | VACUUM FULL is not recommended in Greenplum Database. |
| VALUES                  | YES                    |                                        |
Chapter 17

Greenplum Database UNIX Client Documentation

Information and instructions for installing and using client and load tools on UNIX systems.
Greenplum Database Client Tools for UNIX

Utility programs that connect to Greenplum Database from UNIX systems.

Installing the Greenplum Client Tools

This section contains information for installing the client programs on your client machine and for enabling Greenplum Database to accept remote client connections:

- Running the Client Tools Installer
- Configuring the Command-Line Tools
- Enabling Greenplum Database for Remote Client Connections
- Configuring a Client System for Kerberos Authentication
- Next Steps

See the Greenplum Database Release Notes for the list of currently supported platforms for the Client Tools.

Running the Client Tools Installer

The Greenplum Database client tools installer installs the following client tools:

- PostgreSQL Interactive Terminal (psql)
- Greenplum MapReduce Client Program (gpmapreduce)

To install the Greenplum Database client tools

1. Download the appropriate greenplum-clients-<version>-PLATFORM.bin installer package for your platform from Pivotal Network.
2. Unzip the installer:
   ```shell
cd -r
unzip greenplum-clients-<version>-PLATFORM.bin.zip
```
3. Run the installer:
   ```shell
   /bin/bash greenplum-clients-<version>-PLATFORM.bin
   ```
4. The installer will prompt you to accept the license agreement and to provide an installation path. For the installation path, be sure to enter an absolute path if you choose not to accept the default location (for example, /mydir/gp-client-tools). The client tools are installed into greenplum-db-<version> by default.

About Your Installation

Your Greenplum Database client tools installation contains the following files and directories:

- bin — client command-line tools (psql and gpmapreduce)
- greenplum_clients_path.sh — environment variables
- include — libpq C header files
- lib — client tools library files

Configuring the Command-Line Tools

As a convenience, a greenplum_clients_path.sh file is provided in your client tools installation directory following installation. It has the following environment variable settings:

GPHOME_CLIENTS — The installation directory of the Greenplum Database client tools.
PATH — The paths to the command-line utilities.

LD_LIBRARY_PATH — The path to the library files.

You can source this file in your user's startup shell profile (such as .bashrc or .bash_profile).

For example, you could add a line similar to the following to your chosen profile files (making sure the right install path is used):

```
source greenplum-db-<version>/greenplum_clients_path.sh
```

After editing the chosen profile file, source it as the correct user to make the changes active. For example:

```
source ~/.bashrc
```

Additional Connection Environment Variables

The PostgreSQL command-line tools require several connection parameters in order to be able to connect to a Greenplum Database database. In order to save some typing on the command-line, you can create the following environment variables in your preferred profile file (such as .bashrc).

- **PGDATABASE** — The name of the default Greenplum database to connect to.
- **PGHOST** — The Greenplum master host name or IP address.
- **PGPORT** — The port number that the Greenplum master instance (postmaster process) is running on.
- **PGUSER** — The default database role name to use for login.

Enabling Greenplum Database for Remote Client Connections

In order for Greenplum Database to be able to accept remote client connections, you must configure your Greenplum Database master so that connections are allowed from the client hosts and database users that will be connecting to Greenplum Database.

To enable remote client connections

1. Make sure that the pg_hba.conf file of the Greenplum Database master is correctly configured to allow connections from the users to the database(s) using the authentication method you want. For details, see "Editing the pg_hba.conf File" in the Greenplum Database Administration Guide, and also see the Greenplum Database Security Configuration Guide.

   Make sure the authentication method you choose is supported by the client tool you are using.

2. If you edited pg_hba.conf file, the change requires a server reload (using the gpstop -u command) to take effect.

3. Make sure that the databases and roles you are using to connect exist in the system and that the roles have the correct privileges to the database objects.

Configuring a Client System for Kerberos Authentication

If you use Kerberos authentication to connect to a Greenplum Database with the psql utility, your client system must be configured to use Kerberos authentication. If you are not using Kerberos authentication to connect to a Greenplum Database, Kerberos is not needed on your client system.

- **Requirements**
- **Setting Up a Client System with Kerberos Authentication**
- **Accessing Greenplum Database with psql**

For information about enabling Kerberos authentication with Greenplum Database, see the "Kerberos Authentication" chapter in the Greenplum Database Administrator Guide.
Requirements

The following are requirements to connect to a Greenplum Database that is enabled with Kerberos authentication from a client system with Greenplum Database client software.

- Prerequisites
- Required Software on the Client Machine

Prerequisites

- Kerberos must be installed and configured on the Greenplum Database master host. See Enabling Greenplum Database for Remote Client Connections.
- The client systems require the Kerberos configuration file krb5.conf from the Greenplum Database master.
- The client systems require a Kerberos keytab file that contains the authentication credentials for the Greenplum Database user that is used to log into the database.
- The client machines must be able to connect to Greenplum Database master host.

If necessary, add the Greenplum Database master host name and IP address to the system hosts file. On Linux systems, the hosts file is located in /etc.

Required Software on the Client Machine

The Kerberos kinit utility is required on the client machine. The kinit utility is available when you install the Kerberos packages:

- krb5-libs
- krb5-workstation

Note: When you install the Kerberos packages, you can use other Kerberos utilities such as klist to display Kerberos ticket information.

Setting Up a Client System with Kerberos Authentication

To connect to Greenplum Database with Kerberos authentication requires a Kerberos ticket. On client systems, tickets are generated from Kerberos keytab files with the kinit utility and are stored in a cache file.

1. Install a copy of the Kerberos configuration file krb5.conf from the Greenplum Database master. The file is used by the Greenplum Database client software and the Kerberos utilities.

   Install krb5.conf in the /etc directory.

   If needed, add the parameter default_ccache_name to the [libdefaults] section of the krb5.ini file and specify the location of the Kerberos ticket cache file on the client system.

2. Obtain a Kerberos keytab file that contains the authentication credentials for the Greenplum Database user.

3. Run kinit specifying the keytab file to create a ticket on the client machine. For this example, the keytab file gpdb-kerberos.keytab is in the current directory. The ticket cache file is in the gpadmin user home directory. For example:

   $ kinit -k -t gpdb-kerberos.keytab
   -c /home/gpadmin/cache.txt
   gpadmin/kerberos-gpdb@KRB.EXAMPLE.COM

Accessing Greenplum Database with psql

From a remote system, you can access a Greenplum Database that has Kerberos authentication enabled.
To connect to Greenplum Database with psql

1. As the gpadmin user, open a command window.
2. Start psql from the command window and specify a connection to the Greenplum Database specifying the user that is configured with Kerberos authentication.

   The following example logs into the Greenplum Database on the machine kerberos-gpdb as the gpadmin user with the Kerberos credentials gpadmin/kerberos-gpdb:

   $ psql -U "gpadmin/kerberos-gpdb" -h kerberos-gpdb postgres

Next Steps

Refer to the client tool reference documentation for further instructions:

- Greenplum Database SQL Syntax — See SQL Syntax Summary.

Client Tools Reference

This chapter references the client tools provided with this release. They all require certain connection information such as the Greenplum Database master host name, port, database name, and role name. These can be configured using environment variables. See Configuring the Command-Line Tools.

The following tools are provided:

- gpmapreduce (submits Greenplum MapReduce specifications for execution).
- psql (PostgreSQL interactive terminal)

See also the SQL Syntax Summary for a quick reference to available SQL commands.
Greenplum Database Load Tools for UNIX

Programs that load data into Greenplum Database from UNIX systems.

**Installing the Greenplum Load Tools**

This section contains information for installing the Greenplum data loading programs on your client machine and for enabling Greenplum Database to accept remote client connections:

- Running the Load Tools Installer
- Configuring the Command-Line Load Tools
- Enabling Greenplum Database for Remote Client Connections
- Next Steps

See the *Greenplum Database Release Notes* for the list of currently supported platforms for the Load Tools.

**Running the Load Tools Installer**

The Greenplum Database load tools installer installs the following data loading tools:

- Greenplum parallel file distribution program (*gpfdist*)
- Greenplum data loading utility (*gpload*)

**To install the Greenplum Database load tools**

1. Download the appropriate `greenplum-loaders-<version>-PLATFORM.bin.zip` installer package for your platform from *Pivotal Network*.
2. Unzip the installer:
   
   ```
   unzip greenplum-loaders-<version>-PLATFORM.bin.zip
   ```
3. Run the installer:
   
   ```
   /bin/bash greenplum-loaders-<version>-PLATFORM.bin
   ```
4. The installer will prompt you to accept the license agreement and to provide an installation path. For the installation path, be sure to enter an absolute path if you choose not to accept the default location (for example, `/mydir/gp-loader-tools`). The load tools are installed into `greenplum-db-<version>` by default.

**About Your Installation**

Your Greenplum Database load tools installation contains the following files and directories:

- **bin** — data loading command-line tools and library files (*gpfdist* and *gpload*)
- **docs** — documentation files
- **greenplum_loaders_path.sh** — environment variables

**Configuring the Command-Line Load Tools**

As a convenience, a `greenplum_loaders_path.sh` file is provided in your load tools installation directory following installation. It has the following environment variable settings:

- **GREENPLUM_LOADERS_HOME** — The installation directory of the Greenplum Database load tools.
- **PATH** — The path to the data loading command-line utilities.
- **LD_LIBRARY_PATH** — The path to additional Python library files needed for *gpload*. 
You can source this file in your user's startup shell profile (such as .bashrc or .bash_profile).
For example, you could add a line similar to the following to your chosen profile files (making sure the right
install path is used):

```
source greenplum-db-<version>/greenplum_loaders_path.sh
```

After editing the chosen profile file, source it as the correct user to make the changes active. For example:

```
source ~/.bashrc
```

**Additional Connection Environment Variables**

The Greenplum load tools require several connection parameters in order to be able to connect to a
Greenplum Database instance. In order to save some typing on the command-line, you can create the
following environment variables in your preferred profile file (such as .bashrc).

- **PGDATABASE** — The name of the default Greenplum database to connect to.
- **PGHOST** — The Greenplum master host name or IP address.
- **PGPORT** — The port number that the Greenplum master instance is running on.
- **PGUSER** — The default database role name to use for login.

**Enabling Greenplum Database for Remote Client Connections**

In order for Greenplum Database to be able to accept remote client connections, you must configure your
Greenplum Database master so that connections are allowed from the client hosts and database users that
will be connecting to Greenplum Database.

**To enable remote client connections**

1. Make sure that the pg_hba.conf file of the Greenplum Database master is correctly configured to
   allow connections from the users to the database(s) using the authentication method you want. For
details, see "Editing the pg_hba.conf File" in the Greenplum Database Administration Guide, and also
see the Greenplum Database Security Configuration Guide.
   Make sure the authentication method you choose is supported by the client tool you are using.
2. If you edited pg_hba.conf file, the change requires a server reload (using the gpstop -u command)
to take effect.
3. Make sure that the databases and roles you are using to connect exist in the system and that the roles
have the correct privileges to the database objects.

**Next Steps**

Refer to the load tool reference documentation for further instructions:

- Greenplum Database SQL Syntax — See SQL Syntax Summary.

**Load Tools Reference**

This chapter describes the data loading tools provided with this release. They all require certain connection
information such as the Greenplum Database master host name, port, database name, and role name.
These can be configured using environment variables. For more information, see Configuring the
Command-Line Load Tools.

The following tools are provided:

- Greenplum parallel file distribution program (\texttt{gpfdist})
- Greenplum data loading utility (\texttt{gpload})
See also the *SQL Syntax Summary* for a quick reference to available SQL commands.
Chapter 18

Greenplum Database Windows Client Documentation

Information and instructions for installing and using client and load tools on Microsoft Windows systems.
Greenplum Database Client Tools for Windows

Utility programs that connect to Greenplum Database from Microsoft Windows systems.

**Installing the Greenplum Client Tools**

This section contains information for installing the various client programs on your Windows machine and for enabling Greenplum Database to accept remote client connections:

- Running the Client Tools Installer
- Configuring the Client Tools
- Enabling Greenplum Database for Remote Client Connections
- Configuring a Client System for Kerberos Authentication

See the *Greenplum Database Release Notes* for the list of currently supported platforms for the Client Tools.

**Running the Client Tools Installer**

The Greenplum Database client tools installer installs `psql.exe`, the interactive command-line client interface to Greenplum Database.

**To install the Greenplum Database client tools**

1. Download the `greenplum-clients-<version>-WinXP-x86_32.msi` package from Pivotal Network.
2. Double-click on the `greenplum-clients-<version>-WinXP-x86_32.msi` package to launch the installer.
3. Click Next on the Welcome screen.
4. Click I Agree on the License Agreement screen.
5. By default, the Greenplum Database client tools will be installed into `greenplum-db-<version>`. Click Browse if you want to choose another location.
6. Click Next when you have chosen the install path you want.
7. Click Install to begin the installation.
8. Click Finish to exit the installer.

**About Your Installation**

Your Greenplum Database client tools installation contains the following files and directories:

- **bin** — client tools programs
- **greenplum_clients_path.bat** — sets environment variables
- **lib** — client tools library files

**Configuring the Client Tools**

Greenplum provides a batch program (`greenplum_clients_path.bat`) to set the required environment settings for Greenplum loader (located in `greenplum-db-<version>` by default).

**To set the required environment settings**

1. Open a Windows command prompt (Start > Run and type cmd).
2. At the command prompt, go to the directory where you installed Greenplum loader. For example:

   ```
   cd "Program Files"\Greenplum\greenplum-clients-<version>
   ```
3. Execute the `greenplum_loaders_path.bat` program:

```
 greenplum_clients_path.bat
```

The PostgreSQL command-line tools also require several connection parameters in order to be able to connect to a Greenplum database. In order to save some typing on the command-line, you can optionally create the following environment variables in your Windows Control Panel.

- **PGDATABASE** — The name of the default Greenplum database to connect to.
- **PGHOST** — The Greenplum Database master host name or IP address.
- **PGPORT** — The port number that the Greenplum master instance (postmaster process) is running on.
- **PGUSER** — The default database role name to use for login.

### To add a new user environment variable on Windows XP

1. In Windows Explorer, go to `C:\\Control Panel`.
2. Double-click the **System** icon.
3. On the **Advanced** tab, click **Environment Variables** (bottom).
4. Click **New**.
5. Define the new environment variable. For example:

```
6. Click OK.
```

### Enabling Greenplum Database for Remote Client Connections

In order for Greenplum Database to be able to accept remote client connections, you must configure your Greenplum Database master so that connections are allowed from the client hosts and database users that will be connecting to Greenplum Database.

#### To enable remote client connections

1. Make sure that the `pg_hba.conf` file of the Greenplum Database master is correctly configured to allow connections from the users to the database(s) using the authentication method you want. For details, see “Editing the pg_hba.conf File” in the *Greenplum Database Administration Guide*, and also see the *Greenplum Database Security Configuration Guide*.

   Make sure the authentication method you choose is supported by the client tool you are using.

2. If you edited `pg_hba.conf` file, the change requires a server reload (using the `gpstop -u` command) to take effect.

3. Make sure that the databases and roles you are using to connect exist in the system and that the roles have the correct privileges to the database objects.

### Configuring a Client System for Kerberos Authentication

If you use Kerberos authentication to connect to your Greenplum Database with the `psql` utility, your client system must be configured to use Kerberos authentication. If you are not using Kerberos authentication to connect to a Greenplum Database, Kerberos is not needed on your client system.

- **Requirements**
- **Setting Up a Client System with Kerberos Authentication**
- **Accessing Greenplum Database with psql**

For information about enabling Kerberos authentication with Greenplum Database, see the chapter "Kerberos Authentication" in the *Greenplum Database Administrator Guide*. 
Requirements
The following are requirements to connect to a Greenplum Database that is enabled with Kerberos authentication from a client system with Greenplum Database client software.

- Prerequisites
- Required Software on the Client Machine

Prerequisites
- Kerberos must be installed and configured on the Greenplum Database master host. See "Enabling Greenplum Database for Remote Client Connections."
- The client systems require the Kerberos configuration file krb5.conf from the Greenplum Database master.
- The client systems require a Kerberos keytab file that contains the authentication credentials for the Greenplum Database user that is used to log into the database.
- The client machines must be able to connect to Greenplum Database master host.

If necessary, add the Greenplum Database master host name and IP address to the system hosts file. On Windows 7 systems, the hosts file is located in `C:\Windows\System32\drivers\etc\`

Required Software on the Client Machine

Note: When you install the Kerberos software, you can use other Kerberos utilities such as klist to display Kerberos ticket information.

Setting Up a Client System with Kerberos Authentication
To connect to Greenplum Database with Kerberos authentication requires a Kerberos ticket. On client systems, tickets are generated from Kerberos keytab files with the kinit utility and are stored in a cache file.

1. Install a copy of the Kerberos configuration file krb5.conf from the Greenplum Database master. The file is used by the Greenplum Database client software and the Kerberos utilities.

   Rename krb5.conf to krb5.ini and move it to the Windows directory. On Windows 7, the Windows directory is `C:\Windows`.

   If needed, add the parameter default_ccache_name to the [libdefaults] section of the krb5.ini file and specify the location of the Kerberos ticket cache file on the client system.

2. Obtain a Kerberos keytab file that contains the authentication credentials for the Greenplum Database user.

3. Run kinit specifying the keytab file to create a ticket on the client machine. For the following example, the keytab file gpdb-kerberos.keytab is in the current directory. The ticket cache file is in the gpadmin user home directory.

   ```
   > kinit -k -t gpdb-kerberos.keytab
   -c C:\Users\gpadmin\cache.txt
   gpadmin/kerberos-gpdb@KRB.EXAMPLE.COM
   ```

Accessing Greenplum Database with psql
From a remote system, you can access a Greenplum Database that has Kerberos authentication enabled.

1. As the gpadmin user, open a command window.
2. Run the client tool batch file from command window `greenplum_clients_path.bat`

   Change the current directory to the `bin` directory of the Kerberos for Windows installation. For example:
   
   ```
   > cd C:\test\MIT\Kerberos\bin
   ```

3. Start `psql` from the command window and specify a connection to the Greenplum Database specifying the user that is configured with Kerberos authentication.

   The following example logs into the Greenplum Database on the machine `keberos-gpdb` as the `gpadmin` user with the Kerberos credentials `gpadmin/kerberos-gpdb`:
   
   ```
   > psql -U "gpadmin/kerberos-gpdb" -h kerberos-gpdb template1
   ```

For information about running `psql`, see "Running the Greenplum Client Tools."

**Running the Greenplum Client Tools**

This section contains information for connecting to Greenplum Database using the `psql.exe` command-line client tool.

**Connecting to Greenplum Database**

Users and administrators always connect to Greenplum Database through the master host. In order to establish a connection to the Greenplum Database master, you will need to know the following connection information and configure your client program accordingly. See Configuring the Client Tools for more information.

**Table 247: Connection Parameters**

<table>
<thead>
<tr>
<th>Connection Parameter</th>
<th>Description</th>
<th>Environment Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Database name</td>
<td>The name of the database to which you want to connect. For a newly initialized system, use the <code>postgres</code> database to connect for the first time.</td>
<td>$PGDATABASE</td>
</tr>
<tr>
<td>Host name</td>
<td>The host name of the Greenplum Database master. The default host is the local host.</td>
<td>$PGHOST</td>
</tr>
<tr>
<td>Port</td>
<td>The port number that the Greenplum Database master instance is running on. The default is 5432.</td>
<td>$PGPORT</td>
</tr>
</tbody>
</table>
### Connection Parameter Description Environment Variable

| User name | The database user (role) name to connect as. This is not necessarily the same as your OS user name. Check with your Greenplum administrator if you are not sure what you database user name is. Note that every Greenplum Database system has one superuser account that is created automatically at initialization time. This account has the same name as the OS name of the user who initialized the Greenplum system (typically gpadmin). | $PGUSER |

---

**Running psql.exe**

The `psql.exe` program is invoked from a Windows command-line session. For complete command syntax and options for `psql.exe`, see `psql.exe`.

Depending on the default values used or the environment variables you have set, the following examples show how to access a database in Greenplum Database via `psql`:

```bash
$ psql.exe -d gpdatabase -h master_host -p 5432 -U gpadmin
$ psql.exe gpdatabase
$ psql.exe
```

If a user-defined database has not yet been created, you can access the system by connecting to the `postgres` database. For example:

```bash
$ psql.exe postgres
```

After connecting to a database, `psql` provides a prompt with the name of the database to which `psql` is currently connected, followed by the string `=>` (or `##` if you are the database superuser). For example:

```bash
gpdatabase=>
```

At the prompt, you may type in SQL commands. A SQL command must end with a `;` (semicolon) in order to be sent to the server and executed. For example:

```bash
=> SELECT count(*) FROM mytable;
```

For more information on using the `psql.exe` client application, see `psql.exe`. For more information on SQL commands and syntax, see *SQL Syntax Summary*.

**Client Tools Reference**

This is a reference of the command-line client tools provided with this release. All of these tools can be run from a Windows console session (`cmd`) or a command-line utility such as Cygwin. They all require certain connection information such as the Greenplum master host name, port, database name, and role name. These can be configured using environment variables. For more information, see *Configuring the Client Tools*.
The following tools are provided:

- `psql.exe` (PostgreSQL interactive terminal)

See also the *SQL Syntax Summary* for a quick reference to available SQL commands.
Greenplum Database Load Tools for Windows

Programs that load data into Greenplum Database from Microsoft Windows systems.

**Installing Greenplum Loader**

This section contains information for installing the Greenplum data loading programs on your Windows machine and for enabling Greenplum Database to accept remote client connections:

- Installing Python
- Running the Loader Installer
- Configuring Greenplum Loader
- Enabling Greenplum Database for Remote Client Connections

See the *Greenplum Database Release Notes* for the list of currently supported platforms for the Load Tools.

**Installing Python**

The Greenplum loader program (*gpload.py*) for Windows requires Python 2.5.4 (32-bit version) to also be installed on your machine. If you do not have an installation of Python, you can get one from [https://www.python.org](https://www.python.org).

**Note:** The 64-bit version of Python is not compatible with the Greenplum loader program for Windows.

**To install Python**

1. Download the Python 2.5.4 installer for Windows from [https://www.python.org/downloads/](https://www.python.org/downloads/).
2. Locate, then double-click on the `python Load Tools for Windows-2.5.4.x.msi` package to launch the installer.
3. Select **Install for all users** and click **Next**.
4. By default, Python will be installed into `C:\Pythonxx`. Click **Up** or **New** if you want to choose another location. Click **Next**.
5. Click **Next** to install the selected Python components.
6. Click **Finish** to complete your installation.

**Running the Loader Installer**

The Greenplum loader installer installs the following loader programs:

- *gpload.py* (loader program)
- *gpfdist.exe* (parallel file distribution program used by *gpload.py*)

**To install Greenplum loader**

1. Download the `greenplum-clients-<version>-WinXP-x86_32.msi` package from Pivotal Network.
2. Double-click on the `greenplum-clients-<version>-WinXP-x86_32.msi` package to launch the installer.
3. Click **Next** on the Welcome screen.
4. Click **I Agree** on the License Agreement screen.
5. By default, Greenplum loader will be installed into `greenplum-db-<version>`. Click **Browse** to choose another location.
6. Click **Next**.
7. Click **Install** to begin the installation.
8. Click **Finish** to exit the installer.

### About Your Installation

Your Greenplum loader installation contains the following files and directories:

- **bin** — loader command-line utilities (gpload.py and gpfdist.exe)
- **bin/lib** — additional Python libraries needed by gpload.py
- **greenplum_loaders_path.bat** — sets the required environment variables

### Configuring Greenplum Loader

Greenplum provides a batch program (**greenplum_loaders_path.bat**) to set the required environment settings for Greenplum loader (located in `greenplum-db-<version>` by default).

#### To set the required environment settings

1. Open a Windows command prompt (Start > Run and type cmd).
2. At the command prompt, go to the directory where you installed Greenplum loader. For example:
   ```
   cd "Program Files\Greenplum\greenplum-loaders-<version>\dir
   dir
   ```
3. Execute the **greenplum_loaders_path.bat** program:
   ```
   greenplum_loaders_path.bat
   ```
4. Verify that you can execute the **gpload.py** program:
   ```
   gpload.py -?
   ```

The loader command-line tools also require several connection parameters in order to be able to connect to a Greenplum database. In order to save some typing on the command-line, you can optionally create the following environment variables in your Windows Control Panel.

- **PGDATABASE** — The name of the default Greenplum database to connect to.
- **PGHOST** — The Greenplum Database master host name or IP address.
- **PGPORT** — The port number that the Greenplum master instance (postmaster process) is running on.
- **PGUSER** — The default database role name to use for login.

#### To add a new user environment variable on Windows XP

1. In Windows Explorer, go to `C:\Control Panel`.
2. Double-click the **System** icon.
3. On the Advanced tab, click **Environment Variables** (bottom).
4. Click **New**.
5. Define the new environment variable. For example:

6. Click **OK**.

### Enabling Greenplum Database for Remote Client Connections

In order for Greenplum Database to be able to accept remote client connections, you must configure your Greenplum Database master so that connections are allowed from the client hosts and database users that will be connecting to Greenplum Database.
To enable remote client connections

1. Make sure that the pg_hba.conf file of the Greenplum Database master is correctly configured to allow connections from the users to the database(s) using the authentication method you want. For details, see "Editing the pg_hba.conf File" in the Greenplum Database Administration Guide, and also see the Greenplum Database Security Configuration Guide.

Make sure the authentication method you choose is supported by the client tool you are using.

2. If you edited pg_hba.conf file, the change requires a server reload (using the gpstop -u command) to take effect.

3. Make sure that the databases and roles you are using to connect exist in the system and that the roles have the correct privileges to the database objects.

Running Greenplum Loader

This section contains information for defining a load job and running the Greenplum loader program (gpload.py).

- Before You Begin
- Creating the Load Control File
- Formatting the Input Data
- Running Greenplum Loader
- Greenplum Loader Log Files
- Updating Database Statistics After Data Loads
- Vacuuming the Database After Load Errors

Before You Begin

Before you can run Greenplum loader:

1. Make sure you have installed and configured Python and the Greenplum loader programs. See Installing Greenplum Loader.

2. Make sure that you have network access to and from all hosts in your Greenplum Database array (master and segments), and to and from the hosts where the data to be loaded resides (if not on the local machine).

3. Make sure that the ports you declare in your load control file are unblocked by your Windows firewall.

4. Make sure your Greenplum Database system is up and running and that you know all of the connection information (host name, port, role name, database name, etc.).

5. Create your database, schema, and table structures in Greenplum Database prior to loading data.

6. Prepare your data so that it is in a format acceptable by Greenplum loader. See Formatting the Input Data.

7. Write your control file. The control file specifies the source data, load rules, and target table for loading the data. See Creating the Load Control File.

Creating the Load Control File

Before you can run Greenplum loader (gpload.py), you must create a text file that contains the load specification information. This file must be in valid YAML 1.1 document format and use the Greenplum schema for defining the various steps of a load operation. See gpload.py for details on the correct control file format and schema.

Here is an example of a load control file:

```yaml
---
VERSION: 1.0.0.1
DATABASE: ops
USER: gpadmin
```
HOST: mdw-1
PORT: 5432
GPLOAD:
  INPUT:
    - SOURCE:
      LOCAL_HOSTNAME:
      - etl1-1
      - etl1-2
      - etl1-3
      - etl1-4
      PORT: 8081
      FILE:
        - /var/load/data/*
    - COLUMNS:
      - name: text
      - amount: float4
      - category: text
      - desc: text
      - date: date
    - FORMAT: text
    - DELIMITER: '|' 
    - ERROR_LIMIT: 25
    - ERROR_TABLE: payables.err_expenses
  OUTPUT:
    - TABLE: payables.expenses
    - MODE: INSERT
  SQL:
    - BEFORE: "INSERT INTO audit VALUES('start', current_timestamp)"
    - AFTER: "INSERT INTO audit VALUES('end', current_timestamp)"

Formatting the Input Data

When you use Greenplum loader, you need to specify how your data is formatted. Data can be in either delimited text (TEXT) or comma separated values (CSV) format. External data must be formatted correctly in order to be read by Greenplum Database. This section explains the format of data files expected by Greenplum Database.

- Formatting Rows
- Formatting Columns
- Representing NULL Values
- Escaping
- Character Encoding

Formatting Rows

Greenplum Database expects rows of data to be separated by the LF character (Line feed, 0x0A), CR (Carriage return, 0x0D), or CR followed by LF (CR+LF, 0x0D 0x0A). LF is the standard newline representation on UNIX or UNIX-like operating systems. Other operating systems (such as Windows or Mac OS 9) may use CR individually, or CR+LF. All of these representations of a newline are supported by Greenplum Database as a row delimiter.

Formatting Columns

The default column or field delimiter is the horizontal TAB character (0x09) for text files and the comma character (0x2C) for CSV files. However, it is possible to declare another single character delimiter using the DELIMITER attribute in the load configuration file. The delimiter character must only appear between
any two data value fields. Do not place a delimiter at the beginning or end of a row. For example, if using
the pipe character (|) as your delimiter:

| data value 1 | data value 2 | data value 3 |

**Representing NULL Values**

**NULL** is the value used to represent an unknown piece of data in a column or field. Within your data files
you can designate a string to represent null values. The default string is \N (backslash-N) in **TEXT** mode,
or an empty value with no quotations in **CSV** mode. You can also declare a different string using the **NULL**
attribute in the load configuration file. For example, you might prefer an empty string for cases where you
do not want to distinguish nulls from empty strings. When using the Greenplum Database loading tools,
any data item that matches the designated null string will be considered a null value.

**Escaping**

The data file has two reserved characters that have special meaning to Greenplum Database:

- The designated delimiter character, which is used to separate columns or fields in the data file.
- The newline character used to designate a new row in the data file.

If your data contains either of these characters, you must escape the character so Greenplum treats it as
data and not as a field separator or new row. By default, the escape character is a backslash (\) for text-
formatted files and a double quote ("") for csv-formatted files.

**Escaping in Text Formatted Files**

By default, the escape character is a backslash (\) for text-formatted files. If you want to use a different
escape character, use the **ESCAPE** attribute in the load configuration file. In cases where your selected
escape character is present in your data, you can use it to escape itself.

For example, suppose you have a table with three columns and you want to load the following three fields:

- **backslash** = \  
- **vertical bar** = |  
- **exclamation point** = !

Your designated delimiter character is pipe (|), and your designated escape character is backslash (\).  
The formatted row in your data file would look like this:

```
backslash = \\ | vertical bar = \| | exclamation point = !
```

Notice how the backslash character that is part of the data is escaped with another backslash character,
and the pipe character that is part of the data is escaped with a backslash character.

The escape character can also be used to escape octal and hexadecimal sequences. When used in
this way, the escaped value will get converted to the equivalent character when loaded into Greenplum
Database. For example, to load the ampersand character (&), you could use the escape character to
escape its equivalent hexadecimal (0x26) or octal (046) representation.

If there is no need to escape the data in text-formatted files, you can disable escaping using the **ESCAPE**
clause of the **COPY** and **CREATE EXTERNALTABLE** commands or the **ESCAPE** attribute of the load control
file for **gpload.py** as follows:

```
ESCAPE 'OFF'
```

This is useful for input data that contains a lot of backslash characters within the data itself (such as web
log data).
**Escaping in CSV Formatted Files**

By default, the escape character is a double quote ("), for CSV-formatted files. If you want to use a different escape character, use the `ESCAPE` clause of `COPY` and `CREATE EXTERNALTABLE` commands or the `ESCAPE` attribute of the load control file for `gpload.py` to declare a different escape character. In cases where your selected escape character is present in your data, you can use it to escape itself.

For example, suppose you have a table with three columns and you want to load the following three fields:

- Free trip to A,B
- 5.89
- Special rate "1.79"

Your designated delimiter character is comma (,), and your designated escape character is double quote (""). The formatted row in your data file would look like this:

```
"Free trip to A,B" ,"5.89" ,"Special rate ""1.79""
```

Notice how for the comma character that is part of the data, the entire data value is enclosed in double quotes. Also notice how the double quotes that are part of the data are also escaped with a double quote even though the field value is enclosed in double quotes.

Embedding the entire field inside a set of double quotes also guarantees preservation of leading and trailing whitespace characters:

```
"Free trip to A,B " ,"5.89 " ,"Special rate ""1.79" "
```

**Character Encoding**

A character encoding system consists of a code that pairs each character from a given repertoire with something else, such as a sequence of numbers or octets, in order to facilitate the transmission and storage of data. The character set support in Greenplum Database allows you to store text in a variety of character sets, including single-byte character sets such as the ISO 8859 series and multiple-byte character sets such as EUC (Extended UNIX Code), UTF-8, and Mule internal code. All supported character sets can be used transparently by clients, but a few are not supported for use within the server (that is, as a server-side encoding).

Data files must be in a character encoding recognized by Greenplum Database. See the [Greenplum Database Reference Guide](https://www.greenplum.org/docs enrichment-site/v1.5) for the supported character sets. Data files that contain invalid or unsupported encoding sequences will encounter errors when loading into Greenplum Database.

**Note:** On data files generated on a Microsoft Windows operating system, try running the `dos2unix` system command to remove any Windows-only characters prior to loading into Greenplum Database.

**Running Greenplum Loader**

Greenplum loader is invoked by running the `gpload.py` program from a Windows command-line session. For complete command syntax and options, see `gpload.py`.

**Greenplum Loader Log Files**

By default, `gpload.py` creates a directory called `gpAdminLogs` in the same location from where you execute the program and writes its log files there. Alternatively, you can use the `-l` option when executing `gpload.py` to direct the log output to a different location. See `gpload.py` for the format of these log files.
Updating Database Statistics After Data Loads

After loading data, always run the `ANALYZE` SQL command to update the database statistics used by the query planner. `ANALYZE` collects statistics about the contents of tables in the database, and stores the results in the system table `pg_statistic`. The query planner uses these statistics to help determine the most efficient execution plans for queries. For example, to collect statistics on a newly loaded table, run the following on the Greenplum master host:

```bash
psql dbname -c 'ANALYZE mytable;'
```

Vacuuming the Database After Load Errors

The Greenplum loader will stop a load operation if it encounters an error. When this happens, the target table may already have received earlier rows in the load operation. Although these rows will not be visible or accessible, they still occupy disk space. This may amount to a considerable amount of wasted disk space if the failure happened well into a large load operation. You may wish to invoke the `VACUUM` command to recover the wasted space. For example, run the following command on the master host after a load error:

```bash
vacuumdb dbname [table_name]
```

`VACUUM` reclaims storage occupied by deleted tuples. In normal operation, tuples that are deleted or obsoleted by an update are not physically removed from their table; they remain present until a `VACUUM` is done. Therefore it's recommended to do `VACUUM` periodically, especially on frequently-updated tables.

Running `gpfdist` as a Windows Service

Greenplum Database Loaders allow `gpfdist` to run as a Windows Service.

Follow the instructions below to download, register and activate `gpfdist` as a service:

1. Update your Greenplum Database Loader package to the latest version. This package is available from Pivotal Network.
2. Register `gpfdist` as a Windows service:
   a. Open a Windows command window
   b. Run the following command:

```bash
sc create gpfdist binpath= "path_to_gpfdist.exe -p 8081 -d External\load \files\path -l Log\file\path"
```

You can create multiple instances of `gpfdist` by running the same command again, with a unique name and port number for each instance:

```bash
sc create gpfdistN binpath= "path_to_gpfdist.exe -p 8082 -d External \load\files\path -l Log\file\path"
```

3. Activate the `gpfdist` service:
   a. Open the Windows Control Panel and select Administrative Tools > Services.
   b. Highlight then right-click on the `gpfdist` service in the list of services.
   c. Select Properties from the right-click menu, the Service Properties window opens.
      Note that you can also stop this service from the Service Properties window.
   d. Optional: Change the `Startup Type` to Automatic (after a system restart, this service will be running), then under `Service` status, click `Start`.
   e. Click OK.
Repeat the above steps for each instance of `gpfdist` that you created.

**Loader Program Reference**

This is a reference of the command-line loader programs. These programs can be run from a Windows console session (cmd) or a command-line utility such as Cygwin. They all require certain connection information such as the Greenplum master host name, port, database name, and role name. These can be configured using environment variables. For more information, see *Configuring Greenplum Loader*.

The following loader programs are provided:

- `gpload.py` (loader program)
- `gpfdist.exe` (parallel file distribution program used by `gpload.py`)

See also the *SQL Syntax Summary* for a quick reference to available SQL commands.
Chapter 19

**DataDirect ODBC Drivers for Pivotal Greenplum**

ODBC drivers enable third party applications to connect via a common interface to the Pivotal Greenplum Database system. This document describes how to install DataDirect Connect XE for ODBC drivers for Pivotal Greenplum on either a Linux or Windows system. Unless specified otherwise, references to DataDirect Connect XE for ODBC refer to DataDirect Connect XE for ODBC and DataDirect Connect64 XE for ODBC.

The DataDirect ODBC Drivers for Pivotal Greenplum are available for download from *Pivotal Network*. 
Prerequisites

- Install KornShell (ksh) on your system if it is not available.
- Note the appropriate serial number and license key (use the same number for both the serial number and license key during the installation):

<table>
<thead>
<tr>
<th>Driver</th>
<th>Serial Number / License Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>DataDirect Connect XE for ODBC 7.1 drivers (32-bit drivers)</td>
<td>1076681728</td>
</tr>
<tr>
<td>DataDirect Connect64 XE for ODBC 7.1 drivers (64-bit drivers)</td>
<td>1076681984</td>
</tr>
</tbody>
</table>
Supported Client Platforms

DataDirect Connect64 XE for ODBC drivers for Greenplum support the following 64-bit client platforms:

- AIX 64: 7.1, 7.0, 6.1, 5.3 Fixpack 5 or higher
- HP-UX IPF: 11i v3 (B.11.3X), 11i v2 (B.11.23)
- Linux Itanium: Red Hat Enterprise Linux (RHEL) 7.x, RHEL 6.x, RHEL 5.x, RHEL 4.x
- Linux x64: Red Hat Enterprise Linux (RHEL)/CentOS 7.x, 6.x, 5.x, 4.x, SUSE Linux Enterprise Server (SLES) 12, 11, 10
- Solaris on SPARC: 11 and 11 Express (Solaris 5.11), 10 (Solaris 5.10), 9 (Solaris 5.9), 8 (Solaris 5.8)
- Solaris x64: 11 (Solaris 5.11), 10 (Solaris 5.10)

DataDirect Connect XE for ODBC drivers for Greenplum support the following 32-bit client platforms:

- AIX 32: 7.1, 7.0, 6.1, 5.3 Fixpack 5 or higher
- HP-UX IPF: 11i v3 (B.11.3X), 11i v2 (B.11.23)
- HP-UX PA-RISC: 11i v3 (B.11.3X), 11i v2 (B.11.23) 11i v1 (B.11.11), 11
- Linux x86: Red Hat Enterprise Linux (RHEL)/CentOS 7.x, 6.x, 5.x, 4.x, SUSE Linux Enterprise Server (SLES) 11, SLES 10
- Solaris on SPARC: 11 and 11 Express (Solaris 5.11), 10 (Solaris 5.10), 9 (Solaris 5.9), 8 (Solaris 5.8)
Installing on Linux Systems

To install ODBC drivers on your client:

1. Log into Pivotal Network and download the correct ODBC driver for your operating system. The following Linux and UNIX files are available:

   - PROGRESS_DATADIRECT_CONNECT64_ODBC_7.1.6.HOTFIX_LINUX_64.tar.Z
   - PROGRESS_DATADIRECT_CONNECT_ODBC_7.1.6.HOTFIX_LINUX_32.tar.Z
   - PROGRESS_DATADIRECT_CONNECT64_ODBC_7.1.6.HOTFIX_AIX_64.tar.Z
   - PROGRESS_DATADIRECT_CONNECT_ODBC_7.1.6.HOTFIX_AIX_32.tar.Z

2. Unpack the files. For example:

   ```
   $ tar -zxvf PROGRESS_DATADIRECT_CONNECT64_ODBC_7.1.6.HOTFIX_LINUX_64.tar.Z
   ```

   The files are extracted to the current directory.

3. Execute the installer:

   ```
   $ ksh unixmi.ksh
   Progress DataDirect Connect for ODBC Setup is preparing....
   English has been set as the installation language.
   Log file : /tmp/logfile.492.1
   ---------------------------------------------------------------------
   Progress DataDirect Connect (R) and Connect XE for ODBC 7.1 SP5
   for UNIX operating systems
   ---------------------------------------------------------------------
   The following operating system has been detected:
   LinuxX64
   Is this the current operating system on your machine (Y/N) ?
   ```

4. Press Y to confirm your operating system. The installer displays the license agreement.

5. Enter YES to accept the End User License Agreement. The installer prompts you for registration information:

   ```
   Enter YES to accept the above agreement : YES
   Please enter the following information for proper registration.
   In the Key field, enter either EVAL or the Key provided.
   Name : 
   ```

6. Enter the required registration information at each prompt:

<table>
<thead>
<tr>
<th>Prompt</th>
<th>Enter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
<td>Name to associate with the registration.</td>
</tr>
<tr>
<td>Company:</td>
<td>Your company name.</td>
</tr>
</tbody>
</table>
   | Serial Number:  | • 1076681984 for 64-bit driver, or
   |                 | • 1076681728 for 32-bit driver.                                     |
   | Key:            | • 1076681984 for 64-bit driver, or
   |                 | • 1076681728 for 32-bit driver.                                     |
The installation program displays the registered driver information. For example:

- You have chosen the Greenplum Wire Protocol driver.
- Server Unlimited
- Unlimited Connections

To change this information, enter C. Otherwise, press Enter to continue.

7. Press Enter to continue with the installation. The installer prompts you for a temporary directory:

DataDirect Connect for ODBC Setup is preparing the installation.
Choose a temporary directory.
Enter the full path to the temporary install directory.[/tmp]:

8. Press Enter to accept the default /tmp directory or enter a custom directory to store temporary files. The installer extracts temporary files and prompts you for an installation directory:

Checking for available space...

There is enough space.
Extracting files...

Choose a destination directory.
Enter the full path to the install directory.[/opt/Progress/DataDirect/Connect64_for_ODBC_71]:

9. Press Enter to accept the default directory or enter a custom destination directory. The installer checks for available space and installs the software:

Checking for available space...

There is enough space.
Extracting files...

Creating license file......

DataDirect Connect for ODBC Setup successfully removed all of the temporary files.

Thank you for using Progress DataDirect products under OEM license to Greenplum Inc.

Would you like to install another product (Y/N) ? [Y]

10. Enter N to exit the installer.

**Configuring the Driver on Linux**

After you install the driver software, perform these steps to configure the driver.

1. Change to the installation directory for your driver. For example:

   $ cd /opt/Progress/DataDirect/Connect64_for_ODBC_71/

2. Set the **LD_LIBRARY_PATH**, **ODBCINI** and **ODBCINST** environment variables with the command:

   $ source odbc.sh
3. Open the `odbc.ini` file and create a new DSN entry. You can use the existing “Greenplum Wire Protocol” entry as a template.

```shell
$ vi $ODBCINI
```

You must edit the following entries to add values that match your system:

<table>
<thead>
<tr>
<th>Entry</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Database</td>
<td>Pivotal Greenplum database name.</td>
</tr>
<tr>
<td>HostName</td>
<td>Master host name.</td>
</tr>
<tr>
<td>PortNumber</td>
<td>Master host port number.</td>
</tr>
<tr>
<td>LogonID</td>
<td>Greenplum Database user.</td>
</tr>
<tr>
<td>Password</td>
<td>Password.</td>
</tr>
</tbody>
</table>

4. Verify the driver version:

```shell
$ cd /opt/Progress/DataDirect/Connect64_for_ODBC_71/bin
$ ./ddtestlib ddgplm27.so
Load of ddgplm27.so successful, qehandle is 0x19B4C60
File version: 07.16.0270 (B00357, U0237)
```

### Testing the Driver Connection on Linux

To test the DSN connection:

1. Execute the example utility to test the DSN connection, entering the Greenplum Wire Protocol data source name and the credentials of a Pivotal Greenplum user. For example:

```shell
$ cd /opt/Progress/DataDirect/Connect64_for_ODBC_71/samples/example
$ ./example
./example DataDirect Technologies, Inc. ODBC Example Application.
Enter the data source name : Greenplum Wire Protocol
Enter the user name : gpadmin
Enter the password : gpadmin

Enter SQL statements (Press ENTER to QUIT)
SQL>
```

2. Enter the following select statement to confirm database connectivity:

```sql
Enter SQL statements (Press ENTER to QUIT)
SQL> select version();
version
PostgreSQL 8.3.23 (Greenplum Database 5.0.0 build commit:8c709516061cffe5476c03d6e2da99ae42722ae1) on x86_64-pc-linux-gnu, compiled by GCC gcc (GCC) 6.2.0 compiled on Sep 1 2017-22:39:53

Enter SQL statements (Press ENTER to QUIT)
SQL>
```

3. Press the ENTER key to exit the example application.
Installing on Windows Systems

To install ODBC drivers on your client:

1. Log into Pivotal Network and download the correct ODBC driver for your operating system (32-bit or 64-bit). The following Windows files are available:
   - PROGRESS_DATADIRECT_CONNECT64_ODBC_7.1.6.HOTFIX_WIN_64.zip
   - PROGRESS_DATADIRECT_CONNECT_ODBC_7.1.6.HOTFIX_WIN_32.zip

2. Uncompress the installer.
3. Double-click setup.exe to launch the install wizard.
4. If necessary, permit the InstallAnywhere installer to run.
5. Click Next at the Introduction screen to begin the installation.
6. Accept the End User License Agreement and click Next.
7. Select OEM or Licensed Installation as the installation type and click Next.
8. Enter your licensing information: Division name, Company Name, and serial number/license key found in Prerequisites.
9. Select Add. You should see this driver in the License dialog box: ODBC Greenplum Wire Protocol Third Party All Platform Server Unlimited Cores
10. Select Next.
11. Choose options appropriate for your installation. For example, select to replace the existing drivers and/or to create the default data sources. Click Next.
12. Accept the default installation directory or choose a custom directory. Click Next.
13. Verify the selected installation options, and click Install to begin installation. The installation process may take several minutes.
14. Select Done to complete installing the driver package.

Verifying the Version on Windows

To verify your driver version:

1. Select Start > All Programs > DataDirect > ODBC Administrator to open the Windows ODBC Administrator.
2. Click the Drivers tab, and scroll down to DataDirect <version> Greenplum Wire Protocol. Ensure that you see the expected version number.

Configuring and Testing the Driver on Windows

To configure and test a DSN connection to a Greenplum Database:

1. Open the ODBC Administrator.
2. Select the System DSN tab.
3. Select Add.
5. Enter the details for your chosen Greenplum Database instance. For example:

   Recommended: Set the Max Long Varchar size.

   Select the Advanced tab.

   In Max Long Varchar Size, enter 8192 then select Apply.
6. Select **Test Connect**.
7. Enter your user name and password, then select **OK**.
8. You should see the confirmation message **Connection Established!**

If your connection fails, check the following for accuracy:

- Host Name
- Port Number
- Database Name
- User Name
- Password
- Greenplum instance is active
**DataDirect Driver Documentation**

For more information on working with Data Direct, see documentation that is installed with the driver. By default, you can access the installed documentation by using a Web browser to open the file `/opt/Progress/DataDirect/Connect64_for_ODBC_71/help/index.html`.

Documentation is also available online at https://www.progress.com/documentation/datadirect-connectors. Titles include:

- User's Guide
- Reference
- Troubleshooting Guide
- Installation Help
- Windows Readme
- UNIX/Linux Readme
Chapter 20

DataDirect JDBC Driver for Pivotal Greenplum

DataDirect JDBC drivers are compliant with the Type 4 architecture, but provide advanced features that define them as Type 5 drivers. Additionally, the drivers consistently support the latest database features and are fully compliant with Java™ SE 8 and JDBC 4.0 functionality.

The DataDirect JDBC Driver for Pivotal Greenplum is available for download from Pivotal Network.
Prerequisites

• The DataDirect JDBC Driver requires Java SE 5 or higher. See *System and Product Requirements* in the DataDirect documentation for information and requirements associated with specific features of the JDBC driver.
• The license key is embedded in the greenplum.jar file itself. You do not need to apply a specific license key to the driver to activate it.
Downloading the DataDirect JDBC Driver

To install the JDBC driver on your client:

1. Log into Pivotal Network and download the DataDirect JDBC driver file: greenplum.jar
2. Add the full path to the greenplum.jar to your Java CLASSPATH environment variable, or add it to your classpath with the -classpath option when executing a Java application.
Obtaining Version Details for the Driver

To view the JDBC driver version information:

1. Change to the directory that contains the downloaded `greenplum.jar` driver file. For example:

   ```bash
   $ cd /opt/Progress/DataDirect/Connect_for_JDBC_51/lib
   ``

2. Execute the data source class to display the version information.

   For Linux/Unix systems:

   ```bash
   $ java -classpath greenplum.jar com.pivotal.jdbc.GreenplumDriver
   [Pivotal][Greenplum JDBC Driver]Driver Version: 5.1.4.000143
   (F000337.U000158)
   ``

   For Windows systems:

   ```bash
   java -classpath .;\greenplum.jar com.pivotal.jdbc.GreenplumDriver
   [Pivotal][Greenplum JDBC Driver]Driver Version: 5.1.4.000143
   (F000337.U000158)
   ```
## Usage Information

The JDBC driver is provided in the `greenplum.jar` file. Use the following data source class and connection URL information with the driver.

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver File Name</td>
<td><code>greenplum.jar</code></td>
</tr>
<tr>
<td>Data Source Class</td>
<td><code>com.pivotal.jdbc.GreenplumDriver</code></td>
</tr>
<tr>
<td>Connection URL</td>
<td><code>jdbc:pivotal:greenplum://host:port;DatabaseName=&lt;name&gt;</code></td>
</tr>
</tbody>
</table>

**Driver Defaults**

- `ResultSetMetadataOptions=1`
- `FetchTWFSasTime=true`
- `SupportsCatalogs=true`
- `MaxLongVarcharSize=8190`
- `MaxNumericPrecision=28`
- `MaxNumericScale=6`
DataDirect Driver Documentation

For more information on working with the Data Direct JDBC driver, see documentation available online at https://www.progress.com/documentation/datadirect-connectors. Titles include:

- User's Guide
- Reference
- Installation Help
- Readme
- Quick Start