MySQL Replication

Abstract

This is the MySQL Replication extract from the MySQL 5.7 Reference Manual.

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Preface and Legal Notices

This is the MySQL Replication extract from the MySQL 5.7 Reference Manual.

Legal Notices

Chapter 1 Replication

Replication enables data from one MySQL database server (the master) to be copied to one or more MySQL database servers (the slaves). Replication is asynchronous by default; slaves do not need to be connected permanently to receive updates from the master. Depending on the configuration, you can replicate all databases, selected databases, or even selected tables within a database.

Advantages of replication in MySQL include:

- Scale-out solutions - spreading the load among multiple slaves to improve performance. In this environment, all writes and updates must take place on the master server. Reads, however, may take place on one or more slaves. This model can improve the performance of writes (since the master is dedicated to updates), while dramatically increasing read speed across an increasing number of slaves.

- Data security - because data is replicated to the slave, and the slave can pause the replication process, it is possible to run backup services on the slave without corrupting the corresponding master data.

- Analytics - live data can be created on the master, while the analysis of the information can take place on the slave without affecting the performance of the master.

- Long-distance data distribution - you can use replication to create a local copy of data for a remote site to use, without permanent access to the master.

For information on how to use replication in such scenarios, see Chapter 3, *Replication Solutions*.

MySQL 5.7 supports different methods of replication. The traditional method is based on replicating events from the master's binary log, and requires the log files and positions in them to be synchronized between master and slave. The newer method based on *global transaction identifiers* (GTIDs) is transactional and therefore does not require working with log files or positions within these files, which greatly simplifies many common replication tasks. Replication using GTIDs guarantees consistency between master and slave as long as all transactions committed on the master have also been applied on the slave. For more information about GTIDs and GTID-based replication in MySQL, see Section 2.3, “Replication with Global Transaction Identifiers”. For information on using binary log file position based replication, see Chapter 2, *Configuring Replication*.

Replication in MySQL supports different types of synchronization. The original type of synchronization is one-way, asynchronous replication, in which one server acts as the master, while one or more other servers act as slaves. This is in contrast to the *synchronous* replication which is a characteristic of MySQL Cluster (see MySQL Cluster NDB 7.5). In MySQL 5.7, semisynchronous replication is supported in addition to the built-in asynchronous replication. With semisynchronous replication, a commit performed on the master blocks before returning to the session that performed the transaction until at least one slave acknowledges that it has received and logged the events for the transaction; see Section 3.9, “Semisynchronous Replication”. MySQL 5.7 also supports delayed replication such that a slave server deliberately lags behind the master by at least a specified amount of time; see Section 3.10, “Delayed Replication”. For scenarios where *synchronous* replication is required, use MySQL Cluster (see MySQL Cluster NDB 7.5).

There are a number of solutions available for setting up replication between servers, and the best method to use depends on the presence of data and the engine types you are using. For more information on the available options, see Section 2.2, “Setting Up Binary Log File Position Based Replication”.

There are two core types of replication format, Statement Based Replication (SBR), which replicates entire SQL statements, and Row Based Replication (RBR), which replicates only the changed rows. You can also use a third variety, Mixed Based Replication (MBR). For more information on the different replication formats, see Section 5.1, “Replication Formats”.

Replication is controlled through a number of different options and variables. For more information, see Section 2.6, “Replication and Binary Logging Options and Variables”.

You can use replication to solve a number of different problems, including performance, supporting the backup of different databases, and as part of a larger solution to alleviate system failures. For information on how to address these issues, see Chapter 3, *Replication Solutions*.

For notes and tips on how different data types and statements are treated during replication, including details of replication features, version compatibility, upgrades, and potential problems and their resolution, see Chapter 4, *Replication Notes and Tips*. For answers to some questions often asked by those who are new to MySQL Replication, see MySQL 5.7 FAQ: Replication.

For detailed information on the implementation of replication, how replication works, the process and contents of the binary log, background threads and the rules used to decide how statements are recorded and replicated, see Chapter 5, *Replication Implementation*.

Chapter 2 Configuring Replication

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This section describes how to configure the different types of replication available in MySQL and includes the setup and configuration required for a replication environment, including step-by-step instructions for creating a new replication environment. The major components of this section are:

- For a guide to setting up two or more servers for replication using binary log file positions, Section 2.2, “Setting Up Binary Log File Position Based Replication”, deals with the configuration of the servers and provides methods for copying data between the master and slaves.

- For a guide to setting up two or more servers for replication using GTID transactions, Section 2.3, “Replication with Global Transaction Identifiers”, deals with the configuration of the servers.

- Events in the binary log are recorded using a number of formats. These are referred to as statement-based replication (SBR) or row-based replication (RBR). A third type, mixed-format replication (MIXED), uses SBR or RBR replication automatically to take advantage of the benefits of both SBR and RBR formats when appropriate. The different formats are discussed in Section 5.1, “Replication Formats”.

- Detailed information on the different configuration options and variables that apply to replication is provided in Section 2.6, “Replication and Binary Logging Options and Variables”.
- Once started, the replication process should require little administration or monitoring. However, for advice on common tasks that you may want to execute, see Section 2.7, “Common Replication Administration Tasks”.

2.1 Binary Log File Position Based Replication Configuration Overview

This section describes replication between MySQL servers based on the binary log file position method, where the MySQL instance operating as the master (the source of the database changes) writes updates and changes as “events” to the binary log. The information in the binary log is stored in different logging formats according to the database changes being recorded. Slaves are configured to read the binary log from the master and to execute the events in the binary log on the slave's local database.

Each slave receives a copy of the entire contents of the binary log. It is the responsibility of the slave to decide which statements in the binary log should be executed. Unless you specify otherwise, all events in the master binary log are executed on the slave. If required, you can configure the slave to process only events that apply to particular databases or tables.

Important

You cannot configure the master to log only certain events.

Each slave keeps a record of the binary log coordinates: the file name and position within the file that it has read and processed from the master. This means that multiple slaves can be connected to the master and executing different parts of the same binary log. Because the slaves control this process, individual slaves can be connected and disconnected from the server without affecting the master's operation. Also, because each slave records the current position within the binary log, it is possible for slaves to be disconnected, reconnect and then resume processing.

The master and each slave must be configured with a unique ID (using the `server-id` option). In addition, each slave must be configured with information about the master host name, log file name, and position within that file. These details can be controlled from within a MySQL session using the `CHANGE MASTER TO` statement on the slave. The details are stored within the slave's master info repository, which can be either a file or a table (see Section 5.4, “Replication Relay and Status Logs”).

2.2 Setting Up Binary Log File Position Based Replication

This section describes how to set up a MySQL server to use binary log file position based replication. There are a number of different methods for setting up replication, and the exact method to use depends on how you are setting up replication, and whether you already have data within your master database.

There are some generic tasks that are common to all setups:

- On the master, you must enable binary logging and configure a unique server ID. This might require a server restart. See Section 2.2.1, “Setting the Replication Master Configuration”.
- On each slave that you want to connect to the master, you must configure a unique server ID. This might require a server restart. See Section 2.2.5.1, “Setting the Replication Slave Configuration”.
- Optionally, create a separate user for your slaves to use during authentication with the master when reading the binary log for replication. See Section 2.2.2, “Creating a User for Replication”.

- Before creating a data snapshot or starting the replication process, on the master you should record the current position in the binary log. You need this information when configuring the slave so that the slave knows where within the binary log to start executing events. See Section 2.2.3, "Obtaining the Replication Master Binary Log Coordinates".

- If you already have data on the master and want to use it to synchronize the slave, you need to create a data snapshot to copy the data to the slave. The storage engine you are using has an impact on how you create the snapshot. When you are using `MyISAM`, you must stop processing statements on the master to obtain a read-lock, then obtain its current binary log coordinates and dump its data, before permitting the master to continue executing statements. If you do not stop the execution of statements, the data dump and the master status information will not match, resulting in inconsistent or corrupted databases on the slaves. For more information on replicating a `MyISAM` master, see Section 2.2.3, "Obtaining the Replication Master Binary Log Coordinates". If you are using `InnoDB`, you do not need a read-lock and a transaction that is long enough to transfer the data snapshot is sufficient. For more information, see InnoDB and MySQL Replication.

- Configure the slave with settings for connecting to the master, such as the host name, login credentials, and binary log file name and position. See Section 2.2.5.2, "Setting the Master Configuration on the Slave".

> **Note**
>
> Certain steps within the setup process require the `SUPER` privilege. If you do not have this privilege, it might not be possible to enable replication.

After configuring the basic options, select your scenario:

- To set up replication for a fresh installation of a master and slaves that contain no data, see Section 2.2.5.3, "Setting Up Replication between a New Master and Slaves".

- To set up replication of a new master using the data from an existing MySQL server, see Section 2.2.5.4, "Setting Up Replication with Existing Data".

- To add replication slaves to an existing replication environment, see Section 2.2.6, "Adding Slaves to a Replication Environment".

Before administering MySQL replication servers, read this entire chapter and try all statements mentioned in SQL Statements for Controlling Master Servers, and SQL Statements for Controlling Slave Servers. Also familiarize yourself with the replication startup options described in Section 2.6, "Replication and Binary Logging Options and Variables".

2.2.1 Setting the Replication Master Configuration

To configure a master to use binary log file position based replication, you must enable binary logging and establish a unique server ID. If this has not already been done, a server restart is required.

Binary logging *must* be enabled on the master because the binary log is the basis for replicating changes from the master to its slaves. If binary logging is not enabled on the master using the `log-bin` option, replication is not possible.

Each server within a replication group must be configured with a unique server ID. This ID is used to identify individual servers within the group, and must be a positive integer between 1 and $(2^{32})-1$. How you organize and select the numbers is your choice.

To configure the binary log and server ID options, shut down the MySQL server and edit the `my.cnf` or `my.ini` file. Within the `[mysqld]` section of the configuration file, add the `log-bin` and `server-id` options. If these options already exist, but are commented out, uncomment the options and alter them according to your needs. For example, to enable binary logging using a log file name prefix of `mysql-bin`, and configure a server ID of 1, use these lines:

```
[mysqld]
log-bin=mysql-bin
server-id=1
```

After making the changes, restart the server.

> **Note**
>
> The following options have an impact on this procedure:
>
> - if you omit `server-id` (or set it explicitly to its default value of 0), the master refuses any connections from slaves.
> - For the greatest possible durability and consistency in a replication setup using `InnoDB` with transactions, you should use `innodb_flush_log_at_trx_commit=1` and `sync_binlog=1` in the master `my.cnf` file.
> - Ensure that the `skip-networking` option is not enabled on your replication master. If networking has been disabled, the slave can not communicate with the master and replication fails.

2.2.2 Creating a User for Replication

Each slave connects to the master using a MySQL user name and password, so there must be a user account on the master that the slave can use to connect. Any account can be used for this operation, providing it has been granted the `REPLICATION SLAVE` privilege. You can choose to create a different account for each slave, or connect to the master using the same account for each slave.

Although you do not have to create an account specifically for replication, you should be aware that the replication user name and password are stored in plain text in the master info repository file or table (see Section 5.4.2, “Slave Status Logs”). Therefore, you may want to create a separate account that has privileges only for the replication process, to minimize the possibility of compromise to other accounts.

To create a new account, use `CREATE USER`. To grant this account the privileges required for replication, use the `GRANT` statement. If you create an account solely for the purposes of replication, that account needs only the `REPLICATION SLAVE` privilege. For example, to set up a new user, `repl`, that can connect for replication from any host within the `mydomain.com` domain, issue these statements on the master:

```
mysql> CREATE USER 'repl'@'%.mydomain.com' IDENTIFIED BY 'slavepass';
mysql> GRANT REPLICATION SLAVE ON *.* TO 'repl'@'%.mydomain.com';
```

See Account Management Statements, for more information on statements for manipulation of user accounts.

2.2.3 Obtaining the Replication Master Binary Log Coordinates

To configure the slave to start the replication process at the correct point, you need the master's current coordinates within its binary log.

If the master has been running previously without binary logging enabled, the log file name and position values displayed by `SHOW MASTER STATUS` or `mysqldump --master-data` are empty. In that case, the values that you need to use later when specifying the slave's log file and position are the empty string (`''`) and `4`.

If the master has been binary logging previously, use this procedure to obtain the master binary log coordinates:

> **Warning**
>
> This procedure uses `FLUSH TABLES WITH READ LOCK`, which blocks `COMMIT` operations for `InnoDB` tables.

1. Start a session on the master by connecting to it with the command-line client, and flush all tables and block write statements by executing the `FLUSH TABLES WITH READ LOCK` statement:

   ```
   mysql> FLUSH TABLES WITH READ LOCK;
   ```

   > **Warning**
   >
   > Leave the client from which you issued the `FLUSH TABLES` statement running so that the read lock remains in effect. If you exit the client, the lock is released.

2. In a different session on the master, use the `SHOW MASTER STATUS` statement to determine the current binary log file name and position:

   ```
   mysql > SHOW MASTER STATUS;
   +------------------+----------+--------------+------------------+
   | File             | Position | Binlog_Do_DB | Binlog_Ignore_DB |
   +------------------+----------+--------------+------------------+
   | mysql-bin.000003 | 73       | test         | manual,mysql     |
   +------------------+----------+--------------+------------------+
   ```

   The `File` column shows the name of the log file and the `Position` column shows the position within the file. In this example, the binary log file is `mysql-bin.000003` and the position is 73. Record these values. You need them later when you are setting up the slave. They represent the replication coordinates at which the slave should begin processing new updates from the master.

You now have the information you need to enable the slave to start reading from the binary log in the correct place to start replication.

The next step depends on whether you have existing data on the master. Choose one of the following options:

- If you have existing data that needs be to synchronized with the slave before you start replication, leave the client running so that the lock remains in place. This prevents any further changes being made, so that the data copied to the slave is in synchrony with the master. Proceed to Section 2.2.4, “Choosing a Method for Data Snapshots”.

- If you are setting up a new master and slave replication group, you can exit the first session to release the read lock. See Section 2.2.5.3, “Setting Up Replication between a New Master and Slaves” for how to proceed.

2.2.4 Choosing a Method for Data Snapshots

If the master database contains existing data it is necessary to copy this data to each slave. There are different ways to dump the data from the master database. The following sections describe possible options.

To select the appropriate method of dumping the database, choose between these options:

- Use the mysqldump tool to create a dump of all the databases you want to replicate. This is the recommended method, especially when using InnoDB.
- If your database is stored in binary portable files, you can copy the raw data files to a slave. This can be more efficient than using mysqldump and importing the file on each slave, because it skips the overhead of updating indexes as the INSERT statements are replayed. With storage engines such as InnoDB this is not recommended.

2.2.4.1 Creating a Data Snapshot Using mysqldump

To create a snapshot of the data in an existing master database, use the mysqldump tool. Once the data dump has been completed, import this data into the slave before starting the replication process.

The following example dumps all databases to a file named dbdump.db, and includes the --master-data option which automatically appends the CHANGE MASTER TO statement required on the slave to start the replication process:

```
shell> mysqldump --all-databases --master-data > dbdump.db
```

Note

If you do not use --master-data, then it is necessary to lock all tables in a separate session manually. See Section 2.2.3, “Obtaining the Replication Master Binary Log Coordinates”.

It is possible to exclude certain databases from the dump using the mysqldump tool. If you want to choose which databases to include in the dump, do not use --all-databases. Choose one of these options:

- Exclude all the tables in the database using --ignore-table option.
- Name only those databases which you want dumped using the --databases option.

For more information, see mysqldump — A Database Backup Program.

To import the data, either copy the dump file to the slave, or access the file from the master when connecting remotely to the slave.

2.2.4.2 Creating a Data Snapshot Using Raw Data Files

This section describes how to create a data snapshot using the raw files which make up the database. Employing this method with a table using a storage engine that has complex caching or logging algorithms requires extra steps to produce a perfect “point in time” snapshot: the initial copy command could leave out cache information and logging updates, even if you have acquired a global read lock. How the storage engine responds to this depends on its crash recovery abilities.

If you use InnoDB tables, you can use the mysqlbackup command from the MySQL Enterprise Backup component to produce a consistent snapshot. This command records the log name and offset corresponding to the snapshot to be used on the slave. MySQL Enterprise Backup is a commercial product that is included as part of a MySQL Enterprise subscription. See MySQL Enterprise Backup Overview for detailed information.

This method also does not work reliably if the master and slave have different values for ft_stopword_file, ft_min_word_len, or ft_max_word_len and you are copying tables having full-text indexes.

Assuming the above exceptions do not apply to your database, use the cold backup technique to obtain a reliable binary snapshot of `InnoDB` tables: do a slow shutdown of the MySQL Server, then copy the data files manually.

To create a raw data snapshot of `MyISAM` tables when your MySQL data files exist on a single file system, you can use standard file copy tools such as `cp` or `copy`, a remote copy tool such as `scp` or `rsync`, an archiving tool such as `zip` or `tar`, or a file system snapshot tool such as `dump`. If you are replicating only certain databases, copy only those files that relate to those tables. For `InnoDB`, all tables in all databases are stored in the system tablespace files, unless you have the `innodb_file_per_table` option enabled.

The following files are not required for replication:

- Files relating to the `mysql` database.
- The master info repository file, if used (see Section 5.4, “Replication Relay and Status Logs”).
- The master's binary log files.
- Any relay log files.

Depending on whether you are using `InnoDB` tables or not, choose one of the following:

If you are using `InnoDB` tables, and also to get the most consistent results with a raw data snapshot, shut down the master server during the process, as follows:

1. Acquire a read lock and get the master's status. See Section 2.2.3, “Obtaining the Replication Master Binary Log Coordinates”.
2. In a separate session, shut down the master server:

   ```
   shell> mysqladmin shutdown
   ```
3. Make a copy of the MySQL data files. The following examples show common ways to do this. You need to choose only one of them:

   ```
   shell> tar cf /tmp/db.tar ./data
   shell> zip -r /tmp/db.zip ./data
   shell> rsync --recursive ./data /tmp/dbdata
   ```
4. Restart the master server.

If you are not using `InnoDB` tables, you can get a snapshot of the system from a master without shutting down the server as described in the following steps:

1. Acquire a read lock and get the master's status. See Section 2.2.3, “Obtaining the Replication Master Binary Log Coordinates”.
2. Make a copy of the MySQL data files. The following examples show common ways to do this. You need to choose only one of them:

   ```
   shell> tar cf /tmp/db.tar ./data
   shell> zip -r /tmp/db.zip ./data
   shell> rsync --recursive ./data /tmp/dbdata
   ```
3. In the client where you acquired the read lock, release the lock:

   ```
   mysql> UNLOCK TABLES;
   ```

Once you have created the archive or copy of the database, copy the files to each slave before starting the slave replication process.

2.2.5 Setting Up Replication Slaves

The following sections describe how to set up slaves. Before you proceed, ensure that you have:

- Configured the MySQL master with the necessary configuration properties. See Section 2.2.1, "Setting the Replication Master Configuration".
- Obtained the master status information. See Section 2.2.3, "Obtaining the Replication Master Binary Log Coordinates".
- On the master, released the read lock:

  ```
  mysql> UNLOCK TABLES;
  ```

2.2.5.1 Setting the Replication Slave Configuration

Each replication slave *must* have a unique server ID. If this has not already been done, this part of slave setup requires a server restart.

If the slave server ID is not already set, or the current value conflicts with the value that you have chosen for the master server, shut down the slave server and edit the `[mysqld]` section of the configuration file to specify a unique server ID. For example:

```
[mysqld]
server-id=2
```

After making the changes, restart the server.

If you are setting up multiple slaves, each one must have a unique `server-id` value that differs from that of the master and from any of the other slaves.

Note

If you omit `server-id` (or set it explicitly to its default value of 0), the slave refuses to connect to a master.

You do not have to enable binary logging on the slave for replication to be set up. However, if you enable binary logging on the slave, you can use the slave's binary log for data backups and crash recovery, and also use the slave as part of a more complex replication topology. For example, where this slave then acts as a master to other slaves.

2.2.5.2 Setting the Master Configuration on the Slave

To set up the slave to communicate with the master for replication, configure the slave with the necessary connection information. To do this, execute the following statement on the slave, replacing the option values with the actual values relevant to your system:

```
mysql> CHANGE MASTER TO
    ->     MASTER_HOST='master_host_name',
    ->     MASTER_USER='replication_user_name',
    ->     MASTER_PASSWORD='replication_password',
    ->     MASTER_LOG_FILE='recorded_log_file_name',
    ->     MASTER_LOG_POS=recorded_log_position;
```

> **Note**
>
> Replication cannot use Unix socket files. You must be able to connect to the master MySQL server using TCP/IP.

The `CHANGE MASTER TO` statement has other options as well. For example, it is possible to set up secure replication using SSL. For a full list of options, and information about the maximum permissible length for the string-valued options, see CHANGE MASTER TO Syntax.

The next steps depend on whether you have existing data to import to the slave or not. See Section 2.2.4, "Choosing a Method for Data Snapshots" for more information. Choose one of the following:

- If you do not have a snapshot of a database to import, see Section 2.2.5.3, "Setting Up Replication between a New Master and Slaves".
- If you have a snapshot of a database to import, see Section 2.2.5.4, "Setting Up Replication with Existing Data".

2.2.5.3 Setting Up Replication between a New Master and Slaves

When there is no snapshot of a previous database to import, configure the slave to start the replication from the new master.

To set up replication between a master and a new slave:

1. Start up the MySQL slave and connect to it.
2. Execute a `CHANGE MASTER TO` statement to set the master replication server configuration. See Section 2.2.5.2, "Setting the Master Configuration on the Slave".

Perform these slave setup steps on each slave.

This method can also be used if you are setting up new servers but have an existing dump of the databases from a different server that you want to load into your replication configuration. By loading the data into a new master, the data is automatically replicated to the slaves.

If you are setting up a new replication environment using the data from a different existing database server to create a new master, run the dump file generated from that server on the new master. The database updates are automatically propagated to the slaves:

```
shell> mysql -h master < fulldb.dump
```

2.2.5.4 Setting Up Replication with Existing Data

When setting up replication with existing data, transfer the snapshot from the master to the slave before starting replication. The process for importing data to the slave depends on how you created the snapshot of data on the master.

Choose one of the following:

If you used `mysqldump`:

1. Start the slave, using the `--skip-slave-start` option so that replication does not start.
2. Import the dump file:

   ```
   shell> mysql < fulldb.dump
   ```

If you created a snapshot using the raw data files:

1. Extract the data files into your slave data directory. For example:

   ```
   shell> tar xvf dbdump.tar
   ```

   You may need to set permissions and ownership on the files so that the slave server can access and modify them.

2. Start the slave, using the `--skip-slave-start` option so that replication does not start.

3. Configure the slave with the replication coordinates from the master. This tells the slave the binary log file and position within the file where replication needs to start. Also, configure the slave with the login credentials and host name of the master. For more information on the `CHANGE MASTER TO` statement required, see Section 2.2.5.2, “Setting the Master Configuration on the Slave”.

4. Start the slave threads:

   ```
   mysql> START SLAVE;
   ```

After you have performed this procedure, the slave connects to the master and replicates any updates that have occurred on the master since the snapshot was taken.

If the `server-id` option for the master is not correctly set, slaves cannot connect to it. Similarly, if you have not set the `server-id` option correctly for the slave, you get the following error in the slave's error log:

```
Warning: You should set server-id to a non-0 value if master_host
is set; we will force server id to 2, but this MySQL server will
not act as a slave.
```

You also find error messages in the slave's error log if it is not able to replicate for any other reason.

The slave stores information about the master you have configured in its master info repository. The master info repository can be in the form of files or a table, as determined by the value set for `--master-info-repository`. When a slave uses `--master-info-repository=FILE`, two files are stored in the data directory, named `master.info` and `relay-log.info`. If `--master-info-repository=TABLE` instead, this information is saved in the `master_slave_info` table in the `mysql` database. In either case, do *not* remove or edit the files or table. Always use the `CHANGE MASTER TO` statement to change replication parameters. The slave can use the values specified in the statement to update the status files automatically. See Section 5.4, “Replication Relay and Status Logs”, for more information.

> **Note**
>
> The contents of the master info repository override some of the server options specified on the command line or in `my.cnf`. See Section 2.6, “Replication and Binary Logging Options and Variables”, for more details.

A single snapshot of the master suffices for multiple slaves. To set up additional slaves, use the same master snapshot and follow the slave portion of the procedure just described.

2.2.6 Adding Slaves to a Replication Environment

You can add another slave to an existing replication configuration without stopping the master. Instead, set up the new slave by making a copy of an existing slave, except that you configure the new slave with a different `server-id` value.

To duplicate an existing slave:

1. Shut down the existing slave:

   ```
   shell> mysqladmin shutdown
   ```

2. Copy the data directory from the existing slave to the new slave. You can do this by creating an archive using `tar` or `WinZip`, or by performing a direct copy using a tool such as `cp` or `rsync`. Ensure that you also copy the log files and relay log files.

   A common problem that is encountered when adding new replication slaves is that the new slave fails with a series of warning and error messages like these:

   ```
   071118 16:44:10 [Warning] Neither --relay-log nor --relay-log-index were used; so
   replication may break when this MySQL server acts as a slave and has his hostname
   changed!! Please use '--relay-log=new_slave_hostname-relay-bin' to avoid this problem.
   071118 16:44:10 [ERROR] Failed to open the relay log './old_slave_hostname-relay-bin.003525'
   (relay_log_pos 22940879)
   071118 16:44:10 [ERROR] Could not find target log during relay log initialization
   071118 16:44:10 [ERROR] Failed to initialize the master info structure
   ```

   This situation can occur if the `--relay-log` option is not specified, as the relay log files contain the host name as part of their file names. This is also true of the relay log index file if the `--relay-log-index` option is not used. See Section 2.6, "Replication and Binary Logging Options and Variables", for more information about these options.

   To avoid this problem, use the same value for `--relay-log` on the new slave that was used on the existing slave. If this option was not set explicitly on the existing slave, use `*existing_slave_hostname*-relay-bin`. If this is not possible, copy the existing slave's relay log index file to the new slave and set the `--relay-log-index` option on the new slave to match what was used on the existing slave. If this option was not set explicitly on the existing slave, use `*existing_slave_hostname*-relay-bin.index`. Alternatively, if you have already tried to start the new slave after following the remaining steps in this section and have encountered errors like those described previously, then perform the following steps:

   a. If you have not already done so, issue a `STOP SLAVE` on the new slave.

      If you have already started the existing slave again, issue a `STOP SLAVE` on the existing slave as well.

   b. Copy the contents of the existing slave's relay log index file into the new slave's relay log index file, making sure to overwrite any content already in the file.

   c. Proceed with the remaining steps in this section.

3. Copy the master info and relay log info repositories (see Section 5.4, "Replication Relay and Status Logs") from the existing slave to the new slave. These hold the current log coordinates for the master's binary log and the slave's relay log.

4. Start the existing slave.

5. On the new slave, edit the configuration and give the new slave a unique `server-id` not used by the master or any of the existing slaves.

6. Start the new slave. The slave uses the information in its master info repository to start the replication process.

2.3 Replication with Global Transaction Identifiers

This section explains transaction-based replication using *global transaction identifiers* (GTIDs). When using GTIDs, each transaction can be identified and tracked as it is committed on the originating server and applied by any slaves; this means that it is not necessary when using GTIDs to refer to log files or positions within those files when starting a new slave or failing over to a new master, which greatly simplifies these tasks. Because GTID-based replication is completely transaction-based, it is simple to determine whether masters and slaves are consistent; as long as all transactions committed on a master are also committed on a slave, consistency between the two is guaranteed. You can use either statement-based or row-based replication with GTIDs (see Section 5.1, "Replication Formats"); however, for best results, we recommend that you use the row-based format.

This section discusses the following topics:

- How GTIDs are defined and created, and how they are represented in the MySQL Server (see Section 2.3.1, "GTID Concepts").
- A general procedure for setting up and starting GTID-based replication (see Section 2.3.2, "Setting Up Replication Using GTIDs").
- Suggested methods for provisioning new replication servers when using GTIDs (see Section 2.3.3, "Using GTIDs for Failover and Scaleout").
- Restrictions and limitations that you should be aware of when using GTID-based replication (see Section 2.3.4, "Restrictions on Replication with GTIDs").

For information about MySQL Server options and variables relating to GTID-based replication, see Section 2.6.5, "Global Transaction ID Options and Variables". See also Functions Used with Global Transaction IDs, which describes SQL functions supported by MySQL 5.7 for use with GTIDs.

2.3.1 GTID Concepts

A global transaction identifier (GTID) is a unique identifier created and associated with each transaction committed on the server of origin (master). This identifier is unique not only to the server on which it originated, but is unique across all servers in a given replication setup. There is a 1-to-1 mapping between all transactions and all GTIDs.

The following paragraphs provide a basic description of GTIDs. More advanced concepts are covered later in the following sections:

- GTID Sets
- mysql.gtid_executed Table
- mysql.gtid_executed Table Compression

A GTID is represented as a pair of coordinates, separated by a colon character (`:`), as shown here:

```
GTID = source_id:transaction_id
```

The *`source_id`* identifies the originating server. Normally, the server's `server_uuid` is used for this purpose. The *`transaction_id`* is a sequence number determined by the order in which the transaction was committed on this server; for example, the first transaction to be committed has `1` as its *`transaction_id`*, and the tenth transaction to be committed on the same originating server is assigned a *`transaction_id`* of `10`. It is not possible for a transaction to have `0` as a sequence number in a GTID. For example, the twenty-third transaction to be committed originally on the server with the UUID `3E11FA47-71CA-11E1-9E33-C80AA9429562` has this GTID:

```
3E11FA47-71CA-11E1-9E33-C80AA9429562:23
```

This format is used to represent GTIDs in the output of statements such as `SHOW SLAVE STATUS` as well as in the binary log. They can also be seen when viewing the log file with `mysqlbinlog --base64-output=DECODE-ROWS` or in the output from `SHOW BINLOG EVENTS`.

As written in the output of statements such as `SHOW MASTER STATUS` or `SHOW SLAVE STATUS`, a sequence of GTIDs originating from the same server may be collapsed into a single expression, as shown here.

```
3E11FA47-71CA-11E1-9E33-C80AA9429562:1-5
```

The example just shown represents the first through fifth transactions originating on the MySQL Server whose `server_uuid` is `3E11FA47-71CA-11E1-9E33-C80AA9429562`.

This format is also used to supply the argument required by the `START SLAVE` options `SQL_BEFORE_GTIDS` and `SQL_AFTER_GTIDS`.

GTID Sets

A GTID set is a set of global transaction identifiers which is represented as shown here:

```
gtid_set:
    uuid_set [, uuid_set] ...
    | ''

uuid_set:
    uuid:interval[:interval]...

uuid:
    hhhhhhhh-hhhh-hhhh-hhhh-hhhhhhhhhhhh

h:
    [0-9|A-F]

interval:
    n[-n]

    (n >= 1)
```

GTID sets are used in the MySQL Server in several ways. For example, the values stored by the `gtid_executed` and `gtid_purged` system variables are represented as GTID sets. In addition, the functions `GTID_SUBSET()` and `GTID_SUBTRACT()` require GTID sets as input. When GTID sets are returned from server variables, UUIDs are in alphabetical order and numeric intervals are merged and in ascending order.

GTIDs are always preserved between master and slave. This means that you can always determine the source for any transaction applied on any slave by examining its binary log. In addition, once a transaction with a given GTID is committed on a given server, any subsequent transaction having the same GTID is ignored by that server. Thus, a transaction committed on the master can be applied no more than once on the slave, which helps to guarantee consistency.

When GTIDs are in use, the slave has no need for any nonlocal data, such as the name of a file on the master and a position within that file. All necessary information for synchronizing with the master is obtained directly from the replication data stream. GTIDs replace the file-offset pairs previously required to determine points for starting, stopping, or resuming the flow of data between master and slave. therefore, do not include `MASTER_LOG_FILE` or `MASTER_LOG_POS` options in the `CHANGE MASTER TO` statement used to direct a slave to replicate from a given master; instead it is necessary only to enable the

MASTER_AUTO_POSITION option. For the exact steps needed to configure and start masters and slaves using GTID-based replication, see Section 2.3.2, “Setting Up Replication Using GTIDs”.

The generation and life cycle of a GTID consist of the following steps:

1. A transaction is executed and committed on the master.

   This transaction is assigned a GTID using the master's UUID and the smallest nonzero transaction sequence number not yet used on this server; the GTID is written to the master's binary log (immediately preceding the transaction itself in the log).

2. After the binary log data is transmitted to the slave and stored in the slave's relay log (using established mechanisms for this process—see Chapter 5, *Replication Implementation*, for details), the slave reads the GTID and sets the value of its gtid_next system variable as this GTID. This tells the slave that the next transaction must be logged using this GTID.

   It is important to note that the slave sets gtid_next in a session context.

3. The slave verifies that this GTID has not already been used to log a transaction in its own binary log. If this GTID has not been used, the slave then writes the GTID, applies the transaction, and writes the transaction to its binary log. By reading and checking the transaction's GTID first, before processing the transaction itself, the slave guarantees not only that no previous transaction having this GTID has been applied on the slave, but also that no other session has already read this GTID but has not yet committed the associated transaction. In other words, multiple clients are not permitted to apply the same transaction concurrently.

4. Because gtid_next is not empty, the slave does not attempt to generate a GTID for this transaction but instead writes the GTID stored in this variable—that is, the GTID obtained from the master—immediately preceding the transaction in its binary log.

mysql.gtid_executed Table

Beginning with MySQL 5.7.5, GTIDs are stored in a table named gtid_executed, in the mysql database. A row in this table contains, for each GTID or set of GTIDs that it represents, the UUID of the originating server, and the starting and ending transaction IDs of the set; for a row referencing only a single GTID, these last two values are the same.

The mysql.gtid_executed table is created (if it does not already exist) when the MySQL Server is installed or upgraded, using a CREATE TABLE statement similar to that shown here:

```
CREATE TABLE gtid_executed (
    source_uuid CHAR(36) NOT NULL,
    interval_start BIGINT(20) NOT NULL,
    interval_end BIGINT(20) NOT NULL,
    PRIMARY KEY (source_uuid, interval_start)
)
```

Warning

As with other MySQL system tables, do not attempt to create or modify this table yourself.

GTIDs are stored in the mysql.gtid_executed table only when gtid_mode is ON or ON_PERMISSIVE. GTIDs are stored in this table without regard to whether binary logging is enabled. However, the manner in which they are stored differs depending on whether log_bin is ON or OFF:

- If binary logging is disabled (log_bin is OFF), the server stores the GTID belonging to each transaction together with the transaction in the table.

In addition, when binary logging is disabled, this table is compressed periodically at a user-configurable rate; see mysql.gtid_executed Table Compression, for more information.

- If binary logging is enabled (`log_bin` is `ON`), then in addition to storing the GTIDs in `mysql.gtid_executed`, whenever the binary log is rotated or the server is shut down, the server writes GTIDs for all transactions that were written into the previous binary log into the new binary log.

  In the event of the server stopping unexpectedly, the set of GTIDs from the previous binary log is not saved in the `mysql.gtid_executed` table. In this case, these GTIDs are added to the table and to the set of GTIDs in the `gtid_executed` system variable during recovery.

The `mysql.gtid_executed` table is reset by `RESET MASTER`.

mysql.gtid_executed Table Compression

Over the course of time, the `mysql.gtid_executed` table can become filled with many rows referring to individual GTIDs that originate on the same server, and whose transaction IDs make up a sequence, similar to what is shown here:

```
mysql> SELECT * FROM mysql.gtid_executed;
+--------------------------------------+----------------+--------------+
| source_uuid                          | interval_start | interval_end |
|--------------------------------------+----------------+--------------|
| 3E11FA47-71CA-11E1-9E33-C80AA9429562 | 37             | 37           |
| 3E11FA47-71CA-11E1-9E33-C80AA9429562 | 38             | 38           |
| 3E11FA47-71CA-11E1-9E33-C80AA9429562 | 39             | 39           |
| 3E11FA47-71CA-11E1-9E33-C80AA9429562 | 40             | 40           |
| 3E11FA47-71CA-11E1-9E33-C80AA9429562 | 41             | 41           |
| 3E11FA47-71CA-11E1-9E33-C80AA9429562 | 42             | 42           |
| 3E11FA47-71CA-11E1-9E33-C80AA9429562 | 43             | 43           |
...
```

Considerable space can be saved if this table is compressed periodically by replacing each such set of rows with a single row that spans the entire interval of transaction identifiers, like this:

```
+--------------------------------------+----------------+--------------+
| source_uuid                          | interval_start | interval_end |
|--------------------------------------+----------------+--------------|
| 3E11FA47-71CA-11E1-9E33-C80AA9429562 | 37             | 43           |
...
```

When GTIDs are enabled, the server performs this type of compression on the `mysql.gtid_executed` table periodically. You can control the number of transactions that are allowed to elapse before the table is compressed, and thus the compression rate, by setting the `executed_gtids_compression_period` system variable. This variable's default value is 1000; this means that, by default, compression of the table is performed after each 1000 transactions. Setting `executed_gtid_compression_period` to 0 prevents the compression from being performed at all; however, you should be prepared for a potentially large increase in the amount of disk space that may be required by the `gtid_executed` table if you do this.

> **Note**
>
> When binary logging is enabled, the value of `executed_gtids_compression_period` is *not* used and the `mysql.gtid_executed` table is compressed on each binary log rotation.

Compression of the `mysql.gtid_executed` table is performed by a dedicated foreground thread that is created whenever GTIDs are enabled on the server. This thread is not listed in the output of `SHOW PROCESSLIST`, but it can be viewed as a row in the `threads` table, as shown here:

```
mysql> SELECT * FROM PERFORMANCE_SCHEMA.THREADS WHERE NAME LIKE '%gtid%'\G
*************************** 1. row ***************************
          THREAD_ID: 21
               NAME: thread/sql/compress_gtid_table
               TYPE: FOREGROUND
     PROCESSLIST_ID: 139635685943104
   PROCESSLIST_USER: NULL
   PROCESSLIST_HOST: NULL
     PROCESSLIST_DB: NULL
PROCESSLIST_COMMAND: Daemon
   PROCESSLIST_TIME: 611
  PROCESSLIST_STATE: Suspending
   PROCESSLIST_INFO: NULL
   PARENT_THREAD_ID: 1
               ROLE: NULL
       INSTRUMENTED: YES
```

This thread has the name `thread/sql/compress_gtid_table`, and normally sleeps until `executed_gtids_compression_period` transactions have been executed, then wakes up to perform compression of the `mysql.gtid_executed` table as described previously. It then sleeps until another `executed_gtids_compression_period` transactions have taken place, then wakes up to perform the compression again, repeating this loop indefinitely. Setting this value to 0 when binary logging is disabled means that the thread always sleeps and never wakes up.

2.3.2 Setting Up Replication Using GTIDs

This section describes a process for configuring and starting GTID-based replication in MySQL 5.7. This is a "cold start" procedure that assumes either that you are starting the replication master for the first time, or that it is possible to stop it; for information about provisioning replication slaves using GTIDs from a running master, see Section 2.3.3, "Using GTIDs for Failover and Scaleout". For information about changing GTID mode on servers online, see Section 2.5, "Changing Replication Modes on Online Servers".

The key steps in this startup process for the simplest possible GTID replication topology—consisting of one master and one slave—are as follows:

1. If replication is already running, synchronize both servers by making them read-only.

2. Stop both servers.

3. Restart both servers with GTIDs enabled and the correct options configured.

   The `mysqld` options necessary to start the servers as described are discussed in the example that follows later in this section.

   > **Note**
   >
   > `server_uuid` must exist for GTIDs to function correctly.

4. Instruct the slave to use the master as the replication data source and to use auto-positioning, and then start the slave.

   The SQL statements needed to accomplish this step are described in the example that follows later in this section.

5. Enable read mode again on both servers, so that they can accept updates.

In the following example, two servers are already running as master and slave, using MySQL's binary log position-based replication protocol. If you are starting with new servers, see Section 2.2.2, "Creating a User for Replication" for information about adding a specific user for replication connections and Section 2.2.1, "Setting the Replication Master Configuration" for information about setting the server-id. The following examples show how to use startup options when running `mysqld`. Alternatively you can store startup options in an option file, see Using Option Files for more information.

Most of the steps that follow require the use of the MySQL `root` account or another MySQL user account that has the `SUPER` privilege. `mysqladmin shutdown` requires either the `SUPER` privilege or the `SHUTDOWN` privilege.

Step 1: Synchronize the servers. Make the servers read-only. To do this, enable the `read_only` system variable by executing the following statement on both servers:

```
mysql> SET @@global.read_only = ON;
```

Then, allow the slave to catch up with the master. *It is extremely important that you make sure the slave has processed all updates before continuing*.

Step 2: Stop both servers. Stop each server using `mysqladmin` as shown here, where *`username`* is the user name for a MySQL user having sufficient privileges to shut down the server:

```
shell> mysqladmin -uusername -p shutdown
```

Then supply this user's password at the prompt.

Step 3: Restart both servers with GTIDs enabled. To enable GTID-based replication, each server must be started with GTID mode enabled, by setting the `--gtid-mode` option to `ON`, and with the `--enforce-gtid-consistency` option enabled to ensure that only statements which are safe for GTID-based replication are logged. In addition, you should start the slave with the `--skip-slave-start` option before configuring the slave settings. For more information on GTID related options, see Section 2.6.5, "Global Transaction ID Options and Variables".

It is not mandatory to have binary logging enabled in order to use GTIDs due to the addition of the mysql.gtid_executed Table in MySQL 5.7.5. This means that you can have slave servers using GTIDs but without binary logging. Masters *must* always have binary logging enabled in order to be able to replicate. For example, to start a slave with GTIDs enabled but without binary logging, use at least these options:

```
shell> mysqld --gtid-mode=ON --enforce-gtid-consistency &
```

In MySQL 5.7.4 and earlier, binary logging is required to use GTIDs and both master and slave servers must be started with at least these options:

```
shell> mysqld --gtid-mode=ON --log-bin --enforce-gtid-consistency &
```

Depending on your configuration, supply additional options to `mysqld`.

Step 4: Direct the slave to use the master. Tell the slave to use the master as the replication data source, and to use GTID-based auto-positioning rather than file-based positioning. Execute a `CHANGE MASTER TO` statement on the slave, using the `MASTER_AUTO_POSITION` option to tell the slave that transactions will be identified by GTIDs.

You may also need to supply appropriate values for the master's host name and port number as well as the user name and password for a replication user account which can be used by the slave to connect to the master; if these have already been set prior to Step 1 and no further changes need to be made, the corresponding options can safely be omitted from the statement shown here.

```
mysql> CHANGE MASTER TO
     >     MASTER_HOST = host,
     >     MASTER_PORT = port,
     >     MASTER_USER = user,
     >     MASTER_PASSWORD = password,
     >     MASTER_AUTO_POSITION = 1;
```

Neither the `MASTER_LOG_FILE` option nor the `MASTER_LOG_POS` option may be used with `MASTER_AUTO_POSITION` set equal to 1. Attempting to do so causes the `CHANGE MASTER TO` statement to fail with an error.

Assuming that the `CHANGE MASTER TO` statement has succeeded, you can then start the slave, like this:

```
mysql> START SLAVE;
```

Step 5: Disable read-only mode. Allow the master to begin accepting updates once again by running the following statement:

```
mysql> SET @@global.read_only = OFF;
```

GTID-based replication should now be running, and you can begin (or resume) activity on the master as before. Section 2.3.3, “Using GTIDs for Failover and Scaleout”, discusses creation of new slaves when using GTIDs.

2.3.3 Using GTIDs for Failover and Scaleout

There are a number of techniques when using MySQL Replication with Global Transaction Identifiers (GTIDs) for provisioning a new slave which can then be used for scaleout, being promoted to master as necessary for failover. This section describes the following techniques:

- Simple replication
- Copying data and transactions to the slave
- Injecting empty transactions
- Excluding transactions with gtid_purged
- Restoring GTID mode slaves

Global transaction identifiers were added to MySQL Replication for the purpose of simplifying in general management of the replication data flow and of failover activities in particular. Each identifier uniquely identifies a set of binary log events that together make up a transaction. GTIDs play a key role in applying changes to the database: the server automatically skips any transaction having an identifier which the server recognizes as one that it has processed before. This behavior is critical for automatic replication positioning and correct failover.

The mapping between identifiers and sets of events comprising a given transaction is captured in the binary log. This poses some challenges when provisioning a new server with data from another existing server. To reproduce the identifier set on the new server, it is necessary to copy the identifiers from the old server to the new one, and to preserve the relationship between the identifiers and the actual events. This is neccessary for restoring a slave that is immediately available as a candidate to become a new master on failover or switchover.

Simple replication. The easiest way to reproduce all identifiers and transactions on a new server is to make the new server into the slave of a master that has the entire execution history, and enable global transaction identifiers on both servers. See Section 2.3.2, “Setting Up Replication Using GTIDs”, for more information.

Once replication is started, the new server copies the entire binary log from the master and thus obtains all information about all GTIDs.

This method is simple and effective, but requires the slave to read the binary log from the master; it can sometimes take a comparatively long time for the new slave to catch up with the master, so this method is not suitable for fast failover or restoring from backup. This section explains how to avoid fetching all of the execution history from the master by copying binary log files to the new server.

Copying data and transactions to the slave. Playing back the entire transaction history can be time-consuming, and represents a major bottleneck when setting up a new replication slave. To eliminate this requirement, a snapshot of the data set, the binary logs and the global transaction information the master contains is imported to the slave. The binary log is played back, after which replication can be started, allowing the slave to become current with any remaining transactions.

There are several variants of this method, the difference being in the manner in which data dumps and transactions from binary logs are transfered to the slave, as outlined here:

Data Set	Transaction History
• Use the `mysql` client to import a dump file created with `mysqldump`. Use the `--master-data` option to include binary logging information and `--set-gtid-purged` to `AUTO` (the default) or `ON`, to include information about executed transactions. You should have `--gtid-mode=ON` while importing the dump on the slave. • Stop the slave, copy the contents of the master's data directory to the slave's data directory, then restart the slave.	If `gtid_mode` is not `ON`, restart the server with GTID mode enabled. • Import the binary log using `mysqlbinlog`, with the `--read-from-remote-server` and `--read-from-remote-master` options. • Copy the master's binary log files to the slave. You can make copies from the slave using `mysqlbinlog --read-from-remote-server --raw`. These can be read in to the slave in either of the following ways: • Update the slave's `binlog.index` file to point to the copied log files. Then execute a `CHANGE MASTER TO` statement in the `mysql` client to point to the first log file, and `START SLAVE` to read them. • Use `mysqlbinlog > *file*` (without the `--raw` option) to export the binary log files to SQL files that can be processed by the `mysql` client.

See also Using mysqlbinlog to Back Up Binary Log Files.

This method has the advantage that a new server is available almost immediately; only those transactions that were committed while the snapshot or dump file was being replayed still need to be obtained from the existing master. This means that the slave's availability is not instantanteous—but only a relatively short amount of time should be required for the slave to catch up with these few remaining transactions.

Copying over binary logs to the target server in advance is usually faster than reading the entire transaction execution history from the master in real time. However, it may not always be feasible to move these files to the target when required, due to size or other considerations. The two remaining methods for provisioning a new slave discussed in this section use other means to transfer information about transactions to the new slave.

Injecting empty transactions. The master's global `gtid_executed` variable contains the set of all transactions executed on the master. Rather than copy the binary logs when taking a snapshot to provision a new server, you can instead note the content of `gtid_executed` on the server from which the snapshot was taken. Before adding the new server to the replication chain, simply commit an empty transaction on the new server for each transaction identifier contained in the master's `gtid_executed`, like this:

```
SET GTID_NEXT='aaa-bbb-ccc-ddd:N';

BEGIN;
COMMIT;

SET GTID_NEXT='AUTOMATIC';
```

Once all transaction identifiers have been reinstated in this way using empty transactions, you must flush and purge the slave's binary logs, as shown here, where *`N`* is the nonzero suffix of the current binary log file name:

```
FLUSH LOGS;
PURGE BINARY LOGS TO 'master-bin.00000N';
```

You should do this to prevent this server from flooding the replication stream with false transactions in the event that it is later promoted to master. (The `FLUSH LOGS` statement forces the creation of a new binary log file; `PURGE BINARY LOGS` purges the empty transactions, but retains their identifiers.)

This method creates a server that is essentially a snapshot, but in time is able to become a master as its binary log history converges with that of the replication stream (that is, as it catches up with the master or masters). This outcome is similar in effect to that obtained using the remaining provisioning method, which we discuss in the next few paragraphs.

Excluding transactions with gtid_purged. The master's global `gtid_purged` variable contains the set of all transactions that have been purged from the master's binary log. As with the method discussed previously (see Injecting empty transactions), you can record the value of `gtid_executed` on the server from which the snapshot was taken (in place of copying the binary logs to the new server). Unlike the previous method, there is no need to commit empty transactions (or to issue `PURGE BINARY LOGS`); instead, you can set `gtid_purged` on the slave directly, based on the value of `gtid_executed` on the server from which the backup or snapshot was taken.

As with the method using empty transactions, this method creates a server that is functionally a snapshot, but in time is able to become a master as its binary log history converges with that of the replication master or group.

Restoring GTID mode slaves. When restoring a slave in a GTID based replication setup that has encountered an error, injecting an empty transaction may not solve the problem because an event does not have a GTID.

Use `mysqlbinlog` to find the next transaction, which is probably the first transaction in the next log file after the event. Copy everything up to the `COMMIT` for that transaction, being sure to include the `SET @@SESSION.GTID_NEXT`. Even if you are not using row-based replication, you can still run binary log row events in the command line client.

Stop the slave and run the transaction you copied. The `mysqlbinlog` output sets the delimiter to `/*!*/;`, so set it back:

```
mysql> DELIMITER ;
```

Restart replication from the correct position automatically:

```
mysql> SET GTID_NEXT=automatic;
mysql> RESET SLAVE;
mysql> START SLAVE;
```

2.3.4 Restrictions on Replication with GTIDs

Because GTID-based replication is dependent on transactions, some features otherwise available in MySQL are not supported when using it. This section provides information about restrictions on and limitations of replication with GTIDs.

Updates involving nontransactional storage engines. When using GTIDs, updates to tables using nontransactional storage engines such as `MyISAM` cannot be made in the same statement or transaction as updates to tables using transactional storage engines such as `InnoDB`.

This restriction is due to the fact that updates to tables that use a nontransactional storage engine mixed with updates to tables that use a transactional storage engine within the same transaction can result in multiple GTIDs being assigned to the same transaction.

Such problems can also occur when the master and the slave use different storage engines for their respective versions of the same table, where one storage engine is transactional and the other is not.

In any of the cases just mentioned, the one-to-one correspondence between transactions and GTIDs is broken, with the result that GTID-based replication cannot function correctly.

CREATE TABLE ... SELECT statements. `CREATE TABLE ... SELECT` is not safe for statement-based replication. When using row-based replication, this statement is actually logged as two separate events—one for the creation of the table, and another for the insertion of rows from the source table into the new table just created. When this statement is executed within a transaction, it is possible in some cases for these two events to receive the same transaction identifier, which means that the transaction containing the inserts is skipped by the slave. Therefore, `CREATE TABLE ... SELECT` is not supported when using GTID-based replication.

Temporary tables. `CREATE TEMPORARY TABLE` and `DROP TEMPORARY TABLE` statements are not supported inside transactions when using GTIDs (that is, when the server was started with the `--enforce-gtid-consistency` option). It is possible to use these statements with GTIDs enabled, but only outside of any transaction, and only with `autocommit=1`.

Preventing execution of unsupported statements. To prevent execution of statements that would cause GTID-based replication to fail, all servers must be started with the `--enforce-gtid-consistency` option when enabling GTIDs. This causes statements of any of the types discussed previously in this section to fail with an error.

For information about other required startup options when enabling GTIDs, see Section 2.3.2, “Setting Up Replication Using GTIDs”.

`sql_slave_skip_counter` is not supported when using GTIDs. If you need to skip transactions, use the value of the master's `gtid_executed` variable instead; see Injecting empty transactions, for more information.

GTID mode and mysqldump. It is possible to import a dump made using `mysqldump` into a MySQL Server running with GTID mode enabled, provided that there are no GTIDs in the target server's binary log.

GTID mode and mysql_upgrade. It is possible but is not recommended to use `mysql_upgrade` on a MySQL Server running with `--gtid-mode=ON`, since `mysql_upgrade` can make changes to system tables that use the `MyISAM` storage engine, which is nontransactional.

2.4 MySQL Multi-Source Replication

This section describes MySQL Multi-Source Replication, included in MySQL 5.7.6 and later. Multi-source replication enables you to replicate from multiple immediate masters in parallel. This section describes multi-source replication, and how to configure, monitor and troubleshoot it.

2.4.1 MySQL Multi-Source Replication Overview

MySQL Multi-Source Replication enables a replication slave to receive transactions from multiple sources simultaneously. Multi-source replication can be used to back up multiple servers to a single server, to merge table shards, and consolidate data from multiple servers to a single server. Multi-source replication does not implement any conflict detection or resolution when applying the transactions, and those tasks are left to the application if required. In a multi-source replication topology, a slave creates a replication channel for each master that it should receive transactions from. See Section 5.3, “Replication Channels”. The following sections describe how to set up multi-source replication.

2.4.2 Multi-Source Replication Tutorials

This section provides tutorials on how to configure masters and slaves for multi-source replication, and how to start, stop and reset multi-source slaves.

2.4.2.1 Configuring Multi-Source Replication

This section explains how to configure a multi-source replication topology, and provides details about configuring masters and slaves. Such a topology requires at least two masters and one slave configured.

Masters in a multi-source replication topology can be configured to use either global transaction identifier (GTID) based replication, or binary log position-based replication. See Section 2.3.2, “Setting Up Replication Using GTIDs” for how to configure a master using GTID based replication. See Section 2.2.1, “Setting the Replication Master Configuration” for how to configure a master using file position based replication.

Slaves in a multi-source replication topology require `TABLE` based repositories. Multi-source replication is not compatible with `FILE` based repositories. The type of repository being used by `mysqld` can be configured either at startup, or dynamically.

To configure the type of repository used by a replication slave at startup, start `mysqld` with the following options:

```
--master-info-repository=TABLE --relay-log-info-repository=TABLE
```

To modify an existing replication slave that is using a `FILE` repository to use `TABLE` repositories, convert the existing replication repositories dynamically by running the following commands:

```

STOP SLAVE;
SET GLOBAL master_info_repository = 'TABLE';
SET GLOBAL relay_log_info_repository = 'TABLE';
```

2.4.2.2 Adding a GTID Based Master to a Multi-Source Replication Slave

This section assumes you have enabled GTID based transactions on the master using `gtid_mode=ON`, enabled a replication user, and ensured that the slave is using `TABLE` based replication repositories.

Use the `CHANGE MASTER TO` statement to add a new master to a channel by using a `FOR CHANNEL` *`channel`* clause. For more information on replication channels, see Section 5.3, “Replication Channels”

For example, to add a new master with the host name *`master1`* using port *`3451`* to a channel called *`master-1`*:

```
CHANGE MASTER TO MASTER_HOST='master1', MASTER_USER='rpl', MASTER_PORT=3451, MASTER_PASSWORD='', \
MASTER_AUTO_POSITION = 1 FOR CHANNEL 'master-1';
```

Multi-source replication is compatible with auto-positioning. See CHANGE MASTER TO Syntax for more information.

Repeat this process for each extra master that you want to add to a channel, changing the host name, port and channel as appropriate.

2.4.2.3 Adding a Binary Log Based Master to a Multi-Source Replication Slave

This section assumes you have enabled binary logging on the master using `--log-bin`, enabled a replication user, noted the current binary log position, and ensured that the slave is using `TABLE` based replication repositories. You need to know the current `MASTER_LOG_FILE` and `MASTER_LOG_POSITION`. Use the `CHANGE MASTER TO` statement to add a new master to a channel by specifying a `FOR CHANNEL` *`channel`* clause. For example, to add a new master with the host name *`master1`* using port *`3451`* to a channel called *`master-1`*:

```
CHANGE MASTER TO MASTER_HOST='master1', MASTER_USER='rpl', MASTER_PORT=3451, MASTER_PASSWORD='' \
MASTER_LOG_FILE='master1-bin.000006', MASTER_LOG_POS=628 FOR CHANNEL 'master-1';
```

Repeat this process for each extra master that you want to add to a channel, changing the host name, port and channel as appropriate.

2.4.2.4 Starting Multi-Source Replication Slaves

Once you have added all of the channels you want to use as replication masters, use a `START SLAVE` *`thread_types`* statement to start replication. When you have enabled multiple channels on a slave, you can choose to either start all channels, or select a specific channel to start.

- To start all currently configured replication channels:

  ```
  START SLAVE thread_types;
  ```

- To start only a named channel, use a `FOR CHANNEL` *`channel`* clause:

  ```
  START SLAVE thread_types FOR CHANNEL channel;
  ```

Use the *`thread_types`* option to choose specific threads you want the above statements to start on the slave. See START SLAVE Syntax for more information.

2.4.2.5 Stopping Multi-Source Replication Slaves

The `STOP SLAVE` statement can be used to stop a multi-source replication slave. By default, if you use the `STOP SLAVE` statement on a multi-source replication slave all channels are stopped. Optionally, use the `FOR CHANNEL` *`channel`* clause to stop only a specific channel.

- To stop all currently configured replication channels:

```
STOP SLAVE thread_types;
```

- To stop only a named channel, use a `FOR CHANNEL channel` clause:

```
STOP SLAVE thread_types FOR CHANNEL channel;
```

Use the *`thread_types`* option to choose specific threads you want the above statements to stop on the slave. See STOP SLAVE Syntax for more information.

2.4.2.6 Resetting Multi-Source Replication Slaves

The `RESET SLAVE` statement can be used to reset a multi-source replication slave. By default, if you use the `RESET SLAVE` statement on a multi-source replication slave all channels are reset. Optionally, use the `FOR CHANNEL channel` clause to reset only a specific channel.

- To reset all currently configured replication channels:

```
RESET SLAVE;
```

- To reset only a named channel, use a `FOR CHANNEL channel` clause:

```
RESET SLAVE FOR CHANNEL channel;
```

See RESET SLAVE Syntax for more information.

2.4.3 Multi-Source Replication Monitoring

To monitor the status of replication channels the following options exist:

- Using the replication Performance Schema tables. The first column of these tables is `Channel_Name`. This enables you to write complex queries based on `Channel_Name` as a key. See Performance Schema Replication Tables.
- Using `SHOW SLAVE STATUS FOR CHANNEL channel_name`. By default, if the `FOR CHANNEL channel_name` clause is not used, this statement shows the slave status for all channels with one row per channel. The identifier `channel_name` is added as a column in the result set. If a `FOR CHANNEL channel_name` clause is provided, the results show the status of only the named replication channel.

Note

The `SHOW VARIABLES` statement does not work with multiple replication channels. The information that was available through these variables has been migrated to the replication performance tables. Using a `SHOW VARIABLES` statement in a topology with multiple channels shows the status of only the default channel.

2.4.3.1 Monitoring Channels Using Performance Schema Tables

This section explains how to use the replication Performance Schema tables to monitor channels. You can choose to monitor all channels, or a subset of the existing channels.

To monitor the connection status of all channels:

```
mysql> SELECT * FROM replication_connection_status\G;
*************************** 1. row ***************************
CHANNEL_NAME: master1
GROUP_NAME:
SOURCE_UUID: 046e41f8-a223-11e4-a975-0811960cc264
```

```
THREAD_ID: 24
SERVICE_STATE: ON
COUNT_RECEIVED_HEARTBEATS: 0
LAST_HEARTBEAT_TIMESTAMP: 0000-00-00 00:00:00
RECEIVED_TRANSACTION_SET: 046e41f8-a223-11e4-a975-0811960cc264:4-37
LAST_ERROR_NUMBER: 0
LAST_ERROR_MESSAGE:
LAST_ERROR_TIMESTAMP: 0000-00-00 00:00:00
*************************** 2. row ***************************
CHANNEL_NAME: master2
GROUP_NAME:
SOURCE_UUID: 7475e474-a223-11e4-a978-0811960cc264
THREAD_ID: 26
SERVICE_STATE: ON
COUNT_RECEIVED_HEARTBEATS: 0
LAST_HEARTBEAT_TIMESTAMP: 0000-00-00 00:00:00
RECEIVED_TRANSACTION_SET: 7475e474-a223-11e4-a978-0811960cc264:4-6
LAST_ERROR_NUMBER: 0
LAST_ERROR_MESSAGE:
LAST_ERROR_TIMESTAMP: 0000-00-00 00:00:00
2 rows in set (0.00 sec)
```

In the above output there are two channels enabled, and as shown by the `CHANNEL_NAME` field they are called `master1` and `master2`.

The addition of the `CHANNEL_NAME` field enables you to query the Performance Schema tables for a specific channel. To monitor the connection status of a named channel, use a `WHERE channel_name=channel` clause:

```
mysql> SELECT * FROM replication_connection_status WHERE channel_name='master1'\G
*************************** 1. row ***************************
CHANNEL_NAME: master1
GROUP_NAME:
SOURCE_UUID: 046e41f8-a223-11e4-a975-0811960cc264
THREAD_ID: 24
SERVICE_STATE: ON
COUNT_RECEIVED_HEARTBEATS: 0
LAST_HEARTBEAT_TIMESTAMP: 0000-00-00 00:00:00
RECEIVED_TRANSACTION_SET: 046e41f8-a223-11e4-a975-0811960cc264:4-37
LAST_ERROR_NUMBER: 0
LAST_ERROR_MESSAGE:
LAST_ERROR_TIMESTAMP: 0000-00-00 00:00:00
1 row in set (0.00 sec)
```

Similarly, the `WHERE channel_name=channel` clause can be used to monitor the other replication Performance Schema tables for a specific channel. For more information, see Performance Schema Replication Tables.

2.4.4 Multi-Source Replication Error Messages

New error codes and messages have been added to MySQL 5.7.6 to provide information about errors encountered in a multi-source replication topology. These error codes and messages are only emitted when multi-source replication is enabled, and provide information related to the channel which generated the error. For example:

`Slave is already running` and `Slave is already stopped` have been replaced with `Replication thread(s) for channel channel_name are already running` and `Replication threads(s) for channel channel_name are already stopped` respectively.

The server log messages have also been changed to indicate which channel the log messages relate to. This makes debugging and tracing easier.

2.5 Changing Replication Modes on Online Servers

This section describes how to change the mode of replication being used without having to take the server offline. This is new functionality added in MySQL 5.7.6.

2.5.1 Replication Mode Concepts

To be able to safely configure the replication mode of an online server it is important to understand some key concepts of replication. This section explains these concepts and is essential reading before attempting to modify the replication mode of an online server.

The modes of replication available in MySQL rely on different techniques for identifying transactions which are logged. The types of transactions used by replication are as follows:

- GTID transactions are identified by a global transaction identifier (GTID) in the form `UUID:NUMBER`. Every GTID transaction in a log is always preceded by a `Gtid_log_event`. GTID transactions can be addressed using either the GTID or using the file name and position.

- Anonymous transactions do not have a GTID assigned, and MySQL 5.7.6 and later ensures that every anonymous transaction in a log is preceded by an `Anonymous_gtid_log_event`. In previous versions, anonymous transactions were not preceded by any particular event. Anonymous transactions can only be addressed using file name and position.

When using GTIDs you can take advantage of auto-positioning and automatic fail-over, as well as use `WAIT_FOR_EXECUTED_GTID_SET()`, `session_track_gtids`, and monitor replicated transactions using Performance Schema tables. With GTIDs enabled you cannot use `sql_slave_skip_counter`, instead use empty transactions.

The changes introduced by MySQL 5.7.6 mean that transactions in a relay log that was received from a master running a previous version of MySQL may not be preceded by any particular event at all, but after being replayed and logged in the slave's binary log, they are preceded with an `Anonymous_gtid_log_event`.

The ability to configure the replication mode online means that the `gtid_mode` and `enforce_gtid_consistency` variables are now both dynamic and can be set by `SUPER` from a top-level statement. In previous versions, both of these variables could only be configured using the appropriate option at server start, meaning that changes to the replication mode required a server restart. In all versions `gtid_mode` could be set to `ON` or `OFF`, which corresponded to whether GTIDs were used to identify transactions or not. When `gtid_mode=ON` it is not possible to replicate anonymous transactions, and when `gtid_mode=OFF` only anonymous transactions can be replicated. As of MySQL 5.7.6, the `gtid_mode` variable has two additional states, `OFF_PERMISSIVE` and `ON_PERMISSIVE`. When `gtid_mode=OFF_PERMISSIVE` then *new* transactions are anonymous while permitting replicated transactions to be either GTID or anonymous transactions. When `gtid_mode=ON_PERMISSIVE` then *new* transactions use GTIDs while permitting replicated transactions to be either GTID or anonymous transactions. This means it is possible to have a replication topology that has servers using both anonymous and GTID transactions. For example a master with `gtid_mode=ON` could be replicating to a slave with `gtid_mode=ON_PERMISSIVE`. The valid values for `gtid_mode` are as follows and in this order:

- `OFF`

- `OFF_PERMISSIVE`

- `ON_PERMISSIVE`

- `ON`

It is important to note that the state of gtid_mode can only be changed by one step at a time based on the above order. For example, if gtid_mode is currently set to OFF_PERMISSIVE, it is possible to change to OFF or ON_PERMISSIVE but not to ON. This is to ensure that the process of changing from anonymous transactions to GTID transactions online is correctly handled by the server. When you switch between gtid_mode=ON and gtid_mode=OFF, the GTID state (in other words the value of gtid_executed) is persistent. This ensures that the GTID set that has been applied by the server is always retained, regardless of changes between types of gtid_mode.

As part of the changes introduced by MySQL 5.7.6, the fields related to GTIDs have been modified so that they display the correct information regardless of the currently selected gtid_mode. This means that fields which display GTID sets, such as gtid_executed, gtid_purged, RECEIVED_TRANSACTION_SET in the replication_connection_status Performance Schema table, and the GTID related results of SHOW SLAVE STATUS, now return the empty string when there are no GTIDs present. Fields that display a single GTID, such as CURRENT_TRANSACTION in the replication_applier_status_by_worker Performance Schema table, now display ANONYMOUS when GTID transactions are not being used.

Replication from a master using gtid_mode=ON provides the ability to use auto-positioning, configured using the CHANGE MASTER TO MASTER_AUTO_POSITION = 1; statement. The replication topology being used impacts on whether it is possible to enable auto-positioning or not, as this feature relies on GTIDs and is not compatible with anonymous transactions. An error is generated if auto-positioning is enabled and an anonymous transaction is encountered. It is strongly recommended to ensure there are no anonymous transactions remaining in the topology before enabling auto-positioning, see Section 2.5.2, “Enabling GTID Transactions Online”. The valid combinations of gtid_mode and auto-positioning on master and slave are shown in the following table, where the master's gtid_mode is shown on the horizontal and the slave's gtid_mode is on the vertical:

Table 2.1 Valid Combinations of Master and Slave gtid_mode

Master/Slave gtid_mode	**OFF**	**OFF_PERMISSIVE**	**ON_PERMISSIVE**	**ON**
OFF	Y	Y	N	N
OFF_PERMISSIVE	Y	Y	Y	Y*
ON_PERMISSIVE	Y	Y	Y	Y*
ON	N	N	Y	Y*

In the above table, the entries are:

- Y: the gtid_mode of master and slave is compatible
- N: the gtid_mode of master and slave is not compatible
- *: auto-positioning can be used

The currently selected gtid_mode also impacts on the gtid_next variable. The following table shows the behavior of the server for the different values of gtid_mode and gtid_next.

Table 2.2 Valid Combinations of gtid_mode and gtid_next

gtid_next	**AUTOMATIC binary log on**	**AUTOMATIC binary log off**	**ANONYMOUS**	**UUID:NUMBER**
OFF	ANONYMOUS	ANONYMOUS	ANONYMOUS	Error
OFF_PERMISSIVE	ANONYMOUS	ANONYMOUS	ANONYMOUS	UUID:NUMBER
ON_PERMISSIVE	New GTID	ANONYMOUS	ANONYMOUS	UUID:NUMBER

`gtid_next`	**AUTOMATIC binary log on**	**AUTOMATIC binary log off**	**ANONYMOUS**	**UUID:NUMBER**
`ON`	New GTID	ANONYMOUS	Error	UUID:NUMBER

In the above table, the entries are:

- `ANONYMOUS`: generate an anonymous transaction.
- `Error`: generate an error and fail to execute `SET GTID_NEXT`.
- `UUID:NUMBER`: generate a GTID with the specified UUID:NUMBER.
- `New GTID`: generate a GTID with an automatically generated number.

When the binary log is off and `gtid_next` is set to `AUTOMATIC`, then no GTID is generated. This is consistent with the behavior of previous versions.

2.5.2 Enabling GTID Transactions Online

This section describes how to enable GTID transactions, and optionally auto-positioning, on servers that are already online and using anonymous transactions. This procedure does not require taking the server offline and is suited to use in production. However, if you have the possibility to take the servers offline when enabling GTID transactions that process is easier.

Before you start, ensure that the servers meet the following pre-conditions:

- *All* servers in your topology must use MySQL 5.7.6 or later. You cannot enable GTID transactions online on any single server unless *all* servers which are in the topology are using this version.
- All servers have `gtid_mode` set to the default value `OFF`.

The following procedure can be paused at any time and later resumed where it was, or reversed by jumping to the corresponding step of Section 2.5.3, "Disabling GTID Transactions Online", the online procedure to disable GTIDs. This makes the procedure fault-tolerant because any unrelated issues that may appear in the middle of the procedure can be handled as usual, and then the procedure continued where it was left off.

Note

It is crucial that you complete every step before continuing to the next step.

To enable GTID transactions:

1. On each server, execute:

   ```
   SET @@GLOBAL.ENFORCE_GTID_CONSISTENCY = WARN;
   ```

   Let the server run for a while with your normal workload and monitor the logs. If this step causes any warnings in the log, adjust your application so that it only uses GTID-compatible features and does not generate any warnings.

   Important

   This is the first important step. You must ensure that no warnings are being generated in the error logs before going to the next step.

2. On each server, execute:

```
SET @@GLOBAL.ENFORCE_GTID_CONSISTENCY = ON;
```

3. On each server, execute:

   ```
   SET @@GLOBAL.GTID_MODE = OFF_PERMISSIVE;
   ```

   It does not matter which server executes this statement first, but it is important that all servers complete this step before any server begins the next step.

4. On each server, execute:

   ```
   SET @@GLOBAL.GTID_MODE = ON_PERMISSIVE;
   ```

   It does not matter which server executes this statement first.

5. On each server, wait until the status variable `ONGOING_ANONYMOUS_TRANSACTION_COUNT` is zero. This can be checked using:

   ```
   SHOW STATUS LIKE 'ONGOING_ANONYMOUS_TRANSACTION_COUNT';
   ```

   Note

   On a replication slave, it is theoretically possible that this shows zero and then non-zero again. This is not a problem, it suffices that it shows zero once.

6. Wait for all transactions generated up to step 5 to replicate to all servers. You can do this without stopping updates: the only important thing is that all anonymous transactions get replicated.

   See Section 2.5.4, “Verifying Replication of Anonymous Transactions” for one method of checking that all anonymous transactions have replicated to all servers.

7. If you use binary logs for anything other than replication, for example point in time backup and restore, wait until you do not need the old binary logs having transactions without GTIDs.

   For instance, after step 6 has completed, you can execute `FLUSH LOGS` on the server where you are taking backups. Then either explicitly take a backup or wait for the next iteration of any periodic backup routine you may have set up.

   Ideally, wait for the server to purge all binary logs that existed when step 6 was completed. Also wait for any backup taken before step 6 to expire.

   Important

   This is the second important point. It is vital to understand that binary logs containing anonymous transactions, without GTIDs cannot be used after the next step. After this step, you must be sure that transactions without GTIDs do not exist anywhere in the topology.

8. On each server, execute:

   ```
   SET @@GLOBAL.GTID_MODE = ON;
   ```

9. On each server, add `gtid-mode=ON` to `my.cnf`.

   You are now guaranteed that all transactions have a GTID (except transactions generated in step 5 or earlier, which have already been processed). To start using the GTID protocol so that you can later perform automatic fail-over, execute the following on each slave. Optionally, if you use multi-source replication, do this for each channel and include the `FOR CHANNEL` *`channel`* clause:

```
STOP SLAVE [FOR CHANNEL 'channel'];
CHANGE MASTER TO MASTER_AUTO_POSITION = 1 [FOR CHANNEL 'channel'];
START SLAVE [FOR CHANNEL 'channel'];
```

2.5.3 Disabling GTID Transactions Online

This section describes how to disable GTID transactions on servers that are already online. This procedure does not require taking the server offline and is suited to use in production. However, if you have the possibility to take the servers offline when disabling GTIDs mode that process is easier.

The process is similar to enabling GTID transactions while the server is online, but reversing the steps. The only thing that differs is the point at which you wait for logged transactions to replicate.

Before you start, ensure that the servers meet the following pre-conditions:

- *All* servers in your topology must use MySQL 5.7.6 or later. You cannot disable GTID transactions online on any single server unless *all* servers which are in the topology are using this version.
- All servers have `gtid_mode` set to `ON`.

1. Execute the following on each slave, and if you using multi-source replication, do it for each channel and include the `FOR CHANNEL` channel clause:

   ```
   STOP SLAVE [FOR CHANNEL 'channel'];
   CHANGE MASTER TO MASTER_AUTO_POSITION = 0, MASTER_LOG_FILE = file, \
   MASTER_LOG_POS = position [FOR CHANNEL 'channel'];
   START SLAVE [FOR CHANNEL 'channel'];
   ```

2. On each server, execute:

   ```
   SET @@GLOBAL.GTID_MODE = ON_PERMISSIVE;
   ```

3. On each server, execute:

   ```
   SET @@GLOBAL.GTID_MODE = OFF_PERMISSIVE;
   ```

4. On each server, wait until the variable @@GLOBAL.GTID_OWNED is equal to the empty string. This can be checked using:

   ```
   SELECT @@GLOBAL.GTID_OWNED;
   ```

   On a replication slave, it is theoretically possible that this is empty and then nonempty again. This is not a problem, it suffices that it is empty once.

5. Wait for all transactions that currently exist in any binary log to replicate to all slaves. See Section 2.5.4, “Verifying Replication of Anonymous Transactions” for one method of checking that all anonymous transactions have replicated to all servers.

6. If you use binary logs for anything else than replication, for example to do point in time backup or restore: wait until you do not need the old binary logs having GTID transactions.

   For instance, after step 5 has completed, you can execute `FLUSH LOGS` on the server where you are taking the backup. Then either explicitly take a backup or wait for the next iteration of any periodic backup routine you may have set up.

Ideally, wait for the server to purge all binary logs that existed when step 5 was completed. Also wait for any backup taken before step 5 to expire.

> **Important**
>
> This is the one important point during this procedure. It is important to understand that logs containing GTID transactions cannot be used after the next step. Before proceeding you must be sure that GTID transactions do not exist anywhere in the topology.

7. On each server, execute:

   ```
   SET @@GLOBAL.GTID_MODE = OFF;
   ```

8. On each server, set `gtid-mode=OFF` in `my.cnf`.

   If you want to set `enforce_gtid_consistency=OFF`, you can do so now. After setting it, you should add `enforce_gtid_consistency=OFF` to your configuration file.

If you want to downgrade to an earlier version of MySQL, you can do so now, using the normal downgrade procedure.

2.5.4 Verifying Replication of Anonymous Transactions

This section explains how to monitor a replication topology and verify that all anonymous transactions have been replicated. This is helpful when changing the replication mode online as you can verify that it is safe to change to GTID transactions.

There are several possible ways to wait for transactions to replicate:

The simplest method, which works regardless of your topology but relies on timing is as follows: if you are sure that the slave never lags more than N seconds, just wait for a bit more than N seconds. Or wait for a day, or whatever time period you consider safe for your deployment.

A safer method in the sense that it does not depend on timing: if you only have a master with one or more slaves, do the following:

1. On the master, execute:

   ```
   SHOW MASTER STATUS;
   ```

   Note down the values in the `File` and `Position` column.

2. On every slave, use the file and position information from the master to execute:

   ```
   SELECT MASTER_POS_WAIT(file, position);
   ```

If you have a master and multiple levels of slaves, or in other words you have slaves of slaves, repeat step 2 on each level, starting from the master, then all the direct slaves, then all the slaves of slaves, and so on.

If you use a circular replication topology where multiple servers may have write clients, perform step 2 for each master-slave connection, until you have completed the full circle. Repeat the whole process so that you do the full circle *twice*.

For example, suppose you have three servers A, B, and C, replicating in a circle so that A -> B -> C -> A. The procedure is then:

- Do step 1 on A and step 2 on B.

- Do step 1 on B and step 2 on C.
- Do step 1 on C and step 2 on A.
- Do step 1 on A and step 2 on B.
- Do step 1 on B and step 2 on C.
- Do step 1 on C and step 2 on A.

2.6 Replication and Binary Logging Options and Variables

The following sections contain information about `mysqld` options and server variables that are used in replication and for controlling the binary log. Options and variables for use on replication masters and replication slaves are covered separately, as are options and variables relating to binary logging and global transaction identifiers (GTIDs). A set of quick-reference tables providing basic information about these options and variables is also included.

Of particular importance is the `--server-id` option.

Command-Line Format	`--server-id=#`	
System Variable	**Name**	`server_id`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`4294967295`

This option is common to both master and slave replication servers, and is used in replication to enable master and slave servers to identify themselves uniquely. For additional information, see Section 2.6.2, “Replication Master Options and Variables”, and Section 2.6.3, “Replication Slave Options and Variables”.

On the master and each slave, you *must* use the `--server-id` option to establish a unique replication ID in the range from 1 to $2^{32} - 1$. “Unique”, means that each ID must be different from every other ID in use by any other replication master or slave. For example, `server-id=3`.

In MySQL 5.7.2 and earlier, if you start a master server without using `--server-id` to set its ID, the default ID is 0. In this case, the master refuses connections from all slaves, slaves refuse to connect to the master, and the server sets the `server_id` system variable to 1. In MySQL 5.7.3 and later, the `--server-id` must be used if binary logging is enabled, and a value of 0 is not changed by the server. If you specify `--server-id` without an argument, the effect is the same as using 0. In either case, if the `server_id` is 0, binary logging takes place, but slaves cannot connect to the master, nor can any other servers connect to it as slaves. (Bug #11763963, Bug #56718)

For more information, see Section 2.2.5.1, “Setting the Replication Slave Configuration”.

`server_uuid`

In MySQL 5.7, the server generates a true UUID in addition to the `--server-id` supplied by the user. This is available as the global, read-only variable `server_uuid`.

> **Note**
>
> The presence of the `server_uuid` system variable in MySQL 5.7 does not change the requirement for setting a unique `--server-id` for each MySQL server as part of preparing and running MySQL replication, as described earlier in this section.

System Variable	**Name**	`server_uuid`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`

When starting, the MySQL server automatically obtains a UUID as follows:

1. Attempt to read and use the UUID written in the file *`data_dir`*`/auto.cnf` (where *`data_dir`* is the server's data directory).

2. If *`data_dir`*`/auto.cnf` is not found, generate a new UUID and save it to this file, creating the file if necessary.

The `auto.cnf` file has a format similar to that used for `my.cnf` or `my.ini` files. In MySQL 5.7, `auto.cnf` has only a single `[auto]` section containing a single `server_uuid` setting and value; the file's contents appear similar to what is shown here:

```
[auto]
server_uuid=8a94f357-aab4-11df-86ab-c80aa9429562
```

> **Important**
>
> The `auto.cnf` file is automatically generated; do not attempt to write or modify this file.

When using MySQL replication, masters and slaves know each other's UUIDs. The value of a slave's UUID can be seen in the output of `SHOW SLAVE HOSTS`. Once `START SLAVE` has been executed, the value of the master's UUID is available on the slave in the output of `SHOW SLAVE STATUS`.

> **Note**
>
> Issuing a `STOP SLAVE` or `RESET SLAVE` statement does *not* reset the master's UUID as used on the slave.

A server's `server_uuid` is also used in GTIDs for transactions originating on that server. For more information, see Section 2.3, “Replication with Global Transaction Identifiers”.

When starting, the slave I/O thread generates an error and aborts if its master's UUID is equal to its own unless the `--replicate-same-server-id` option has been set. In addition, the slave I/O thread generates a warning if either of the following is true:

- No master having the expected `server_uuid` exists.

- The master's `server_uuid` has changed, although no `CHANGE MASTER TO` statement has ever been executed.

2.6.1 Replication and Binary Logging Option and Variable Reference

The following tables list basic information about the MySQL command-line options and system variables applicable to replication and the binary log.

Table 2.3 Summary of Replication options and variables in MySQL 5.7

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`abort-slave-event-count`		
Yes	No	No
Yes		No
DESCRIPTION: Option used by mysql-test for debugging and testing of replication		
`binlog_gtid_simple_recovery`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Controls how binary logs are iterated during GTID recovery		
`Com_change_master`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of CHANGE MASTER TO statements		
`Com_show_master_status`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW MASTER STATUS statements		
`Com_show_new_master`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW NEW MASTER statements		
`Com_show_slave_hosts`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW SLAVE HOSTS statements		
`Com_show_slave_status`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW SLAVE STATUS statements		
`Com_show_slave_status_nonblocking`		
No	No	Yes
No	Both	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Count of SHOW SLAVE STATUS NONBLOCKING statements		
`Com_slave_start`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of START SLAVE statements		
`Com_slave_stop`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of STOP SLAVE statements		
`disconnect-slave-event-count`		
Yes	No	No
Yes		No
DESCRIPTION: Option used by mysql-test for debugging and testing of replication		
`enforce-gtid-consistency`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Prevents execution of statements that cannot be logged in a transactionally safe manner		
`enforce_gtid_consistency`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Prevents execution of statements that cannot be logged in a transactionally safe manner		
`executed-gtids-compression-period`		
Yes	No	No
Yes		No
DESCRIPTION: Deprecated and will be removed in a future version. Use the renamed gtid-executed-compression-period instead.		
`executed_gtids_compression_period`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Deprecated and will be removed in a future version. Use the renamed gtid_executed_compression_period instead.		
`gtid-executed-compression-period`		
Yes	No	No
Yes		No
DESCRIPTION: Compress gtid_executed table each time this many transactions have occurred. 0 means never compress this table. Applies only when binary logging is disabled.		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
gtid-mode		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Controls whether GTID based logging is enabled and what type of transactions the logs can contain		
gtid_executed		
No	Yes	No
No	Global	No
DESCRIPTION: Global: All GTIDs in the binary log (global) or current transaction (session). Read-only.		
gtid_executed_compression_period		
No	Yes	No
No	Global	Yes
DESCRIPTION: Compress gtid_executed table each time this many transactions have occurred. 0 means never compress this table. Applies only when binary logging is disabled.		
gtid_mode		
No	Yes	No
No	Global	Yes
DESCRIPTION: Controls whether GTID based logging is enabled and what type of transactions the logs can contain		
gtid_next		
No	Yes	No
No	Session	Yes
DESCRIPTION: Specifies the GTID for the next statement to execute. See documentation for details.		
gtid_owned		
No	Yes	No
No	Both	No
DESCRIPTION: The set of GTIDs owned by this client (session), or by all clients, together with the thread ID of the owner (global). Read-only.		
gtid_purged		
No	Yes	No
No	Global	Yes
DESCRIPTION: The set of all GTIDs that have been purged from the binary log.		
init_slave		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Statements that are executed when a slave connects to a master		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`log-slave-updates`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Tells the slave to log the updates performed by its SQL thread to its own binary log		
`log_slave_updates`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Whether the slave should log the updates performed by its SQL thread to its own binary log. Read-only; set using the --log-slave-updates server option.		
`log_statements_unsafe_for_binlog`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Disables error 1592 warnings being written to the error log		
`master-info-file`		
Yes	No	No
Yes		No
DESCRIPTION: The location and name of the file that remembers the master and where the I/O replication thread is in the master's binary logs		
`master-info-repository`		
Yes	No	No
Yes		No
DESCRIPTION: Whether to write master status information and replication I/O thread location in the master's binary logs to a file or table.		
`master-retry-count`		
Yes	No	No
Yes		No
DESCRIPTION: Number of tries the slave makes to connect to the master before giving up		
`master_info_repository`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Whether to write master status information and replication I/O thread location in the master's binary logs to a file or table		
`relay-log`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The location and base name to use for relay logs		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
relay-log-index		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The location and name to use for the file that keeps a list of the last relay logs		
relay-log-info-file		
Yes	No	No
Yes		No
DESCRIPTION: The location and name of the file that remembers where the SQL replication thread is in the relay logs		
relay-log-info-repository		
Yes	No	No
Yes		No
DESCRIPTION: Whether to write the replication SQL thread's location in the relay logs to a file or a table.		
relay-log-recovery		
Yes	No	No
Yes		No
DESCRIPTION: Enables automatic recovery of relay log files from master at startup		
relay_log_basename		
No	Yes	No
No	Global	No
DESCRIPTION: Complete path to relay log, including filename		
relay_log_index		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The name of the relay log index file		
relay_log_info_file		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The name of the file in which the slave records information about the relay logs		
relay_log_info_repository		
No	Yes	No
No	Global	Yes
DESCRIPTION: Whether to write the replication SQL thread's location in the relay logs to a file or a table		
relay_log_purge		
Yes	Yes	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	Global	Yes
DESCRIPTION: Determines whether relay logs are purged		
`relay_log_recovery`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Whether automatic recovery of relay log files from master at startup is enabled; must be enabled for a crash-safe slave.		
`relay_log_space_limit`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Maximum space to use for all relay logs		
`replicate-do-db`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave SQL thread to restrict replication to the specified database		
`replicate-do-table`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave SQL thread to restrict replication to the specified table		
`replicate-ignore-db`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave SQL thread not to replicate to the specified database		
`replicate-ignore-table`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave SQL thread not to replicate to the specified table		
`replicate-rewrite-db`		
Yes	No	No
Yes		No
DESCRIPTION: Updates to a database with a different name than the original		
`replicate-same-server-id`		
Yes	No	No
Yes		No
DESCRIPTION: In replication, if set to 1, do not skip events having our server id		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`replicate-wild-do-table`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave thread to restrict replication to the tables that match the specified wildcard pattern		
`replicate-wild-ignore-table`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave thread not to replicate to the tables that match the given wildcard pattern		
`report-host`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Host name or IP of the slave to be reported to the master during slave registration		
`report-password`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: An arbitrary password that the slave server should report to the master. Not the same as the password for the MySQL replication user account.		
`report-port`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Port for connecting to slave reported to the master during slave registration		
`report-user`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: An arbitrary user name that a slave server should report to the master. Not the same as the name used with the MySQL replication user account.		
`Rpl_semi_sync_master_clients`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of semisynchronous slaves		
`rpl_semi_sync_master_enabled`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Whether semisynchronous replication is enabled on the master		
`Rpl_semi_sync_master_net_avg_wait_time`		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	No	Yes
No	Global	No
DESCRIPTION: The average time the master waited for a slave reply		
`Rpl_semi_sync_master_net_wait_time`		
No	No	Yes
No	Global	No
DESCRIPTION: The total time the master waited for slave replies		
`Rpl_semi_sync_master_net_waits`		
No	No	Yes
No	Global	No
DESCRIPTION: The total number of times the master waited for slave replies		
`Rpl_semi_sync_master_no_times`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times the master turned off semisynchronous replication		
`Rpl_semi_sync_master_no_tx`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of commits not acknowledged successfully		
`Rpl_semi_sync_master_status`		
No	No	Yes
No	Global	No
DESCRIPTION: Whether semisynchronous replication is operational on the master		
`Rpl_semi_sync_master_timefunc_failures`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times the master failed when calling time functions		
`rpl_semi_sync_master_timeout`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Number of milliseconds to wait for slave acknowledgment		
`rpl_semi_sync_master_trace_level`		
No	Yes	No
No	Global	Yes
DESCRIPTION: The semisynchronous replication debug trace level on the master		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`Rpl_semi_sync_master_tx_avg_wait_time`		
No	No	Yes
No	Global	No
DESCRIPTION: The average time the master waited for each transaction		
`Rpl_semi_sync_master_tx_wait_time`		
No	No	Yes
No	Global	No
DESCRIPTION: The total time the master waited for transactions		
`Rpl_semi_sync_master_tx_waits`		
No	No	Yes
No	Global	No
DESCRIPTION: The total number of times the master waited for transactions		
`rpl_semi_sync_master_wait_for_slave_count`		
No	Yes	No
No	Global	Yes
DESCRIPTION: How many slave acknowledgments the master must receive per transaction before proceeding		
`rpl_semi_sync_master_wait_no_slave`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Whether master waits for timeout even with no slaves		
`rpl_semi_sync_master_wait_point`		
No	Yes	No
No	Global	Yes
DESCRIPTION: The wait point for slave transaction receipt acknowledgment		
`Rpl_semi_sync_master_wait_pos_backtraverse`		
No	No	Yes
No	Global	No
DESCRIPTION: The total number of times the master waited for an event with binary coordinates lower than events waited for previously		
`Rpl_semi_sync_master_wait_sessions`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of sessions currently waiting for slave replies		
`Rpl_semi_sync_master_yes_tx`		
No	No	Yes

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	Global	No
DESCRIPTION: Number of commits acknowledged successfully		
rpl_semi_sync_slave_enabled		
No	Yes	No
No	Global	Yes
DESCRIPTION: Whether semisynchronous replication is enabled on slave		
Rpl_semi_sync_slave_status		
No	No	Yes
No	Global	No
DESCRIPTION: Whether semisynchronous replication is operational on slave		
rpl_semi_sync_slave_trace_level		
No	Yes	No
No	Global	Yes
DESCRIPTION: The semisynchronous replication debug trace level on the slave		
rpl_stop_slave_timeout		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Set the number of seconds that STOP SLAVE waits before timing out.		
server_uuid		
No	Yes	No
No	Global	No
DESCRIPTION: The server's globally unique ID, automatically (re)generated at server start		
show-slave-auth-info		
Yes	No	No
Yes		No
DESCRIPTION: Show user name and password in SHOW SLAVE HOSTS on this master		
simplified_binlog_gtid_recovery		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Controls how binary logs are iterated during GTID recovery		
skip-slave-start		
Yes	No	No
Yes		No
DESCRIPTION: If set, slave is not autostarted		
slave-checkpoint-group		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	No	No
Yes		No
DESCRIPTION: Maximum number of transactions processed by a multi-threaded slave before a checkpoint operation is called to update progress status. Not supported by MySQL Cluster.		
`slave-checkpoint-period`		
Yes	No	No
Yes		No
DESCRIPTION: Update progress status of multi-threaded slave and flush relay log info to disk after this number of milliseconds. Not supported by MySQL Cluster.		
`slave-load-tmpdir`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The location where the slave should put its temporary files when replicating a LOAD DATA INFILE statement		
`slave-max-allowed-packet`		
Yes	No	No
Yes		No
DESCRIPTION: Maximum size, in bytes, of a packet that can be sent from a replication master to a slave; overrides max_allowed_packet.		
`slave_net_timeout`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Number of seconds to wait for more data from a master/slave connection before aborting the read		
`slave-parallel-type`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave to use database partioning (DATABASE) or timestamp information (LOGICAL_CLOCK) from the master to parallelize transactions. The default is DATABASE.		
`slave-parallel-workers`		
Yes	No	No
Yes		No
DESCRIPTION: Number of worker threads for executing events in parallel. Set to 0 (the default) to disable slave multi-threading. Not supported by MySQL Cluster.		
`slave-pending-jobs-size-max`		
Yes	No	No
No		No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Maximum size of slave worker queues holding events not yet applied.		
`slave-rows-search-algorithms`		
Yes	No	No
Yes		No
DESCRIPTION: Determines search algorithms used for slave update batching. Any 2 or 3 from the list INDEX_SEARCH, TABLE_SCAN, HASH_SCAN; the default is TABLE_SCAN,INDEX_SCAN.		
`slave-skip-errors`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Tells the slave thread to continue replication when a query returns an error from the provided list		
`slave_checkpoint_group`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Maximum number of transactions processed by a multi-threaded slave before a checkpoint operation is called to update progress status. Not supported by MySQL Cluster.		
`slave_checkpoint_period`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Update progress status of multi-threaded slave and flush relay log info to disk after this number of milliseconds. Not supported by MySQL Cluster.		
`slave_compressed_protocol`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Use compression on master/slave protocol		
`slave_exec_mode`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Allows for switching the slave thread between IDEMPOTENT mode (key and some other errors suppressed) and STRICT mode; STRICT mode is the default, except for MySQL Cluster, where IDEMPOTENT is always used		
`Slave_heartbeat_period`		
No	No	Yes
No	Global	No
DESCRIPTION: The slave's replication heartbeat interval, in seconds		
`slave_max_allowed_packet`		
No	Yes	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	Global	Yes
DESCRIPTION: Maximum size, in bytes, of a packet that can be sent from a replication master to a slave; overrides max_allowed_packet.		
`Slave_open_temp_tables`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of temporary tables that the slave SQL thread currently has open		
`slave_parallel_type`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Tells the slave to use database partioning (DATABASE) or information (LOGICAL_CLOCK) from master to parallelize transactions. The default is DATABASE.		
`slave_parallel_workers`		
Yes	Yes	No
No	Global	Yes
DESCRIPTION: Number of worker threads for executing events in parallel. Set to 0 (the default) to disable slave multi-threading. Not supported by MySQL Cluster.		
`slave_pending_jobs_size_max`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Maximum size of slave worker queues holding events not yet applied.		
`slave_preserve_commit_order`		
Yes	Yes	No
No	Global	Yes
DESCRIPTION: Ensures that all commits by slave workers happen in the same order as on the master to maintain consistency when using parallel worker threads.		
`Slave_retried_transactions`		
No	No	Yes
No	Global	No
DESCRIPTION: The total number of times since startup that the replication slave SQL thread has retried transactions		
`slave_rows_search_algorithms`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Determines search algorithms used for slave update batching. Any 2 or 3 from the list INDEX_SEARCH, TABLE_SCAN, HASH_SCAN; the default is TABLE_SCAN,INDEX_SCAN.		
`Slave_running`		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	No	Yes
No	Global	No
DESCRIPTION: The state of this server as a replication slave (slave I/O thread status)		
`slave_transaction_retries`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Number of times the slave SQL thread will retry a transaction in case it failed with a deadlock or elapsed lock wait timeout, before giving up and stopping		
`slave_type_conversions`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Controls type conversion mode on replication slave. Value is a list of zero or more elements from the list: ALL_LOSSY, ALL_NON_LOSSY. Set to an empty string to disallow type conversions between master and slave.		
`sql_slave_skip_counter`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Number of events from the master that a slave server should skip. Not compatible with GTID replication.		
`sync_binlog`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Synchronously flush binary log to disk after every #th event		
`sync_master_info`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Synchronize master.info to disk after every #th event.		
`sync_relay_log`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Synchronize relay log to disk after every #th event.		
`sync_relay_log_info`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Synchronize relay.info file to disk after every #th event.		

Section 2.6.2, “Replication Master Options and Variables”, provides more detailed information about options and variables relating to replication master servers. For more information about options and variables relating to replication slaves, see Section 2.6.3, “Replication Slave Options and Variables”.

Table 2.4 Summary of Binary Logging options and variables in MySQL 5.7

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`binlog-checksum`		
Yes	No	No
Yes		No
DESCRIPTION: Enable/disable binary log checksums		
`binlog-do-db`		
Yes	No	No
Yes		No
DESCRIPTION: Limits binary logging to specific databases		
`binlog_format`		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Specifies the format of the binary log		
`binlog-ignore-db`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the master that updates to the given database should not be logged to the binary log		
`binlog-row-event-max-size`		
Yes	No	No
Yes		No
DESCRIPTION: Binary log max event size		
`binlog-rows-query-log-events`		
Yes	No	No
Yes		No
DESCRIPTION: Enables logging of rows query log events when using row-based logging. Disabled by default. Do not enable when producing logs for pre-5.6.2 slaves/readers.		
`Binlog_cache_disk_use`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions that used a temporary file instead of the binary log cache		
`binlog_cache_size`		
Yes	Yes	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	Global	Yes
DESCRIPTION: Size of the cache to hold the SQL statements for the binary log during a transaction		
`Binlog_cache_use`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions that used the temporary binary log cache		
`binlog_checksum`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Enable/disable binary log checksums		
`binlog_direct_non_transactional_updates`		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Causes updates using statement format to nontransactional engines to be written directly to binary log. See documentation before using.		
`binlog_error_action`		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Controls what happens when the server cannot write to the binary log.		
`binlog_group_commit_sync_delay`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Sets the number of microseconds to wait before synchronizing transactions to disk.		
`binlog_group_commit_sync_no_delay_count`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Sets the maximum number of transactions to wait for before aborting the current delay specified by binlog_group_commit_sync_delay.		
`binlog_max_flush_queue_time`		
No	Yes	No
No	Global	Yes
DESCRIPTION: How long to read transactions before flushing to binary log		
`binlog_order_commits`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Whether to commit in same order as writes to binary log		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`binlog_row_image`		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Use full or minimal images when logging row changes. Allowed values are full, minimal, and noblob.		
`binlog_rows_query_log_events`		
No	Yes	No
No	Both	Yes
DESCRIPTION: When TRUE, enables logging of rows query log events in row-based logging mode. FALSE by default. Do not enable when producing logs for pre-5.6.2 replication slaves or other readers.		
`Binlog_stmt_cache_disk_use`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of nontransactional statements that used a temporary file instead of the binary log statement cache		
`binlog_stmt_cache_size`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Size of the cache to hold nontransactional statements for the binary log during a transaction		
`Binlog_stmt_cache_use`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of statements that used the temporary binary log statement cache		
`binlogging_impossible_mode`		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Deprecated and will be removed in a future version. Use the renamed binlog_error_action instead.		
`Com_show_binlog_events`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW BINLOG EVENTS statements		
`Com_show_binlogs`		
No	No	Yes
No	Both	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Count of SHOW BINLOGS statements		
log-bin-use-v1-row-events		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Use version 1 binary log row events		
log_bin_basename		
No	Yes	No
No	Global	No
DESCRIPTION: Complete path to binary log, including filename		
log_bin_use_v1_row_events		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Shows whether server is using version 1 binary log row events		
master-verify-checksum		
Yes	No	No
Yes		No
DESCRIPTION: Cause master to examine checksums when reading from the binary log		
master_verify_checksum		
No	Yes	No
No	Global	Yes
DESCRIPTION: Cause master to read checksums from binary log.		
max-binlog-dump-events		
Yes	No	No
Yes		No
DESCRIPTION: Option used by mysql-test for debugging and testing of replication		
max_binlog_cache_size		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Can be used to restrict the total size used to cache a multi-statement transaction		
max_binlog_size		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Binary log will be rotated automatically when size exceeds this value		
max_binlog_stmt_cache_size		
Yes	Yes	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	Global	Yes
DESCRIPTION: Can be used to restrict the total size used to cache all nontransactional statements during a transaction		
`slave-sql-verify-checksum`		
Yes	No	No
Yes		No
DESCRIPTION: Cause slave to examine checksums when reading from the relay log		
`slave_sql_verify_checksum`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Cause slave to examine checksums when reading from relay log.		
`sporadic-binlog-dump-fail`		
Yes	No	No
Yes		No
DESCRIPTION: Option used by mysql-test for debugging and testing of replication		

Section 2.6.4, “Binary Logging Options and Variables”, provides more detailed information about options and variables relating to binary logging. For additional general information about the binary log, see The Binary Log.

For information about the `sql_log_bin` and `sql_log_off` variables, see Server System Variables.

For a table showing *all* command-line options, system and status variables used with `mysqld`, see Server Option and Variable Reference.

2.6.2 Replication Master Options and Variables

This section describes the server options and system variables that you can use on replication master servers. You can specify the options either on the command line or in an option file. You can specify system variable values using `SET`.

On the master and each slave, you must use the `server-id` option to establish a unique replication ID. For each server, you should pick a unique positive integer in the range from 1 to $2^{32} - 1$, and each ID must be different from every other ID in use by any other replication master or slave. Example: `server-id=3`.

For options used on the master for controlling binary logging, see Section 2.6.4, “Binary Logging Options and Variables”.

System Variables Used on Replication Masters

The following system variables are used to control replication masters:

- `auto_increment_increment`

System Variable	Name	`auto_increment_increment`

	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`1`
	Min Value	`1`
	Max Value	`65535`

`auto_increment_increment` and `auto_increment_offset` are intended for use with master-to-master replication, and can be used to control the operation of `AUTO_INCREMENT` columns. Both variables have global and session values, and each can assume an integer value between 1 and 65,535 inclusive. Setting the value of either of these two variables to 0 causes its value to be set to 1 instead. Attempting to set the value of either of these two variables to an integer greater than 65,535 or less than 0 causes its value to be set to 65,535 instead. Attempting to set the value of `auto_increment_increment` or `auto_increment_offset` to a noninteger value produces an error, and the actual value of the variable remains unchanged.

Note

`auto_increment_increment` is also supported for use with `NDB` tables.

These two variables affect `AUTO_INCREMENT` column behavior as follows:

- `auto_increment_increment` controls the interval between successive column values. For example:

```
mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 1     |
| auto_increment_offset    | 1     |
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> CREATE TABLE autoinc1
    -> (col INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
  Query OK, 0 rows affected (0.04 sec)

mysql> SET @@auto_increment_increment=10;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 1     |
+--------------------------+-------+
2 rows in set (0.01 sec)

mysql> INSERT INTO autoinc1 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0
```

```
mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
|   1 |
|  11 |
|  21 |
|  31 |
+-----+
4 rows in set (0.00 sec)
```

- auto_increment_offset determines the starting point for the AUTO_INCREMENT column value. Consider the following, assuming that these statements are executed during the same session as the example given in the description for auto_increment_increment:

```
mysql> SET @@auto_increment_offset=5;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 5     |
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> CREATE TABLE autoinc2
    -> (col INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
Query OK, 0 rows affected (0.06 sec)

mysql> INSERT INTO autoinc2 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc2;
+-----+
| col |
+-----+
|   5 |
|  15 |
|  25 |
|  35 |
+-----+
4 rows in set (0.02 sec)
```

  When the value of auto_increment_offset is greater than that of auto_increment_increment, the value of auto_increment_offset is ignored.

If either of these variables is changed, and then new rows inserted into a table containing an AUTO_INCREMENT column, the results may seem counterintuitive because the series of AUTO_INCREMENT values is calculated without regard to any values already present in the column, and the next value inserted is the least value in the series that is greater than the maximum existing value in the AUTO_INCREMENT column. The series is calculated like this:

auto_increment_offset + *N* × auto_increment_increment

where *N* is a positive integer value in the series [1, 2, 3, ...]. For example:

```
mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 5     |
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
|   1 |
|  11 |
|  21 |
|  31 |
+-----+
4 rows in set (0.00 sec)

mysql> INSERT INTO autoinc1 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
|   1 |
|  11 |
|  21 |
|  31 |
|  35 |
|  45 |
|  55 |
|  65 |
+-----+
8 rows in set (0.00 sec)
```

The values shown for `auto_increment_increment` and `auto_increment_offset` generate the series 5 + *N* × 10, that is, [5, 15, 25, 35, 45, ...]. The highest value present in the `col` column prior to the `INSERT` is 31, and the next available value in the `AUTO_INCREMENT` series is 35, so the inserted values for `col` begin at that point and the results are as shown for the `SELECT` query.

It is not possible to restrict the effects of these two variables to a single table; these variables control the behavior of all `AUTO_INCREMENT` columns in *all* tables on the MySQL server. If the global value of either variable is set, its effects persist until the global value is changed or overridden by setting the session value, or until `mysqld` is restarted. If the local value is set, the new value affects `AUTO_INCREMENT` columns for all tables into which new rows are inserted by the current user for the duration of the session, unless the values are changed during that session.

The default value of `auto_increment_increment` is 1. See Section 4.1.1, “Replication and AUTO_INCREMENT”.

- `auto_increment_offset`

System Variable	**Name**	`auto_increment_offset`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`

	Default	`1`
	Min Value	`1`
	Max Value	`65535`

This variable has a default value of 1. For more information, see the description for `auto_increment_increment`.

> **Note**
>
> `auto_increment_offset` is also supported for use with `NDB` tables.

2.6.3 Replication Slave Options and Variables

This section explains the server options and system variables that apply to slave replication servers and contains the following:

Startup Options for Replication Slaves

Options for Logging Slave Status to Tables

System Variables Used on Replication Slaves

Specify the options either on the command line or in an option file. Many of the options can be set while the server is running by using the `CHANGE MASTER TO` statement. Specify system variable values using `SET`.

Server ID. On the master and each slave, you must use the `server-id` option to establish a unique replication ID in the range from 1 to $2^{32} - 1$. “Unique” means that each ID must be different from every other ID in use by any other replication master or slave. Example `my.cnf` file:

```
[mysqld]
server-id=3
```

Startup Options for Replication Slaves

This section explains startup options for controlling replication slave servers. Many of these options can be set while the server is running by using the `CHANGE MASTER TO` statement. Others, such as the `--replicate-*` options, can be set only when the slave server starts. Replication-related system variables are discussed later in this section.

- `--log-slave-updates`

Command-Line Format	`--log-slave-updates`	
System Variable	**Name**	`log_slave_updates`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`
	Default	`OFF`

Normally, a slave does not write any updates that are received from a master server to its own binary log. This option causes the slave to write the updates performed by its SQL thread to its own binary log. For this option to have any effect, the slave must also be started with the `--log-bin` option to enable binary logging. `--log-slave-updates` is used when you want to chain replication servers. For example, you might want to set up replication servers using this arrangement:

```
A -> B -> C
```

Here, `A` serves as the master for the slave `B`, and `B` serves as the master for the slave `C`. For this to work, `B` must be both a master *and* a slave. You must start both `A` and `B` with `--log-bin` to enable binary logging, and `B` with the `--log-slave-updates` option so that updates received from `A` are logged by `B` to its binary log.

- `--log-slow-slave-statements`

Removed	5.7.1	
Command-Line Format	`--log-slow-slave-statements` (5.7.0)	
Permitted Values	**Type**	`boolean`
	Default	`OFF`

When the slow query log is enabled, this option enables logging for queries that have taken more than `long_query_time` seconds to execute on the slave.

This command-line option was removed in MySQL 5.7.1 and replaced by the `log_slow_slave_statements` system variable. The system variable can be set on the command line or in option files the same way as the option, so there is no need for any changes at server startup, but the system variable also makes it possible to examine or set the value at runtime.

- `--log-warnings[=`*`level`*`]`

Deprecated	5.7.2	
Command-Line Format	`--log-warnings[=#]`	
System Variable	**Name**	`log_warnings`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms, <= 5.7.1)	**Type**	`integer`
	Default	`1`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (32-bit platforms, >= 5.7.2)	**Type**	`integer`
	Default	`2`
	Min Value	`0`
	Max Value	`4294967295`

Permitted Values (64-bit platforms, <= 5.7.1)	**Type**	`integer`
	Default	`1`
	Min Value	`0`
	Max Value	`18446744073709551615`
Permitted Values (64-bit platforms, >= 5.7.2)	**Type**	`integer`
	Default	`2`
	Min Value	`0`
	Max Value	`18446744073709551615`

> **Note**
>
> As of MySQL 5.7.2, the `log_error_verbosity` system variable is preferred over, and should be used instead of, the `--log-warnings` option or `log_warnings` system variable. For more information, see the descriptions of `log_error_verbosity` and `log_warnings`. The `--log-warnings` command-line option and `log_warnings` system variable are deprecated and will be removed in a future MySQL release.

Causes the server to record more messages to the error log about what it is doing. With respect to replication, the server generates warnings that it succeeded in reconnecting after a network or connection failure, and provides information about how each slave thread started. This variable is enabled by default (the default is 1 before MySQL 5.7.2, 2 as of 5.7.2). To disable it, set it to 0. The server logs messages about statements that are unsafe for statement-based logging if the value is greater than 0. Aborted connections and access-denied errors for new connection attempts are logged if the value is greater than 1. See Communication Errors and Aborted Connections.

> **Note**
>
> The effects of this option are not limited to replication. It produces warnings across a spectrum of server activities.

- `--master-info-file=`*`file_name`*

Command-Line Format	`--master-info-file=file_name`	
Permitted Values	**Type**	`file name`
	Default	`master.info`

The name to use for the file in which the slave records information about the master. The default name is `master.info` in the data directory. For information about the format of this file, see Section 5.4.2, “Slave Status Logs”.

- `--master-retry-count=`*`count`*

Deprecated	5.6.1
Command-Line Format	`--master-retry-count=#`

Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`86400`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`86400`
	Min Value	`0`
	Max Value	`18446744073709551615`

The number of times that the slave tries to connect to the master before giving up. Reconnects are attempted at intervals set by the `MASTER_CONNECT_RETRY` option of the `CHANGE MASTER TO` statement (default 60). Reconnects are triggered when data reads by the slave time out according to the `--slave-net-timeout` option. The default value is 86400. A value of 0 means “infinite”; the slave attempts to connect forever.

This option is deprecated and will be removed in a future MySQL release. Applications should be updated to use the `MASTER_RETRY_COUNT` option of the `CHANGE MASTER TO` statement instead.

- `--max-relay-log-size=`*`size`*

Command-Line Format	`--max_relay_log_size=#`	
System Variable	**Name**	`max_relay_log_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`1073741824`

The size at which the server rotates relay log files automatically. If this value is nonzero, the relay log is rotated automatically when its size exceeds this value. If this value is zero (the default), the size at which relay log rotation occurs is determined by the value of `max_binlog_size`. For more information, see Section 5.4.1, “The Slave Relay Log”.

- `--relay-log=`*`file_name`*

Command-Line Format	`--relay-log=file_name`	
System Variable	**Name**	`relay_log`
	Variable Scope	Global

	Dynamic Variable	No
Permitted Values	**Type**	`file name`

The base name for the relay log. For the default replication channel, the default base name for relay logs is `*host_name*-relay-bin`. For non-default replication channels, the default base name for relay logs is `*host_name*-*channel*-relay-bin`, where `*channel*` is the name of the replication channel recorded in this relay log. The server writes the file in the data directory unless the base name is given with a leading absolute path name to specify a different directory. The server creates relay log files in sequence by adding a numeric suffix to the base name.

Due to the manner in which MySQL parses server options, if you specify this option, you must supply a value; *the default base name is used only if the option is not actually specified*. If you use the `--relay-log` option without specifying a value, unexpected behavior is likely to result; this behavior depends on the other options used, the order in which they are specified, and whether they are specified on the command line or in an option file. For more information about how MySQL handles server options, see Specifying Program Options.

If you specify this option, the value specified is also used as the base name for the relay log index file. You can override this behavior by specifying a different relay log index file base name using the `--relay-log-index` option.

When the server reads an entry from the index file, it checks whether the entry contains a relative path. If it does, the relative part of the path is replaced with the absolute path set using the `--relay-log` option. An absolute path remains unchanged; in such a case, the index must be edited manually to enable the new path or paths to be used. Previously, manual intervention was required whenever relocating the binary log or relay log files. (Bug #11745230, Bug #12133)

You may find the `--relay-log` option useful in performing the following tasks:

- Creating relay logs whose names are independent of host names.
- If you need to put the relay logs in some area other than the data directory because your relay logs tend to be very large and you do not want to decrease `max_relay_log_size`.
- To increase speed by using load-balancing between disks.

You can obtain the relay log file name (and path) from the `relay_log_basename` system variable.

- `--relay-log-index=*file_name*`

Command-Line Format	`--relay-log-index=file_name`	
System Variable	**Name**	`relay_log_index`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`

The name to use for the relay log index file. The default name is `*host_name*-relay-bin.index` in the data directory, where `*host_name*` is the name of the server. For the default replication channel, the default name is `*host_name*-relay-bin.index`. For non-default replication channels, the default name is `host_name-channel-relay-bin.index`, where `channel` is the name of the replication channel recorded in this relay log index.

Due to the manner in which MySQL parses server options, if you specify this option, you must supply a value; *the default base name is used only if the option is not actually specified*. If you use the `--relay-log-index` option without specifying a value, unexpected behavior is likely to result; this behavior depends on the other options used, the order in which they are specified, and whether they are specified on the command line or in an option file. For more information about how MySQL handles server options, see Specifying Program Options.

If you specify this option, the value specified is also used as the base name for the relay logs. You can override this behavior by specifying a different relay log file base name using the `--relay-log` option.

- `--relay-log-info-file=file_name`

Command-Line Format	`--relay-log-info-file=file_name`	
Permitted Values	Type	`file name`
	Default	`relay-log.info`

The name to use for the file in which the slave records information about the relay logs. The default name is `relay-log.info` in the data directory. For information about the format of this file, see Section 5.4.2, “Slave Status Logs”.

- `--relay-log-purge={0|1}`

Command-Line Format	`--relay_log_purge`	
System Variable	Name	`relay_log_purge`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	Type	`boolean`
	Default	`TRUE`

Disable or enable automatic purging of relay logs as soon as they are no longer needed. The default value is 1 (enabled). This is a global variable that can be changed dynamically with `SET GLOBAL relay_log_purge = N`. Disabling purging of relay logs when using the `--relay-log-recovery` option puts data consistency at risk.

- `--relay-log-recovery={0|1}`

Command-Line Format	`--relay-log-recovery`	
Permitted Values	Type	`boolean`
	Default	`FALSE`

Enables automatic relay log recovery immediately following server startup. The recovery process creates a new relay log file, initializes the SQL thread position to this new relay log, and initializes the I/O thread to the SQL thread position. Reading of the relay log from the master then continues. This should be used following an unexpected halt of a replication slave to ensure that no possibly corrupted relay logs are processed. The default value is 0 (disabled).

This variable can be set to 1 to make a slave resilient to unexpected halts, see Section 3.2, “Handling an Unexpected Halt of a Replication Slave” for more information. Enabling the `--relay-log-recovery` option when `relay-log-purge` is disabled risks reading the relay log from files that were not purged, leading to data inconsistency.

When using a multi-threaded slave (in other words `slave_parallel_workers` is greater than 0), inconsistencies such as gaps can occur in the sequence of transactions that have been executed from the relay log. Enabling the `--relay-log-recovery` option when there are inconsistencies causes an error and the option has no effect. The solution in this situation is to issue `START SLAVE UNTIL SQL_AFTER_MTS_GAPS`, which brings the server to a more consistent state, then issue `RESET SLAVE` to remove the relay logs. See Section 4.1.34, “Replication and Transaction Inconsistencies” for more information.

- `--relay-log-space-limit=*size*`

Command-Line Format	`--relay_log_space_limit=#`	
System Variable	**Name**	`relay_log_space_limit`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`18446744073709551615`

This option places an upper limit on the total size in bytes of all relay logs on the slave. A value of 0 means “no limit”. This is useful for a slave server host that has limited disk space. When the limit is reached, the I/O thread stops reading binary log events from the master server until the SQL thread has caught up and deleted some unused relay logs. Note that this limit is not absolute: There are cases where the SQL thread needs more events before it can delete relay logs. In that case, the I/O thread exceeds the limit until it becomes possible for the SQL thread to delete some relay logs because not doing so would cause a deadlock. You should not set `--relay-log-space-limit` to less than twice the value of `--max-relay-log-size` (or `--max-binlog-size` if `--max-relay-log-size` is 0). In that case, there is a chance that the I/O thread waits for free space because `--relay-log-space-limit` is exceeded, but the SQL thread has no relay log to purge and is unable to satisfy the I/O thread. This forces the I/O thread to ignore `--relay-log-space-limit` temporarily.

- `--replicate-do-db=*db_name*`

Command-Line Format	`--replicate-do-db=name`

Permitted Values	**Type**	`string`

Creates a replication filter using the name of a database. In MySQL 5.7.3 and later, such filters can also be created using `CHANGE REPLICATION FILTER REPLICATE_DO_DB`. The precise effect of this filtering depends on whether statement-based or row-based replication is in use, and are described in the next several paragraphs.

Statement-based replication. Tell the slave SQL thread to restrict replication to statements where the default database (that is, the one selected by `USE`) is *`db_name`*. To specify more than one database, use this option multiple times, once for each database; however, doing so does *not* replicate cross-database statements such as `UPDATE` *`some_db.some_table`* `SET foo='bar'` while a different database (or no database) is selected.

> **Warning**
>
> To specify multiple databases you *must* use multiple instances of this option. Because database names can contain commas, if you supply a comma separated list then the list will be treated as the name of a single database.

An example of what does not work as you might expect when using statement-based replication: If the slave is started with `--replicate-do-db=sales` and you issue the following statements on the master, the `UPDATE` statement is *not* replicated:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The main reason for this “check just the default database” behavior is that it is difficult from the statement alone to know whether it should be replicated (for example, if you are using multiple-table `DELETE` statements or multiple-table `UPDATE` statements that act across multiple databases). It is also faster to check only the default database rather than all databases if there is no need.

Row-based replication. Tells the slave SQL thread to restrict replication to database *`db_name`*. Only tables belonging to *`db_name`* are changed; the current database has no effect on this. Suppose that the slave is started with `--replicate-do-db=sales` and row-based replication is in effect, and then the following statements are run on the master:

```
USE prices;
UPDATE sales.february SET amount=amount+100;
```

The `february` table in the `sales` database on the slave is changed in accordance with the `UPDATE` statement; this occurs whether or not the `USE` statement was issued. However, issuing the following statements on the master has no effect on the slave when using row-based replication and `--replicate-do-db=sales`:

```
USE prices;
UPDATE prices.march SET amount=amount-25;
```

Even if the statement `USE prices` were changed to `USE sales`, the `UPDATE` statement's effects would still not be replicated.

Another important difference in how `--replicate-do-db` is handled in statement-based replication as opposed to row-based replication occurs with regard to statements that refer to multiple databases. Suppose that the slave is started with `--replicate-do-db=db1`, and the following statements are executed on the master:

```
USE db1;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

If you are using statement-based replication, then both tables are updated on the slave. However, when using row-based replication, only `table1` is affected on the slave; since `table2` is in a different database, `table2` on the slave is not changed by the `UPDATE`. Now suppose that, instead of the `USE db1` statement, a `USE db4` statement had been used:

```
USE db4;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

In this case, the `UPDATE` statement would have no effect on the slave when using statement-based replication. However, if you are using row-based replication, the `UPDATE` would change `table1` on the slave, but not `table2`—in other words, only tables in the database named by `--replicate-do-db` are changed, and the choice of default database has no effect on this behavior.

If you need cross-database updates to work, use `--replicate-wild-do-table=`*`db_name`*`.%` instead. See Section 5.5, “How Servers Evaluate Replication Filtering Rules”.

Note

This option affects replication in the same manner that `--binlog-do-db` affects binary logging, and the effects of the replication format on how `--replicate-do-db` affects replication behavior are the same as those of the logging format on the behavior of `--binlog-do-db`.

This option has no effect on `BEGIN`, `COMMIT`, or `ROLLBACK` statements.

- `--replicate-ignore-db=`*`db_name`*

Command-Line Format	`--replicate-ignore-db=name`	
Permitted Values	Type	`string`

Creates a replication filter using the name of a database. In MySQL 5.7.3 and later, such filters can also be created using `CHANGE REPLICATION FILTER REPLICATE_IGNORE_DB`. As with `--replicate-do-db`, the precise effect of this filtering depends on whether statement-based or row-based replication is in use, and are described in the next several paragraphs.

Statement-based replication. Tells the slave SQL thread not to replicate any statement where the default database (that is, the one selected by `USE`) is *`db_name`*.

Row-based replication. Tells the slave SQL thread not to update any tables in the database *`db_name`*. The default database has no effect.

When using statement-based replication, the following example does not work as you might expect. Suppose that the slave is started with `--replicate-ignore-db=sales` and you issue the following statements on the master:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The `UPDATE` statement *is* replicated in such a case because `--replicate-ignore-db` applies only to the default database (determined by the `USE` statement). Because the `sales` database was specified explicitly in the statement, the statement has not been filtered. However, when using row-based replication, the `UPDATE` statement's effects are *not* propagated to the slave, and the slave's copy of the `sales.january` table is unchanged; in this instance, `--replicate-ignore-db=sales` causes *all* changes made to tables in the master's copy of the `sales` database to be ignored by the slave.

To specify more than one database to ignore, use this option multiple times, once for each database. Because database names can contain commas, if you supply a comma separated list then the list will be treated as the name of a single database.

You should not use this option if you are using cross-database updates and you do not want these updates to be replicated. See Section 5.5, "How Servers Evaluate Replication Filtering Rules".

If you need cross-database updates to work, use `--replicate-wild-ignore-table=db_name.%` instead. See Section 5.5, "How Servers Evaluate Replication Filtering Rules".

> **Note**
>
> This option affects replication in the same manner that `--binlog-ignore-db` affects binary logging, and the effects of the replication format on how `--replicate-ignore-db` affects replication behavior are the same as those of the logging format on the behavior of `--binlog-ignore-db`.
>
> This option has no effect on `BEGIN`, `COMMIT`, or `ROLLBACK` statements.

- `--replicate-do-table=db_name.tbl_name`

Command-Line Format	`--replicate-do-table=name`	
Permitted Values	**Type**	`string`

Creates a replication filter by telling the slave SQL thread to restrict replication to a given table. To specify more than one table, use this option multiple times, once for each table. This works for both cross-database updates and default database updates, in contrast to `--replicate-do-db`. See Section 5.5, "How Servers Evaluate Replication Filtering Rules".

In MySQL 5.7.3 and later, you can also create such a filter by issuing a `CHANGE REPLICATION FILTER REPLICATE_DO_TABLE` statement.

This option affects only statements that apply to tables. It does not affect statements that apply only to other database objects, such as stored routines. To filter statements operating on stored routines, use one or more of the `--replicate-*-db` options.

- `--replicate-ignore-table=db_name.tbl_name`

Command-Line Format	`--replicate-ignore-table=name`	
Permitted Values	**Type**	`string`

Creates a replication filter by telling the slave SQL thread not to replicate any statement that updates the specified table, even if any other tables might be updated by the same statement. To specify more than one table to ignore, use this option multiple times, once for each table. This works for cross-database updates, in contrast to `--replicate-ignore-db`. See Section 5.5, "How Servers Evaluate Replication Filtering Rules".

In MySQL 5.7.3 and later, you can also create such a filter by issuing a `CHANGE REPLICATION FILTER REPLICATE_IGNORE_TABLE` statement.

This option affects only statements that apply to tables. It does not affect statements that apply only to other database objects, such as stored routines. To filter statements operating on stored routines, use one or more of the `--replicate-*-db` options.

- `--replicate-rewrite-db=from_name->to_name`

Command-Line Format	`--replicate-rewrite-db=old_name->new_name`	
Permitted Values	Type	`string`

Tells the slave to create a replication filter that translates the default database (that is, the one selected by `USE`) to *`to_name`* if it was *`from_name`* on the master. Only statements involving tables are affected (not statements such as `CREATE DATABASE`, `DROP DATABASE`, and `ALTER DATABASE`), and only if *`from_name`* is the default database on the master. To specify multiple rewrites, use this option multiple times. The server uses the first one with a *`from_name`* value that matches. The database name translation is done *before* the `--replicate-*` rules are tested.

In MySQL 5.7.3 and later, you can also create such a filter by issuing a `CHANGE REPLICATION FILTER REPLICATE_REWRITE_DB` statement.

Statements in which table names are qualified with database names when using this option do not work with table-level replication filtering options such as `--replicate-do-table`. Suppose we have a database named `a` on the master, one named `b` on the slave, each containing a table `t`, and have started the master with `--replicate-rewrite-db='a->b'`. At a later point in time, we execute `DELETE FROM a.t`. In this case, no relevant filtering rule works, for the reasons shown here:

1. `--replicate-do-table=a.t` does not work because the slave has table `t` in database `b`.

2. `--replicate-do-table=b.t` does not match the original statement and so is ignored.

3. `--replicate-do-table=*.t` is handled identically to `--replicate-do-table=a.t`, and thus does not work, either.

Similarly, the `--replication-rewrite-db` option does not work with cross-database updates.

If you use this option on the command line and the “`>`” character is special to your command interpreter, quote the option value. For example:

```
shell> mysqld --replicate-rewrite-db="olddb->newdb"
```

- `--replicate-same-server-id`

Command-Line Format	`--replicate-same-server-id`	
Permitted Values	Type	`boolean`
	Default	`FALSE`

To be used on slave servers. Usually you should use the default setting of 0, to prevent infinite loops caused by circular replication. If set to 1, the slave does not skip events having its own server ID. Normally, this is useful only in rare configurations. Cannot be set to 1 if `--log-slave-updates` is used. By default, the slave I/O thread does not write binary log events to the relay log if they have the slave's server ID (this optimization helps save disk usage). If you want to use `--replicate-same-server-id`, be sure to start the slave with this option before you make the slave read its own events that you want the slave SQL thread to execute.

- `--replicate-wild-do-table=`*`db_name.tbl_name`*

Command-Line Format	`--replicate-wild-do-table=name`	
Permitted Values	**Type**	`string`

  Creates a replication filter by telling the slave thread to restrict replication to statements where any of the updated tables match the specified database and table name patterns. Patterns can contain the "`%`" and "`_`" wildcard characters, which have the same meaning as for the `LIKE` pattern-matching operator. To specify more than one table, use this option multiple times, once for each table. This works for cross-database updates. See Section 5.5, "How Servers Evaluate Replication Filtering Rules".

  In MySQL 5.7.3 and later, you can also create such a filter by issuing a `CHANGE REPLICATION FILTER REPLICATE_WILD_DO_TABLE` statement.

  This option applies to tables, views, and triggers. It does not apply to stored procedures and functions, or events. To filter statements operating on the latter objects, use one or more of the `--replicate-*-db` options.

  Example: `--replicate-wild-do-table=foo%.bar%` replicates only updates that use a table where the database name starts with `foo` and the table name starts with `bar`.

  If the table name pattern is `%`, it matches any table name and the option also applies to database-level statements (`CREATE DATABASE`, `DROP DATABASE`, and `ALTER DATABASE`). For example, if you use `--replicate-wild-do-table=foo%.%`, database-level statements are replicated if the database name matches the pattern `foo%`.

  To include literal wildcard characters in the database or table name patterns, escape them with a backslash. For example, to replicate all tables of a database that is named `my_own%db`, but not replicate tables from the `my1ownAABCdb` database, you should escape the "`_`" and "`%`" characters like this: `--replicate-wild-do-table=my\_own\%db`. If you use the option on the command line, you might need to double the backslashes or quote the option value, depending on your command interpreter. For example, with the `bash` shell, you would need to type `--replicate-wild-do-table=my\\_own\\%db`.

- `--replicate-wild-ignore-table=`*`db_name.tbl_name`*

Command-Line Format	`--replicate-wild-ignore-table=name`	
Permitted Values	**Type**	`string`

  Creates a replication filter which keeps the slave thread from replicating a statement in which any table matches the given wildcard pattern. To specify more than one table to ignore, use this option multiple times, once for each table. This works for cross-database updates. See Section 5.5, "How Servers Evaluate Replication Filtering Rules".

  In MySQL 5.7.3 and later, you can also create such a filter by issuing a `CHANGE REPLICATION FILTER REPLICATE_WILD_IGNORE_TABLE` statement.

  Example: `--replicate-wild-ignore-table=foo%.bar%` does not replicate updates that use a table where the database name starts with `foo` and the table name starts with `bar`.

  For information about how matching works, see the description of the `--replicate-wild-do-table` option. The rules for including literal wildcard characters in the option value are the same as for `--replicate-wild-ignore-table` as well.

- `--report-host=`*`host_name`*

Command-Line Format	`--report-host=host_name`	
System Variable	**Name**	`report_host`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`

The host name or IP address of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server. Leave the value unset if you do not want the slave to register itself with the master.

> **Note**
>
> It is not sufficient for the master to simply read the IP address of the slave from the TCP/IP socket after the slave connects. Due to NAT and other routing issues, that IP may not be valid for connecting to the slave from the master or other hosts.

- `--report-password=`*`password`*

Command-Line Format	`--report-password=name`	
System Variable	**Name**	`report_password`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`

The account password of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server if the `--show-slave-auth-info` option is given.

Although the name of this option might imply otherwise, `--report-password` is not connected to the MySQL user privilege system and so is not necessarily (or even likely to be) the same as the password for the MySQL replication user account.

- `--report-port=`*`slave_port_num`*

Command-Line Format	`--report-port=#`	
System Variable	**Name**	`report_port`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`integer`
	Default	`[slave_port]`

	Min Value	0
	Max Value	65535

The TCP/IP port number for connecting to the slave, to be reported to the master during slave registration. Set this only if the slave is listening on a nondefault port or if you have a special tunnel from the master or other clients to the slave. If you are not sure, do not use this option.

The default value for this option is the port number actually used by the slave (Bug #13333431). This is also the default value displayed by `SHOW SLAVE HOSTS`.

- `--report-user=*user_name*`

Command-Line Format	`--report-user=name`	
System Variable	Name	`report_user`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	Type	`string`

The account user name of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server if the `--show-slave-auth-info` option is given.

Although the name of this option might imply otherwise, `--report-user` is not connected to the MySQL user privilege system and so is not necessarily (or even likely to be) the same as the name of the MySQL replication user account.

- `--show-slave-auth-info`

Command-Line Format	`--show-slave-auth-info`	
Permitted Values	Type	`boolean`
	Default	`FALSE`

Display slave user names and passwords in the output of `SHOW SLAVE HOSTS` on the master server for slaves started with the `--report-user` and `--report-password` options.

- `--slave-checkpoint-group=#`

Command-Line Format	`--slave-checkpoint-group=#`	
Permitted Values	Type	`integer`
	Default	`512`
	Min Value	`32`
	Max Value	`524280`
	Block Size	`8`

Sets the maximum number of transactions that can be processed by a multi-threaded slave before a checkpoint operation is called to update its status as shown by `SHOW SLAVE STATUS`. Setting this option has no effect on slaves for which multi-threading is not enabled.

> **Note**
>
> Multi-threaded slaves are not currently supported by MySQL Cluster, which silently ignores the setting for this option. See Known Issues in MySQL Cluster Replication, for more information.

This option works in combination with the `--slave-checkpoint-period` option in such a way that, when either limit is exceeded, the checkpoint is executed and the counters tracking both the number of transactions and the time elapsed since the last checkpoint are reset.

The minimum allowed value for this option is 32, unless the server was built using `-DWITH_DEBUG`, in which case the minimum value is 1. The effective value is always a multiple of 8; you can set it to a value that is not such a multiple, but the server rounds it down to the next lower multiple of 8 before storing the value. (*Exception*: No such rounding is performed by the debug server.) Regardless of how the server was built, the default value is 512, and the maximum allowed value is 524280.

- `--slave-checkpoint-period=#`

Command-Line Format	`--slave-checkpoint-period=#`	
Permitted Values	**Type**	`integer`
	Default	`300`
	Min Value	`1`
	Max Value	`4G`

Sets the maximum time (in milliseconds) that is allowed to pass before a checkpoint operation is called to update the status of a multi-threaded slave as shown by `SHOW SLAVE STATUS`. Setting this option has no effect on slaves for which multi-threading is not enabled.

> **Note**
>
> Multi-threaded slaves are not currently supported by MySQL Cluster, which silently ignores the setting for this option. See Known Issues in MySQL Cluster Replication, for more information.

This option works in combination with the `--slave-checkpoint-group` option in such a way that, when either limit is exceeded, the checkpoint is executed and the counters tracking both the number of transactions and the time elapsed since the last checkpoint are reset.

The minimum allowed value for this option is 1, unless the server was built using `-DWITH_DEBUG`, in which case the minimum value is 0. Regardless of how the server was built, the default value is 300, and the maximum possible value is 4294967296 (4GB).

- `--slave-parallel-workers`

Command-Line Format	`--slave-parallel-workers=#`	
Permitted Values	**Type**	`integer`

	Default	`0`
	Min Value	`0`
	Max Value	`1024`

Sets the number of slave applier threads for executing replication transactions in parallel. Setting this variable to a number greater than 0 creates a multi-threaded slave with this number of applier threads. When set to 0 (the default) parallel execution is disabled and the slave uses a single applier thread.

A multi-threaded slave provides parallel execution by using a coordinator thread and the number of applier threads configured by this option. The way which transactions are distributed among applier threads is configured by `--slave-parallel-type`. For more information about multi-threaded slaves see `slave-parallel-workers`.

> **Note**
>
> Multi-threaded slaves are not currently supported by MySQL Cluster, which silently ignores the setting for this option. See Known Issues in MySQL Cluster Replication, for more information.

- `--slave-pending-jobs-size-max=#`

Command-Line Format	`--slave-pending-jobs-size-max=#`	
Permitted Values	Type	`integer`
	Default	`16M`
	Min Value	`1024`
	Max Value	`18EB`
	Block Size	`1024`

For multi-threaded slaves, this option sets the maximum amount of memory (in bytes) available to slave worker queues holding events not yet applied. Setting this option has no effect on slaves for which multi-threading is not enabled.

The minimum possible value for this option is 1024; the default is 16MB. The maximum possible value is 18446744073709551615 (16 exabytes). Values that are not exact multiples of 1024 are rounded down to the next-highest multiple of 1024 prior to being stored.

> **Important**
>
> The value for this option must not be less than the master's value for `max_allowed_packet`; otherwise a slave worker queue may become full while there remain events coming from the master to be processed.

- `--skip-slave-start`

Command-Line Format	`--skip-slave-start`	
Permitted Values	Type	`boolean`

	Default	`FALSE`

Tells the slave server not to start the slave threads when the server starts. To start the threads later, use a `START SLAVE` statement.

- `--slave_compressed_protocol={0|1}`

Command-Line Format	`--slave_compressed_protocol`	
System Variable	**Name**	`slave_compressed_protocol`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

If this option is set to 1, use compression for the slave/master protocol if both the slave and the master support it. The default is 0 (no compression).

- `--slave-load-tmpdir=`*`dir_name`*

Command-Line Format	`--slave-load-tmpdir=dir_name`	
System Variable	**Name**	`slave_load_tmpdir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`directory name`
	Default	`/tmp`

The name of the directory where the slave creates temporary files. This option is by default equal to the value of the `tmpdir` system variable. When the slave SQL thread replicates a `LOAD DATA INFILE` statement, it extracts the file to be loaded from the relay log into temporary files, and then loads these into the table. If the file loaded on the master is huge, the temporary files on the slave are huge, too. Therefore, it might be advisable to use this option to tell the slave to put temporary files in a directory located in some file system that has a lot of available space. In that case, the relay logs are huge as well, so you might also want to use the `--relay-log` option to place the relay logs in that file system.

The directory specified by this option should be located in a disk-based file system (not a memory-based file system) because the temporary files used to replicate `LOAD DATA INFILE` must survive machine restarts. The directory also should not be one that is cleared by the operating system during the system startup process.

- `slave-max-allowed-packet=`*`bytes`*

Command-Line Format	`--slave-max-allowed-packet=#`	
Permitted Values	**Type**	`integer`
	Default	`1073741824`

	Min Value	1024
	Max Value	1073741824

This option sets the maximum packet size in bytes for the slave SQL and I/O threads, so that large updates using row-based replication do not cause replication to fail because an update exceeded `max_allowed_packet`. (Bug #12400221, Bug #60926)

The corresponding server variable `slave_max_allowed_packet` always has a value that is a positive integer multiple of 1024; if you set it to some value that is not such a multiple, the value is automatically rounded down to the next highest multiple of 1024. (For example, if you start the server with `--slave-max-allowed-packet=10000`, the value used is 9216; setting 0 as the value causes 1024 to be used.) A truncation warning is issued in such cases.

The maximum (and default) value is 1073741824 (1 GB); the minimum is 1024.

- `--slave-net-timeout=`*`seconds`*

Command-Line Format	`--slave-net-timeout=#`	
System Variable	**Name**	`slave_net_timeout`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`3600`
	Min Value	`1`
Permitted Values (>= 5.7.7)	**Type**	`integer`
	Default	`60`
	Min Value	`1`

The number of seconds to wait for more data from the master before the slave considers the connection broken, aborts the read, and tries to reconnect. The first retry occurs immediately after the timeout. The interval between retries is controlled by the `MASTER_CONNECT_RETRY` option for the `CHANGE MASTER TO` statement, and the number of reconnection attempts is limited by the `--master-retry-count` option. Prior to MySQL 5.7.7, the default was 3600 seconds (one hour). In MySQL 5.7.7 and later the default is 60 (one minute).

- `--slave-parallel-type=`*`type`*

Introduced	5.7.2	
Command-Line Format	`--slave-parallel-type=type`	
Permitted Values	**Type**	`enumeration`
	Default	`DATABASE`
	Valid Values	`DATABASE`

		LOGICAL_CLOCK

When using a multi-threaded slave (slave_parallel_workers is greater than 0), this option specifies the policy used to decide which transactions are allowed to execute in parallel on the slave. The possible values are:

- DATABASE: Transactions that update different databases are applied in parallel. This value is only appropriate if data is partitioned into multiple databases which are being updated independently and concurrently on the master. Only recommended if there are no cross-database constraints, as such constraints may be violated on the slave.
- LOGICAL_CLOCK: Transactions that are part of the same binary log group commit on a master are applied in parallel on a slave. There are no cross-database constraints, and data does not need to be partitioned into multiple databases.

Regardless of the value of this variable, there is no special configuration required on the master. When slave_preserve_commit_order=1, you can only use LOGICAL_CLOCK. If your replication topology uses multiple levels of slaves, LOGICAL_CLOCK may achieve less parallelization for each level the slave is away from the master.

- slave-rows-search-algorithms=*list*

Command-Line Format	--slave-rows-search-algorithms=list	
Permitted Values	**Type**	set
	Default	TABLE_SCAN,INDEX_SCAN
	Valid Values	TABLE_SCAN,INDEX_SCAN
		INDEX_SCAN,HASH_SCAN
		TABLE_SCAN,HASH_SCAN
		TABLE_SCAN,INDEX_SCAN,HASH_SCAN (equivalent to INDEX_SCAN,HASH_SCAN)

When preparing batches of rows for row-based logging and replication, this option controls how the rows are searched for matches—that is, whether or not hashing is used for searches using a primary or unique key, some other key, or no key at all. This option takes a comma-separated list of any 2 (or possibly 3) values from the list INDEX_SCAN, TABLE_SCAN, HASH_SCAN. The list need not be quoted, but must contain no spaces, whether or not quotes are used. Possible combinations (lists) and their effects are shown in the following table:

Index used / option value	**INDEX_SCAN,HASH_SCAN or INDEX_SCAN,TABLE_SCAN,HASH_SCAN**	**INDEX_SCAN,TABLE_SCAN**	**TABLE_SCAN,HASH_SCAN**
Primary key or unique key	Index scan	Index scan	Hash scan over index
(Other) Key	Hash scan over index	Index scan	Hash scan over index
No index	Hash scan	Table scan	Hash scan

The order in which the algorithms are specified in the list does not make any difference in the order in which they are displayed by a SELECT or SHOW VARIABLES statement (which is the same as that used in the table just shown previously).The default value is TABLE_SCAN,INDEX_SCAN, which means that all searches that can use indexes do use them, and searches without any indexes use table scans.

Specifying `INDEX_SCAN,TABLE_SCAN,HASH_SCAN` has the same effect as specifying `INDEX_SCAN,HASH_SCAN`. To use hashing for any searches that does not use a primary or unique key, set this option to `INDEX_SCAN,HASH_SCAN`. To force hashing for *all* searches, set it to `TABLE_SCAN,HASH_SCAN`.

> **Note**
>
> There is only a performance advantage for `INDEX_SCAN` and `HASH_SCAN` if the row events are big enough. The size of row events is configured using `--binlog-row-event-max-size`. For example, suppose a `DELETE` statement which deletes 25,000 rows generates large `Delete_row_event` events. In this case if `slave_rows_search_algorithms` is set to `INDEX_SCAN` or `HASH_SCAN` there is a performance improvement. However, if there are 25,000 `DELETE` statements and each is represented by a separate event then setting `slave_rows_search_algorithms` to `INDEX_SCAN` or `HASH_SCAN` provides no performance improvement while executing these separate events.

- `--slave-skip-errors=[`*`err_code1,err_code2,...`*`|all|ddl_exist_errors]`

Command-Line Format	`--slave-skip-errors=name`	
System Variable	**Name**	`slave_skip_errors`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`
	Default	`OFF`
	Valid Values	`OFF`
		`[list of error codes]`
		`all`
		`ddl_exist_errors`
Permitted Values	**Type**	`string`
	Default	`OFF`
	Valid Values	`OFF`
		`[list of error codes]`
		`all`
		`ddl_exist_errors`
Permitted Values	**Type**	`string`
	Default	`OFF`
	Valid Values	`OFF`
		`[list of error codes]`
		`all`
		`ddl_exist_errors`

Normally, replication stops when an error occurs on the slave, which gives you the opportunity to resolve the inconsistency in the data manually. This option causes the slave SQL thread to continue replication when a statement returns any of the errors listed in the option value.

Do not use this option unless you fully understand why you are getting errors. If there are no bugs in your replication setup and client programs, and no bugs in MySQL itself, an error that stops replication should never occur. Indiscriminate use of this option results in slaves becoming hopelessly out of synchrony with the master, with you having no idea why this has occurred.

For error codes, you should use the numbers provided by the error message in your slave error log and in the output of `SHOW SLAVE STATUS`. Errors, Error Codes, and Common Problems, lists server error codes.

You can also (but should not) use the very nonrecommended value of `all` to cause the slave to ignore all error messages and keeps going regardless of what happens. Needless to say, if you use `all`, there are no guarantees regarding the integrity of your data. Please do not complain (or file bug reports) in this case if the slave's data is not anywhere close to what it is on the master. *You have been warned*.

MySQL 5.7 supports an additional shorthand value `ddl_exist_errors`, which is equivalent to the error code list `1007,1008,1050,1051,1054,1060,1061,1068,1094,1146`.

Examples:

```
--slave-skip-errors=1062,1053
--slave-skip-errors=all
--slave-skip-errors=ddl_exist_errors
```

- `--slave-sql-verify-checksum={0|1}`

Command-Line Format	`--slave-sql-verify-checksum=value`	
Permitted Values	**Type**	`boolean`
	Default	`0`
	Valid Values	`0`
		`1`

When this option is enabled, the slave examines checksums read from the relay log, in the event of a mismatch, the slave stops with an error. Disabled by default.

The following options are used internally by the MySQL test suite for replication testing and debugging. They are not intended for use in a production setting.

- `--abort-slave-event-count`

Command-Line Format	`--abort-slave-event-count=#`	
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`

When this option is set to some positive integer *`value`* other than 0 (the default) it affects replication behavior as follows: After the slave SQL thread has started, *`value`* log events are permitted to be executed; after that, the slave SQL thread does not receive any more events, just as if the network connection from the master were cut. The slave thread continues to run, and the output from `SHOW SLAVE STATUS` displays `Yes` in both the `Slave_IO_Running` and the `Slave_SQL_Running` columns, but no further events are read from the relay log.

- `--disconnect-slave-event-count`

Command-Line Format	`--disconnect-slave-event-count=#`	
Permitted Values	**Type**	`integer`
	Default	`0`

Options for Logging Slave Status to Tables

MySQL 5.7 supports logging of replication slave status information to tables rather than files. Writing of the master info log and the relay log info log can be configured separately using the two server options listed here:

- `--master-info-repository={FILE|TABLE}`

Command-Line Format	`--master-info-repository=FILE|TABLE`	
Permitted Values	**Type**	`string`
	Default	`FILE`
	Valid Values	`FILE`
		`TABLE`

This option causes the server to write its master info log to a file or a table. The name of the file defaults to `master.info`; you can change the name of the file using the `--master-info-file` server option.

The default value for this option is `FILE`. If you use `TABLE`, the log is written to the `slave_master_info` table in the `mysql` database.

- `--relay-log-info-repository={FILE|TABLE}`

Command-Line Format	`--relay-log-info-repository=FILE|TABLE`	
Permitted Values	**Type**	`string`
	Default	`FILE`
	Valid Values	`FILE`
		`TABLE`

This option causes the server to log its relay log info to a file or a table. The name of the file defaults to `relay-log.info`; you can change the name of the file using the `--relay-log-info-file` server option.

The default value for this option is `FILE`. If you use `TABLE`, the log is written to the `slave_relay_log_info` table in the `mysql` database.

These options can be used to make replication slaves resilient to unexpected halts. See Section 3.2, “Handling an Unexpected Halt of a Replication Slave”, for more information.

The info log tables and their contents are considered local to a given MySQL Server. They are not replicated, and changes to them are not written to the binary log.

For more information, see Section 5.4, “Replication Relay and Status Logs”.

System Variables Used on Replication Slaves

The following list describes system variables for controlling replication slave servers. They can be set at server startup and some of them can be changed at runtime using `SET`. Server options used with replication slaves are listed earlier in this section.

- `init_slave`

Command-Line Format	`--init-slave=name`	
System Variable	**Name**	`init_slave`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`string`

This variable is similar to `init_connect`, but is a string to be executed by a slave server each time the SQL thread starts. The format of the string is the same as for the `init_connect` variable. The setting of this variable takes effect for subsequent `START SLAVE` statements.

> **Note**
>
> The SQL thread sends an acknowledgment to the client before it executes `init_slave`. Therefore, it is not guaranteed that `init_slave` has been executed when `START SLAVE` returns. See START SLAVE Syntax, for more information.

- `log_slow_slave_statements`

Introduced	5.7.1	
System Variable	**Name**	`log_slow_slave_statements`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

When the slow query log is enabled, this variable enables logging for queries that have taken more than `long_query_time` seconds to execute on the slave. This variable was added in MySQL 5.7.1. Setting this variable has no immediate effect. The state of the variable applies on all subsequent `START SLAVE` statements.

- `master_info_repository`

Command-Line Format	`--master-info-repository=FILE|TABLE`	
System Variable	**Name**	`master_info_repository`
	Variable Scope	Global

	Dynamic Variable	Yes
Permitted Values	**Type**	`string`
	Default	`FILE`
	Valid Values	`FILE`
		`TABLE`

The setting of this variable determines whether the slave logs master status and connection information to a `FILE` (`master.info`), or to a `TABLE` (`mysql.slave_master_info`). You can only change the value of this variable when no replication threads are executing.

The setting of this variable also has a direct influence on the effect had by the setting of the `sync_master_info` system variable; see that variable's description for further information.

This variable must be set to `TABLE` before configuring multiple replication channels. If you are using multiple replication channels then you cannot set this variable back to `FILE`.

- `relay_log`

Command-Line Format	`--relay-log=file_name`	
System Variable	**Name**	`relay_log`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`

The base name of the relay log file, with no paths and no file extension. By default `relay-log`. The file name of individual files for the default replication channel is `relay-log.XXXXXX`, and for additional replication channels is `relay-log-`*`channel`*`.XXXXXX`.

- `relay_log_basename`

System Variable	**Name**	`relay_log_basename`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`
	Default	`datadir + '/' + hostname + '-relay-bin'`

Holds the name and complete path to the relay log file.

- `relay_log_index`

Command-Line Format	`--relay-log-index`	
System Variable	**Name**	`relay_log_index`
	Variable Scope	Global

	Dynamic Variable	No
Permitted Values	**Type**	`file name`
	Default	`*host_name*-relay-bin.index`

The name of the relay log index file for the default replication channel. The default name is *`host_name`*`-relay-bin.index` in the data directory, where *`host_name`* is the name of the slave server.

- `relay_log_info_file`

Command-Line Format	`--relay-log-info-file=file_name`	
System Variable	**Name**	`relay_log_info_file`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`
	Default	`relay-log.info`

The name of the file in which the slave records information about the relay logs, when `relay_log_info_repository=FILE`. If `relay_log_info_repository=TABLE`, it is the file name that would be used in case the repository was changed to `FILE`). The default name is `relay-log.info` in the data directory.

- `relay_log_info_repository`

System Variable	**Name**	`relay_log_info_repository`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`string`
	Default	`FILE`
	Valid Values	`FILE`
		`TABLE`

This variable determines whether the slave's position in the relay logs is written to a `FILE` (`relay-log.info`) or to a `TABLE` (`mysql.slave_relay_log_info`). You can only change the value of this variable when no replication threads are executing.

The setting of this variable also has a direct influence on the effect had by the setting of the `sync_relay_log_info` system variable; see that variable's description for further information.

This variable must be set to `TABLE` before configuring multiple replication channels. If you are using multiple replication channels then you cannot set this variable back to `FILE`.

- `relay_log_recovery`

Command-Line Format	`--relay-log-recovery`

System Variable	**Name**	relay_log_recovery
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	boolean
	Default	FALSE

Enables automatic relay log recovery immediately following server startup. The recovery process creates a new relay log file, initializes the SQL thread position to this new relay log, and initializes the I/O thread to the SQL thread position. Reading of the relay log from the master then continues. In MySQL 5.7, this global variable is read-only; its value can be changed by starting the slave with the `--relay-log-recovery` option, which should be used following an unexpected halt of a replication slave to ensure that no possibly corrupted relay logs are processed. See Section 3.2, “Handling an Unexpected Halt of a Replication Slave” for more information.

This variable also interacts with `relay-log-purge`, which controls purging of logs when they are no longer needed. Enabling the `--relay-log-recovery` option when `relay-log-purge` is disabled risks reading the relay log from files that were not purged, leading to data inconsistency.

When `relay_log_recovery` is enabled and the slave has stopped due to errors encountered while running in multi-threaded mode, you can use `START SLAVE UNTIL SQL_AFTER_MTS_GAPS` to ensure that all gaps are processed before switching back to single-threaded mode or executing a `CHANGE MASTER TO` statement.

- `rpl_stop_slave_timeout`

Introduced	5.7.2	
Command-Line Format	--rpl-stop-slave-timeout=seconds	
System Variable	**Name**	rpl_stop_slave_timeout
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	integer
	Default	31536000
	Min Value	2
	Max Value	31536000

In MySQL 5.7.2 and later, you can control the length of time (in seconds) that `STOP SLAVE` waits before timing out by setting this variable. This can be used to avoid deadlocks between `STOP SLAVE` and other slave SQL statements using different client connections to the slave. The maximum and default value of `rpl_stop_slave_timeout` is 31536000 seconds (1 year). The minimum is 2 seconds. Changes to this variable take effect for subsequent `STOP SLAVE` statements. This variable affects only the client that issues a `STOP SLAVE` statement. When the timeout is reached, the issuing client stops waiting for the slave threads to stop, but the slave threads continue to try to stop.

- `slave_checkpoint_group`

Command-Line Format	`--slave-checkpoint-group=#`	
System Variable	**Name**	`slave_checkpoint_group=#`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`512`
	Min Value	`32`
	Max Value	`524280`
	Block Size	`8`

Sets the maximum number of transactions that can be processed by a multi-threaded slave before a checkpoint operation is called to update its status as shown by `SHOW SLAVE STATUS`. Setting this variable has no effect on slaves for which multi-threading is not enabled. Setting this variable has no immediate effect. The state of the variable applies on all subsequent `START SLAVE` commands.

Note

Multi-threaded slaves are not currently supported by MySQL Cluster, which silently ignores the setting for this variable. See Known Issues in MySQL Cluster Replication, for more information.

This variable works in combination with the `slave_checkpoint_period` system variable in such a way that, when either limit is exceeded, the checkpoint is executed and the counters tracking both the number of transactions and the time elapsed since the last checkpoint are reset.

The minimum allowed value for this variable is 32, unless the server was built using `-DWITH_DEBUG`, in which case the minimum value is 1. The effective value is always a multiple of 8; you can set it to a value that is not such a multiple, but the server rounds it down to the next lower multiple of 8 before storing the value. (*Exception*: No such rounding is performed by the debug server.) Regardless of how the server was built, the default value is 512, and the maximum allowed value is 524280.

- `slave_checkpoint_period`

Command-Line Format	`--slave-checkpoint-period=#`	
System Variable	**Name**	`slave_checkpoint_period=#`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`300`
	Min Value	`1`

	Max Value	4G

Sets the maximum time (in milliseconds) that is allowed to pass before a checkpoint operation is called to update the status of a multi-threaded slave as shown by `SHOW SLAVE STATUS`. Setting this variable has no effect on slaves for which multi-threading is not enabled. Setting this variable takes effect for all replication channels immediately, including running channels.

> **Note**
>
> Multi-threaded slaves are not currently supported by MySQL Cluster, which silently ignores the setting for this variable. See Known Issues in MySQL Cluster Replication, for more information.

This variable works in combination with the `slave_checkpoint_group` system variable in such a way that, when either limit is exceeded, the checkpoint is executed and the counters tracking both the number of transactions and the time elapsed since the last checkpoint are reset.

The minimum allowed value for this variable is 1, unless the server was built using `-DWITH_DEBUG`, in which case the minimum value is 0. Regardless of how the server was built, the default value is 300, and the maximum possible value is 4294967296 (4GB).

- `slave_compressed_protocol`

Command-Line Format	`--slave_compressed_protocol`	
System Variable	**Name**	`slave_compressed_protocol`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

Whether to use compression of the slave/master protocol if both the slave and the master support it. Changes to this variable take effect on subsequent connection attempts; this includes after issuing a `START SLAVE` statement, as well as reconnections made by a running I/O thread (for example after issuing a `CHANGE MASTER TO MASTER_RETRY_COUNT` statement).

- `slave_exec_mode`

Command-Line Format	`--slave-exec-mode=mode`	
System Variable	**Name**	`slave_exec_mode`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`enumeration`
	Default	`STRICT` (ALL)
	Default	`IDEMPOTENT` (NDB)

	Valid Values	`IDEMPOTENT`
		`STRICT`

Controls how a slave thread resolves conflicts and errors during replication. `IDEMPOTENT` mode causes suppression of duplicate-key and no-key-found errors. This mode should be employed in multi-master replication, circular replication, and some other special replication scenarios. `STRICT` mode is the default, and is suitable for most other cases. Setting this variable takes effect for all replication channels immediately, including running channels.

This mode is needed for multi-master replication, circular replication, and some other special replication scenarios for MySQL Cluster Replication. (See MySQL Cluster Replication: Multi-Master and Circular Replication, and MySQL Cluster Replication Conflict Resolution, for more information.) The `mysqld` supplied with MySQL Cluster ignores any value explicitly set for `slave_exec_mode`, and always treats it as `IDEMPOTENT`.

In MySQL Server 5.7, `STRICT` mode is the default value. This should not be changed; currently, `IDEMPOTENT` mode is supported only by `NDB` and is used when replicating `NDB` to `InnoDB`.

- `slave_load_tmpdir`

Command-Line Format	`--slave-load-tmpdir=dir_name`	
System Variable	**Name**	`slave_load_tmpdir`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`directory name`
	Default	`/tmp`

The name of the directory where the slave creates temporary files for replicating `LOAD DATA INFILE` statements. Setting this variable takes effect for all replication channels immediately, including running channels.

- `slave_max_allowed_packet`

System Variable	**Name**	`slave_max_allowed_packet`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`1073741824`
	Min Value	`1024`
	Max Value	`1073741824`

This variable sets the maximum packet size for the slave SQL and I/O threads, so that large updates using row-based replication do not cause replication to fail because an update exceeded max_allowed_packet. Setting this variable takes effect for all replication channels immediately, including running channels.

This global variable always has a value that is a positive integer multiple of 1024; if you set it to some value that is not, the value is rounded down to the next highest multiple of 1024 for it is stored or used; setting slave_max_allowed_packet to 0 causes 1024 to be used. (A truncation warning is issued in all such cases.) The default and maximum value is 1073741824 (1 GB); the minimum is 1024.

slave_max_allowed_packet can also be set at startup, using the --slave-max-allowed-packet option.

- slave_net_timeout

Command-Line Format	--slave-net-timeout=#	
System Variable	**Name**	slave_net_timeout
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	integer
	Default	3600
	Min Value	1
Permitted Values (>= 5.7.7)	**Type**	integer
	Default	60
	Min Value	1

The number of seconds to wait for more data from a master/slave connection before aborting the read. Setting this variable has no immediate effect. The state of the variable applies on all subsequent START SLAVE commands.

- slave_parallel_type=*type*

Introduced	5.7.2	
Command-Line Format	--slave-parallel-type=type	
Permitted Values	**Type**	enumeration
	Default	DATABASE
	Valid Values	DATABASE
		LOGICAL_CLOCK

When using a multi-threaded slave (slave_parallel_workers is greater than 0), this variable specifies the policy used to decide which transactions are allowed to execute in parallel on the slave. See --slave-parallel-type for more information.

- slave_parallel_workers

Command-Line Format	--slave-parallel-workers=#	
System Variable	**Name**	slave_parallel_workers

	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	integer
	Default	0
	Min Value	0
	Max Value	1024

Sets the number of slave applier threads for executing replication transactions in parallel. Setting this variable to a number greater than 0 creates a multi-threaded slave with this number of applier threads. When set to 0 (the default) parallel execution is disabled and the slave uses a single applier thread. Setting `slave_parallel_workers` has no immediate effect. The state of the variable applies on all subsequent `START SLAVE` statements.

> **Note**
>
> Multi-threaded slaves are not currently supported by MySQL Cluster, which silently ignores the setting for this variable. See Known Issues in MySQL Cluster Replication, for more information.

A multi-threaded slave provides parallel execution by using a coordinator thread and the number of applier threads configured by this variable. The way which transactions are distributed among applier threads is configured by `slave_parallel_type`. The transactions that the slave applies in parallel may commit out of order, unless `slave_preserve_commit_order=1`. Therefore, checking for the most recently executed transaction does not guarantee that all previous transactions from the master have been executed on the slave. This has implications for logging and recovery when using a multi-threaded slave. For example, on a multi-threaded slave the `START SLAVE UNTIL` statement only supports using `SQL_AFTER_MTS_GAPS`.

In MySQL 5.7.5 and later, retrying of transactions is supported when multi-threading is enabled on a slave. In previous versions, `slave_transaction_retries` was treated as equal to 0 when using multi-threaded slaves.

- `slave_pending_jobs_size_max`

System Variable	**Name**	`slave_pending_jobs_size_max`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	integer
	Default	16M
	Min Value	1024
	Max Value	18EB

	Block Size	1024

For multi-threaded slaves, this variable sets the maximum amount of memory (in bytes) available to slave worker queues holding events not yet applied. Setting this variable has no effect on slaves for which multi-threading is not enabled. Setting this variable has no immediate effect. The state of the variable applies on all subsequent `START SLAVE` commands.

The minimum possible value for this variable is 1024; the default is 16MB. The maximum possible value is 18446744073709551615 (16 exabytes). Values that are not exact multiples of 1024 are rounded down to the next-highest multiple of 1024 prior to being stored.

> **Important**
>
> The value of this variable must not be less than the master's value for `max_allowed_packet`; otherwise a slave worker queue may become full while there remain events coming from the master to be processed.

- `slave_preserve_commit_order`

Introduced	5.7.5	
Command-Line Format	`--slave-preserve-commit-order=value`	
System Variable	**Name**	`slave_preserve_commit_order`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`0`
	Valid Values	`0`
		`1`

For multi-threaded slaves, enabling this variable ensures that transactions are externalized on the slave in the same order as they appear in the slave's relay log. Setting this variable has no effect on slaves for which multi-threading is not enabled. All replication threads (for all replication channels if you are using multiple replication channels) must be stopped before changing this variable. `--log-bin` and `--log-slave-updates` must be enabled on the slave. In addition `--slave-parallel-type` must be set to `LOGICAL_CLOCK`.

Once a multi-threaded slave has been started, transactions can begin to execute in parallel. With `slave_preserve_commit_order` enabled, the executing thread waits until all previous transactions are committed before committing. While the slave thread is waiting for other workers to commit their transactions it reports its status as `Waiting for preceding transaction to commit`. (Prior to MySQL 5.7.8, this was shown as `Waiting for its turn to commit`.) Enabling this mode on a multi-threaded slave ensures that it never enters a state that the master was not in. This makes it well suited to using replication for read scale-out. See Section 3.4, "Using Replication for Scale-Out".

When using a multi-threaded slave, if `slave_preserve_commit_order` is not enabled, there is a chance of gaps in the sequence of transactions that have been executed from the slave's relay log. When this option is enabled, there is not this chance of gaps, but `Exec_master_log_pos` may be behind the position up to which has been executed. See Section 4.1.34, “Replication and Transaction Inconsistencies” for more information.

- `slave_rows_search_algorithms`

System Variable	Name	`slave_rows_search_algorithms=list`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`set`
	Default	`TABLE_SCAN,INDEX_SCAN`
	Valid Values	`TABLE_SCAN,INDEX_SCAN`
		`INDEX_SCAN,HASH_SCAN`
		`TABLE_SCAN,HASH_SCAN`
		`TABLE_SCAN,INDEX_SCAN,HASH_SCAN` (equivalent to INDEX_SCAN,HASH_SCAN)

When preparing batches of rows for row-based logging and replication, this variable controls how the rows are searched for matches—that is, whether or not hashing is used for searches using a primary or unique key, using some other key, or using no key at all. Setting this variable takes effect for all replication channels immediately, including running channels.

This variable takes a comma-separated list of at least 2 values from the list `INDEX_SCAN`, `TABLE_SCAN`, `HASH_SCAN`. The value expected as a string, so the value must be quoted. In addition, the value must not contain any spaces. Possible combinations (lists) and their effects are shown in the following table:

Index used / option value	**`INDEX_SCAN,HASH_SCAN`** or **`INDEX_SCAN,TABLE_SCAN,HASH_SCAN`**	**`INDEX_SCAN,TABLE_SCAN`**	**`TABLE_SCAN,HASH_SCAN`**
Primary key or unique key	Index scan	index scan	Index hash
(Other) Key	Index hash	Index scan	Index hash
No index	Table hash	Table scan	Table hash

The order in which the algorithms are specified in the list does not make any difference in the order in which they are displayed by a `SELECT` or `SHOW VARIABLES` statement, as shown here:

```
mysql> SET GLOBAL slave_rows_search_algorithms = "INDEX_SCAN,TABLE_SCAN";
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE '%algorithms%';
+------------------------------+-----------------------+
| Variable_name                | Value                 |
+------------------------------+-----------------------+
| slave_rows_search_algorithms | TABLE_SCAN,INDEX_SCAN |
+------------------------------+-----------------------+
1 row in set (0.00 sec)

mysql> SET GLOBAL slave_rows_search_algorithms = "TABLE_SCAN,INDEX_SCAN";
Query OK, 0 rows affected (0.00 sec)
```

```
mysql> SHOW VARIABLES LIKE '%algorithms%';
+------------------------------+-----------------------+
| Variable_name                | Value                 |
+------------------------------+-----------------------+
| slave_rows_search_algorithms | TABLE_SCAN,INDEX_SCAN |
+------------------------------+-----------------------+
1 row in set (0.00 sec)
```

The default value is `TABLE_SCAN,INDEX_SCAN`, which means that all searches that can use indexes do use them, and searches without any indexes use table scans.

Specifying `INDEX_SCAN,TABLE_SCAN,HASH_SCAN` has the same effect as specifying `INDEX_SCAN,HASH_SCAN`. To use hashing for any searches that does not use a primary or unique key, set this variable to `INDEX_SCAN,HASH_SCAN`. To force hashing for *all* searches, set it to `TABLE_SCAN,HASH_SCAN`.

- `slave_skip_errors`

Command-Line Format	`--slave-skip-errors=name`	
System Variable	**Name**	`slave_skip_errors`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`
	Default	`OFF`
	Valid Values	`OFF`
		`[list of error codes]`
		`all`
		`ddl_exist_errors`
Permitted Values	**Type**	`string`
	Default	`OFF`
	Valid Values	`OFF`
		`[list of error codes]`
		`all`
		`ddl_exist_errors`
Permitted Values	**Type**	`string`
	Default	`OFF`
	Valid Values	`OFF`
		`[list of error codes]`
		`all`
		`ddl_exist_errors`

Normally, replication stops when an error occurs on the slave, which gives you the opportunity to resolve the inconsistency in the data manually. This variable causes the slave SQL thread to continue replication when a statement returns any of the errors listed in the variable value. The setting of this variable takes effect immediately, even for running replication threads.

- `slave_sql_verify_checksum`

System Variable	**Name**	`slave_sql_verify_checksum`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`1`
	Valid Values	`0`
		`1`

Cause the slave SQL thread to verify data using the checksums read from the relay log. In the event of a mismatch, the slave stops with an error. Setting this variable takes effect for all replication channels immediately, including running channels.

> **Note**
>
> The slave I/O thread always reads checksums if possible when accepting events from over the network.

- `slave_transaction_retries`

Command-Line Format	`--slave_transaction_retries=#`	
System Variable	**Name**	`slave_transaction_retries`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`10`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`10`
	Min Value	`0`
	Max Value	`18446744073709551615`

If a replication slave SQL thread fails to execute a transaction because of an `InnoDB` deadlock or because the transaction's execution time exceeded `InnoDB`'s `innodb_lock_wait_timeout` or `NDB`'s `TransactionDeadlockDetectionTimeout` or `TransactionInactiveTimeout`, it automatically retries `slave_transaction_retries` times before stopping with an error. The default value is 10. Setting this variable takes effect for all replication channels immediately, including running channels.

As of MySQL 5.7.5, retrying of transactions is supported when multi-threading is enabled on a slave. In previous versions, `slave_transaction_retries` was treated as equal to 0 when using multi-threaded slaves.

- `slave_type_conversions`

Command-Line Format	`--slave_type_conversions=set`	
System Variable	**Name**	`slave_type_conversions`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values (<= 5.7.1)	**Type**	`set`
	Default	
	Valid Values	`ALL_LOSSY`
		`ALL_NON_LOSSY`
Permitted Values (>= 5.7.2)	**Type**	`set`
	Default	
	Valid Values	`ALL_LOSSY`
		`ALL_NON_LOSSY`
		`ALL_SIGNED`
		`ALL_UNSIGNED`

Controls the type conversion mode in effect on the slave when using row-based replication. In MySQL 5.7.2 and later, its value is a comma-delimited set of zero or more elements from the list: `ALL_LOSSY`, `ALL_NON_LOSSY`, `ALL_SIGNED`, `ALL_UNSIGNED`. Set this variable to an empty string to disallow type conversions between the master and the slave. Setting this variable takes effect for all replication channels immediately, including running channels.

`ALL_SIGNED` and `ALL_UNSIGNED` were added in MySQL 5.7.2 (Bug#15831300). For additional information on type conversion modes applicable to attribute promotion and demotion in row-based replication, see Row-based replication: attribute promotion and demotion.

- `sql_slave_skip_counter`

System Variable	**Name**	`sql_slave_skip_counter`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`

The number of events from the master that a slave server should skip. Setting the option has no immediate effect. The variable applies to the next `START SLAVE` statement; the next `START SLAVE` statement also changes the value back to 0. When this variable is set to a non-zero value and there are multiple replication channels configured, the `START SLAVE` statement can only be used with the `FOR CHANNEL` *`channel`* clause.

This option is incompatible with GTID-based replication, and must not be set to a nonzero value when `--gtid-mode=ON`. In MySQL 5.7.1 and later, trying to do so is specifically disallowed. (Bug #15833516) If you need to skip transactions when employing GTIDs, use `gtid_executed` from the master instead. See Injecting empty transactions, for information about how to do this.

> **Important**
>
> If skipping the number of events specified by setting this variable would cause the slave to begin in the middle of an event group, the slave continues to skip until it finds the beginning of the next event group and begins from that point. For more information, see SET GLOBAL sql_slave_skip_counter Syntax.

- `sync_master_info`

Command-Line Format	`--sync-master-info=#`	
System Variable	**Name**	`sync_master_info`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`10000`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`10000`
	Min Value	`0`
	Max Value	`18446744073709551615`

The effects of this variable on a replication slave depend on whether the slave's `master_info_repository` is set to `FILE` or `TABLE`, as explained in the following paragraphs.

master_info_repository = FILE. If the value of `sync_master_info` is greater than 0, the slave synchronizes its `master.info` file to disk (using `fdatasync()`) after every `sync_master_info` events. If it is 0, the MySQL server performs no synchronization of the `master.info` file to disk; instead, the server relies on the operating system to flush its contents periodically as with any other file.

master_info_repository = TABLE. If the value of `sync_master_info` is greater than 0, the slave updates its master info repository table after every `sync_master_info` events. If it is 0, the table is never updated.

The default value for `sync_master_info` is 10000. Setting this variable takes effect for all replication channels immediately, including running channels.

- `sync_relay_log`

Command-Line Format	`--sync-relay-log=#`	
System Variable	**Name**	`sync_relay_log`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`10000`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`10000`
	Min Value	`0`
	Max Value	`18446744073709551615`

If the value of this variable is greater than 0, the MySQL server synchronizes its relay log to disk (using `fdatasync()`) after every `sync_relay_log` events are written to the relay log. Setting this variable takes effect for all replication channels immediately, including running channels.

Setting `sync_relay_log` to 0 causes no synchronization to be done to disk; in this case, the server relies on the operating system to flush the relay log's contents from time to time as for any other file.

A value of 1 is the safest choice because in the event of a crash you lose at most one event from the relay log. However, it is also the slowest choice (unless the disk has a battery-backed cache, which makes synchronization very fast).

- `sync_relay_log_info`

Command-Line Format	`--sync-relay-log-info=#`	
System Variable	**Name**	`sync_relay_log_info`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`10000`
	Min Value	`0`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`

	Default	`10000`
	Min Value	`0`
	Max Value	`18446744073709551615`

The effects of this variable on the slave depend on the server's `relay_log_info_repository` setting (`FILE` or `TABLE`), and if this is `TABLE`, additionally on whether the storage engine used by the relay log info table is transactional (such as `InnoDB`) or not (`MyISAM`). The effects of these factors on the behavior of the server for `sync_relay_log_info` values of zero and greater than zero are shown in the following table:

`sync_relay_log_info`	`relay_log_info_repository`		
	`FILE`	`TABLE`	
		Transactional	**Nontransactional**
`N` `> 0`	The slave synchronizes its `relay-log.info` file to disk (using `fdatasync()`) after every *`N`* transactions.	The table is updated after each transaction. (*`N`* is effectively ignored.)	The table is updated after every *`N`* events.
`0`	The MySQL server performs no synchronization of the `relay-log.info` file to disk; instead, the server relies on the operating system to flush its contents periodically as with any other file.		The table is never updated.

The default value for `sync_relay_log_info` is 10000. Setting this variable takes effect for all replication channels immediately, including running channels.

2.6.4 Binary Logging Options and Variables

Startup Options Used with Binary Logging

System Variables Used with Binary Logging

You can use the `mysqld` options and system variables that are described in this section to affect the operation of the binary log as well as to control which statements are written to the binary log. For additional information about the binary log, see The Binary Log. For additional information about using MySQL server options and system variables, see Server Command Options, and Server System Variables.

Startup Options Used with Binary Logging

The following list describes startup options for enabling and configuring the binary log. System variables used with binary logging are discussed later in this section.

- `--binlog-row-event-max-size=`*`N`*

Command-Line Format	`--binlog-row-event-max-size=#`	
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`8192`

	Min Value	`256`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`8192`
	Min Value	`256`
	Max Value	`18446744073709551615`

Specify the maximum size of a row-based binary log event, in bytes. Rows are grouped into events smaller than this size if possible. The value should be a multiple of 256. The default is 8192. See Section 5.1, “Replication Formats”.

- `--log-bin[=base_name]`

Command-Line Format	`--log-bin`	
System Variable	**Name**	`log_bin`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`

Enable binary logging. The server logs all statements that change data to the binary log, which is used for backup and replication. See The Binary Log.

The option value, if given, is the base name for the log sequence. The server creates binary log files in sequence by adding a numeric suffix to the base name. It is recommended that you specify a base name (see Known Issues in MySQL, for the reason). Otherwise, MySQL uses `*host_name*-bin` as the base name.

When the server reads an entry from the index file, it checks whether the entry contains a relative path, and if it does, the relative part of the path in replaced with the absolute path set using the `--log-bin` option. An absolute path remains unchanged; in such a case, the index must be edited manually to enable the new path or paths to be used. (In older versions of MySQL, manual intervention was required whenever relocating the binary log or relay log files.) (Bug #11745230, Bug #12133)

Setting this option causes the `log_bin` system variable to be set to `ON` (or `1`), and not to the base name. The binary log file name (with path) is available as the `log_bin_basename` system variable.

In MySQL 5.7.3 and later, if you specify this option without also specifying a `--server-id`, the server is not allowed to start. (Bug #11763963, Bug #56739)

- `--log-bin-index[=file_name]`

Command-Line Format	`--log-bin-index=file_name`	
Permitted Values	**Type**	`file name`

The index file for binary log file names. See The Binary Log. If you omit the file name, and if you did not specify one with `--log-bin`, MySQL uses `*host_name*-bin.index` as the file name.

- `--log-bin-trust-function-creators[={0|1}]`

Command-Line Format	`--log-bin-trust-function-creators`	
System Variable	**Name**	`log_bin_trust_function_creators`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

This option sets the corresponding `log_bin_trust_function_creators` system variable. If no argument is given, the option sets the variable to 1. `log_bin_trust_function_creators` affects how MySQL enforces restrictions on stored function and trigger creation. See Binary Logging of Stored Programs.

- `--log-bin-use-v1-row-events[={0|1}]`

Command-Line Format	`--log-bin-use-v1-row-events[={0|1}]`	
System Variable	**Name**	`log_bin_use_v1_row_events`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`
	Default	`0`

MySQL 5.7 uses Version 2 binary log row events, which cannot be read by MySQL Server releases prior to MySQL 5.6.6. Setting this option to 1 causes `mysqld` to write the binary log using Version 1 logging events, which is the only version of binary log events used in previous releases, and thus produce binary logs that can be read by older slaves. Setting `--log-bin-use-v1-row-events` to 0 (the default) causes `mysqld` to use Version 2 binary log events.

The value used for this option can be obtained from the read-only `log_bin_use_v1_row_events` system variable.

`--log-bin-use-v1-row-events` is chiefly of interest when setting up replication conflict detection and resolution using `NDB$EPOCH_TRANS()` as the conflict detection function, which requires Version 2 binary log row events. Thus, this option and `--ndb-log-transaction-id` are not compatible.

For more information, see MySQL Cluster Replication Conflict Resolution.

Statement selection options. The options in the following list affect which statements are written to the binary log, and thus sent by a replication master server to its slaves. There are also options for slave servers that control which statements received from the master should be executed or ignored. For details, see Section 2.6.3, “Replication Slave Options and Variables”.

- `--binlog-do-db=*db_name*`

Command-Line Format	`--binlog-do-db=name`	
Permitted Values	**Type**	`string`

This option affects binary logging in a manner similar to the way that `--replicate-do-db` affects replication.

The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of `--replicate-do-db` depend on whether statement-based or row-based replication is in use. You should keep in mind that the format used to log a given statement may not necessarily be the same as that indicated by the value of `binlog_format`. For example, DDL statements such as `CREATE TABLE` and `ALTER TABLE` are always logged as statements, without regard to the logging format in effect, so the following statement-based rules for `--binlog-do-db` always apply in determining whether or not the statement is logged.

Statement-based logging. Only those statements are written to the binary log where the default database (that is, the one selected by `USE`) is *`db_name`*. To specify more than one database, use this option multiple times, once for each database; however, doing so does *not* cause cross-database statements such as `UPDATE` *`some_db.some_table`* `SET foo='bar'` to be logged while a different database (or no database) is selected.

> **Warning**
>
> To specify multiple databases you *must* use multiple instances of this option. Because database names can contain commas, the list will be treated as the name of a single database if you supply a comma-separated list.

An example of what does not work as you might expect when using statement-based logging: If the server is started with `--binlog-do-db=sales` and you issue the following statements, the `UPDATE` statement is *not* logged:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The main reason for this “just check the default database” behavior is that it is difficult from the statement alone to know whether it should be replicated (for example, if you are using multiple-table `DELETE` statements or multiple-table `UPDATE` statements that act across multiple databases). It is also faster to check only the default database rather than all databases if there is no need.

Another case which may not be self-evident occurs when a given database is replicated even though it was not specified when setting the option. If the server is started with `--binlog-do-db=sales`, the following `UPDATE` statement is logged even though `prices` was not included when setting `--binlog-do-db`:

```
USE sales;
UPDATE prices.discounts SET percentage = percentage + 10;
```

Because `sales` is the default database when the `UPDATE` statement is issued, the `UPDATE` is logged.

Row-based logging. Logging is restricted to database *`db_name`*. Only changes to tables belonging to *`db_name`* are logged; the default database has no effect on this. Suppose that the server is started with `--binlog-do-db=sales` and row-based logging is in effect, and then the following statements are executed:

```
USE prices;
UPDATE sales.february SET amount=amount+100;
```

The changes to the `february` table in the `sales` database are logged in accordance with the `UPDATE` statement; this occurs whether or not the `USE` statement was issued. However, when using the row-based logging format and `--binlog-do-db=sales`, changes made by the following `UPDATE` are not logged:

```
USE prices;
UPDATE prices.march SET amount=amount-25;
```

Even if the `USE prices` statement were changed to `USE sales`, the `UPDATE` statement's effects would still not be written to the binary log.

Another important difference in `--binlog-do-db` handling for statement-based logging as opposed to the row-based logging occurs with regard to statements that refer to multiple databases. Suppose that the server is started with `--binlog-do-db=db1`, and the following statements are executed:

```
USE db1;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

If you are using statement-based logging, the updates to both tables are written to the binary log. However, when using the row-based format, only the changes to `table1` are logged; `table2` is in a different database, so it is not changed by the `UPDATE`. Now suppose that, instead of the `USE db1` statement, a `USE db4` statement had been used:

```
USE db4;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

In this case, the `UPDATE` statement is not written to the binary log when using statement-based logging. However, when using row-based logging, the change to `table1` is logged, but not that to `table2`—in other words, only changes to tables in the database named by `--binlog-do-db` are logged, and the choice of default database has no effect on this behavior.

- `--binlog-ignore-db=`*`db_name`*

Command-Line Format	`--binlog-ignore-db=name`	
Permitted Values	**Type**	`string`

This option affects binary logging in a manner similar to the way that `--replicate-ignore-db` affects replication.

The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of `--replicate-ignore-db` depend on whether statement-based or row-based replication is in use. You should keep in mind that the format used to log a given statement may not necessarily be the same as that indicated by the value of `binlog_format`. For example, DDL statements such as `CREATE TABLE` and `ALTER TABLE` are always logged as statements, without regard to the logging format in effect, so the following statement-based rules for `--binlog-ignore-db` always apply in determining whether or not the statement is logged.

Statement-based logging. Tells the server to not log any statement where the default database (that is, the one selected by `USE`) is *`db_name`*.

Prior to MySQL 5.7.2, this option caused any statements containing fully qualified table names not to be logged if there was no default database specified (that is, when `SELECT DATABASE()` returned `NULL`). In MySQL 5.7.2 and later, when there is no default database, no `--binlog-ignore-db` options are applied, and such statements are always logged. (Bug #11829838, Bug #60188)

Row-based format. Tells the server not to log updates to any tables in the database *`db_name`*. The current database has no effect.

When using statement-based logging, the following example does not work as you might expect. Suppose that the server is started with `--binlog-ignore-db=sales` and you issue the following statements:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The `UPDATE` statement *is* logged in such a case because `--binlog-ignore-db` applies only to the default database (determined by the `USE` statement). Because the `sales` database was specified explicitly in the statement, the statement has not been filtered. However, when using row-based logging, the `UPDATE` statement's effects are *not* written to the binary log, which means that no changes to the `sales.january` table are logged; in this instance, `--binlog-ignore-db=sales` causes *all* changes made to tables in the master's copy of the `sales` database to be ignored for purposes of binary logging.

To specify more than one database to ignore, use this option multiple times, once for each database. Because database names can contain commas, the list will be treated as the name of a single database if you supply a comma-separated list.

You should not use this option if you are using cross-database updates and you do not want these updates to be logged.

Checksum options. MySQL 5.7 supports reading and writing of binary log checksums. These are enabled using the two options listed here:

- `--binlog-checksum={NONE|CRC32}`

Command-Line Format	`--binlog-checksum=type`	
Permitted Values	**Type**	`string`
	Default	`CRC32`
	Valid Values	`NONE`
		`CRC32`

  Enabling this option causes the master to write checksums for events written to the binary log. Set to `NONE` to disable, or the name of the algorithm to be used for generating checksums; currently, only CRC32 checksums are supported, and CRC32 is the default.

- `--master-verify-checksum={0|1}`

Command-Line Format	`--master-verify-checksum=name`	
Permitted Values	**Type**	`boolean`
	Default	`OFF`

  Enabling this option causes the master to verify events from the binary log using checksums, and to stop with an error in the event of a mismatch. Disabled by default.

To control reading of checksums by the slave (from the relay) log, use the `--slave-sql-verify-checksum` option.

Testing and debugging options. The following binary log options are used in replication testing and debugging. They are not intended for use in normal operations.

- `--max-binlog-dump-events=N`

Command-Line Format	`--max-binlog-dump-events=#`	
Permitted Values	**Type**	`integer`
	Default	`0`

  This option is used internally by the MySQL test suite for replication testing and debugging.

- `--sporadic-binlog-dump-fail`

Command-Line Format	`--sporadic-binlog-dump-fail`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

  This option is used internally by the MySQL test suite for replication testing and debugging.

- `--binlog-rows-query-log-events`

Command-Line Format	`--binlog-rows-query-log-events`	
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

  This option enables `binlog_rows_query_log_events`.

System Variables Used with Binary Logging

The following list describes system variables for controlling binary logging. They can be set at server startup and some of them can be changed at runtime using `SET`. Server options used to control binary logging are listed earlier in this section. For information about the `sql_log_bin` and `sql_log_off` variables, see Server System Variables.

- `binlog_cache_size`

Command-Line Format	`--binlog_cache_size=#`	
System Variable	**Name**	`binlog_cache_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`32768`
	Min	`4096`
	Value	102

	Max Value	4294967295
Permitted Values (64-bit platforms)	**Type**	integer
	Default	32768
	Min Value	4096
	Max Value	18446744073709551615

The size of the cache to hold changes to the binary log during a transaction. A binary log cache is allocated for each client if the server supports any transactional storage engines and if the server has the binary log enabled (`--log-bin` option). If you often use large transactions, you can increase this cache size to get better performance. The `Binlog_cache_use` and `Binlog_cache_disk_use` status variables can be useful for tuning the size of this variable. See The Binary Log.

`binlog_cache_size` sets the size for the transaction cache only; the size of the statement cache is governed by the `binlog_stmt_cache_size` system variable.

- `binlog_checksum`

System Variable	**Name**	binlog_checksum
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	string
	Default	CRC32
	Valid Values	NONE
		CRC32

When enabled, this variable causes the master to write a checksum for each event in the binary log. `binlog_checksum` supports the values `NONE` (disabled) and `CRC32`. The default is `CRC32`.

When `binlog_checksum` is disabled (value `NONE`), the server verifies that it is writing only complete events to the binary log by writing and checking the event length (rather than a checksum) for each event.

Changing the value of this variable causes the binary log to be rotated; checksums are always written to an entire binary log file, and never to only part of one.

Setting this variable on the master to a value unrecognized by the slave causes the slave to set its own `binlog_checksum` value to `NONE`, and to stop replication with an error. (Bug #13553750, Bug #61096) If backward compatibility with older slaves is a concern, you may want to set the value explicitly to `NONE`.

- `binlog_direct_non_transactional_updates`

Command-Line Format	--binlog_direct_non_transactional_updates[=value]	
System Variable	**Name**	binlog_direct_non_transactional_updates
	Variable Scope	Global, Session

	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

Due to concurrency issues, a slave can become inconsistent when a transaction contains updates to both transactional and nontransactional tables. MySQL tries to preserve causality among these statements by writing nontransactional statements to the transaction cache, which is flushed upon commit. However, problems arise when modifications done to nontransactional tables on behalf of a transaction become immediately visible to other connections because these changes may not be written immediately into the binary log.

The `binlog_direct_non_transactional_updates` variable offers one possible workaround to this issue. By default, this variable is disabled. Enabling `binlog_direct_non_transactional_updates` causes updates to nontransactional tables to be written directly to the binary log, rather than to the transaction cache.

`binlog_direct_non_transactional_updates` works only for statements that are replicated using the statement-based binary logging format; that is, it works only when the value of `binlog_format` is `STATEMENT`, or when `binlog_format` is `MIXED` and a given statement is being replicated using the statement-based format. This variable has no effect when the binary log format is `ROW`, or when `binlog_format` is set to `MIXED` and a given statement is replicated using the row-based format.

Important

Before enabling this variable, you must make certain that there are no dependencies between transactional and nontransactional tables; an example of such a dependency would be the statement `INSERT INTO myisam_table SELECT * FROM innodb_table`. Otherwise, such statements are likely to cause the slave to diverge from the master.

In MySQL 5.7, this variable has no effect when the binary log format is `ROW` or `MIXED`. (Bug #51291)

- `binlog_error_action`

Introduced	5.7.6	
Command-Line Format	`--binlog_error_action[=value]`	
System Variable	**Name**	`binlog_error_action`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`enumeration`
	Default	`IGNORE_ERROR`
	Valid Values	`IGNORE_ERROR`
		`ABORT_SERVER`
Permitted Values (>= 5.7.7)	**Type**	`enumeration`
	Default	`ABORT_SERVER`
	Valid Values	`IGNORE_ERROR`

		ABORT_SERVER

Controls what happens when the server encounters an error such as not being able to write to, flush or synchronize the binary log, which can cause the master's log to become inconsistent and replication slaves to lose synchronization.

In MySQL 5.7.7 and later, this variable defaults to `ABORT_SERVER`, which makes the server halt logging and shut down whenever it encounters such an error with the binary log. Upon server restart, all of the previously prepared and binary logged transactions are committed, while any transactions which were prepared but not binary logged due to the error are aborted.

When `binlog_error_action` is set to `IGNORE_ERROR`, if the server encounters such an error it continues the ongoing transaction, logs the error then halts logging, and continues performing updates. To resume binary logging `log_bin` must be enabled again. This provides backward compatibility with older versions of MySQL.

In previous releases this variable was named `binlogging_impossible_mode`.

- `binlog_format`

Command-Line Format	`--binlog-format=format`	
System Variable	**Name**	`binlog_format`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values (<= 5.7.6)	**Type**	`enumeration`
	Default	`STATEMENT`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.7.7)	**Type**	`enumeration`
	Default	`ROW`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`

This variable sets the binary logging format, and can be any one of `STATEMENT`, `ROW`, or `MIXED`. See Section 5.1, “Replication Formats”. `binlog_format` is set by the `--binlog-format` option at startup, or by the `binlog_format` variable at runtime.

> **Note**
>
> While you can change the logging format at runtime, it is *not* recommended that you change it while replication is ongoing. This is due in part to the fact that slaves do not honor the master's `binlog_format` setting; a given MySQL Server can change only its own logging format.

Prior to MySQL 5.7.7, the default format was `STATEMENT`. In MySQL 5.7.7 and later the default is `ROW`. *Exception*: In MySQL Cluster, the default is `MIXED`; statement-based replication is not supported for MySQL Cluster.

You must have the `SUPER` privilege to set either the global or session `binlog_format` value.

The rules governing when changes to this variable take effect and how long the effect lasts are the same as for other MySQL server system variables. For more information, see SET Syntax for Variable Assignment.

When `MIXED` is specified, statement-based replication is used, except for cases where only row-based replication is guaranteed to lead to proper results. For example, this happens when statements contain user-defined functions (UDF) or the `UUID()` function. An exception to this rule is that `MIXED` always uses statement-based replication for stored functions and triggers.

There are exceptions when you cannot switch the replication format at runtime:

- From within a stored function or a trigger.
- If the session is currently in row-based replication mode and has open temporary tables.
- From within a transaction.

Trying to switch the format in those cases results in an error.

The binary log format affects the behavior of the following server options:

- `--replicate-do-db`
- `--replicate-ignore-db`
- `--binlog-do-db`
- `--binlog-ignore-db`

These effects are discussed in detail in the descriptions of the individual options.

- `binlog_group_commit_sync_delay`

Introduced	5.7.5	
Command-Line Format	`--binlog-group-commit-sync-delay=#`	
System Variable	**Name**	`binlog_group_commit_sync_delay`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`1000000`

Controls how many microseconds the binary log commit waits before synchronizing the binary log file to disk. By default `binlog-group-commit-sync-delay` is set to 0, meaning that there is no delay. Setting `binlog-group-commit-sync-delay` to a microsecond delay enables more transactions to be synchronized together to disk at once, reducing the overall time to commit a group of transactions because the larger groups require fewer time units per group. With the correct tuning, this can increase slave performance without compromising the master's throughput.

- `binlog_group_commit_sync_no_delay_count`

Introduced	5.7.5	
Command-Line Format	`--binlog-group-commit-sync-no-delay-count=#`	
System Variable	**Name**	`binlog_group_commit_sync_no_delay_count`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`1000000`

The maximum number of transactions to wait for before aborting the current delay as specified by `binlog-group-commit-sync-delay`. If `binlog-group-commit-sync-delay` is set to 0, then this option has no effect.

- `binlogging_impossible_mode`

Introduced	5.7.5	
Deprecated	5.7.6	
Command-Line Format	`--binlogging_impossible_mode[=value]`	
System Variable	**Name**	`binlogging_impossible_mode`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`enumeration`
	Default	`IGNORE_ERROR`
	Valid Values	`IGNORE_ERROR`
		`ABORT_SERVER`

This option is deprecated and will be removed in a future MySQL release. Use the renamed `binlog_error_action` to control what happens when the server cannot write to the binary log.

- `binlog_max_flush_queue_time`

Deprecated	5.7.9	
System Variable	**Name**	`binlog_max_flush_queue_time`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`0`
	Min Value	`0`
	Max Value	`100000`

Formerly, this controlled the time in microseconds to continue reading transactions from the flush queue before proceeding with group commit. In MySQL 5.7, this variable no longer has any effect.

`binlog_max_flush_queue_time` is deprecated as of MySQL 5.7.9, and is marked for eventual removal in a future MySQL release.

- `binlog_order_commits`

System Variable	**Name**	`binlog_order_commits`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`ON`

When this variable is enabled on a master (the default), transactions are externalized in the same order as they are written to the binary log. If disabled, transactions may be committed in parallel. In some cases, disabling this variable might produce a performance increment.

- `binlog_row_image`

Command-Line Format	`--binlog-row-image=image_type`	
System Variable	**Name**	`binlog_row_image=image_type`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`enumeration`
	Default	`full`
	Valid Values	`full` (Log all columns)
		`minimal` (Log only changed columns, and columns needed to identify rows)

		noblob (Log all columns, except for unneeded BLOB and TEXT columns)

In MySQL row-based replication, each row change event contains two images, a “before” image whose columns are matched against when searching for the row to be updated, and an “after” image containing the changes. Normally, MySQL logs full rows (that is, all columns) for both the before and after images. However, it is not strictly necessary to include every column in both images, and we can often save disk, memory, and network usage by logging only those columns which are actually required.

> **Note**
>
> When deleting a row, only the before image is logged, since there are no changed values to propagate following the deletion. When inserting a row, only the after image is logged, since there is no existing row to be matched. Only when updating a row are both the before and after images required, and both written to the binary log.

For the before image, it is necessary only that the minimum set of columns required to uniquely identify rows is logged. If the table containing the row has a primary key, then only the primary key column or columns are written to the binary log. Otherwise, if the table has a unique key all of whose columns are `NOT NULL`, then only the columns in the unique key need be logged. (If the table has neither a primary key nor a unique key without any `NULL` columns, then all columns must be used in the before image, and logged.) In the after image, it is necessary to log only the columns which have actually changed.

You can cause the server to log full or minimal rows using the `binlog_row_image` system variable. This variable actually takes one of three possible values, as shown in the following list:

- `full`: Log all columns in both the before image and the after image.
- `minimal`: Log only those columns in the before image that are required to identify the row to be changed; log only those columns in the after image that are actually changed.
- `noblob`: Log all columns (same as `full`), except for `BLOB` and `TEXT` columns that are not required to identify rows, or that have not changed.

> **Note**
>
> This variable is not supported by MySQL Cluster; setting it has no effect on the logging of `NDB` tables.

The default value is `full`.

In MySQL 5.5 and earlier, full row images are always used for both before images and after images. If you need to replicate from a newer master to a slave running MySQL 5.5 or earlier, the master should always use this value.

When using `minimal` or `noblob`, deletes and updates are guaranteed to work correctly for a given table if and only if the following conditions are true for both the source and destination tables:

- All columns must be present and in the same order; each column must use the same data type as its counterpart in the other table.
- The tables must have identical primary key definitions.

(In other words, the tables must be identical with the possible exception of indexes that are not part of the tables' primary keys.)

If these conditions are not met, it is possible that the primary key column values in the destination table may prove insufficient to provide a unique match for a delete or update. In this event, no warning or error is issued; the master and slave silently diverge, thus breaking consistency.

Setting this variable has no effect when the binary logging format is `STATEMENT`. When `binlog_format` is `MIXED`, the setting for `binlog_row_image` is applied to changes that are logged using row-based format, but this setting no effect on changes logged as statements.

Setting `binlog_row_image` on either the global or session level does not cause an implicit commit; this means that this variable can be changed while a transaction is in progress without affecting the transaction.

- `binlog_rows_query_log_events`

System Variable	**Name**	`binlog_rows_query_log_events`
	Variable Scope	Global, Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

The `binlog_rows_query_log_events` system variable affects row-based logging only. When enabled, it causes the MySQL Server to write informational log events such as row query log events into its binary log. This information can be used for debugging and related purposes; such as obtaining the original query issued on the master when it cannot be reconstructed from the row updates.

These events are normally ignored by MySQL programs reading the binary log and so cause no issues when replicating or restoring from backup. To view them, increase the verbosity level by using mysqlbinlog's `--verbose` option twice, either as "-vv" or "--verbose --verbose".

- `binlog_stmt_cache_size`

Command-Line Format	`--binlog_stmt_cache_size=#`	
System Variable	**Name**	`binlog_stmt_cache_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (32-bit platforms)	**Type**	`integer`
	Default	`32768`
	Min Value	`4096`
	Max Value	`4294967295`
Permitted Values (64-bit platforms)	**Type**	`integer`
	Default	`32768`

	Min Value	4096
	Max Value	18446744073709551615

This variable determines the size of the cache for the binary log to hold nontransactional statements issued during a transaction. Separate binary log transaction and statement caches are allocated for each client if the server supports any transactional storage engines and if the server has the binary log enabled (`--log-bin` option). If you often use large nontransactional statements during transactions, you can increase this cache size to get better performance. The `Binlog_stmt_cache_use` and `Binlog_stmt_cache_disk_use` status variables can be useful for tuning the size of this variable. See The Binary Log.

The `binlog_cache_size` system variable sets the size for the transaction cache.

- `log_bin`

System Variable	**Name**	`log_bin`
	Variable Scope	Global
	Dynamic Variable	No

Whether the binary log is enabled. If the `--log-bin` option is used, then the value of this variable is `ON`; otherwise it is `OFF`. This variable reports only on the status of binary logging (enabled or disabled); it does not actually report the value to which `--log-bin` is set.

See The Binary Log.

- `log_bin_basename`

System Variable	**Name**	`log_bin_basename`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`
	Default	`datadir + '/' + hostname + '-bin'`

Holds the name and complete path to the binary log file. Unlike the `log_bin` system variable, `log_bin_basename` reflects the name set with the `--log-bin` server option.

- `log_bin_index`

System Variable	**Name**	`log_bin_index`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`file name`

The index file for binary log file names.

- `log_bin_use_v1_row_events`

Command-Line Format	`--log-bin-use-v1-row-events[={0|1}]`	
System Variable	**Name**	`log_bin_use_v1_row_events`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`
	Default	`0`

Shows whether Version 2 binary logging is in use. A value of 1 shows that the server is writing the binary log using Version 1 logging events (the only version of binary log events used in previous releases), and thus producing a binary log that can be read by older slaves. 0 indicates that Version 2 binary log events are in use.

This variable is read-only. To switch between Version 1 and Version 2 binary event binary logging, it is necessary to restart `mysqld` with the `--log-bin-use-v1-row-events` option.

Other than when performing upgrades of MySQL Cluster Replication, `--log-bin-use-v1-events` is chiefly of interest when setting up replication conflict detection and resolution using `NDB$EPOCH_TRANS()`, which requires Version 2 binary row event logging. Thus, this option and `--ndb-log-transaction-id` are not compatible.

> **Note**
>
> MySQL Cluster NDB 7.5 uses Version 2 binary log row events by default. You should keep this mind when planning upgrades or downgrades, and for setups using MySQL Cluster Replication.

For more information, see MySQL Cluster Replication Conflict Resolution.

- `log_slave_updates`

Command-Line Format	`--log-slave-updates`	
System Variable	**Name**	`log_slave_updates`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

Whether updates received by a slave server from a master server should be logged to the slave's own binary log. Binary logging must be enabled on the slave for this variable to have any effect. See Section 2.6, “Replication and Binary Logging Options and Variables”.

- `log_statements_unsafe_for_binlog`

Introduced	5.7.11	
System Variable	**Name**	`log_statements_unsafe_for_binlog`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`ON`

If error 1592 is encountered, controls whether the generated warnings are added to the error log or not.

- `master_verify_checksum`

System Variable	**Name**	`master_verify_checksum`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`boolean`
	Default	`OFF`

Enabling this variable causes the master to examine checksums when reading from the binary log. `master_verify_checksum` is disabled by default; in this case, the master uses the event length from the binary log to verify events, so that only complete events are read from the binary log.

- `max_binlog_cache_size`

Command-Line Format	`--max_binlog_cache_size=#`	
System Variable	**Name**	`max_binlog_cache_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`18446744073709551615`
	Min Value	`4096`
	Max Value	`18446744073709551615`

If a transaction requires more than this many bytes of memory, the server generates a `Multi-statement transaction required more than 'max_binlog_cache_size' bytes of storage` error. The minimum value is 4096. The maximum possible value is 16EB (exabytes). The maximum recommended value is 4GB; this is due to the fact that MySQL currently cannot work with binary log positions greater than 4GB.

`max_binlog_cache_size` sets the size for the transaction cache only; the upper limit for the statement cache is governed by the `max_binlog_stmt_cache_size` system variable.

In MySQL 5.7, the visibility to sessions of `max_binlog_cache_size` matches that of the `binlog_cache_size` system variable; in other words, changing its value effects only new sessions that are started after the value is changed.

- `max_binlog_size`

Command-Line Format	`--max_binlog_size=#`	
System Variable	**Name**	`max_binlog_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`1073741824`
	Min Value	`4096`
	Max Value	`1073741824`

If a write to the binary log causes the current log file size to exceed the value of this variable, the server rotates the binary logs (closes the current file and opens the next one). The minimum value is 4096 bytes. The maximum and default value is 1GB.

A transaction is written in one chunk to the binary log, so it is never split between several binary logs. Therefore, if you have big transactions, you might see binary log files larger than `max_binlog_size`.

If `max_relay_log_size` is 0, the value of `max_binlog_size` applies to relay logs as well.

- `max_binlog_stmt_cache_size`

Command-Line Format	`--max_binlog_stmt_cache_size=#`	
System Variable	**Name**	`max_binlog_stmt_cache_size`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`18446744073709547520`
	Min Value	`4096`
	Max Value	`18446744073709547520`

If nontransactional statements within a transaction require more than this many bytes of memory, the server generates an error. The minimum value is 4096. The maximum and default values are 4GB on 32-bit platforms and 16EB (exabytes) on 64-bit platforms.

max_binlog_stmt_cache_size sets the size for the statement cache only; the upper limit for the transaction cache is governed exclusively by the max_binlog_cache_size system variable.

- sync_binlog

Command-Line Format	--sync-binlog=#	
System Variable	**Name**	sync_binlog
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (>= 5.7.7)	**Type**	integer
	Default	1
	Min Value	0
	Max Value	4294967295
Permitted Values (32-bit platforms)	**Type**	integer
	Default	0
	Min Value	0
	Max Value	4294967295
Permitted Values (64-bit platforms)	**Type**	integer
	Default	0
	Min Value	0
	Max Value	4294967295

Controls the number of binary log commit groups to collect before synchronizing the binary log to disk. When sync_binlog=0, the binary log is never synchronized to disk, and when sync_binlog is set to a value greater than 0 this number of binary log commit groups is periodically synchronized to disk. When sync_binlog=1, all transactions are synchronized to the binary log before they are committed. Therefore, even in the event of an unexpected restart, any transactions that are missing from the binary log are only in prepared state. This causes the server's automatic recovery routine to rollback those transactions. This guarantees that no transaction is lost from the binary log, and is the safest option. However this can have a negative impact on performance because of an increased number of disk writes. Using a higher value improves performance, but with the increased risk of data loss.

When sync_binlog=0 or sync_binlog is greater than 1, transactions are committed without having been synchronized to disk. Therefore, in the event of a power failure or operating system crash, it is possible that the server has committed some transactions that have not been synchronized to the binary log. Therefore it is impossible for the recovery routine to recover these transactions and they will be lost from the binary log.

Prior to MySQL 5.7.7, the default value of sync_binlog was 0, which configures no synchronizing to disk—in this case, the server relies on the operating system to flush the binary log's contents from time to time as for any other file. MySQL 5.7.7 and later use a default value of 1, which is the safest choice, but as noted above can impact performance.

2.6.5 Global Transaction ID Options and Variables

The MySQL Server options and system variables described in this section are used to monitor and control Global Transaction Identifiers (GTIDs).

For additional information, see Section 2.3, “Replication with Global Transaction Identifiers”.

Startup Options Used with GTID Replication

The following server startup options are used with GTID-based replication:

- `--enforce-gtid-consistency`

Command-Line Format	`--enforce-gtid-consistency[=value]`	
System Variable (<= 5.7.5)	**Name**	`enforce_gtid_consistency`
	Variable Scope	Global
	Dynamic Variable	No
System Variable (>= 5.7.6)	**Name**	`enforce_gtid_consistency`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (<= 5.7.5)	**Type**	`boolean`
	Default	`false`
Permitted Values (>= 5.7.6)	**Type**	`enumeration`
	Default	`OFF`
	Valid Values	`OFF`
		`ON`
		`WARN`

When enabled, the server enforces GTID consistency by allowing execution of only statements that can be safely logged using a GTID. You *must* set this option to `ON` before enabling GTID based replication.

The values that `--enforce-gtid-consistency` can be configured to are:

- `OFF`: all transactions are allowed to violate GTID consistency.
- `ON`: no transaction is allowed to violate GTID consistency.
- `WARN`: all transactions are allowed to violate GTID consistency, but a warning is generated in this case. Added in MySQL 5.7.6.

Setting `--enforce-gtid-consistency` without a value is an alias for `--enforce-gtid-consistency=ON`. This impacts on the behavior of the variable, see `enforce_gtid_consistency`.

Only statements that can be logged using GTID safe statements can be logged when `enforce-gtid-consistency` is set to `ON`, so the operations listed here cannot be used with this option:

- `CREATE TABLE ... SELECT` statements
- `CREATE TEMPORARY TABLE` or `DROP TEMPORARY TABLE` statements inside transactions
- Transactions or statements that update both transactional and nontransactional tables. There is an exception that nontransactional DML is allowed in the same transaction or in the same statement as transactional DML, if all *nontransactional* tables are temporary.

For more information, see Section 2.3.4, “Restrictions on Replication with GTIDs”.

- `--executed-gtids-compression-period`

Introduced	5.7.5	
Deprecated	5.7.6	
Command-Line Format	`--executed-gtids-compression-period=#`	
Permitted Values	**Type**	`integer`
	Default	`1000`
	Min Value	`0`
	Max Value	`4294967295`

This option is deprecated and will be removed in a future MySQL release. Use the renamed gtid_executed_compression_period to control how the gtid_executed table is compressed.

- `--gtid-mode`

Command-Line Format	`--gtid-mode=MODE`	
System Variable (<= 5.7.5)	**Name**	`gtid_mode`
	Variable Scope	Global
	Dynamic Variable	No
System Variable (>= 5.7.6)	**Name**	`gtid_mode`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (<= 5.7.5)	**Type**	`enumeration`
	Default	`OFF`
	Valid Values	`OFF`
		`UPGRADE_STEP_1`

		UPGRADE_STEP_2
		ON
Permitted Values (>= 5.7.6)	**Type**	enumeration
	Default	OFF
	Valid Values	OFF
		OFF_PERMISSIVE
		ON_PERMISSIVE
		ON

This option specifies whether global transaction identifiers (GTIDs) are used to identify transactions. Setting this option to `--gtid-mode=ON` requires that `enforce-gtid-consistency` be set to `ON`. Prior to MySQL 5.7.6 the `gtid_mode` variable which this option controls could only be set at server startup. In MySQL 5.7.6 and later the `gtid_mode` variable is dynamic and enables GTID based replication to be configured online. Before using this feature, see Section 2.5, “Changing Replication Modes on Online Servers”.

Prior to MySQL 5.7.5, starting the server with `--gtid-mode=ON` required that the server also be started with the `--log-bin`, `--log-slave-updates`, options. In versions of MySQL 5.7.5 and later this is not a requirement. See mysql.gtid_executed Table.

- `--gtid-executed-compression-period`

Introduced	5.7.6	
Command-Line Format	`--gtid-executed-compression-period=#`	
Permitted Values	**Type**	integer
	Default	1000
	Min Value	0
	Max Value	4294967295

Compress the `mysql.gtid_executed` table each time this many transactions have taken place. A setting of 0 means that this table is not compressed. No compression of the table occurs when binary logging is enabled, therefore the option has no effect unless `log_bin` is `OFF`.

See mysql.gtid_executed Table Compression, for more information.

In MySQL version 5.7.5, this variable was added as `executed_gtids_compression_period` and in MySQL version 5.7.6 it was renamed to `gtid_executed_compression_period`.

System Variables Used with GTID Replication

The following system variables are used with GTID-based replication:

- `binlog_gtid_simple_recovery`

Introduced	5.7.6	
Command-Line Format	`--binlog-gtid-simple-recovery`	
System Variable	**Name**	binlog_gtid_simple_recovery

	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	boolean
	Default	FALSE
Permitted Values (>= 5.7.7)	**Type**	boolean
	Default	TRUE

This variable controls how binary log files are iterated during the search for GTIDs when MySQL starts or restarts. In MySQL version 5.7.5, this variable was added as simplified_binlog_gtid_recovery and in MySQL version 5.7.6 it was renamed to binlog_gtid_simple_recovery.

When binlog_gtid_simple_recovery=FALSE, the method of iterating the binary log files is:

- To initialize gtid_executed, binary log files are iterated from the newest file, stopping at the first binary log that has any Previous_gtids_log_event. All GTIDs from Previous_gtids_log_event and Gtid_log_events are read from this binary log file. This GTID set is stored internally and called gtids_in_binlog. The value of gtid_executed is computed as the union of this set and the GTIDs stored in the mysql.gtid_executed table.

  This process could take a long time if you had a large number of binary log files without GTID events, for example created when gtid_mode=OFF.

- To initialize gtid_purged, binary log files are iterated from the oldest to the newest, stopping at the first binary log that contains either a Previous_gtids_log_event that is non-empty (that has at least one GTID) or that has at least one Gtid_log_event. From this binary log it reads Previous_gtids_log_event. This GTID set is subtracted from gtids_in_binlog and the result stored in the internal variable gtids_in_binlog_not_purged. The value of gtid_purged is initialized to the value of gtid_executed, minus gtids_in_binlog_not_purged.

When binlog_gtid_simple_recovery=TRUE, which is the default in MySQL 5.7.7 and later, the server iterates only the oldest and the newest binary log files and the values of gtid_purged and gtid_executed are computed based only on Previous_gtids_log_event or Gtid_log_event found in these files. This ensures only two binary log files are iterated during server restart or when binary logs are being purged.

Note

If this option is enabled, gtid_executed and gtid_purged may be initialized incorrectly in the following situations:

- The newest binary log was generated by MySQL 5.7.5 or older, and gtid_mode was ON for some binary logs but OFF for the newest binary log.

- A SET GTID_PURGED statement was issued on a MySQL version prior to 5.7.7, and the binary log that was active at the time of the SET GTID_PURGED has not yet been purged.

If an incorrect GTID set is computed in either situation, it will remain incorrect even if the server is later restarted, regardless of the value of this option.

- enforce_gtid_consistency

Command-Line Format	`--enforce-gtid-consistency[=value]`	
System Variable (<= 5.7.5)	**Name**	`enforce_gtid_consistency`
	Variable Scope	Global
	Dynamic Variable	No
System Variable (>= 5.7.6)	**Name**	`enforce_gtid_consistency`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (<= 5.7.5)	**Type**	`boolean`
	Default	`false`
Permitted Values (>= 5.7.6)	**Type**	`enumeration`
	Default	`OFF`
	Valid Values	`OFF`
		`ON`
		`WARN`

Depending on the value of this variable, the server enforces GTID consistency by allowing execution of only statements that can be safely logged using a GTID. You *must* set this variable to `ON` before enabling GTID based replication.

The values that `enforce_gtid_consistency` can be configured to are:

- `OFF`: all transactions are allowed to violate GTID consistency.
- `ON`: no transaction is allowed to violate GTID consistency.
- `WARN`: all transactions are allowed to violate GTID consistency, but a warning is generated in this case. Added in MySQL 5.7.6.

For more information on statements that can be logged using GTID based replication, see `--enforce-gtid-consistency`.

Prior to MySQL 5.7.6, the boolean `enforce-gtid-consistency` defaulted to `OFF`. To maintain compatibility with previous versions, in MySQL 5.7.6 the enumeration defaults to `OFF`, and setting `--enforce-gtid-consistency` without a value is interpreted as setting the value to `ON`. The variable also has multiple textual aliases for the values: `0=OFF=FALSE`, `1=ON=TRUE`,`2=WARN`. This differs from other enumeration types but maintains compatibility with the boolean type used in previous versions. These changes impact on what is returned by the variable. Using `SELECT @@ENFORCE_GTID_CONSISTENCY`, `SHOW VARIABLES LIKE 'ENFORCE_GTID_CONSISTENCY'`, and `SELECT * FROM INFORMATION_SCHEMA.VARIABLES WHERE 'VARIABLE_NAME' = 'ENFORCE_GTID_CONSISTENCY'`, all return the textual form, not the numeric form. This is an incompatible change, since `@@ENFORCE_GTID_CONSISTENCY` returns the numeric form for booleans but returns the textual form for `SHOW` and the Information Schema.

- `executed_gtids_compression_period`

Introduced	5.7.5	
Deprecated	5.7.6	
System Variable (>= 5.7.5)	**Name**	`executed_gtids_compression_period`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`1000`
	Min Value	`0`
	Max Value	`4294967295`

This option is deprecated and will be removed in a future MySQL release. Use the renamed `gtid_executed_compression_period` to control how the `gtid_executed` table is compressed.

- `gtid_executed`

System Variable	**Name**	`gtid_executed`
	Variable Scope	Global, Session
	Dynamic Variable	No
System Variable (>= 5.7.7)	**Name**	`gtid_executed`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`string`

When used with global scope, this variable contains a representation of the set of all transactions executed on the server and GTIDs that have been set by a `SET gtid_purged` statement. This is the same as the value of the `Executed_Gtid_Set` column in the output of `SHOW MASTER STATUS` and `SHOW SLAVE STATUS`. The value of this variable is a GTID set, see GTID Sets for more information.

When the server starts, `@@global.gtid_executed` is initialized. See `binlog_gtid_simple_recovery` for more information on how binary logs are iterated to populate `gtid_executed`. GTIDs are then added to the set as transactions are executed, or if any `SET gtid_purged` statement is executed.

The set of transactions that can be found in the binary logs at any given time is equal to `GTID_SUBTRACT(@@global.gtid_executed, @@global.gtid_purged)`; that is, to all transactions in the binary log that have not yet been purged.

Issuing `RESET MASTER` causes the global value (but not the session value) of this variable to be reset to an empty string. GTIDs are not otherwise removed from this set other than when the set is cleared due to `RESET MASTER`.

Prior to MySQL 5.7.7, this variable could also be used with session scope, where it contained a representation of the set of transactions that are written to the cache in the current session. The session scope was deprecated in MySQL 5.7.7.

- `gtid_executed_compression_period`

Introduced	5.7.6	
System Variable (>= 5.7.6)	**Name**	`gtid_executed_compression_period`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`integer`
	Default	`1000`
	Min Value	`0`
	Max Value	`4294967295`

Compress the `mysql.gtid_executed` table each time this many transactions have been processed. A setting of 0 means that this table is not compressed. Since no compression of the table occurs when using the binary log, setting the value of the variable has no effect unless binary logging is disabled.

See mysql.gtid_executed Table Compression, for more information.

In MySQL version 5.7.5, this variable was added as `executed_gtids_compression_period` and in MySQL version 5.7.6 it was renamed to `gtid_executed_compression_period`.

- `gtid_mode`

System Variable (<= 5.7.5)	**Name**	`gtid_mode`
	Variable Scope	Global
	Dynamic Variable	No
System Variable (>= 5.7.6)	**Name**	`gtid_mode`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values (<= 5.7.5)	**Type**	`enumeration`
	Default	`OFF`
	Valid Values	`OFF`
		`UPGRADE_STEP_1`
		`UPGRADE_STEP_2`
		`ON`

Permitted Values (>= 5.7.6)	**Type**	`enumeration`
	Default	`OFF`
	Valid Values	`OFF`
		`OFF_PERMISSIVE`
		`ON_PERMISSIVE`
		`ON`

Controls whether GTID based logging is enabled and what type of transactions the logs can contain. Prior to MySQL 5.7.6 this variable was read-only and was set using the `--gtid-mode` option only. MySQL 5.7.6 enables this variable to be set dynamically. You must have the `SUPER` privilege to set this variable. `enforce_gtid_consistency` must be true before you can set `gtid_mode=ON`. Before modifying this variable, see Section 2.5, "Changing Replication Modes on Online Servers".

Transactions logged in MySQL 5.7.6 and later can be either anonymous or use GTIDs. Anonymous transactions rely on binary log file and position to identify specific transactions. GTID transactions have a unique identifier that is used to refer to transactions. The `OFF_PERMISSIVE` and `ON_PERMISSIVE` modes added in MySQL 5.7.6 permit a mix of these transaction types in the topology. The different modes are now:

- `OFF`: Both new and replicated transactions must be anonymous.
- `OFF_PERMISSIVE`: New transactions are anonymous. Replicated transactions can be either anonymous or GTID transactions.
- `ON_PERMISSIVE`: New transactions are GTID transactions. Replicated transactions can be either anonymous or GTID transactions.
- `ON`: Both new and replicated transactions must be GTID transactions.

Changes from one value to another can only be one step at a time. For example, if `gtid_mode` is currently set to `OFF_PERMISSIVE`, it is possible to change to `OFF` or `ON_PERMISSIVE` but not to `ON`.

In MySQL 5.7.6 and later, the values of `gtid_purged` and `gtid_executed` are persistent regardless of the value of `gtid_mode`. Therefore even after changing the value of `gtid_mode`, these variables contain the correct values. In MySQL 5.7.5 and earlier, the values of `gtid_purged` and `gtid_executed` are not persistent while `gtid_mode=OFF`. Therefore, after changing `gtid_mode` to `OFF`, once all binary logs containing GTIDs are purged, the values of these variables are lost.

- `gtid_next`

System Variable	**Name**	`gtid_next`
	Variable Scope	Session
	Dynamic Variable	Yes
Permitted Values	**Type**	`enumeration`
	Default	`AUTOMATIC`
	Valid Values	`AUTOMATIC`
		`ANONYMOUS`
		`UUID:NUMBER`

This variable is used to specify whether and how the next GTID is obtained. `gtid_next` can take any of the following values:

- `AUTOMATIC`: Use the next automatically-generated global transaction ID.
- `ANONYMOUS`: Transactions do not have global identifiers, and are identified by file and position only.
- A global transaction ID in *`UUID`*:*`NUMBER`* format.

Exactly which of the above options are valid depends on the setting of `gtid_mode`, see Section 2.5.1, “Replication Mode Concepts” for more information. Setting this variable has no effect if `gtid_mode` is `OFF`.

After this variable has been set to *`UUID`*:*`NUMBER`*, and a transaction has been committed or rolled back, an explicit `SET GTID_NEXT` statement must again be issued before any other statement.

In MySQL 5.7.5 and later, `DROP TABLE` or `DROP TEMPORARY TABLE` fails with an explicit error when used on a combination of nontemporary tables with temporary tables, or of temporary tables using transactional storage engines with temporary tables using nontransactional storage engines. Prior to MySQL 5.7.5, when GTIDs were enabled but `gtid_next` was not `AUTOMATIC`, `DROP TABLE` did not work correctly when used with either of these combinations of tables. (Bug #17620053)

In MySQL 5.7.1, you cannot execute any of the statements `CHANGE MASTER TO`, `START SLAVE`, `STOP SLAVE`, `REPAIR TABLE`, `OPTIMIZE TABLE`, `ANALYZE TABLE`, `CHECK TABLE`, `CREATE SERVER`, `ALTER SERVER`, `DROP SERVER`, `CACHE INDEX`, `LOAD INDEX INTO CACHE`, `FLUSH`, or `RESET` when `gtid_next` is set to any value other than `AUTOMATIC`; in such cases, the statement fails with an error. Such statements are *not* disallowed in MySQL 5.7.2 and later. (Bug #16062608, Bug #16715809, Bug #69045) (Bug #16062608)

- `gtid_owned`

System Variable	**Name**	`gtid_owned`
	Variable Scope	Global, Session
	Dynamic Variable	No
Permitted Values	**Type**	`string`

This read-only variable holds a list whose contents depend on its scope. When used with session scope, the list holds all GTIDs that are owned by this client; when used with global scope, it holds a list of all GTIDs along with their owners.

- `gtid_purged`

System Variable	**Name**	`gtid_purged`
	Variable Scope	Global
	Dynamic Variable	Yes
Permitted Values	**Type**	`string`

The set of all transactions that have been purged from the binary log. This is a subset of the set of transactions in `gtid_executed`. The value of this variable is a GTID set, see GTID Sets for more information.

When the server starts, the global value of `gtid_purged` is initialized to a set of GTIDs. See `binlog_gtid_simple_recovery` for more information on how binary logs are iterated to populate `gtid_purged`. Issuing `RESET MASTER` causes the value of this variable to be reset to an empty string.

It is possible to update the value of this variable, but only when `gtid_executed` is the empty string, and therefore `gtid_purged` is the empty string. This can occur either when replication has not been started previously, or when replication was not previously using GTIDs. Prior to MySQL 5.7.6, this variable was settable only when `gtid_mode=ON`. In MySQL 5.7.6 and later, this variable is settable regardless of the value of `gtid_mode`.

If all existing binary logs were generated using MySQL 5.7.6 or later, after issuing a `SET gtid_purged` statement, `binlog_gtid_simple_recovery=TRUE` (the default setting in MySQL 5.7.7 and later) can safely be used. If binary logs from MySQL 5.7.7 or earlier exist, there is a chance that `gtid_purged` may be computed incorrectly. See `binlog_gtid_simple_recovery` for more information. If you are using MySQL 5.7.7 or earlier, after issuing a `SET gtid_purged` statement note down the current binary log file name, which can be checked using `SHOW MASTER STATUS`. If the server is restarted before this file has been purged, then you should use `binlog_gtid_simple_recovery=FALSE` to avoid `gtid_purged` or `gtid_executed` being computed incorrectly.

- `simplified_binlog_gtid_recovery`

Introduced	5.7.5	
Deprecated	5.7.6	
Command-Line Format	`--simplified-binlog-gtid-recovery`	
System Variable	**Name**	`simplified_binlog_gtid_recovery`
	Variable Scope	Global
	Dynamic Variable	No
Permitted Values	**Type**	`boolean`
	Default	`FALSE`

This option is deprecated and will be removed in a future MySQL release. Use the renamed `binlog_gtid_simple_recovery` to control how MySQL iterates through binary log files after a crash.

2.7 Common Replication Administration Tasks

Once replication has been started it executes without requiring much regular administration. This section describes how to check the status of replication and how to pause a slave.

2.7.1 Checking Replication Status

The most common task when managing a replication process is to ensure that replication is taking place and that there have been no errors between the slave and the master. The primary statement for this is `SHOW SLAVE STATUS`, which you must execute on each slave:

```
mysql> SHOW SLAVE STATUS\G
*************************** 1. row ***************************
               Slave_IO_State: Waiting for master to send event
                  Master_Host: master1
                  Master_User: root
                  Master_Port: 3306
                Connect_Retry: 60
              Master_Log_File: mysql-bin.000004
          Read_Master_Log_Pos: 931
               Relay_Log_File: slave1-relay-bin.000056
                Relay_Log_Pos: 950
        Relay_Master_Log_File: mysql-bin.000004
             Slave_IO_Running: Yes
            Slave_SQL_Running: Yes
              Replicate_Do_DB:
          Replicate_Ignore_DB:
           Replicate_Do_Table:
       Replicate_Ignore_Table:
      Replicate_Wild_Do_Table:
  Replicate_Wild_Ignore_Table:
                   Last_Errno: 0
                   Last_Error:
                 Skip_Counter: 0
          Exec_Master_Log_Pos: 931
              Relay_Log_Space: 1365
              Until_Condition: None
               Until_Log_File:
                Until_Log_Pos: 0
           Master_SSL_Allowed: No
           Master_SSL_CA_File:
           Master_SSL_CA_Path:
              Master_SSL_Cert:
            Master_SSL_Cipher:
               Master_SSL_Key:
        Seconds_Behind_Master: 0
Master_SSL_Verify_Server_Cert: No
                Last_IO_Errno: 0
                Last_IO_Error:
               Last_SQL_Errno: 0
               Last_SQL_Error:
  Replicate_Ignore_Server_Ids: 0
```

The key fields from the status report to examine are:

- `Slave_IO_State`: The current status of the slave. See Replication Slave I/O Thread States, and Replication Slave SQL Thread States, for more information.

- `Slave_IO_Running`: Whether the I/O thread for reading the master's binary log is running. Normally, you want this to be `Yes` unless you have not yet started replication or have explicitly stopped it with `STOP SLAVE`.

- `Slave_SQL_Running`: Whether the SQL thread for executing events in the relay log is running. As with the I/O thread, this should normally be `Yes`.

- `Last_IO_Error`, `Last_SQL_Error`: The last errors registered by the I/O and SQL threads when processing the relay log. Ideally these should be blank, indicating no errors.

- `Seconds_Behind_Master`: The number of seconds that the slave SQL thread is behind processing the master binary log. A high number (or an increasing one) can indicate that the slave is unable to handle events from the master in a timely fashion.

  A value of 0 for `Seconds_Behind_Master` can usually be interpreted as meaning that the slave has caught up with the master, but there are some cases where this is not strictly true. For example, this can occur if the network connection between master and slave is broken but the slave I/O thread has not yet noticed this—that is, `slave_net_timeout` has not yet elapsed.

It is also possible that transient values for `Seconds_Behind_Master` may not reflect the situation accurately. When the slave SQL thread has caught up on I/O, `Seconds_Behind_Master` displays 0; but when the slave I/O thread is still queuing up a new event, `Seconds_Behind_Master` may show a large value until the SQL thread finishes executing the new event. This is especially likely when the events have old timestamps; in such cases, if you execute `SHOW SLAVE STATUS` several times in a relatively short period, you may see this value change back and forth repeatedly between 0 and a relatively large value.

Several pairs of fields provide information about the progress of the slave in reading events from the master binary log and processing them in the relay log:

- (`Master_Log_file`, `Read_Master_Log_Pos`): Coordinates in the master binary log indicating how far the slave I/O thread has read events from that log.
- (`Relay_Master_Log_File`, `Exec_Master_Log_Pos`): Coordinates in the master binary log indicating how far the slave SQL thread has executed events received from that log.
- (`Relay_Log_File`, `Relay_Log_Pos`): Coordinates in the slave relay log indicating how far the slave SQL thread has executed the relay log. These correspond to the preceding coordinates, but are expressed in slave relay log coordinates rather than master binary log coordinates.

On the master, you can check the status of connected slaves using `SHOW PROCESSLIST` to examine the list of running processes. Slave connections have `Binlog Dump` in the `Command` field:

```
mysql> SHOW PROCESSLIST \G;
*************************** 4. row ***************************
     Id: 10
   User: root
   Host: slave1:58371
     db: NULL
Command: Binlog Dump
   Time: 777
  State: Has sent all binlog to slave; waiting for binlog to be updated
   Info: NULL
```

Because it is the slave that drives the replication process, very little information is available in this report.

For slaves that were started with the `--report-host` option and are connected to the master, the `SHOW SLAVE HOSTS` statement on the master shows basic information about the slaves. The output includes the ID of the slave server, the value of the `--report-host` option, the connecting port, and master ID:

```
mysql> SHOW SLAVE HOSTS;
+-----------+--------+------+-------------------+-----------+
| Server_id | Host   | Port | Rpl_recovery_rank | Master_id |
+-----------+--------+------+-------------------+-----------+
|        10 | slave1 | 3306 |                 0 |         1 |
+-----------+--------+------+-------------------+-----------+
1 row in set (0.00 sec)
```

2.7.2 Pausing Replication on the Slave

You can stop and start replication on the slave using the `STOP SLAVE` and `START SLAVE` statements.

To stop processing of the binary log from the master, use `STOP SLAVE`:

```
mysql> STOP SLAVE;
```

When replication is stopped, the slave I/O thread stops reading events from the master binary log and writing them to the relay log, and the SQL thread stops reading events from the relay log and executing them. You can pause the I/O or SQL thread individually by specifying the thread type:

```
mysql> STOP SLAVE IO_THREAD;
mysql> STOP SLAVE SQL_THREAD;
```

To start execution again, use the `START SLAVE` statement:

```
mysql> START SLAVE;
```

To start a particular thread, specify the thread type:

```
mysql> START SLAVE IO_THREAD;
mysql> START SLAVE SQL_THREAD;
```

For a slave that performs updates only by processing events from the master, stopping only the SQL thread can be useful if you want to perform a backup or other task. The I/O thread will continue to read events from the master but they are not executed. This makes it easier for the slave to catch up when you restart the SQL thread.

Stopping only the I/O thread enables the events in the relay log to be executed by the SQL thread up to the point where the relay log ends. This can be useful when you want to pause execution to catch up with events already received from the master, when you want to perform administration on the slave but also ensure that it has processed all updates to a specific point. This method can also be used to pause event receipt on the slave while you conduct administration on the master. Stopping the I/O thread but permitting the SQL thread to run helps ensure that there is not a massive backlog of events to be executed when replication is started again.

Chapter 3 Replication Solutions

Table of Contents

Replication can be used in many different environments for a range of purposes. This section provides general notes and advice on using replication for specific solution types.

For information on using replication in a backup environment, including notes on the setup, backup procedure, and files to back up, see Section 3.1, “Using Replication for Backups”.

For advice and tips on using different storage engines on the master and slaves, see Section 3.3, “Using Replication with Different Master and Slave Storage Engines”.

Using replication as a scale-out solution requires some changes in the logic and operation of applications that use the solution. See Section 3.4, “Using Replication for Scale-Out”.

For performance or data distribution reasons, you may want to replicate different databases to different replication slaves. See Section 3.5, “Replicating Different Databases to Different Slaves”

As the number of replication slaves increases, the load on the master can increase and lead to reduced performance (because of the need to replicate the binary log to each slave). For tips on improving your replication performance, including using a single secondary server as a replication master, see Section 3.6, “Improving Replication Performance”.

For guidance on switching masters, or converting slaves into masters as part of an emergency failover solution, see Section 3.7, “Switching Masters During Failover”.

To secure your replication communication, you can encrypt the communication channel. For step-by-step instructions, see Section 3.8, “Setting Up Replication to Use Secure Connections”.

3.1 Using Replication for Backups

To use replication as a backup solution, replicate data from the master to a slave, and then back up the data slave. The slave can be paused and shut down without affecting the running operation of the master, so you can produce an effective snapshot of “live” data that would otherwise require the master to be shut down.

How you back up a database depends on its size and whether you are backing up only the data, or the data and the replication slave state so that you can rebuild the slave in the event of failure. There are therefore two choices:

- If you are using replication as a solution to enable you to back up the data on the master, and the size of your database is not too large, the `mysqldump` tool may be suitable. See Section 3.1.1, “Backing Up a Slave Using mysqldump”.
- For larger databases, where `mysqldump` would be impractical or inefficient, you can back up the raw data files instead. Using the raw data files option also means that you can back up the binary and relay logs that will enable you to recreate the slave in the event of a slave failure. For more information, see Section 3.1.2, “Backing Up Raw Data from a Slave”.

Another backup strategy, which can be used for either master or slave servers, is to put the server in a read-only state. The backup is performed against the read-only server, which then is changed back to its usual read/write operational status. See Section 3.1.3, “Backing Up a Master or Slave by Making It Read Only”.

3.1.1 Backing Up a Slave Using mysqldump

Using `mysqldump` to create a copy of a database enables you to capture all of the data in the database in a format that enables the information to be imported into another instance of MySQL Server (see `mysqldump` — A Database Backup Program). Because the format of the information is SQL statements, the file can easily be distributed and applied to running servers in the event that you need access to the data in an emergency. However, if the size of your data set is very large, `mysqldump` may be impractical.

When using `mysqldump`, you should stop replication on the slave before starting the dump process to ensure that the dump contains a consistent set of data:

1. Stop the slave from processing requests. You can stop replication completely on the slave using `mysqladmin`:

   ```
   shell> mysqladmin stop-slave
   ```

   Alternatively, you can stop only the slave SQL thread to pause event execution:

   ```
   shell> mysql -e 'STOP SLAVE SQL_THREAD;'
   ```

   This enables the slave to continue to receive data change events from the master's binary log and store them in the relay logs using the I/O thread, but prevents the slave from executing these events and changing its data. Within busy replication environments, permitting the I/O thread to run during backup may speed up the catch-up process when you restart the slave SQL thread.

2. Run `mysqldump` to dump your databases. You may either dump all databases or select databases to be dumped. For example, to dump all databases:

   ```
   shell> mysqldump --all-databases > fulldb.dump
   ```

3. Once the dump has completed, start slave operations again:

   ```
   shell> mysqladmin start-slave
   ```

In the preceding example, you may want to add login credentials (user name, password) to the commands, and bundle the process up into a script that you can run automatically each day.

If you use this approach, make sure you monitor the slave replication process to ensure that the time taken to run the backup does not affect the slave's ability to keep up with events from the master. See Section 2.7.1, “Checking Replication Status”. If the slave is unable to keep up, you may want to add another slave and distribute the backup process. For an example of how to configure this scenario, see Section 3.5, “Replicating Different Databases to Different Slaves”.

3.1.2 Backing Up Raw Data from a Slave

To guarantee the integrity of the files that are copied, backing up the raw data files on your MySQL replication slave should take place while your slave server is shut down. If the MySQL server is still running, background tasks may still be updating the database files, particularly those involving storage engines with background processes such as `InnoDB`. With `InnoDB`, these problems should be resolved during crash recovery, but since the slave server can be shut down during the backup process without affecting the execution of the master it makes sense to take advantage of this capability.

To shut down the server and back up the files:

1. Shut down the slave MySQL server:

   ```
   shell> mysqladmin shutdown
   ```

2. Copy the data files. You can use any suitable copying or archive utility, including `cp`, `tar` or `WinZip`. For example, assuming that the data directory is located under the current directory, you can archive the entire directory as follows:

   ```
   shell> tar cf /tmp/dbbackup.tar ./data
   ```

3. Start the MySQL server again. Under Unix:

   ```
   shell> mysqld_safe &
   ```

   Under Windows:

   ```
   C:\> "C:\Program Files\MySQL\MySQL Server 5.7\bin\mysqld"
   ```

Normally you should back up the entire data directory for the slave MySQL server. If you want to be able to restore the data and operate as a slave (for example, in the event of failure of the slave), then in addition to the slave's data, you should also back up the slave status files, the master info and relay log info repositories, and the relay log files. These files are needed to resume replication after you restore the slave's data.

If you lose the relay logs but still have the `relay-log.info` file, you can check it to determine how far the SQL thread has executed in the master binary logs. Then you can use `CHANGE MASTER TO` with the `MASTER_LOG_FILE` and `MASTER_LOG_POS` options to tell the slave to re-read the binary logs from that point. This requires that the binary logs still exist on the master server.

If your slave is replicating `LOAD DATA INFILE` statements, you should also back up any `SQL_LOAD-*` files that exist in the directory that the slave uses for this purpose. The slave needs these files to resume replication of any interrupted `LOAD DATA INFILE` operations. The location of this directory is the value of the `--slave-load-tmpdir` option. If the server was not started with that option, the directory location is the value of the `tmpdir` system variable.

3.1.3 Backing Up a Master or Slave by Making It Read Only

It is possible to back up either master or slave servers in a replication setup by acquiring a global read lock and manipulating the `read_only` system variable to change the read-only state of the server to be backed up:

1. Make the server read-only, so that it processes only retrievals and blocks updates.
2. Perform the backup.
3. Change the server back to its normal read/write state.

> **Note**
>
> The instructions in this section place the server to be backed up in a state that is safe for backup methods that get the data from the server, such as `mysqldump` (see `mysqldump` — A Database Backup Program). You should not attempt to use these instructions to make a binary backup by copying files directly because the server may still have modified data cached in memory and not flushed to disk.

The following instructions describe how to do this for a master server and for a slave server. For both scenarios discussed here, suppose that you have the following replication setup:

- A master server M1
- A slave server S1 that has M1 as its master
- A client C1 connected to M1
- A client C2 connected to S1

In either scenario, the statements to acquire the global read lock and manipulate the `read_only` variable are performed on the server to be backed up and do not propagate to any slaves of that server.

Scenario 1: Backup with a Read-Only Master

Put the master M1 in a read-only state by executing these statements on it:

```
mysql> FLUSH TABLES WITH READ LOCK;
mysql> SET GLOBAL read_only = ON;
```

While M1 is in a read-only state, the following properties are true:

- Requests for updates sent by C1 to M1 will block because the server is in read-only mode.
- Requests for query results sent by C1 to M1 will succeed.
- Making a backup on M1 is safe.
- Making a backup on S1 is not safe. This server is still running, and might be processing the binary log or update requests coming from client C2

While M1 is read only, perform the backup. For example, you can use `mysqldump`.

After the backup operation on M1 completes, restore M1 to its normal operational state by executing these statements:

```
mysql> SET GLOBAL read_only = OFF;
mysql> UNLOCK TABLES;
```

Although performing the backup on M1 is safe (as far as the backup is concerned), it is not optimal for performance because clients of M1 are blocked from executing updates.

This strategy applies to backing up a master server in a replication setup, but can also be used for a single server in a nonreplication setting.

Scenario 2: Backup with a Read-Only Slave

Put the slave S1 in a read-only state by executing these statements on it:

```
mysql> FLUSH TABLES WITH READ LOCK;
mysql> SET GLOBAL read_only = ON;
```

While S1 is in a read-only state, the following properties are true:

- The master M1 will continue to operate, so making a backup on the master is not safe.
- The slave S1 is stopped, so making a backup on the slave S1 is safe.

These properties provide the basis for a popular backup scenario: Having one slave busy performing a backup for a while is not a problem because it does not affect the entire network, and the system is still running during the backup. In particular, clients can still perform updates on the master server, which remains unaffected by backup activity on the slave.

While S1 is read only, perform the backup. For example, you can use `mysqldump`.

After the backup operation on S1 completes, restore S1 to its normal operational state by executing these statements:

```
mysql> SET GLOBAL read_only = OFF;
mysql> UNLOCK TABLES;
```

After the slave is restored to normal operation, it again synchronizes to the master by catching up with any outstanding updates from the binary log of the master.

3.2 Handling an Unexpected Halt of a Replication Slave

In order for replication to be resilient to unexpected halts of the server (sometimes described as crash-safe) it must be possible for the slave to recover its state before halting. This section describes the impact of an unexpected halt of a slave during replication and how to configure a slave for the best chance of recovery to continue replication.

After an unexpected halt of a slave, upon restart the I/O thread must recover the information about which transactions have been received, and the SQL thread must recover which transactions have been executed already. For information on the slave logs required for recovery, see Section 5.4, “Replication Relay and Status Logs”. The information required for recovery was traditionally stored in files, which had the risk of losing synchrony with the master depending at which stage of processing a transaction the slave halted at, or even corruption of the files themselves. In MySQL 5.7 you can instead use tables to store this information. These tables are created using `InnoDB`, and by using this transactional storage engine the information is always recoverable upon restart. To configure MySQL 5.7 to store the replication information in tables, set `relay_log_info_repository` and `master_info_repository` to `TABLE`. The server then stores information required for the recovery of the I/O thread in the `mysql.slave_master_info` table and information required for the recovery of the SQL thread in the `mysql.slave_relay_log_info` table.

Exactly how a replication slave recovers from an unexpected halt is influenced by the chosen method of replication, whether the slave is single-threaded or multi-threaded, the setting of variables such as `relay_log_recovery`, and whether features such as `MASTER_AUTO_POSITION` are being used.

The following table shows the impact of these different factors on how a single-threaded slave recovers from an unexpected halt.

Table 3.1 Factors Influencing Single-threaded Replication Slave Recovery

GTID	MASTER_AUTO_POSITION	`relay_log_recovery`	`relay_log_info_repository`	Crash type	Recovery guaranteed	Relay log impact
OFF	Any	1	TABLE	Any	Yes	Lost
OFF	Any	1	TABLE	Server	Yes	Lost
OFF	Any	1	Any	OS	No	Lost
OFF	Any	0	TABLE	Server	Yes	Remains
OFF	Any	0	TABLE	OS	No	Remains
ON	ON	Any	Any	Any	Yes	Lost
ON	OFF	0	TABLE	Server	Yes	Remains
ON	OFF	0	Any	OS	No	Remains

As the table shows, when using a single-threaded slave the following configurations are most resilient to unexpected halts:

- When using GTIDs and `MASTER_AUTO_POSITION`, set `relay_log_recovery=0`. With this configuration the setting of `relay_log_info_repository` and other variables does not impact on recovery.
- When using file position based replication, set `relay_log_recovery=1` and `relay_log_info_repository=TABLE`.

Note

During recovery the relay log is lost.

The following table shows the impact of these different factors on how a multi-threaded slave recovers from an unexpected halt.

Table 3.2 Factors Influencing Multi-threaded Replication Slave Recovery

GTID	`sync_relay_log`	`MASTER_AUTO_POSITION`	`relay_log_recovery`	`relay_log_info_repository`	Crash type	Recovery guaranteed	Relay log impact
OFF	1	Any	1	TABLE	Any	Yes	Lost
OFF	>1	Any	1	TABLE	Server	Yes	Lost
OFF	>1	Any	1	Any	OS	No	Lost
OFF	1	Any	0	TABLE	Server	Yes	Remains
OFF	1	Any	0	TABLE	OS	No	Remains
ON	Any	ON	Any	Any	Any	Yes	Lost
ON	1	OFF	0	TABLE	Server	Yes	Remains
ON	1	OFF	0	Any	OS	No	Remains

As the table shows, when using a multi-threaded slave the following configurations are most resilient to unexpected halts:

- When using GTIDs and MASTER_AUTO_POSITION, set relay_log_recovery=0. With this configuration the setting of relay_log_info_repository and other variables does not impact on recovery.
- When using file position based replication, set relay_log_recovery=1, sync_relay_log=1, and relay_log_info_repository=TABLE.

Note

During recovery the relay log is lost.

It is important to note the impact of sync_relay_log=1, which requires a write of to the relay log per transaction. Although this setting is the most resilient to an unexpected halt, with at most one unwritten transaction being lost, it also has the potential to greatly increase the load on storage. Without sync_relay_log=1, the effect of an unexpected halt depends on how the relay log is handled by the operating system. Also note that when relay_log_recovery=0, the next time the slave is started after an unexpected halt the relay log is processed as part of recovery. After this process completes, the relay log is deleted.

An unexpected halt of a multi-threaded replication slave using the recommended file position based replication configuration above may result in a relay log with transaction inconsistencies (gaps in the sequence of transactions) caused by the unexpected halt. See Section 4.1.34, “Replication and Transaction Inconsistencies”. In MySQL 5.7.13 and later, if the relay log recovery process encounters such transaction inconsistencies they are filled and the recovery process continues automatically. In MySQL versions prior to MySQL 5.7.13, this process is not automatic and requires starting the server with relay_log_recovery=0, starting the slave with START SLAVE UNTIL SQL_AFTER_MTS_GAPS to fix any transaction inconsistencies and then restarting the slave with relay_log_recovery=1.

When you are using multi-source replication and relay_log_recovery=1, after restarting due to an unexpected halt all replication channels go through the relay log recovery process. Any inconsistencies found in the relay log due to an unexpected halt of a multi-threaded slave are filled.

3.3 Using Replication with Different Master and Slave Storage Engines

It does not matter for the replication process whether the source table on the master and the replicated table on the slave use different engine types. In fact, the default_storage_engine and storage_engine system variables are not replicated.

This provides a number of benefits in the replication process in that you can take advantage of different engine types for different replication scenarios. For example, in a typical scale-out scenario (see Section 3.4, “Using Replication for Scale-Out”), you want to use InnoDB tables on the master to take advantage of the transactional functionality, but use MyISAM on the slaves where transaction support is not required because the data is only read. When using replication in a data-logging environment you may want to use the Archive storage engine on the slave.

Configuring different engines on the master and slave depends on how you set up the initial replication process:

- If you used mysqldump to create the database snapshot on your master, you could edit the dump file text to change the engine type used on each table.

  Another alternative for mysqldump is to disable engine types that you do not want to use on the slave before using the dump to build the data on the slave. For example, you can add the --skip-federated option on your slave to disable the FEDERATED engine. If a specific engine does not exist for a table to be created, MySQL will use the default engine type, usually MyISAM. (This requires that the

NO_ENGINE_SUBSTITUTION SQL mode is not enabled.) If you want to disable additional engines in this way, you may want to consider building a special binary to be used on the slave that only supports the engines you want.

- If you are using raw data files (a binary backup) to set up the slave, you will be unable to change the initial table format. Instead, use ALTER TABLE to change the table types after the slave has been started.
- For new master/slave replication setups where there are currently no tables on the master, avoid specifying the engine type when creating new tables.

If you are already running a replication solution and want to convert your existing tables to another engine type, follow these steps:

1. Stop the slave from running replication updates:

   ```
   mysql> STOP SLAVE;
   ```

   This will enable you to change engine types without interruptions.

2. Execute an ALTER TABLE ... ENGINE='*engine_type*' for each table to be changed.
3. Start the slave replication process again:

   ```
   mysql> START SLAVE;
   ```

Although the default_storage_engine variable is not replicated, be aware that CREATE TABLE and ALTER TABLE statements that include the engine specification will be correctly replicated to the slave. For example, if you have a CSV table and you execute:

```
mysql> ALTER TABLE csvtable Engine='MyISAM';
```

The above statement will be replicated to the slave and the engine type on the slave will be converted to MyISAM, even if you have previously changed the table type on the slave to an engine other than CSV. If you want to retain engine differences on the master and slave, you should be careful to use the default_storage_engine variable on the master when creating a new table. For example, instead of:

```
mysql> CREATE TABLE tablea (columna int) Engine=MyISAM;
```

Use this format:

```
mysql> SET default_storage_engine=MyISAM;
mysql> CREATE TABLE tablea (columna int);
```

When replicated, the default_storage_engine variable will be ignored, and the CREATE TABLE statement will execute on the slave using the slave's default engine.

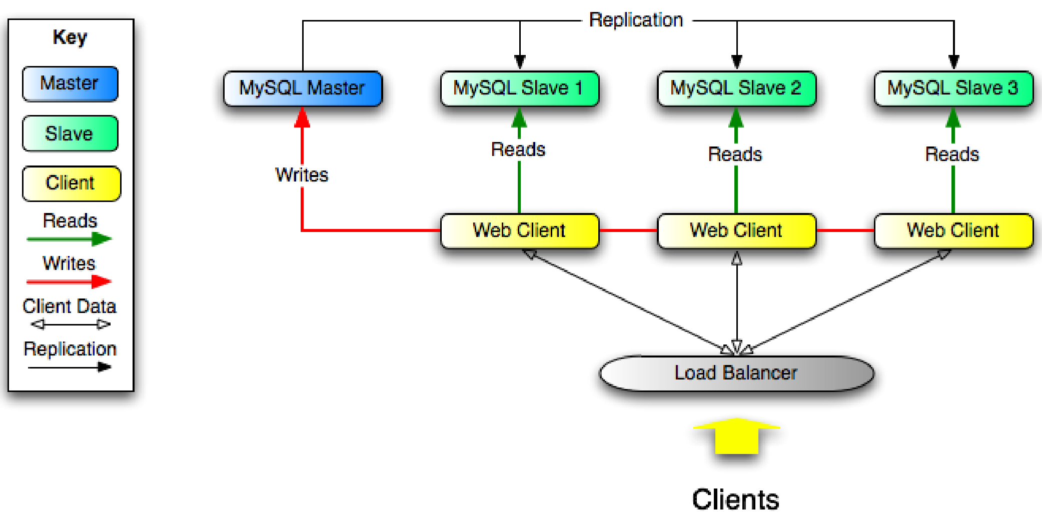
3.4 Using Replication for Scale-Out

You can use replication as a scale-out solution; that is, where you want to split up the load of database queries across multiple database servers, within some reasonable limitations.

Because replication works from the distribution of one master to one or more slaves, using replication for scale-out works best in an environment where you have a high number of reads and low number of writes/updates. Most Web sites fit into this category, where users are browsing the Web site, reading articles, posts, or viewing products. Updates only occur during session management, or when making a purchase or adding a comment/message to a forum.

Replication in this situation enables you to distribute the reads over the replication slaves, while still enabling your web servers to communicate with the replication master when a write is required. You can see a sample replication layout for this scenario in Figure 3.1, “Using Replication to Improve Performance During Scale-Out”.

Figure 3.1 Using Replication to Improve Performance During Scale-Out



If the part of your code that is responsible for database access has been properly abstracted/modularized, converting it to run with a replicated setup should be very smooth and easy. Change the implementation of your database access to send all writes to the master, and to send reads to either the master or a slave. If your code does not have this level of abstraction, setting up a replicated system gives you the opportunity and motivation to clean it up. Start by creating a wrapper library or module that implements the following functions:

- `safe_writer_connect()`
- `safe_reader_connect()`
- `safe_reader_statement()`
- `safe_writer_statement()`

`safe_` in each function name means that the function takes care of handling all error conditions. You can use different names for the functions. The important thing is to have a unified interface for connecting for reads, connecting for writes, doing a read, and doing a write.

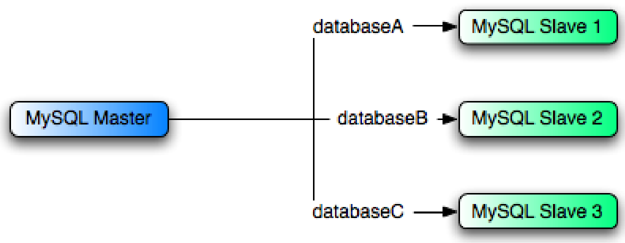
Then convert your client code to use the wrapper library. This may be a painful and scary process at first, but it pays off in the long run. All applications that use the approach just described are able to take advantage of a master/slave configuration, even one involving multiple slaves. The code is much easier to maintain, and adding troubleshooting options is trivial. You need modify only one or two functions; for example, to log how long each statement took, or which statement among those issued gave you an error.

If you have written a lot of code, you may want to automate the conversion task by using the `replace` utility that comes with standard MySQL distributions, or write your own conversion script. Ideally, your code uses consistent programming style conventions. If not, then you are probably better off rewriting it anyway, or at least going through and manually regularizing it to use a consistent style.

3.5 Replicating Different Databases to Different Slaves

There may be situations where you have a single master and want to replicate different databases to different slaves. For example, you may want to distribute different sales data to different departments to help spread the load during data analysis. A sample of this layout is shown in Figure 3.2, “Using Replication to Replicate Databases to Separate Replication Slaves”.

Figure 3.2 Using Replication to Replicate Databases to Separate Replication Slaves



You can achieve this separation by configuring the master and slaves as normal, and then limiting the binary log statements that each slave processes by using the `--replicate-wild-do-table` configuration option on each slave.

Important

You should *not* use `--replicate-do-db` for this purpose when using statement-based replication, since statement-based replication causes this option's affects to vary according to the database that is currently selected. This applies to mixed-format replication as well, since this enables some updates to be replicated using the statement-based format.

However, it should be safe to use `--replicate-do-db` for this purpose if you are using row-based replication only, since in this case the currently selected database has no effect on the option's operation.

For example, to support the separation as shown in Figure 3.2, “Using Replication to Replicate Databases to Separate Replication Slaves”, you should configure each replication slave as follows, before executing `START SLAVE`:

- Replication slave 1 should use `--replicate-wild-do-table=databaseA.%`.
- Replication slave 2 should use `--replicate-wild-do-table=databaseB.%`.
- Replication slave 3 should use `--replicate-wild-do-table=databaseC.%`.

Each slave in this configuration receives the entire binary log from the master, but executes only those events from the binary log that apply to the databases and tables included by the `--replicate-wild-do-table` option in effect on that slave.

If you have data that must be synchronized to the slaves before replication starts, you have a number of choices:

- Synchronize all the data to each slave, and delete the databases, tables, or both that you do not want to keep.
- Use `mysqldump` to create a separate dump file for each database and load the appropriate dump file on each slave.

- Use a raw data file dump and include only the specific files and databases that you need for each slave.

> **Note**
>
> This does not work with `InnoDB` databases unless you use `innodb_file_per_table`.

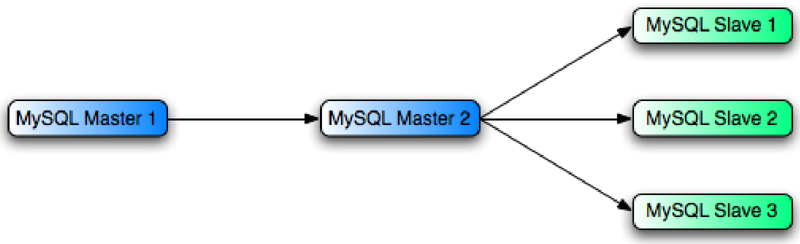
3.6 Improving Replication Performance

As the number of slaves connecting to a master increases, the load, although minimal, also increases, as each slave uses a client connection to the master. Also, as each slave must receive a full copy of the master binary log, the network load on the master may also increase and create a bottleneck.

If you are using a large number of slaves connected to one master, and that master is also busy processing requests (for example, as part of a scale-out solution), then you may want to improve the performance of the replication process.

One way to improve the performance of the replication process is to create a deeper replication structure that enables the master to replicate to only one slave, and for the remaining slaves to connect to this primary slave for their individual replication requirements. A sample of this structure is shown in Figure 3.3, “Using an Additional Replication Host to Improve Performance”.

Figure 3.3 Using an Additional Replication Host to Improve Performance



For this to work, you must configure the MySQL instances as follows:

- Master 1 is the primary master where all changes and updates are written to the database. Binary logging should be enabled on this machine.
- Master 2 is the slave to the Master 1 that provides the replication functionality to the remainder of the slaves in the replication structure. Master 2 is the only machine permitted to connect to Master 1. Master 2 also has binary logging enabled, and the `--log-slave-updates` option so that replication instructions from Master 1 are also written to Master 2's binary log so that they can then be replicated to the true slaves.
- Slave 1, Slave 2, and Slave 3 act as slaves to Master 2, and replicate the information from Master 2, which actually consists of the upgrades logged on Master 1.

The above solution reduces the client load and the network interface load on the primary master, which should improve the overall performance of the primary master when used as a direct database solution.

If your slaves are having trouble keeping up with the replication process on the master, there are a number of options available:

- If possible, put the relay logs and the data files on different physical drives. To do this, use the `--relay-log` option to specify the location of the relay log.

- If the slaves are significantly slower than the master, you may want to divide up the responsibility for replicating different databases to different slaves. See Section 3.5, "Replicating Different Databases to Different Slaves".
- If your master makes use of transactions and you are not concerned about transaction support on your slaves, use `MyISAM` or another nontransactional engine on the slaves. See Section 3.3, "Using Replication with Different Master and Slave Storage Engines".
- If your slaves are not acting as masters, and you have a potential solution in place to ensure that you can bring up a master in the event of failure, then you can switch off `--log-slave-updates`. This prevents "dumb" slaves from also logging events they have executed into their own binary log.

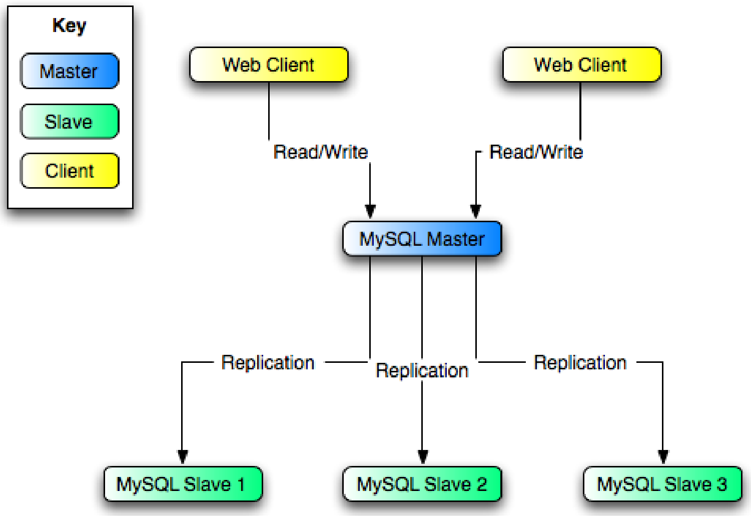
3.7 Switching Masters During Failover

When using replication with GTIDs (see Section 2.3, "Replication with Global Transaction Identifiers"), you can provide failover between master and slaves in the event of a failure using `mysqlfailover`, which is provided by the MySQL Utilities; see `mysqlfailover` — Automatic replication health monitoring and failover, for more information. If you are not using GTIDs and therefore cannot use `mysqlfailover`, you must set up a master and one or more slaves; then, you need to write an application or script that monitors the master to check whether it is up, and instructs the slaves and applications to change to another master in case of failure. This section discusses some of the issues encountered when setting up failover in this way.

You can tell a slave to change to a new master using the `CHANGE MASTER TO` statement. The slave does not check whether the databases on the master are compatible with those on the slave; it simply begins reading and executing events from the specified coordinates in the new master's binary log. In a failover situation, all the servers in the group are typically executing the same events from the same binary log file, so changing the source of the events should not affect the structure or integrity of the database, provided that you exercise care in making the change.

Slaves should be run with the `--log-bin` option, and if not using GTIDs then they should also be run without `--log-slave-updates`. In this way, the slave is ready to become a master without restarting the slave `mysqld`. Assume that you have the structure shown in Figure 3.4, "Redundancy Using Replication, Initial Structure".

Figure 3.4 Redundancy Using Replication, Initial Structure



In this diagram, the MySQL Master holds the master database, the MySQL Slave hosts are replication slaves, and the Web Client machines are issuing database reads and writes. Web clients that issue only reads (and would normally be connected to the slaves) are not shown, as they do not need to switch to a new server in the event of failure. For a more detailed example of a read/write scale-out replication structure, see Section 3.4, “Using Replication for Scale-Out”.

Each MySQL Slave (Slave 1, Slave 2, and Slave 3) is a slave running with --log-bin and without --log-slave-updates. Because updates received by a slave from the master are not logged in the binary log unless --log-slave-updates is specified, the binary log on each slave is empty initially. If for some reason MySQL Master becomes unavailable, you can pick one of the slaves to become the new master. For example, if you pick Slave 1, all Web Clients should be redirected to Slave 1, which writes the updates to its binary log. Slave 2 and Slave 3 should then replicate from Slave 1.

The reason for running the slave without --log-slave-updates is to prevent slaves from receiving updates twice in case you cause one of the slaves to become the new master. If Slave 1 has --log-slave-updates enabled, it writes any updates that it receives from Master in its own binary log. This means that, when Slave 2 changes from Master to Slave 1 as its master, it may receive updates from Slave 1 that it has already received from Master.

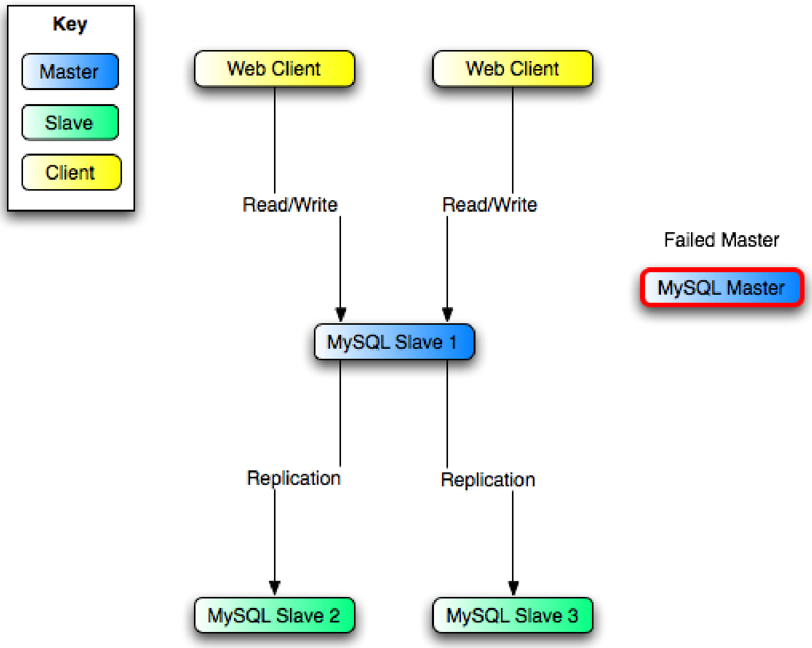
Make sure that all slaves have processed any statements in their relay log. On each slave, issue STOP SLAVE IO_THREAD, then check the output of SHOW PROCESSLIST until you see Has read all relay log. When this is true for all slaves, they can be reconfigured to the new setup. On the slave Slave 1 being promoted to become the master, issue STOP SLAVE and RESET MASTER.

On the other slaves Slave 2 and Slave 3, use STOP SLAVE and CHANGE MASTER TO MASTER_HOST='Slave1' (where 'Slave1' represents the real host name of Slave 1). To use CHANGE MASTER TO, add all information about how to connect to Slave 1 from Slave 2 or Slave 3 (*user*, *password*, *port*). When issuing the CHANGE MASTER TO statement in this, there is no need to specify the name of the Slave 1 binary log file or log position to read from, since the first binary log file and position 4, are the defaults. Finally, execute START SLAVE on Slave 2 and Slave 3.

Once the new replication setup is in place, you need to tell each Web Client to direct its statements to Slave 1. From that point on, all updates statements sent by Web Client to Slave 1 are written to the binary log of Slave 1, which then contains every update statement sent to Slave 1 since Master died.

The resulting server structure is shown in Figure 3.5, “Redundancy Using Replication, After Master Failure”.

Figure 3.5 Redundancy Using Replication, After Master Failure



When `Master` becomes available again, you should make it a slave of `Slave 1`. To do this, issue on `Master` the same `CHANGE MASTER TO` statement as that issued on `Slave 2` and `Slave 3` previously. `Master` then becomes a slave of `S1ave 1` and picks up the `Web Client` writes that it missed while it was offline.

To make `Master` a master again, use the preceding procedure as if `Slave 1` was unavailable and `Master` was to be the new master. During this procedure, do not forget to run `RESET MASTER` on `Master` before making `Slave 1`, `Slave 2`, and `Slave 3` slaves of `Master`. If you fail to do this, the slaves may pick up stale writes from the `Web Client` applications dating from before the point at which `Master` became unavailable.

You should be aware that there is no synchronization between slaves, even when they share the same master, and thus some slaves might be considerably ahead of others. This means that in some cases the procedure outlined in the previous example might not work as expected. In practice, however, relay logs on all slaves should be relatively close together.

One way to keep applications informed about the location of the master is to have a dynamic DNS entry for the master. With `bind` you can use `nsupdate` to update the DNS dynamically.

3.8 Setting Up Replication to Use Secure Connections

To use a secure connection for encrypting the transfer of the binary log required during replication, both the master and the slave servers must support encrypted network connections. If either server does not support secure connections (because it has not been compiled or configured for them), replication through an encrypted connection is not possible.

Setting up secure connections for replication is similar to doing so for client/server connections. You must obtain (or create) a suitable security certificate that you can use on the master, and a similar certificate (from the same certificate authority) on each slave. You must also obtain suitable key files.

For more information on setting up a server and client for secure connections, see Configuring MySQL to Use Secure Connections.

To enable secure connections on the master, you must create or obtain suitable certificate and key files, and then add the following configuration options to the master's configuration within the `[mysqld]` section of the master's `my.cnf` file, changing the file names as necessary:

```
[mysqld]
ssl-ca=cacert.pem
ssl-cert=server-cert.pem
ssl-key=server-key.pem
```

The paths to the files may be relative or absolute; we recommend that you always use complete paths for this purpose.

The options are as follows:

- `ssl-ca` identifies the Certificate Authority (CA) certificate.
- `ssl-cert` identifies the server public key certificate. This can be sent to the client and authenticated against the CA certificate that it has.
- `ssl-key` identifies the server private key.

On the slave, there are two ways to specify the information required for connecting securely to the master. You can either name the slave certificate and key files in the `[client]` section of the slave's `my.cnf` file, or you can explicitly specify that information using the `CHANGE MASTER TO` statement:

- To name the slave certificate and key files using an option file, add the following lines to the `[client]` section of the slave's `my.cnf` file, changing the file names as necessary:

  ```
  [client]
  ssl-ca=cacert.pem
  ssl-cert=client-cert.pem
  ssl-key=client-key.pem
  ```

  Restart the slave server, using the `--skip-slave-start` option to prevent the slave from connecting to the master. Use `CHANGE MASTER TO` to specify the master configuration, using the `MASTER_SSL` option to connect securely:

  ```
  mysql> CHANGE MASTER TO
      -> MASTER_HOST='master_hostname',
      -> MASTER_USER='replicate',
      -> MASTER_PASSWORD='password',
      -> MASTER_SSL=1;
  ```

- To specify the certificate and key names using the `CHANGE MASTER TO` statement, append the appropriate `MASTER_SSL_xxx` options:

  ```
  mysql> CHANGE MASTER TO
      -> MASTER_HOST='master_hostname',
      -> MASTER_USER='replicate',
      -> MASTER_PASSWORD='password',
      -> MASTER_SSL=1,
      -> MASTER_SSL_CA = 'ca_file_name',
      -> MASTER_SSL_CAPATH = 'ca_directory_name',
      -> MASTER_SSL_CERT = 'cert_file_name',
  ```

```
    -> MASTER_SSL_KEY = 'key_file_name';
```

After the master information has been updated, start the slave replication process:

```
mysql> START SLAVE;
```

You can use the SHOW SLAVE STATUS statement to confirm that a secure connection was established successfully.

For more information on the CHANGE MASTER TO statement, see CHANGE MASTER TO Syntax.

If you want to enforce the use of secure connections during replication, create a user and use the REQUIRE SSL option, then grant that user the REPLICATION SLAVE privilege. For example:

```
mysql> CREATE USER 'repl'@'%.mydomain.com' IDENTIFIED BY 'slavepass'
    -> REQUIRE SSL;
mysql> GRANT REPLICATION SLAVE ON *.*
    -> TO 'repl'@'%.mydomain.com';
```

If the account already exists, you can add REQUIRE SSL to it with this statement:

```
mysql> ALTER USER 'repl'@'%.mydomain.com' REQUIRE SSL;
```

3.9 Semisynchronous Replication

In addition to the built-in asynchronous replication, MySQL 5.7 supports an interface to semisynchronous replication that is implemented by plugins. This section discusses what semisynchronous replication is and how it works. The following sections cover the administrative interface to semisynchronous replication and how to install, configure, and monitor it.

MySQL replication by default is asynchronous. The master writes events to its binary log but does not know whether or when a slave has retrieved and processed them. With asynchronous replication, if the master crashes, transactions that it has committed might not have been transmitted to any slave. Consequently, failover from master to slave in this case may result in failover to a server that is missing transactions relative to the master.

Semisynchronous replication can be used as an alternative to asynchronous replication:

- A slave indicates whether it is semisynchronous-capable when it connects to the master.
- If semisynchronous replication is enabled on the master side and there is at least one semisynchronous slave, a thread that performs a transaction commit on the master blocks and waits until at least one semisynchronous slave acknowledges that it has received all events for the transaction, or until a timeout occurs.
- The slave acknowledges receipt of a transaction's events only after the events have been written to its relay log and flushed to disk.
- If a timeout occurs without any slave having acknowledged the transaction, the master reverts to asynchronous replication. When at least one semisynchronous slave catches up, the master returns to semisynchronous replication.
- Semisynchronous replication must be enabled on both the master and slave sides. If semisynchronous replication is disabled on the master, or enabled on the master but on no slaves, the master uses asynchronous replication.

While the master is blocking (waiting for acknowledgment from a slave), it does not return to the session that performed the transaction. When the block ends, the master returns to the session, which then can proceed to execute other statements. At this point, the transaction has committed on the master side, and receipt of its events has been acknowledged by at least one slave.

As of MySQL 5.7.3, the number of slave acknowledgments the master must receive per transaction before proceeding is configurable using the `rpl_semi_sync_master_wait_for_slave_count` system variable. The default value is 1.

Blocking also occurs after rollbacks that are written to the binary log, which occurs when a transaction that modifies nontransactional tables is rolled back. The rolled-back transaction is logged even though it has no effect for transactional tables because the modifications to the nontransactional tables cannot be rolled back and must be sent to slaves.

For statements that do not occur in transactional context (that is, when no transaction has been started with `START TRANSACTION` or `SET autocommit = 0`), autocommit is enabled and each statement commits implicitly. With semisynchronous replication, the master blocks for each such statement, just as it does for explicit transaction commits.

To understand what the “semi” in “semisynchronous replication” means, compare it with asynchronous and fully synchronous replication:

- With asynchronous replication, the master writes events to its binary log and slaves request them when they are ready. There is no guarantee that any event will ever reach any slave.
- With fully synchronous replication, when a master commits a transaction, all slaves also will have committed the transaction before the master returns to the session that performed the transaction. The drawback of this is that there might be a lot of delay to complete a transaction.
- Semisynchronous replication falls between asynchronous and fully synchronous replication. The master waits only until at least one slave has received and logged the events. It does not wait for all slaves to acknowledge receipt, and it requires only receipt, not that the events have been fully executed and committed on the slave side.

Compared to asynchronous replication, semisynchronous replication provides improved data integrity because when a commit returns successfully, it is known that the data exists in at least two places. Until a semisynchronous master receives acknowledgment from the number of slaves configured by `rpl_semi_sync_master_wait_for_slave_count`, the transaction is on hold and not committed.

Semisynchronous replication also places a rate limit on busy sessions by constraining the speed at which binary log events can be sent from master to slave. When one user is too busy, this will slow it down, which is useful in some deployment situations.

Semisynchronous replication does have some performance impact because commits are slower due to the need to wait for slaves. This is the tradeoff for increased data integrity. The amount of slowdown is at least the TCP/IP roundtrip time to send the commit to the slave and wait for the acknowledgment of receipt by the slave. This means that semisynchronous replication works best for close servers communicating over fast networks, and worst for distant servers communicating over slow networks.

The `rpl_semi_sync_master_wait_point` system variable controls the point at which a semisynchronous replication master waits for slave acknowledgment of transaction receipt before returning a status to the client that committed the transaction. These values are permitted:

- `AFTER_SYNC` (the default): The master writes each transaction to its binary log and the slave, and syncs the binary log to disk. The master waits for slave acknowledgment of transaction receipt after the sync.

Upon receiving acknowledgment, the master commits the transaction to the storage engine and returns a result to the client, which then can proceed.

- `AFTER_COMMIT`: The master writes each transaction to its binary log and the slave, syncs the binary log, and commits the transaction to the storage engine. The master waits for slave acknowledgment of transaction receipt after the commit. Upon receiving acknowledgment, the master returns a result to the client, which then can proceed.

The replication characteristics of these settings differ as follows:

- With `AFTER_SYNC`, all clients see the committed transaction at the same time: After it has been acknowledged by the slave and committed to the storage engine on the master. Thus, all clients see the same data on the master.

  In the event of master failure, all transactions committed on the master have been replicated to the slave (saved to its relay log). A crash of the master and failover to the slave is lossless because the slave is up to date.

- With `AFTER_COMMIT`, the client issuing the transaction gets a return status only after the server commits to the storage engine and receives slave acknowledgment. After the commit and before slave acknowledgment, other clients can see the committed transaction before the committing client.

  If something goes wrong such that the slave does not process the transaction, then in the event of a master crash and failover to the slave, it is possible that such clients will see a loss of data relative to what they saw on the master.

3.9.1 Semisynchronous Replication Administrative Interface

The administrative interface to semisynchronous replication has several components:

- Two plugins implement semisynchronous capability. There is one plugin for the master side and one for the slave side.
- System variables control plugin behavior. Some examples:
  - `rpl_semi_sync_master_enabled`

    Controls whether semisynchronous replication is enabled on the master. To enable or disable the plugin, set this variable to 1 or 0, respectively. The default is 0 (off).
  - `rpl_semi_sync_master_timeout`

    A value in milliseconds that controls how long the master waits on a commit for acknowledgment from a slave before timing out and reverting to asynchronous replication. The default value is 10000 (10 seconds).
  - `rpl_semi_sync_slave_enabled`

    Similar to `rpl_semi_sync_master_enabled`, but controls the slave plugin.

  All `rpl_semi_sync_*xxx*` system variables are described at Server System Variables.
- Status variables enable semisynchronous replication monitoring. Some examples:
  - `Rpl_semi_sync_master_clients`

    The number of semisynchronous slaves.

- `Rpl_semi_sync_master_status`

  Whether semisynchronous replication currently is operational on the master. The value is 1 if the plugin has been enabled and a commit acknowledgment has not occurred. It is 0 if the plugin is not enabled or the master has fallen back to asynchronous replication due to commit acknowledgment timeout.

- `Rpl_semi_sync_master_no_tx`

  The number of commits that were not acknowledged successfully by a slave.

- `Rpl_semi_sync_master_yes_tx`

  The number of commits that were acknowledged successfully by a slave.

- `Rpl_semi_sync_slave_status`

  Whether semisynchronous replication currently is operational on the slave. This is 1 if the plugin has been enabled and the slave I/O thread is running, 0 otherwise.

All `Rpl_semi_sync_xxx` status variables are described at Server Status Variables.

The system and status variables are available only if the appropriate master or slave plugin has been installed with `INSTALL PLUGIN`.

3.9.2 Semisynchronous Replication Installation and Configuration

Semisynchronous replication is implemented using plugins, so the plugins must be installed into the server to make them available. After a plugin has been installed, you control it by means of the system variables associated with it. These system variables are unavailable until the associated plugin has been installed.

This section describes how to install the semisynchronous replication plugins. For general information about installing plugins, see Installing and Uninstalling Plugins.

To use semisynchronous replication, the following requirements must be satisfied:

- MySQL 5.5 or higher must be installed.
- The capability of installing plugins requires a MySQL server that supports dynamic loading. To verify this, check that the value of the `have_dynamic_loading` system variable is `YES`. Binary distributions should support dynamic loading.
- Replication must already be working. For information on creating a master/slave relationship, see Section 2.2, “Setting Up Binary Log File Position Based Replication”.
- There must not be multiple replication channels configured. Semisynchronous replication is only compatible with the default replication channel.

To set up semisynchronous replication, use the following instructions. The `INSTALL PLUGIN`, `SET GLOBAL`, `STOP SLAVE`, and `START SLAVE` statements mentioned here require the `SUPER` privilege.

MySQL distributions include semisynchronous replication plugin files for the master side and the slave side.

To be usable by a master or slave server, the appropriate plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

The plugin library file base names are `semisync_master` and `semisync_slave`. The file name suffix differs per platform (for example, `.so` for Unix and Unix-like systems, `.dll` for Windows).

The master plugin library file must be present in the plugin directory of the master server. The slave plugin library file must be present in the plugin directory of each slave server.

To load the plugins, use the `INSTALL PLUGIN` statement on the master and on each slave that is to be semisynchronous (adjust the `.so` suffix for your platform as necessary).

On the master:

```
INSTALL PLUGIN rpl_semi_sync_master SONAME 'semisync_master.so';
```

On each slave:

```
INSTALL PLUGIN rpl_semi_sync_slave SONAME 'semisync_slave.so';
```

If an attempt to install a plugin results in an error on Linux similar to that shown here, you must install `libimf`:

```
mysql> INSTALL PLUGIN rpl_semi_sync_master SONAME 'semisync_master.so';
ERROR 1126 (HY000): Can't open shared library
'/usr/local/mysql/lib/plugin/semisync_master.so'
(errno: 22 libimf.so: cannot open shared object file:
No such file or directory)
```

You can obtain `libimf` from http://dev.mysql.com/downloads/os-linux.html.

To see which plugins are installed, use the `SHOW PLUGINS` statement, or query the `INFORMATION_SCHEMA.PLUGINS` table.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Obtaining Server Plugin Information). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS FROM INFORMATION_SCHEMA.PLUGINS
    -> WHERE PLUGIN_NAME LIKE '%semi%';
+----------------------+---------------+
| PLUGIN_NAME          | PLUGIN_STATUS |
+----------------------+---------------+
| rpl_semi_sync_master | ACTIVE        |
+----------------------+---------------+
```

After a semisynchronous replication plugin has been installed, it is disabled by default. The plugins must be enabled both on the master side and the slave side to enable semisynchronous replication. If only one side is enabled, replication will be asynchronous.

To control whether an installed plugin is enabled, set the appropriate system variables. You can set these variables at runtime using `SET GLOBAL`, or at server startup on the command line or in an option file.

At runtime, these master-side system variables are available:

```
SET GLOBAL rpl_semi_sync_master_enabled = {0|1};
SET GLOBAL rpl_semi_sync_master_timeout = N;
```

On the slave side, this system variable is available:

```
SET GLOBAL rpl_semi_sync_slave_enabled = {0|1};
```

For `rpl_semi_sync_master_enabled` or `rpl_semi_sync_slave_enabled`, the value should be 1 to enable semisynchronous replication or 0 to disable it. By default, these variables are set to 0.

For `rpl_semi_sync_master_timeout`, the value *`N`* is given in milliseconds. The default value is 10000 (10 seconds).

If you enable semisynchronous replication on a slave at runtime, you must also start the slave I/O thread (stopping it first if it is already running) to cause the slave to connect to the master and register as a semisynchronous slave:

```
STOP SLAVE IO_THREAD;
START SLAVE IO_THREAD;
```

If the I/O thread is already running and you do not restart it, the slave continues to use asynchronous replication.

At server startup, the variables that control semisynchronous replication can be set as command-line options or in an option file. A setting listed in an option file takes effect each time the server starts. For example, you can set the variables in `my.cnf` files on the master and slave sides as follows.

On the master:

```
[mysqld]
rpl_semi_sync_master_enabled=1
rpl_semi_sync_master_timeout=1000 # 1 second
```

On each slave:

```
[mysqld]
rpl_semi_sync_slave_enabled=1
```

3.9.3 Semisynchronous Replication Monitoring

The plugins for the semisynchronous replication capability expose several system and status variables that you can examine to determine its configuration and operational state.

The system variable reflect how semisynchronous replication is configured. To check their values, use `SHOW VARIABLES`:

```
mysql> SHOW VARIABLES LIKE 'rpl_semi_sync%';
```

The status variables enable you to monitor the operation of semisynchronous replication. To check their values, use `SHOW STATUS`:

```
mysql> SHOW STATUS LIKE 'Rpl_semi_sync%';
```

When the master switches between asynchronous or semisynchronous replication due to commit-blocking timeout or a slave catching up, it sets the value of the `Rpl_semi_sync_master_status` status variable appropriately. Automatic fallback from semisynchronous to asynchronous replication on the master means that it is possible for the `rpl_semi_sync_master_enabled` system variable to have a value of 1 on the master side even when semisynchronous replication is in fact not operational at the moment. You can monitor the `Rpl_semi_sync_master_status` status variable to determine whether the master currently is using asynchronous or semisynchronous replication.

To see how many semisynchronous slaves are connected, check `Rpl_semi_sync_master_clients`.

The number of commits that have been acknowledged successfully or unsuccessfully by slaves are indicated by the `Rpl_semi_sync_master_yes_tx` and `Rpl_semi_sync_master_no_tx` variables.

On the slave side, `Rpl_semi_sync_slave_status` indicates whether semisynchronous replication currently is operational.

3.10 Delayed Replication

MySQL 5.7 supports delayed replication such that a slave server deliberately lags behind the master by at least a specified amount of time. The default delay is 0 seconds. Use the `MASTER_DELAY` option for `CHANGE MASTER TO` to set the delay to *N* seconds:

```
CHANGE MASTER TO MASTER_DELAY = N;
```

An event received from the master is not executed until at least *N* seconds later than its execution on the master. The exceptions are that there is no delay for format description events or log file rotation events, which affect only the internal state of the SQL thread.

Delayed replication can be used for several purposes:

- To protect against user mistakes on the master. A DBA can roll back a delayed slave to the time just before the disaster.
- To test how the system behaves when there is a lag. For example, in an application, a lag might be caused by a heavy load on the slave. However, it can be difficult to generate this load level. Delayed replication can simulate the lag without having to simulate the load. It can also be used to debug conditions related to a lagging slave.
- To inspect what the database looked like long ago, without having to reload a backup. For example, if the delay is one week and the DBA needs to see what the database looked like before the last few days' worth of development, the delayed slave can be inspected.

`START SLAVE` and `STOP SLAVE` take effect immediately and ignore any delay. `RESET SLAVE` resets the delay to 0.

`SHOW SLAVE STATUS` has three fields that provide information about the delay:

- `SQL_Delay`: A nonnegative integer indicating the number of seconds that the slave must lag the master.
- `SQL_Remaining_Delay`: When `Slave_SQL_Running_State` is `Waiting until MASTER_DELAY seconds after master executed event`, this field contains an integer indicating the number of seconds left of the delay. At other times, this field is `NULL`.
- `Slave_SQL_Running_State`: A string indicating the state of the SQL thread (analogous to `Slave_IO_State`). The value is identical to the `State` value of the SQL thread as displayed by `SHOW PROCESSLIST`.

When the slave SQL thread is waiting for the delay to elapse before executing an event, `SHOW PROCESSLIST` displays its `State` value as `Waiting until MASTER_DELAY seconds after master executed event`.

Chapter 4 Replication Notes and Tips

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4.1 Replication Features and Issues

The following sections provide information about what is supported and what is not in MySQL replication, and about specific issues and situations that may occur when replicating certain statements.

Statement-based replication depends on compatibility at the SQL level between the master and slave. In others, successful SBR requires that any SQL features used be supported by both the master and the slave servers. For example, if you use a feature on the master server that is available only in MySQL 5.7 (or later), you cannot replicate to a slave that uses MySQL 5.6 (or earlier).

Such incompatibilities also can occur within a release series when using pre-production releases of MySQL. For example, the `SLEEP()` function is available beginning with MySQL 5.0.12. If you use this function on the master, you cannot replicate to a slave that uses MySQL 5.0.11 or earlier.

For this reason, use Generally Available (GA) releases of MySQL for statement-based replication in a production setting, since we do not introduce new SQL statements or change their behavior within a given release series once that series reaches GA release status.

If you are planning to use statement-based replication between MySQL 5.7 and a previous MySQL release series, it is also a good idea to consult the edition of the *MySQL Reference Manual* corresponding to the earlier release series for information regarding the replication characteristics of that series.

With MySQL's statement-based replication, there may be issues with replicating stored routines or triggers. You can avoid these issues by using MySQL's row-based replication instead. For a detailed list of issues, see Binary Logging of Stored Programs. For more information about row-based logging and row-based replication, see Binary Logging Formats, and Section 5.1, “Replication Formats”.

For additional information specific to replication and `InnoDB`, see InnoDB and MySQL Replication. For information relating to replication with MySQL Cluster, see MySQL Cluster Replication.

4.1.1 Replication and AUTO_INCREMENT

Statement-based replication of `AUTO_INCREMENT`, `LAST_INSERT_ID()`, and `TIMESTAMP` values is done correctly, subject to the following exceptions:

- When using statement-based replication prior to MySQL 5.7.1, `AUTO_INCREMENT` columns in tables on the slave must match the same columns on the master; that is, `AUTO_INCREMENT` columns must be replicated to `AUTO_INCREMENT` columns.

- A statement invoking a trigger or function that causes an update to an `AUTO_INCREMENT` column is not replicated correctly using statement-based replication. In MySQL 5.7, such statements are marked as unsafe. (Bug #45677)

- An `INSERT` into a table that has a composite primary key that includes an `AUTO_INCREMENT` column that is not the first column of this composite key is not safe for statement-based logging or replication. In MySQL 5.7 and later, such statements are marked as unsafe. (Bug #11754117, Bug #45670)

  This issue does not affect tables using the `InnoDB` storage engine, since an `InnoDB` table with an AUTO_INCREMENT column requires at least one key where the auto-increment column is the only or leftmost column.

- Adding an `AUTO_INCREMENT` column to a table with `ALTER TABLE` might not produce the same ordering of the rows on the slave and the master. This occurs because the order in which the rows are numbered depends on the specific storage engine used for the table and the order in which the rows were inserted. If it is important to have the same order on the master and slave, the rows must be ordered before assigning an `AUTO_INCREMENT` number. Assuming that you want to add an `AUTO_INCREMENT` column to a table `t1` that has columns `col1` and `col2`, the following statements produce a new table `t2` identical to `t1` but with an `AUTO_INCREMENT` column:

```
CREATE TABLE t2 LIKE t1;
ALTER TABLE t2 ADD id INT AUTO_INCREMENT PRIMARY KEY;
INSERT INTO t2 SELECT * FROM t1 ORDER BY col1, col2;
```

Important

To guarantee the same ordering on both master and slave, the `ORDER BY` clause must name *all* columns of `t1`.

The instructions just given are subject to the limitations of `CREATE TABLE ... LIKE`: Foreign key definitions are ignored, as are the `DATA DIRECTORY` and `INDEX DIRECTORY` table options. If a table definition includes any of those characteristics, create `t2` using a `CREATE TABLE` statement that is identical to the one used to create `t1`, but with the addition of the `AUTO_INCREMENT` column.

Regardless of the method used to create and populate the copy having the `AUTO_INCREMENT` column, the final step is to drop the original table and then rename the copy:

```
DROP t1;
ALTER TABLE t2 RENAME t1;
```

See also Problems with ALTER TABLE.

4.1.2 Replication and BLACKHOLE Tables

The `BLACKHOLE` storage engine accepts data but discards it and does not store it. When performing binary logging, all inserts to such tables are always logged, regardless of the logging format in use. Updates and deletes are handled differently depending on whether statement based or row based logging is in use. With the statement based logging format, all statements affecting `BLACKHOLE` tables are logged, but their effects ignored. When using row-based logging, updates and deletes to such tables are simply skipped—they are not written to the binary log. In MySQL 5.7.2 and later, a warning is logged whenever this occurs (Bug #13004581)

For this reason we recommend when you replicate to tables using the `BLACKHOLE` storage engine that you have the `binlog_format` server variable set to `STATEMENT`, and not to either `ROW` or `MIXED`.

4.1.3 Replication and Character Sets

The following applies to replication between MySQL servers that use different character sets:

- If the master has databases with a character set different from the global `character_set_server` value, you should design your `CREATE TABLE` statements so that they do not implicitly rely on the database default character set. A good workaround is to state the character set and collation explicitly in `CREATE TABLE` statements.

4.1.4 Replication and CHECKSUM TABLE

`CHECKSUM TABLE` returns a checksum that is calculated row by row, using a method that depends on the table row storage format, which is not guaranteed to remain the same between MySQL release series. For example, the storage format for temporal types such as `TIME`, `DATETIME`, and `TIMESTAMP` changed in MySQL 5.6 prior to MySQL 5.6.5, so if a 5.5 table is upgraded to MySQL 5.6, the checksum value may change.

4.1.5 Replication of CREATE ... IF NOT EXISTS Statements

MySQL applies these rules when various `CREATE ... IF NOT EXISTS` statements are replicated:

- Every `CREATE DATABASE IF NOT EXISTS` statement is replicated, whether or not the database already exists on the master.
- Similarly, every `CREATE TABLE IF NOT EXISTS` statement without a `SELECT` is replicated, whether or not the table already exists on the master. This includes `CREATE TABLE IF NOT EXISTS ... LIKE`. Replication of `CREATE TABLE IF NOT EXISTS ... SELECT` follows somewhat different rules; see Section 4.1.6, "Replication of CREATE TABLE ... SELECT Statements", for more information.
- `CREATE EVENT IF NOT EXISTS` is always replicated in MySQL 5.7, whether or not the event named in the statement already exists on the master.

See also Bug #45574.

4.1.6 Replication of CREATE TABLE ... SELECT Statements

This section discusses how MySQL replicates `CREATE TABLE ... SELECT` statements.

MySQL 5.7 does not allow a `CREATE TABLE ... SELECT` statement to make any changes in tables other than the table that is created by the statement. Some older versions of MySQL permitted these statements to do so; this means that, when using statement-based replication between a MySQL 5.6 or later slave and a master running a previous version of MySQL, a `CREATE TABLE ... SELECT` statement causing changes in other tables on the master fails on the slave, causing replication to stop. To prevent this from happening, you should use row-based replication, rewrite the offending statement before running it on the master, or upgrade the master to MySQL 5.7. (If you choose to upgrade the master, keep in mind that such a `CREATE TABLE ... SELECT` statement fails following the upgrade unless it is rewritten to remove any side effects on other tables.) This is not an issue when using row-based replication, because the statement is logged as a `CREATE TABLE` statement with any changes to table data logged as row-insert events, rather than as the entire `CREATE TABLE ... SELECT`.

These behaviors are not dependent on MySQL version:

- `CREATE TABLE ... SELECT` always performs an implicit commit (Statements That Cause an Implicit Commit).
- If destination table does not exist, logging occurs as follows. It does not matter whether `IF NOT EXISTS` is present.
  - `STATEMENT` or `MIXED` format: The statement is logged as written.
  - `ROW` format: The statement is logged as a `CREATE TABLE` statement followed by a series of insert-row events.
- If the statement fails, nothing is logged. This includes the case that the destination table exists and `IF NOT EXISTS` is not given.

When the destination table exists and `IF NOT EXISTS` is given, MySQL 5.7 ignores the statement completely; nothing is inserted or logged. The handling of such statements in this regard has changed considerably in previous MySQL releases; if you are replicating from a MySQL 5.5.6 or older master to a newer slave, see Replication of CREATE ... IF NOT EXISTS Statements, for more information.

4.1.7 Replication of CREATE SERVER, ALTER SERVER, and DROP SERVER

In MySQL 5.7, the statements `CREATE SERVER`, `ALTER SERVER`, and `DROP SERVER` are not written to the binary log, regardless of the binary logging format that is in use.

4.1.8 Replication of CURRENT_USER()

The following statements support use of the `CURRENT_USER()` function to take the place of the name of (and, possibly, the host for) an affected user or a definer; in such cases, `CURRENT_USER()` is expanded where and as needed:

- `DROP USER`
- `RENAME USER`
- `GRANT`
- `REVOKE`
- `CREATE FUNCTION`
- `CREATE PROCEDURE`
- `CREATE TRIGGER`
- `CREATE EVENT`
- `CREATE VIEW`
- `ALTER EVENT`
- `ALTER VIEW`
- `SET PASSWORD`

When `CURRENT_USER()` or `CURRENT_USER` is used as the definer in any of the statements `CREATE FUNCTION`, `CREATE PROCEDURE`, `CREATE TRIGGER`, `CREATE EVENT`, `CREATE VIEW`, or `ALTER VIEW` when binary logging is enabled, the function reference is expanded before it is written to the binary log, so that the statement refers to the same user on both the master and the slave when the statement is replicated. `CURRENT_USER()` or `CURRENT_USER` is also expanded prior to being written to the binary log when used in `DROP USER`, `RENAME USER`, `GRANT`, `REVOKE`, or `ALTER EVENT`.

4.1.9 Replication of DROP ... IF EXISTS Statements

The `DROP DATABASE IF EXISTS`, `DROP TABLE IF EXISTS`, and `DROP VIEW IF EXISTS` statements are always replicated, even if the database, table, or view to be dropped does not exist on the master. This is to ensure that the object to be dropped no longer exists on either the master or the slave, once the slave has caught up with the master.

`DROP ... IF EXISTS` statements for stored programs (stored procedures and functions, triggers, and events) are also replicated, even if the stored program to be dropped does not exist on the master.

4.1.10 Replication with Differing Table Definitions on Master and Slave

Source and target tables for replication do not have to be identical. A table on the master can have more or fewer columns than the slave's copy of the table. In addition, corresponding table columns on the master and the slave can use different data types, subject to certain conditions.

> **Note**
>
> Replication between tables which are partitioned differently from one another is not supported. See Section 4.1.19, “Replication and Partitioning”.

In all cases where the source and target tables do not have identical definitions, the database and table names must be the same on both the master and the slave. Additional conditions are discussed, with examples, in the following two sections.

4.1.10.1 Replication with More Columns on Master or Slave

You can replicate a table from the master to the slave such that the master and slave copies of the table have differing numbers of columns, subject to the following conditions:

- Columns common to both versions of the table must be defined in the same order on the master and the slave.

  (This is true even if both tables have the same number of columns.)

- Columns common to both versions of the table must be defined before any additional columns.

  This means that executing an `ALTER TABLE` statement on the slave where a new column is inserted into the table within the range of columns common to both tables causes replication to fail, as shown in the following example:

  Suppose that a table `t`, existing on the master and the slave, is defined by the following `CREATE TABLE` statement:

  ```
  CREATE TABLE t (
      c1 INT,
      c2 INT,
      c3 INT
  );
  ```

  Suppose that the `ALTER TABLE` statement shown here is executed on the slave:

  ```
  ALTER TABLE t ADD COLUMN cnew1 INT AFTER c3;
  ```

  The previous `ALTER TABLE` is permitted on the slave because the columns `c1`, `c2`, and `c3` that are common to both versions of table `t` remain grouped together in both versions of the table, before any columns that differ.

  However, the following `ALTER TABLE` statement cannot be executed on the slave without causing replication to break:

  ```
  ALTER TABLE t ADD COLUMN cnew2 INT AFTER c2;
  ```

  Replication fails after execution on the slave of the `ALTER TABLE` statement just shown, because the new column `cnew2` comes between columns common to both versions of `t`.

- Each “extra” column in the version of the table having more columns must have a default value.

  A column's default value is determined by a number of factors, including its type, whether it is defined with a `DEFAULT` option, whether it is declared as `NULL`, and the server SQL mode in effect at the time of its creation; for more information, see Data Type Default Values).

In addition, when the slave's copy of the table has more columns than the master's copy, each column common to the tables must use the same data type in both tables.

Examples. The following examples illustrate some valid and invalid table definitions:

More columns on the master. The following table definitions are valid and replicate correctly:

```
master> CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT);
```

The following table definitions would raise an error because the definitions of the columns common to both versions of the table are in a different order on the slave than they are on the master:

```
master> CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
slave>  CREATE TABLE t1 (c2 INT, c1 INT);
```

The following table definitions would also raise an error because the definition of the extra column on the master appears before the definitions of the columns common to both versions of the table:

```
master> CREATE TABLE t1 (c3 INT, c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT);
```

More columns on the slave. The following table definitions are valid and replicate correctly:

```
master> CREATE TABLE t1 (c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
```

The following definitions raise an error because the columns common to both versions of the table are not defined in the same order on both the master and the slave:

```
master> CREATE TABLE t1 (c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c2 INT, c1 INT, c3 INT);
```

The following table definitions also raise an error because the definition for the extra column in the slave's version of the table appears before the definitions for the columns which are common to both versions of the table:

```
master> CREATE TABLE t1 (c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c3 INT, c1 INT, c2 INT);
```

The following table definitions fail because the slave's version of the table has additional columns compared to the master's version, and the two versions of the table use different data types for the common column `c2`:

```
master> CREATE TABLE t1 (c1 INT, c2 BIGINT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
```

4.1.10.2 Replication of Columns Having Different Data Types

Corresponding columns on the master's and the slave's copies of the same table ideally should have the same data type. However, this is not always strictly enforced, as long as certain conditions are met.

It is usually possible to replicate from a column of a given data type to another column of the same type and same size or width, where applicable, or larger. For example, you can replicate from a `CHAR(10)` column to another `CHAR(10)`, or from a `CHAR(10)` column to a `CHAR(25)` column without any problems. In certain cases, it also possible to replicate from a column having one data type (on the master) to a column having a different data type (on the slave); when the data type of the master's version of the column is promoted to a type that is the same size or larger on the slave, this is known as *attribute promotion*.

Attribute promotion can be used with both statement-based and row-based replication, and is not dependent on the storage engine used by either the master or the slave. However, the choice of logging format does have an effect on the type conversions that are permitted; the particulars are discussed later in this section.

> **Important**
>
> Whether you use statement-based or row-based replication, the slave's copy of the table cannot contain more columns than the master's copy if you wish to employ attribute promotion.

Statement-based replication. When using statement-based replication, a simple rule of thumb to follow is, “If the statement run on the master would also execute successfully on the slave, it should also replicate successfully”. In other words, if the statement uses a value that is compatible with the type of a given column on the slave, the statement can be replicated. For example, you can insert any value that fits in a `TINYINT` column into a `BIGINT` column as well; it follows that, even if you change the type of a `TINYINT` column in the slave's copy of a table to `BIGINT`, any insert into that column on the master that succeeds should also succeed on the slave, since it is impossible to have a legal `TINYINT` value that is large enough to exceed a `BIGINT` column.

Prior to MySQL 5.7.1, when using statement-based replication, `AUTO_INCREMENT` columns were required to be the same on both the master and the slave; otherwise, updates could be applied to the wrong table on the slave. (Bug #12669186)

Row-based replication: attribute promotion and demotion. Row-based replication in MySQL 5.7 supports attribute promotion and demotion between smaller data types and larger types. It is also possible to specify whether or not to permit lossy (truncated) or non-lossy conversions of demoted column values, as explained later in this section.

Lossy and non-lossy conversions. In the event that the target type cannot represent the value being inserted, a decision must be made on how to handle the conversion. If we permit the conversion but truncate (or otherwise modify) the source value to achieve a “fit” in the target column, we make what is known as a *lossy conversion*. A conversion which does not require truncation or similar modifications to fit the source column value in the target column is a *non-lossy* conversion.

Type conversion modes (slave_type_conversions variable). The setting of the `slave_type_conversions` global server variable controls the type conversion mode used on the slave. This variable takes a set of values from the following table, which shows the effects of each mode on the slave's type-conversion behavior:

Mode	Effect
`ALL_LOSSY`	In this mode, type conversions that would mean loss of information are permitted. This does not imply that non-lossy conversions are permitted, merely that only cases requiring either lossy conversions or no conversion at all are permitted; for example, enabling *only* this mode permits an `INT` column to be converted to `TINYINT` (a lossy conversion), but not a `TINYINT` column to an `INT` column (non-lossy). Attempting the latter conversion in this case would cause replication to stop with an error on the slave.
`ALL_NON_LOSSY`	This mode permits conversions that do not require truncation or other special handling of the source value; that is, it permits conversions where the target type has a wider range than the source type. Setting this mode has no bearing on whether lossy conversions are permitted; this is controlled with the `ALL_LOSSY` mode. If only

Mode	Effect
	`ALL_NON_LOSSY` is set, but not `ALL_LOSSY`, then attempting a conversion that would result in the loss of data (such as `INT` to `TINYINT`, or `CHAR(25)` to `VARCHAR(20)`) causes the slave to stop with an error.
`ALL_LOSSY,ALL_NON_LOSSY`	When this mode is set, all supported type conversions are permitted, whether or not they are lossy conversions.
`ALL_SIGNED`	Treat promoted integer types as signed values (the default behavior).
`ALL_UNSIGNED`	Treat promoted integer types as unsigned values.
`ALL_SIGNED,ALL_UNSIGNED`	Treat promoted integer types as signed if possible, otherwise as unsigned.
[*empty*]	When `slave_type_conversions` is not set, no attribute promotion or demotion is permitted; this means that all columns in the source and target tables must be of the same types. This mode is the default.

When an integer type is promoted, its signedness is not preserved. By default, the slave treats all such values as signed. Beginning with MySQL 5.7.2, you can control this behavior using `ALL_SIGNED`, `ALL_UNSIGNED`, or both. (Bug#15831300) `ALL_SIGNED` tells the slave to treat all promoted integer types as signed; `ALL_UNSIGNED` instructs it to treat these as unsigned. Specifying both causes the slave to treat the value as signed if possible, otherwise to treat it as unsigned; the order in which they are listed is not significant. Neither `ALL_SIGNED` nor `ALL_UNSIGNED` has any effect if at least one of `ALL_LOSSY` or `ALL_NONLOSSY` is not also used.

Changing the type conversion mode requires restarting the slave with the new `slave_type_conversions` setting.

Supported conversions. Supported conversions between different but similar data types are shown in the following list:

- Between any of the integer types `TINYINT`, `SMALLINT`, `MEDIUMINT`, `INT`, and `BIGINT`.

  This includes conversions between the signed and unsigned versions of these types.

  Lossy conversions are made by truncating the source value to the maximum (or minimum) permitted by the target column. For ensuring non-lossy conversions when going from unsigned to signed types, the target column must be large enough to accommodate the range of values in the source column. For example, you can demote `TINYINT UNSIGNED` non-lossily to `SMALLINT`, but not to `TINYINT`.

- Between any of the decimal types `DECIMAL`, `FLOAT`, `DOUBLE`, and `NUMERIC`.

  `FLOAT` to `DOUBLE` is a non-lossy conversion; `DOUBLE` to `FLOAT` can only be handled lossily. A conversion from `DECIMAL(M,D)` to `DECIMAL(M',D')` where `D' >= D` and `(M'-D') >= (M-D)` is non-lossy; for any case where `M' < M`, `D' < D`, or both, only a lossy conversion can be made.

  For any of the decimal types, if a value to be stored cannot be fit in the target type, the value is rounded down according to the rounding rules defined for the server elsewhere in the documentation. See Rounding Behavior, for information about how this is done for decimal types.

- Between any of the string types `CHAR`, `VARCHAR`, and `TEXT`, including conversions between different widths.

Conversion of a `CHAR`, `VARCHAR`, or `TEXT` to a `CHAR`, `VARCHAR`, or `TEXT` column the same size or larger is never lossy. Lossy conversion is handled by inserting only the first *`N`* characters of the string on the slave, where *`N`* is the width of the target column.

> **Important**
>
> Replication between columns using different character sets is not supported.

- Between any of the binary data types `BINARY`, `VARBINARY`, and `BLOB`, including conversions between different widths.

  Conversion of a `BINARY`, `VARBINARY`, or `BLOB` to a `BINARY`, `VARBINARY`, or `BLOB` column the same size or larger is never lossy. Lossy conversion is handled by inserting only the first *`N`* bytes of the string on the slave, where *`N`* is the width of the target column.

- Between any 2 `BIT` columns of any 2 sizes.

  When inserting a value from a `BIT(M)` column into a `BIT(M')` column, where `M' > M`, the most significant bits of the `BIT(M')` columns are cleared (set to zero) and the *`M`* bits of the `BIT(M)` value are set as the least significant bits of the `BIT(M')` column.

  When inserting a value from a source `BIT(M)` column into a target `BIT(M')` column, where `M' < M`, the maximum possible value for the `BIT(M')` column is assigned; in other words, an “all-set” value is assigned to the target column.

Conversions between types not in the previous list are not permitted.

4.1.11 Replication and DIRECTORY Table Options

If a `DATA DIRECTORY` or `INDEX DIRECTORY` table option is used in a `CREATE TABLE` statement on the master server, the table option is also used on the slave. This can cause problems if no corresponding directory exists in the slave host file system or if it exists but is not accessible to the slave server. This can be overridden by using the `NO_DIR_IN_CREATE` server SQL mode on the slave, which causes the slave to ignore the `DATA DIRECTORY` and `INDEX DIRECTORY` table options when replicating `CREATE TABLE` statements. The result is that `MyISAM` data and index files are created in the table's database directory.

For more information, see Server SQL Modes.

4.1.12 Replication of Invoked Features

Replication of invoked features such as user-defined functions (UDFs) and stored programs (stored procedures and functions, triggers, and events) provides the following characteristics:

- The effects of the feature are always replicated.

- The following statements are replicated using statement-based replication:

  - `CREATE EVENT`
  - `ALTER EVENT`
  - `DROP EVENT`
  - `CREATE PROCEDURE`
  - `DROP PROCEDURE`

  - CREATE FUNCTION
  - DROP FUNCTION
  - CREATE TRIGGER
  - DROP TRIGGER

  However, the *effects* of features created, modified, or dropped using these statements are replicated using row-based replication.

  > **Note**
  >
  > Attempting to replicate invoked features using statement-based replication produces the warning Statement is not safe to log in statement format. For example, trying to replicate a UDF with statement-based replication generates this warning because it currently cannot be determined by the MySQL server whether the UDF is deterministic. If you are absolutely certain that the invoked feature's effects are deterministic, you can safely disregard such warnings.

- In the case of CREATE EVENT and ALTER EVENT:

  - The status of the event is set to SLAVESIDE_DISABLED on the slave regardless of the state specified (this does not apply to DROP EVENT).
  - The master on which the event was created is identified on the slave by its server ID. The ORIGINATOR column in INFORMATION_SCHEMA.EVENTS and the originator column in mysql.event store this information. See The INFORMATION_SCHEMA EVENTS Table, and SHOW EVENTS Syntax, for more information.

- The feature implementation resides on the slave in a renewable state so that if the master fails, the slave can be used as the master without loss of event processing.

To determine whether there are any scheduled events on a MySQL server that were created on a different server (that was acting as a replication master), query the INFORMATION_SCHEMA.EVENTS table in a manner similar to what is shown here:

```
SELECT EVENT_SCHEMA, EVENT_NAME
    FROM INFORMATION_SCHEMA.EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED';
```

Alternatively, you can use the SHOW EVENTS statement, like this:

```
SHOW EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED';
```

When promoting a replication slave having such events to a replication master, you must enable each event using ALTER EVENT *event_name* ENABLE, where *event_name* is the name of the event.

If more than one master was involved in creating events on this slave, and you wish to identify events that were created only on a given master having the server ID *master_id*, modify the previous query on the EVENTS table to include the ORIGINATOR column, as shown here:

```
SELECT EVENT_SCHEMA, EVENT_NAME, ORIGINATOR
```

```
    FROM INFORMATION_SCHEMA.EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED'
    AND   ORIGINATOR = 'master_id'
```

You can employ `ORIGINATOR` with the `SHOW EVENTS` statement in a similar fashion:

```
SHOW EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED'
    AND   ORIGINATOR = 'master_id'
```

Before enabling events that were replicated from the master, you should disable the MySQL Event Scheduler on the slave (using a statement such as `SET GLOBAL event_scheduler = OFF;`), run any necessary `ALTER EVENT` statements, restart the server, then re-enable the Event Scheduler on the slave afterward (using a statement such as `SET GLOBAL event_scheduler = ON;`)-

If you later demote the new master back to being a replication slave, you must disable manually all events enabled by the `ALTER EVENT` statements. You can do this by storing in a separate table the event names from the `SELECT` statement shown previously, or using `ALTER EVENT` statements to rename the events with a common prefix such as `replicated_` to identify them.

If you rename the events, then when demoting this server back to being a replication slave, you can identify the events by querying the `EVENTS` table, as shown here:

```
SELECT CONCAT(EVENT_SCHEMA, '.', EVENT_NAME) AS 'Db.Event'
      FROM INFORMATION_SCHEMA.EVENTS
      WHERE INSTR(EVENT_NAME, 'replicated_') = 1;
```

4.1.13 Replication and Floating-Point Values

With statement-based replication, values are converted from decimal to binary. Because conversions between decimal and binary representations of them may be approximate, comparisons involving floating-point values are inexact. This is true for operations that use floating-point values explicitly, or that use values that are converted to floating-point implicitly. Comparisons of floating-point values might yield different results on master and slave servers due to differences in computer architecture, the compiler used to build MySQL, and so forth. See Type Conversion in Expression Evaluation, and Problems with Floating-Point Values.

4.1.14 Replication and Fractional Seconds Support

MySQL 5.7 permits fractional seconds for `TIME`, `DATETIME`, and `TIMESTAMP` values, with up to microseconds (6 digits) precision. See Fractional Seconds in Time Values.

There may be problems replicating from a master server that understands fractional seconds to an older slave (MySQL 5.6.3 and earlier) that does not:

- For `CREATE TABLE` statements containing columns that have an *`fsp`* (fractional seconds precision) value greater than 0, replication will fail due to parser errors.

- Statements that use temporal data types with an *`fsp`* value of 0 will work for with statement-based logging but not row-based logging. In the latter case, the data types have binary formats and type codes on the master that differ from those on the slave.

- Some expression results will differ on master and slave. Examples: On the master, the `timestamp` system variable returns a value that includes a microseconds fractional part; on the slave, it returns an integer. On the master, functions that return a result that includes the current time (such as `CURTIME()`, SYSDATE(), or UTC_TIMESTAMP()) interpret an argument as an *fsp* value and the return value includes a fractional seconds part of that many digits. On the slave, these functions permit an argument but ignore it.

4.1.15 Replication and FLUSH

Some forms of the FLUSH statement are not logged because they could cause problems if replicated to a slave: FLUSH LOGS, FLUSH MASTER, FLUSH SLAVE, and FLUSH TABLES WITH READ LOCK. For a syntax example, see FLUSH Syntax. The FLUSH TABLES, ANALYZE TABLE, OPTIMIZE TABLE, and REPAIR TABLE statements are written to the binary log and thus replicated to slaves. This is not normally a problem because these statements do not modify table data.

However, this behavior can cause difficulties under certain circumstances. If you replicate the privilege tables in the mysql database and update those tables directly without using GRANT, you must issue a FLUSH PRIVILEGES on the slaves to put the new privileges into effect. In addition, if you use FLUSH TABLES when renaming a MyISAM table that is part of a MERGE table, you must issue FLUSH TABLES manually on the slaves. These statements are written to the binary log unless you specify NO_WRITE_TO_BINLOG or its alias LOCAL.

4.1.16 Replication and System Functions

Certain functions do not replicate well under some conditions:

- The USER(), CURRENT_USER() (or CURRENT_USER), UUID(), VERSION(), and LOAD_FILE() functions are replicated without change and thus do not work reliably on the slave unless row-based replication is enabled. (See Section 5.1, “Replication Formats”.)

  USER() and CURRENT_USER() are automatically replicated using row-based replication when using MIXED mode, and generate a warning in STATEMENT mode. (See also Section 4.1.8, “Replication of CURRENT_USER()”.) This is also true for VERSION() and RAND().

- For NOW(), the binary log includes the timestamp. This means that the value *as returned by the call to this function on the master* is replicated to the slave. To avoid unexpected results when replicating between MySQL servers in different time zones, set the time zone on both master and slave. See also Section 4.1.32, “Replication and Time Zones”

  To explain the potential problems when replicating between servers which are in different time zones, suppose that the master is located in New York, the slave is located in Stockholm, and both servers are using local time. Suppose further that, on the master, you create a table mytable, perform an INSERT statement on this table, and then select from the table, as shown here:

  ```
  mysql> CREATE TABLE mytable (mycol TEXT);
  Query OK, 0 rows affected (0.06 sec)
  mysql> INSERT INTO mytable VALUES ( NOW() );
  Query OK, 1 row affected (0.00 sec)
  mysql> SELECT * FROM mytable;
  +---------------------+
  | mycol               |
  +---------------------+
  | 2009-09-01 12:00:00 |
  +---------------------+
  1 row in set (0.00 sec)
  ```

  Local time in Stockholm is 6 hours later than in New York; so, if you issue SELECT NOW() on the slave at that exact same instant, the value 2009-09-01 18:00:00 is returned. For this reason, if you select from the slave's copy of mytable after the CREATE TABLE and INSERT statements just shown have been replicated, you might expect `mycol` to contain the value `2009-09-01 18:00:00`. However, this is not the case; when you select from the slave's copy of `mytable`, you obtain exactly the same result as on the master:

```
mysql> SELECT * FROM mytable;
+---------------------+
| mycol               |
+---------------------+
| 2009-09-01 12:00:00 |
+---------------------+
1 row in set (0.00 sec)
```

Unlike `NOW()`, the `SYSDATE()` function is not replication-safe because it is not affected by `SET TIMESTAMP` statements in the binary log and is nondeterministic if statement-based logging is used. This is not a problem if row-based logging is used.

An alternative is to use the `--sysdate-is-now` option to cause `SYSDATE()` to be an alias for `NOW()`. This must be done on the master and the slave to work correctly. In such cases, a warning is still issued by this function, but can safely be ignored as long as `--sysdate-is-now` is used on both the master and the slave.

`SYSDATE()` is automatically replicated using row-based replication when using `MIXED` mode, and generates a warning in `STATEMENT` mode.

See also Section 4.1.32, "Replication and Time Zones".

- *The following restriction applies to statement-based replication only, not to row-based replication.* The `GET_LOCK()`, `RELEASE_LOCK()`, `IS_FREE_LOCK()`, and `IS_USED_LOCK()` functions that handle user-level locks are replicated without the slave knowing the concurrency context on the master. Therefore, these functions should not be used to insert into a master table because the content on the slave would differ. For example, do not issue a statement such as `INSERT INTO mytable VALUES(GET_LOCK(...))`.

  These functions are automatically replicated using row-based replication when using `MIXED` mode, and generate a warning in `STATEMENT` mode.

As a workaround for the preceding limitations when statement-based replication is in effect, you can use the strategy of saving the problematic function result in a user variable and referring to the variable in a later statement. For example, the following single-row `INSERT` is problematic due to the reference to the `UUID()` function:

```
INSERT INTO t VALUES(UUID());
```

To work around the problem, do this instead:

```
SET @my_uuid = UUID();
INSERT INTO t VALUES(@my_uuid);
```

That sequence of statements replicates because the value of `@my_uuid` is stored in the binary log as a user-variable event prior to the `INSERT` statement and is available for use in the `INSERT`.

The same idea applies to multiple-row inserts, but is more cumbersome to use. For a two-row insert, you can do this:

```
SET @my_uuid1 = UUID(); @my_uuid2 = UUID();
INSERT INTO t VALUES(@my_uuid1),(@my_uuid2);
```

However, if the number of rows is large or unknown, the workaround is difficult or impracticable. For example, you cannot convert the following statement to one in which a given individual user variable is associated with each row:

```
INSERT INTO t2 SELECT UUID(), * FROM t1;
```

Within a stored function, `RAND()` replicates correctly as long as it is invoked only once during the execution of the function. (You can consider the function execution timestamp and random number seed as implicit inputs that are identical on the master and slave.)

The `FOUND_ROWS()` and `ROW_COUNT()` functions are not replicated reliably using statement-based replication. A workaround is to store the result of the function call in a user variable, and then use that in the `INSERT` statement. For example, if you wish to store the result in a table named `mytable`, you might normally do so like this:

```
SELECT SQL_CALC_FOUND_ROWS FROM mytable LIMIT 1;
INSERT INTO mytable VALUES( FOUND_ROWS() );
```

However, if you are replicating `mytable`, you should use `SELECT ... INTO`, and then store the variable in the table, like this:

```
SELECT SQL_CALC_FOUND_ROWS INTO @found_rows FROM mytable LIMIT 1;
INSERT INTO mytable VALUES(@found_rows);
```

In this way, the user variable is replicated as part of the context, and applied on the slave correctly.

These functions are automatically replicated using row-based replication when using `MIXED` mode, and generate a warning in `STATEMENT` mode. (Bug #12092, Bug #30244)

Prior to MySQL 5.7.3, the value of `LAST_INSERT_ID()` was not replicated correctly if any filtering options such as `--replicate-ignore-db` and `--replicate-do-table` were enabled on the slave. (Bug #17234370, BUG# 69861)

4.1.17 Replication and LIMIT

Statement-based replication of `LIMIT` clauses in `DELETE`, `UPDATE`, and `INSERT ... SELECT` statements is unsafe since the order of the rows affected is not defined. (Such statements can be replicated correctly with statement-based replication only if they also contain an `ORDER BY` clause.) When such a statement is encountered:

- When using `STATEMENT` mode, a warning that the statement is not safe for statement-based replication is now issued.

  When using `STATEMENT` mode, warnings are issued for DML statements containing `LIMIT` even when they also have an `ORDER BY` clause (and so are made deterministic). This is a known issue. (Bug #42851)

- When using `MIXED` mode, the statement is now automatically replicated using row-based mode.

4.1.18 Replication and LOAD DATA INFILE

In MySQL 5.7, `LOAD DATA INFILE` is considered unsafe (see Section 5.1.3, “Determination of Safe and Unsafe Statements in Binary Logging”). It causes a warning when using statement-based logging format, and is logged using row-based format when using mixed-format logging.

4.1.19 Replication and Partitioning

Replication is supported between partitioned tables as long as they use the same partitioning scheme and otherwise have the same structure except where an exception is specifically allowed (see Section 4.1.10, “Replication with Differing Table Definitions on Master and Slave”).

Replication between tables having different partitioning is generally not supported. This because statements (such as `ALTER TABLE ... DROP PARTITION`) acting directly on partitions in such cases may produce different results on master and slave. In the case where a table is partitioned on the master but not on the slave, any statements operating on partitions on the master's copy of the slave fail on the slave. When the slave's copy of the table is partitioned but the master's copy is not, statements acting on partitions cannot be run on the master without causing errors there.

Due to these dangers of causing replication to fail entirely (on account of failed statements) and of inconsistencies (when the result of a partition-level SQL statement produces different results on master and slave), we recommend that insure that the partitioning of any tables to be replicated from the master is matched by the slave's versions of these tables.

4.1.20 Replication and REPAIR TABLE

When used on a corrupted or otherwise damaged table, it is possible for the `REPAIR TABLE` statement to delete rows that cannot be recovered. However, any such modifications of table data performed by this statement are not replicated, which can cause master and slave to lose synchronization. For this reason, in the event that a table on the master becomes damaged and you use `REPAIR TABLE` to repair it, you should first stop replication (if it is still running) before using `REPAIR TABLE`, then afterward compare the master's and slave's copies of the table and be prepared to correct any discrepancies manually, before restarting replication.

4.1.21 Replication and Master or Slave Shutdowns

It is safe to shut down a master server and restart it later. When a slave loses its connection to the master, the slave tries to reconnect immediately and retries periodically if that fails. The default is to retry every 60 seconds. This may be changed with the `CHANGE MASTER TO` statement. A slave also is able to deal with network connectivity outages. However, the slave notices the network outage only after receiving no data from the master for `slave_net_timeout` seconds. If your outages are short, you may want to decrease `slave_net_timeout`. See Server System Variables.

An unclean shutdown (for example, a crash) on the master side can result in the master binary log having a final position less than the most recent position read by the slave, due to the master binary log file not being flushed. This can cause the slave not to be able to replicate when the master comes back up. Setting `sync_binlog=1` in the master `my.cnf` file helps to minimize this problem because it causes the master to flush its binary log more frequently.

Shutting down a slave cleanly is safe because it keeps track of where it left off. However, be careful that the slave does not have temporary tables open; see Section 4.1.24, “Replication and Temporary Tables”. Unclean shutdowns might produce problems, especially if the disk cache was not flushed to disk before the problem occurred:

- For transactions, the slave commits and then updates `relay-log.info`. If a crash occurs between these two operations, relay log processing will have proceeded further than the information file indicates and the slave will re-execute the events from the last transaction in the relay log after it has been restarted.

- A similar problem can occur if the slave updates `relay-log.info` but the server host crashes before the write has been flushed to disk. To minimize the chance of this occurring, set sync_relay_log_info=1 in the slave my.cnf file. The default value of sync_relay_log_info is 0, which does not cause writes to be forced to disk; the server relies on the operating system to flush the file from time to time.

The fault tolerance of your system for these types of problems is greatly increased if you have a good uninterruptible power supply.

4.1.22 Replication and max_allowed_packet

max_allowed_packet sets an upper limit on the size of any single message between the MySQL server and clients, including replication slaves. If you are replicating large column values (such as might be found in TEXT or BLOB columns) and max_allowed_packet is too small on the master, the master fails with an error, and the slave shuts down the I/O thread. If max_allowed_packet is too small on the slave, this also causes the slave to stop the I/O thread.

Row-based replication currently sends all columns and column values for updated rows from the master to the slave, including values of columns that were not actually changed by the update. This means that, when you are replicating large column values using row-based replication, you must take care to set max_allowed_packet large enough to accommodate the largest row in any table to be replicated, even if you are replicating updates only, or you are inserting only relatively small values.

4.1.23 Replication and MEMORY Tables

When a master server shuts down and restarts, its MEMORY tables become empty. To replicate this effect to slaves, the first time that the master uses a given MEMORY table after startup, it logs an event that notifies slaves that the table must to be emptied by writing a DELETE statement for that table to the binary log.

When a slave server shuts down and restarts, its MEMORY tables become empty. This causes the slave to be out of synchrony with the master and may lead to other failures or cause the slave to stop:

- Row-format updates and deletes received from the master may fail with Can't find record in '*memory_table*'.
- Statements such as INSERT INTO ... SELECT FROM *memory_table* may insert a different set of rows on the master and slave.

The safe way to restart a slave that is replicating MEMORY tables is to first drop or delete all rows from the MEMORY tables on the master and wait until those changes have replicated to the slave. Then it is safe to restart the slave.

An alternative restart method may apply in some cases. When binlog_format=ROW, you can prevent the slave from stopping if you set slave_exec_mode=IDEMPOTENT before you start the slave again. This allows the slave to continue to replicate, but its MEMORY tables will still be different from those on the master. This can be okay if the application logic is such that the contents of MEMORY tables can be safely lost (for example, if the MEMORY tables are used for caching). slave_exec_mode=IDEMPOTENT applies globally to all tables, so it may hide other replication errors in non-MEMORY tables.

(The method just described is not applicable in MySQL Cluster, where slave_exec_mode is always IDEMPOTENT, and cannot be changed.)

The size of MEMORY tables is limited by the value of the max_heap_table_size system variable, which is not replicated (see Section 4.1.38, “Replication and Variables”). A change in max_heap_table_size takes effect for MEMORY tables that are created or updated using ALTER TABLE ... ENGINE = MEMORY or TRUNCATE TABLE following the change, or for all MEMORY tables following a server restart. If you increase the value of this variable on the master without doing so on the slave, it becomes possible for a table on the master to grow larger than its counterpart on the slave, leading to inserts that succeed on the master but fail on the slave with `Table is full` errors. This is a known issue (Bug #48666). In such cases, you must set the global value of `max_heap_table_size` on the slave as well as on the master, then restart replication. It is also recommended that you restart both the master and slave MySQL servers, to insure that the new value takes complete (global) effect on each of them.

See The MEMORY Storage Engine, for more information about `MEMORY` tables.

4.1.24 Replication and Temporary Tables

The discussion in the following paragraphs does not apply when `binlog_format=ROW` because, in that case, temporary tables are not replicated; this means that there are never any temporary tables on the slave to be lost in the event of an unplanned shutdown by the slave. The remainder of this section applies only when using statement-based or mixed-format replication. Loss of replicated temporary tables on the slave can be an issue, whenever `binlog_format` is `STATEMENT` or `MIXED`, for statements involving temporary tables that can be logged safely using statement-based format. For more information about row-based replication and temporary tables, see Row-based logging of temporary tables.

Safe slave shutdown when using temporary tables. Temporary tables are replicated except in the case where you stop the slave server (not just the slave threads) and you have replicated temporary tables that are open for use in updates that have not yet been executed on the slave. If you stop the slave server, the temporary tables needed by those updates are no longer available when the slave is restarted. To avoid this problem, do not shut down the slave while it has temporary tables open. Instead, use the following procedure:

1. Issue a `STOP SLAVE SQL_THREAD` statement.
2. Use `SHOW STATUS` to check the value of the `Slave_open_temp_tables` variable.
3. If the value is not 0, restart the slave SQL thread with `START SLAVE SQL_THREAD` and repeat the procedure later.
4. When the value is 0, issue a `mysqladmin shutdown` command to stop the slave.

Temporary tables and replication options. By default, all temporary tables are replicated; this happens whether or not there are any matching `--replicate-do-db`, `--replicate-do-table`, or `--replicate-wild-do-table` options in effect. However, the `--replicate-ignore-table` and `--replicate-wild-ignore-table` options are honored for temporary tables.

A recommended practice when using statement-based or mixed-format replication is to designate a prefix for exclusive use in naming temporary tables that you do not want replicated, then employ a `--replicate-wild-ignore-table` option to match that prefix. For example, you might give all such tables names beginning with `norep` (such as `norepmytable`, `norepyourtable`, and so on), then use `--replicate-wild-ignore-table=norep%` to prevent them from being replicated.

4.1.25 Replication of the mysql System Database

Data modification statements made to tables in the `mysql` database are replicated according to the value of `binlog_format`; if this value is `MIXED`, these statements are replicated using row-based format. However, statements that would normally update this information indirectly—such `GRANT`, `REVOKE`, and statements manipulating triggers, stored routines, and views—are replicated to slaves using statement-based replication.

4.1.26 Replication and the Query Optimizer

It is possible for the data on the master and slave to become different if a statement is written in such a way that the data modification is nondeterministic; that is, left up the query optimizer. (In general, this is not a good practice, even outside of replication.) Examples of nondeterministic statements include `DELETE` or `UPDATE` statements that use `LIMIT` with no `ORDER BY` clause; see Section 4.1.17, “Replication and LIMIT”, for a detailed discussion of these.

4.1.27 Replication and Reserved Words

You can encounter problems when you attempt to replicate from an older master to a newer slave and you make use of identifiers on the master that are reserved words in the newer MySQL version running on the slave. An example of this is using a table column named `virtual` on a 5.6 master that is replicating to a 5.7 or higher slave because `VIRTUAL` is a reserved word beginning in MySQL 5.7. Replication can fail in such cases with Error 1064 `You have an error in your SQL syntax...`, *even if a database or table named using the reserved word or a table having a column named using the reserved word is excluded from replication*. This is due to the fact that each SQL event must be parsed by the slave prior to execution, so that the slave knows which database object or objects would be affected; only after the event is parsed can the slave apply any filtering rules defined by `--replicate-do-db`, `--replicate-do-table`, `--replicate-ignore-db`, and `--replicate-ignore-table`.

To work around the problem of database, table, or column names on the master which would be regarded as reserved words by the slave, do one of the following:

- Use one or more `ALTER TABLE` statements on the master to change the names of any database objects where these names would be considered reserved words on the slave, and change any SQL statements that use the old names to use the new names instead.

- In any SQL statements using these database object names, write the names as quoted identifiers using backtick characters (`` ` ``).

For listings of reserved words by MySQL version, see Reserved Words, in the *MySQL Server Version Reference*. For identifier quoting rules, see Schema Object Names.

4.1.28 Slave Errors During Replication

If a statement produces the same error (identical error code) on both the master and the slave, the error is logged, but replication continues.

If a statement produces different errors on the master and the slave, the slave SQL thread terminates, and the slave writes a message to its error log and waits for the database administrator to decide what to do about the error. This includes the case that a statement produces an error on the master or the slave, but not both. To address the issue, connect to the slave manually and determine the cause of the problem. `SHOW SLAVE STATUS` is useful for this. Then fix the problem and run `START SLAVE`. For example, you might need to create a nonexistent table before you can start the slave again.

If this error code validation behavior is not desirable, some or all errors can be masked out (ignored) with the `--slave-skip-errors` option.

For nontransactional storage engines such as `MyISAM`, it is possible to have a statement that only partially updates a table and returns an error code. This can happen, for example, on a multiple-row insert that has one row violating a key constraint, or if a long update statement is killed after updating some of the rows. If that happens on the master, the slave expects execution of the statement to result in the same error code. If it does not, the slave SQL thread stops as described previously.

If you are replicating between tables that use different storage engines on the master and slave, keep in mind that the same statement might produce a different error when run against one version of the table, but not the other, or might cause an error for one version of the table, but not the other. For example, since `MyISAM` ignores foreign key constraints, an `INSERT` or `UPDATE` statement accessing an `InnoDB` table on the master might cause a foreign key violation but the same statement performed on a `MyISAM` version of the same table on the slave would produce no such error, causing replication to stop.

4.1.29 Replication of Server-Side Help Tables

The server maintains tables in the `mysql` database that store information for the `HELP` statement (see HELP Syntax. These tables can be loaded manually as described at Server-Side Help.

Help table content is derived from the MySQL Reference Manual. There are versions of the manual specific to each MySQL release series, so help content is specific to each series as well. Normally, you load a version of help content that matches the server version. This has implications for replication. For example, you would load MySQL 5.6 help content into a MySQL 5.6 master server, but not necessarily replicate that content to a MySQL 5.7 slave server for which 5.7 help content is more appropriate.

This section describes how to manage help table content upgrades when your servers participate in replication. Server versions are one factor in this task. Another is that the help table structure may differ between the master and the slave.

Assume that help content is stored in a file named `fill_help_tables.sql`. In MySQL distributions, this file is located under the `share` or `share/mysql` directory, and the most recent version is always available for download from http://dev.mysql.com/doc/index-other.html.

To upgrade help tables, using the following procedure. Connection parameters are not shown for the `mysql` commands discussed here; in all cases, connect to the server using an account such as `root` that has privileges for modifying tables in the `mysql` database.

1. Upgrade your servers by running `mysql_upgrade`, first on the slaves and then on the master. This is the usual principle of upgrading slaves first.

2. Decide whether you want to replicate help table content from the master to its slaves. If not, load the content on the master and each slave individually. Otherwise, check for and resolve any incompatibilities between help table structure on the master and its slaves, then load the content into the master and let it replicate to the slaves.

   More detail about these two methods of loading help table content follows.

Loading Help Table Content Without Replication to Slaves

To load help table content without replication, run this command on the master and each slave individually, using a `fill_help_tables.sql` file containing content appropriate to the server version (enter the command on one line):

```
mysql --init-command="SET sql_log_bin=0"
  mysql < fill_help_tables.sql
```

Use the `--init-command` option on each server, including the slaves, in case a slave also acts as a master to other slaves in your replication topology. The `SET` statement suppresses binary logging. After the command has been run on each server to be upgraded, you are done.

> **Note**
>
> As of MySQL 5.7.5, the `fill_help_tables.sql` file includes the `SET` statement to cause the file contents not to replicate. Thus, for 5.7.5 and higher, the command is simpler:

```
mysql mysql < fill_help_tables.sql
```

Loading Help Table Content With Replication to Slaves

Note

As mentioned previously, `fill_help_tables.sql` in MySQL 5.7.5 and up includes a `SET` statement to suppress binary logging of the file contents. If you want to replicate help table contents for MySQL 5.7.5 or later, you must edit `fill_help_tables.sql` to remove the `SET` statement. This should rarely be desireable because help table contents are specific to the version of the server into which they are loaded, which may differ for master and slave.

If you do want to replicate help table content, check for help table incompatibilities between your master and its slaves. The `url` column in the `help_category` and `help_topic` tables was originally `CHAR(128)`, but is `TEXT` in newer MySQL versions to accommodate longer URLs. To check help table structure, use this statement:

```
SELECT TABLE_NAME, COLUMN_NAME, COLUMN_TYPE
FROM INFORMATION_SCHEMA.COLUMNS
WHERE TABLE_SCHEMA = 'mysql'
AND COLUMN_NAME = 'url';
```

For tables with the old structure, the statement produces this result:

```
+---------------+-------------+-------------+
| TABLE_NAME    | COLUMN_NAME | COLUMN_TYPE |
+---------------+-------------+-------------+
| help_category | url         | char(128)   |
| help_topic    | url         | char(128)   |
+---------------+-------------+-------------+
```

For tables with the new structure, the statement produces this result:

```
+---------------+-------------+-------------+
| TABLE_NAME    | COLUMN_NAME | COLUMN_TYPE |
+---------------+-------------+-------------+
| help_category | url         | text        |
| help_topic    | url         | text        |
+---------------+-------------+-------------+
```

If the master and slave both have the old structure or both have the new structure, they are compatible and you can replicate help table content by executing this command on the master:

```
mysql mysql < fill_help_tables.sql
```

The table content will load into the master, then replicate to the slaves.

If the master and slave have incompatible help tables (one server has the old structure and the other has the new), you have a choice between not replicating help table content after all, or making the table structures compatible so that you can replicate the content.

- If you decide not to replicate the content after all, upgrade the master and slaves individually using `mysql` with the `--init-command` option, as described previously.
- If instead you decide to make the table structures compatible, upgrade the tables on the server that has the old structure. Suppose that your master server has the old table structure. Upgrade its tables to

the new structure manually by executing these statements (binary logging is disabled here to prevent replication of the changes to the slaves, which already have the new structure):

```
SET sql_log_bin=0;
ALTER TABLE mysql.help_category ALTER COLUMN url TEXT;
ALTER TABLE mysql.help_topic ALTER COLUMN url TEXT;
```

Then run this command on the master:

```
mysql mysql < fill_help_tables.sql
```

The table content will load into the master, then replicate to the slaves.

4.1.30 Replication and Server SQL Mode

Using different server SQL mode settings on the master and the slave may cause the same `INSERT` statements to be handled differently on the master and the slave, leading the master and slave to diverge. For best results, you should always use the same server SQL mode on the master and on the slave. This advice applies whether you are using statement-based or row-based replication.

If you are replicating partitioned tables, using different SQL modes on the master and the slave is likely to cause issues. At a minimum, this is likely to cause the distribution of data among partitions to be different in the master's and slave's copies of a given table. It may also cause inserts into partitioned tables that succeed on the master to fail on the slave.

For more information, see Server SQL Modes. In particular, see SQL Mode Changes in MySQL 5.7, which describes changes in MySQL 5.7 so that you can assess whether your applications will be affected.

4.1.31 Replication Retries and Timeouts

The global system variable `slave_transaction_retries` affects replication as follows: If the slave SQL thread fails to execute a transaction because of an `InnoDB` deadlock or because it exceeded the `InnoDB` `innodb_lock_wait_timeout` value, or the `NDB` `TransactionDeadlockDetectionTimeout` or `TransactionInactiveTimeout` value, the slave automatically retries the transaction `slave_transaction_retries` times before stopping with an error. The default value is 10. The total retry count can be seen in the output of `SHOW STATUS`; see Server Status Variables.

4.1.32 Replication and Time Zones

By default, master and slave servers assume that they are in the same time zone. If you are replicating between servers in different time zones, the time zone must be set on both master and slave. Otherwise, statements depending on the local time on the master are not replicated properly, such as statements that use the `NOW()` or `FROM_UNIXTIME()` functions. Set the time zone in which MySQL server runs by using the `--timezone=`*`timezone_name`* option of the `mysqld_safe` script or by setting the `TZ` environment variable. See also Section 4.1.16, “Replication and System Functions”.

4.1.33 Replication and Transactions

Mixing transactional and nontransactional statements within the same transaction. In general, you should avoid transactions that update both transactional and nontransactional tables in a replication environment. You should also avoid using any statement that accesses both transactional (or temporary) and nontransactional tables and writes to any of them.

The server uses these rules for binary logging:

- If the initial statements in a transaction are nontransactional, they are written to the binary log immediately. The remaining statements in the transaction are cached and not written to the binary log until the transaction is committed. (If the transaction is rolled back, the cached statements are written to the binary log only if they make nontransactional changes that cannot be rolled back. Otherwise, they are discarded.)

- For statement-based logging, logging of nontransactional statements is affected by the `binlog_direct_non_transactional_updates` system variable. When this variable is `OFF` (the default), logging is as just described. When this variable is `ON`, logging occurs immediately for nontransactional statements occurring anywhere in the transaction (not just initial nontransactional statements). Other statements are kept in the transaction cache and logged when the transaction commits. `binlog_direct_non_transactional_updates` has no effect for row-format or mixed-format binary logging.

Transactional, nontransactional, and mixed statements.
To apply those rules, the server considers a statement nontransactional if it changes only nontransactional tables, and transactional if it changes only transactional tables. In MySQL 5.7, a statement that references both nontransactional and transactional tables and updates *any* of the tables involved, is considered a “mixed” statement. (In previous MySQL release series, a statement that changed both nontransactional and transactional tables was considered mixed.) Mixed statements, like transactional statements, are cached and logged when the transaction commits.

A mixed statement that updates a transactional table is considered unsafe if the statement also performs either of the following actions:

- Updates or reads a transactional table

- Reads a nontransactional table and the transaction isolation level is less than REPEATABLE_READ

A mixed statement following the update of a transactional table within a transaction is considered unsafe if it performs either of the following actions:

- Updates any table and reads from any temporary table

- Updates a nontransactional table and binlog_direct_non_trans_update is OFF

For more information, see Section 5.1.3, “Determination of Safe and Unsafe Statements in Binary Logging”.

> **Note**
>
> A mixed statement is unrelated to mixed binary logging format.

In situations where transactions mix updates to transactional and nontransactional tables, the order of statements in the binary log is correct, and all needed statements are written to the binary log even in case of a `ROLLBACK`. However, when a second connection updates the nontransactional table before the first connection transaction is complete, statements can be logged out of order because the second connection update is written immediately after it is performed, regardless of the state of the transaction being performed by the first connection.

Using different storage engines on master and slave. It is possible to replicate transactional tables on the master using nontransactional tables on the slave. For example, you can replicate an `InnoDB` master table as a `MyISAM` slave table. However, if you do this, there are problems if the slave is stopped in the middle of a `BEGIN` ... `COMMIT` block because the slave restarts at the beginning of the `BEGIN` block.

In MySQL 5.7, it is also safe to replicate transactions from `MyISAM` tables on the master to transactional tables—such as tables that use the `InnoDB` storage engine—on the slave. In such cases, an

AUTOCOMMIT=1 statement issued on the master is replicated, thus enforcing AUTOCOMMIT mode on the slave.

When the storage engine type of the slave is nontransactional, transactions on the master that mix updates of transactional and nontransactional tables should be avoided because they can cause inconsistency of the data between the master transactional table and the slave nontransactional table. That is, such transactions can lead to master storage engine-specific behavior with the possible effect of replication going out of synchrony. MySQL does not issue a warning about this currently, so extra care should be taken when replicating transactional tables from the master to nontransactional tables on the slaves.

Changing the binary logging format within transactions. The binlog_format system variable is read-only as long as a transaction is in progress.

Every transaction (including autocommit transactions) is recorded in the binary log as though it starts with a BEGIN statement, and ends with either a COMMIT or a ROLLBACK statement. In MySQL 5.7, this true is even for statements affecting tables that use a nontransactional storage engine (such as MyISAM).

4.1.34 Replication and Transaction Inconsistencies

Inconsistencies in the sequence of transactions that have been executed from the relay log can occur depending on your replication configuration. This section explains how to avoid inconsistencies and solve any problems they cause.

The following types of inconsistencies can exist:

- *Half-applied transactions*. A transaction which updates non-transactional tables has applied some but not all of its changes.
- *Gaps*. A gap is a transaction that has not been (fully) applied, even though some later transaction has been applied. Gaps can only appear when using a multi-threaded slave. To avoid gaps occurring, set slave_preserve_commit_order=1, which requires slave_parallel_type=LOGICAL_CLOCK, and that log-bin and log-slave-updates are also enabled.
- *Gap-free low-watermark position*. Even in the absence of gaps, it is possible that transactions after Exec_master_log_pos have not been applied. That is, all transactions up to point N have been applied, and no transactions after N have been applied, but Exec_master_log_pos has a value smaller than N. This can only happen on multi-threaded slaves. Enabling slave_preserve_commit_order does *not* prevent gap-free low-watermark positions.

The following scenarios are relevant to the existence of half-applied transactions, gaps, and gap-free low-watermark position inconsistencies:

1. While slave threads are running, there may be gaps and half-applied transactions.
2. mysqld shuts down. Both clean and unclean shutdown abort ongoing transactions and may leave gaps and half-applied transactions.
3. KILL of replication threads (the SQL thread when using a single-threaded slave, the coordinator thread when using a multi-threaded slave). This aborts ongoing transactions and may leave gaps and half-applied transactions.
4. Error in applier threads. This may leave gaps. If the error is in a mixed transaction, that transaction is half-applied. When using a multi-threaded slave, workers which have not received an error complete their queues, so it may take time to stop all threads.
5. STOP SLAVE when using a multi-threaded slave. After issuing STOP SLAVE, the slave waits for any gaps to be filled and then updates Exec_master_log_pos. This ensures it never leaves gaps or

gap-free low-watermark positions, unless any of the cases above applies (in other words, before STOP SLAVE completes, either an error happens, or another thread issues KILL, or the server restarts. In these cases, STOP SLAVE returns successfully.)

6. If the last transaction in the relay log is only half-received and the multi-threaded slave coordinator has started to schedule the transaction to a worker, then STOP SLAVE waits up to 60 seconds for the transaction to be received. After this timeout, the coordinator gives up and aborts the transaction. If the transaction is mixed, it may be left half-completed.

7. STOP SLAVE when using a single-threaded slave. If the ongoing transaction only updates transactional tables, it is rolled back and STOP SLAVE stops immediately. If the ongoing transaction is mixed, STOP SLAVE waits up to 60 seconds for the transaction to complete. After this timeout, it aborts the transaction, so it may be left half-completed.

The global variable rpl_stop_slave_timeout is unrelated to the process of stopping the replication threads. It only makes the client that issues STOP SLAVE return to the client, but the replication threads continue to try to stop.

If a replication channel has gaps, it has the following consequences:

1. The slave database is in a state that may never have existed on the master.

2. The field Exec_master_log_pos in SHOW SLAVE STATUS is only a "low-watermark". In other words, transactions appearing before the position are guaranteed to have committed, but transactions after the position may have committed or not.

3. CHANGE MASTER TO statements for that channel fail with an error, unless the applier threads are running and the CHANGE MASTER TO statement only sets receiver options.

4. If mysqld is started with --relay-log-recovery, no recovery is done for that channel, and a warning is printed.

5. If mysqldump is used with --dump-slave, it does not record the existence of gaps; thus it prints CHANGE MASTER TO with RELAY_LOG_POS set to the low-watermark position in Exec_master_log_pos.

   After applying the dump on another server, and starting the replication threads, transactions appearing after the position are replicated again. Note that this is harmless if GTIDs are enabled (however, in that case it is not recommended to use --dump-slave).

If a replication channel has a gap-free low-watermark position, cases 2 to 5 above apply, but case 1 does not.

The gap-free low-watermark position information is persisted in binary format in the internal table mysql.slave_worker_info. START SLAVE [SQL_THREAD] always consults this information so that it applies only the correct transactions. This remains true even if slave_parallel_workers has been changed to 0 before START SLAVE, and even if START SLAVE is used with UNTIL clauses. START SLAVE UNTIL SQL_AFTER_MTS_GAPS only applies as many transactions as needed in order to fill in the gaps. If START SLAVE is used with UNTIL clauses that tell it to stop before it has consumed all the gaps, then it leaves remaining gaps.

> **Warning**
>
> RESET SLAVE removes the relay logs and resets the replication position. Thus issuing RESET SLAVE on a slave with gaps means the slave loses any information about the gaps, without correcting the gaps.

slave-preserve-commit-order ensures that there are no gaps. However, it is still possible that Exec_master_log_pos is just a gap-free low-watermark position in scenarios 1 to 4 above. That is, there may be transactions after Exec_master_log_pos which have been applied. Therefore the cases numbered 2 to 5 above (but not case 1) apply, even when slave-preserve-commit-order is enabled.

4.1.35 Replication and Triggers

With statement-based replication, triggers executed on the master also execute on the slave. With row-based replication, triggers executed on the master do not execute on the slave. Instead, the row changes on the master resulting from trigger execution are replicated and applied on the slave.

This behavior is by design. If under row-based replication the slave applied the triggers as well as the row changes caused by them, the changes would in effect be applied twice on the slave, leading to different data on the master and the slave.

If you want triggers to execute on both the master and the slave—perhaps because you have different triggers on the master and slave—you must use statement-based replication. However, to enable slave-side triggers, it is not necessary to use statement-based replication exclusively. It is sufficient to switch to statement-based replication only for those statements where you want this effect, and to use row-based replication the rest of the time.

A statement invoking a trigger (or function) that causes an update to an AUTO_INCREMENT column is not replicated correctly using statement-based replication. MySQL 5.7 marks such statements as unsafe. (Bug #45677)

A trigger can have triggers for different combinations of trigger event (INSERT, UPDATE, DELETE) and action time (BEFORE, AFTER), but before MySQL 5.7.2 cannot have multiple triggers that have the same trigger event and action time. MySQL 5.7.2 lifts this limitation and multiple triggers are permitted. This change has replication implications for upgrades and downgrades.

For brevity, “multiple triggers” here is shorthand for “multiple triggers that have the same trigger event and action time.”

Upgrades. Suppose that you upgrade an old server that does not support multiple triggers to MySQL 5.7.2 or higher. If the new server is a replication master and has old slaves that do not support multiple triggers, an error occurs on those slaves if a trigger is created on the master for a table that already has a trigger with the same trigger event and action time. To avoid this problem, upgrade the slaves first, then upgrade the master.

Downgrades. If you downgrade a server that supports multiple triggers to an older version that does not, the downgrade has these effects:

- For each table that has triggers, all trigger definitions remain in the .TRG file for the table. However, if there are multiple triggers with the same trigger event and action time, the server executes only one of them when the trigger event occurs. For information about .TRG files, see Table Trigger Storage.
- If triggers for the table are added or dropped subsequent to the downgrade, the server rewrites the table's .TRG file. The rewritten file retains only one trigger per combination of trigger event and action time; the others are lost.

To avoid these problems, modify your triggers before downgrading. For each table that has multiple triggers per combination of trigger event and action time, convert each such set of triggers to a single trigger as follows:

1. For each trigger, create a stored routine that contains all the code in the trigger. Values accessed using NEW and OLD can be passed to the routine using parameters. If the trigger needs a single result value from the code, you can put the code in a stored function and have the function return the value. If the

trigger needs multiple result values from the code, you can put the code in a stored procedure and return the values using `OUT` parameters.

2. Drop all triggers for the table.
3. Create one new trigger for the table that invokes the stored routines just created. The effect for this trigger is thus the same as the multiple triggers it replaces.

4.1.36 Replication and TRUNCATE TABLE

`TRUNCATE TABLE` is normally regarded as a DML statement, and so would be expected to be logged and replicated using row-based format when the binary logging mode is `ROW` or `MIXED`. However this caused issues when logging or replicating, in `STATEMENT` or `MIXED` mode, tables that used transactional storage engines such as `InnoDB` when the transaction isolation level was `READ COMMITTED` or `READ UNCOMMITTED`, which precludes statement-based logging.

`TRUNCATE TABLE` is treated for purposes of logging and replication as DDL rather than DML so that it can be logged and replicated as a statement. However, the effects of the statement as applicable to `InnoDB` and other transactional tables on replication slaves still follow the rules described in TRUNCATE TABLE Syntax governing such tables. (Bug #36763)

4.1.37 Replication and User Name Length

The maximum length of MySQL user names was increased from 16 characters to 32 characters in MySQL 5.7.8. Replication of user names longer than 16 characters to a slave that supports only shorter user names will fail. However, this should occur only when replicating from a newer master to an older slave, which is not a recommended configuration.

4.1.38 Replication and Variables

System variables are not replicated correctly when using `STATEMENT` mode, except for the following variables when they are used with session scope:

- `auto_increment_increment`
- `auto_increment_offset`
- `character_set_client`
- `character_set_connection`
- `character_set_database`
- `character_set_server`
- `collation_connection`
- `collation_database`
- `collation_server`
- `foreign_key_checks`
- `identity`
- `last_insert_id`
- `lc_time_names`

- `pseudo_thread_id`
- `sql_auto_is_null`
- `time_zone`
- `timestamp`
- `unique_checks`

When `MIXED` mode is used, the variables in the preceding list, when used with session scope, cause a switch from statement-based to row-based logging. See Mixed Binary Logging Format.

`sql_mode` is also replicated except for the `NO_DIR_IN_CREATE` mode; the slave always preserves its own value for `NO_DIR_IN_CREATE`, regardless of changes to it on the master. This is true for all replication formats.

However, when `mysqlbinlog` parses a `SET @@sql_mode = mode` statement, the full *`mode`* value, including `NO_DIR_IN_CREATE`, is passed to the receiving server. For this reason, replication of such a statement may not be safe when `STATEMENT` mode is in use.

The `default_storage_engine` and `storage_engine` system variables are not replicated, regardless of the logging mode; this is intended to facilitate replication between different storage engines.

The `read_only` system variable is not replicated. In addition, the enabling this variable has different effects with regard to temporary tables, table locking, and the `SET PASSWORD` statement in different MySQL versions.

The `max_heap_table_size` system variable is not replicated. Increasing the value of this variable on the master without doing so on the slave can lead eventually to `Table is full` errors on the slave when trying to execute `INSERT` statements on a `MEMORY` table on the master that is thus permitted to grow larger than its counterpart on the slave. For more information, see Section 4.1.23, “Replication and MEMORY Tables”.

In statement-based replication, session variables are not replicated properly when used in statements that update tables. For example, the following sequence of statements will not insert the same data on the master and the slave:

```
SET max_join_size=1000;
INSERT INTO mytable VALUES(@@max_join_size);
```

This does not apply to the common sequence:

```
SET time_zone=...;
INSERT INTO mytable VALUES(CONVERT_TZ(..., ..., @@time_zone));
```

Replication of session variables is not a problem when row-based replication is being used, in which case, session variables are always replicated safely. See Section 5.1, “Replication Formats”.

In MySQL 5.7, the following session variables are written to the binary log and honored by the replication slave when parsing the binary log, regardless of the logging format:

- `sql_mode`
- `foreign_key_checks`
- `unique_checks`
- `character_set_client`

- `collation_connection`
- `collation_database`
- `collation_server`
- `sql_auto_is_null`

> **Important**
>
> Even though session variables relating to character sets and collations are written to the binary log, replication between different character sets is not supported.

To help reduce possible confusion, we recommend that you always use the same setting for the `lower_case_table_names` system variable on both master and slave, especially when you are running MySQL on platforms with case-sensitive file systems.

4.1.39 Replication and Views

Views are always replicated to slaves. Views are filtered by their own name, not by the tables they refer to. This means that a view can be replicated to the slave even if the view contains a table that would normally be filtered out by `replication-ignore-table` rules. Care should therefore be taken to ensure that views do not replicate table data that would normally be filtered for security reasons.

Replication from a table to a same-named view is supported using statement-based logging, but not when using row-based logging. In MySQL 5.7.1 and later, trying to do so when row-based logging is in effect causes an error. (Bug #11752707, Bug #43975)

4.2 Replication Compatibility Between MySQL Versions

MySQL supports replication from one release series to the next higher release series. For example, you can replicate from a master running MySQL 5.5 to a slave running MySQL 5.6, from a master running MySQL 5.6 to a slave running MySQL 5.7, and so on.

However, you may encounter difficulties when replicating from an older master to a newer slave if the master uses statements or relies on behavior no longer supported in the version of MySQL used on the slave. For example, in MySQL 5.5, `CREATE TABLE ... SELECT` statements are permitted to change tables other than the one being created, but are no longer allowed to do so in MySQL 5.6 (see Section 4.1.6, "Replication of CREATE TABLE ... SELECT Statements").

The use of more than two MySQL Server versions is not supported in replication setups involving multiple masters, regardless of the number of master or slave MySQL servers. This restriction applies not only to release series, but to version numbers within the same release series as well. For example, if you are using a chained or circular replication setup, you cannot use MySQL 5.7.1, MySQL 5.7.2, and MySQL 5.7.4 concurrently, although you could use any two of these releases together.

> **Important**
>
> It is strongly recommended to use the most recent release available within a given MySQL release series because replication (and other) capabilities are continually being improved. It is also recommended to upgrade masters and slaves that use early releases of a release series of MySQL to GA (production) releases when the latter become available for that release series.

Replication from newer masters to older slaves may be possible, but is generally not supported. This is due to a number of factors:

- **Binary log format changes.** The binary log format can change between major releases. While we attempt to maintain backward compatibility, this is not always possible.

  This also has significant implications for upgrading replication servers; see Section 4.3, “Upgrading a Replication Setup”, for more information.

- For more information about row-based replication, see Section 5.1, “Replication Formats”.

- **SQL incompatibilities.** You cannot replicate from a newer master to an older slave using statement-based replication if the statements to be replicated use SQL features available on the master but not on the slave.

  However, if both the master and the slave support row-based replication, and there are no data definition statements to be replicated that depend on SQL features found on the master but not on the slave, you can use row-based replication to replicate the effects of data modification statements even if the DDL run on the master is not supported on the slave.

For more information on potential replication issues, see Section 4.1, “Replication Features and Issues”.

4.3 Upgrading a Replication Setup

When you upgrade servers that participate in a replication setup, the procedure for upgrading depends on the current server versions and the version to which you are upgrading. This section provides information about how upgrading affects replication. For general information about upgrading MySQL, see Upgrading MySQL

When you upgrade a master to 5.7 from an earlier MySQL release series, you should first ensure that all the slaves of this master are using the same 5.7.x release. If this is not the case, you should first upgrade the slaves. To upgrade each slave, shut it down, upgrade it to the appropriate 5.7.x version, restart it, and restart replication. Relay logs created by the slave after the upgrade are in 5.7 format.

Changes affecting operations in strict SQL mode may result in replication failure on an updated slave. For example, as of MySQL 5.7.2, the server restricts insertion of a `DEFAULT` value of 0 for temporal data types in strict mode (`STRICT_TRANS_TABLES` or `STRICT_ALL_TABLES`). A resulting incompatibility for replication if you use statement-based logging (`binlog_format=STATEMENT`) is that if a slave is upgraded, a nonupgraded master will execute statements without error that may fail on the slave and replication will stop. To deal with this, stop all new statements on the master and wait until the slaves catch up. Then upgrade the slaves. Alternatively, if you cannot stop new statements, temporarily change to row-based logging on the master (`binlog_format=ROW`) and wait until all slaves have processed all binary logs produced up to the point of this change. Then upgrade the slaves.

After the slaves have been upgraded, shut down the master, upgrade it to the same 5.7.x release as the slaves, and restart it. If you had temporarily changed the master to row-based logging, change it back to statement-based logging. The 5.7 master is able to read the old binary logs written prior to the upgrade and to send them to the 5.7 slaves. The slaves recognize the old format and handle it properly. Binary logs created by the master subsequent to the upgrade are in 5.7 format. These too are recognized by the 5.7 slaves.

In other words, when upgrading to MySQL 5.7, the slaves must be MySQL 5.7 before you can upgrade the master to 5.7. Note that downgrading from 5.7 to older versions does not work so simply: You must ensure that any 5.7 binary log or relay log has been fully processed, so that you can remove it before proceeding with the downgrade.

Downgrading a replication setup to a previous version cannot be done once you have switched from statement-based to row-based replication, and after the first row-based statement has been written to the binary log. See Section 5.1, “Replication Formats”.

Some upgrades may require that you drop and re-create database objects when you move from one MySQL series to the next. For example, collation changes might require that table indexes be rebuilt. Such operations, if necessary, are detailed at Changes Affecting Upgrades to MySQL 5.7. It is safest to perform these operations separately on the slaves and the master, and to disable replication of these operations from the master to the slave. To achieve this, use the following procedure:

1. Stop all the slaves and upgrade them. Restart them with the `--skip-slave-start` option so that they do not connect to the master. Perform any table repair or rebuilding operations needed to re-create database objects, such as use of `REPAIR TABLE` or `ALTER TABLE`, or dumping and reloading tables or triggers.

2. Disable the binary log on the master. To do this without restarting the master, execute a `SET sql_log_bin = 0` statement. Alternatively, stop the master and restart it without the `--log-bin` option. If you restart the master, you might also want to disallow client connections. For example, if all clients connect using TCP/IP, use the `--skip-networking` option when you restart the master.

3. With the binary log disabled, perform any table repair or rebuilding operations needed to re-create database objects. The binary log must be disabled during this step to prevent these operations from being logged and sent to the slaves later.

4. Re-enable the binary log on the master. If you set `sql_log_bin` to 0 earlier, execute a `SET sql_log_bin = 1` statement. If you restarted the master to disable the binary log, restart it with `--log-bin`, and without `--skip-networking` so that clients and slaves can connect.

5. Restart the slaves, this time without the `--skip-slave-start` option.

If you are upgrading an existing replication setup from a version of MySQL that does not support global transaction identifiers to a version that does, you should not enable GTIDs on either the master or the slave before making sure that the setup meets all the requirements for GTID-based replication. For example `server_uuid`, which was added in MySQL 5.6, must exist for GTIDs to function correctly. See Section 2.3.2, “Setting Up Replication Using GTIDs”, which contains information about converting existing replication setups to use GTID-based replication.

4.4 Troubleshooting Replication

If you have followed the instructions but your replication setup is not working, the first thing to do is *check the error log for messages*. Many users have lost time by not doing this soon enough after encountering problems.

If you cannot tell from the error log what the problem was, try the following techniques:

- Verify that the master has binary logging enabled by issuing a `SHOW MASTER STATUS` statement. If logging is enabled, `Position` is nonzero. If binary logging is not enabled, verify that you are running the master with the `--log-bin` option.

- Verify that the master and slave both were started with the `--server-id` option and that the ID value is unique on each server.

- Verify that the slave is running. Use `SHOW SLAVE STATUS` to check whether the `Slave_IO_Running` and `Slave_SQL_Running` values are both `Yes`. If not, verify the options that were used when starting the slave server. For example, `--skip-slave-start` prevents the slave threads from starting until you issue a `START SLAVE` statement.

- If the slave is running, check whether it established a connection to the master. Use `SHOW PROCESSLIST`, find the I/O and SQL threads and check their `State` column to see what they display. See Section 5.2, “Replication Implementation Details”. If the I/O thread state says `Connecting to master`, check the following:

    - Verify the privileges for the user being used for replication on the master.
    - Check that the host name of the master is correct and that you are using the correct port to connect to the master. The port used for replication is the same as used for client network communication (the default is `3306`). For the host name, ensure that the name resolves to the correct IP address.
    - Check that networking has not been disabled on the master or slave. Look for the `skip-networking` option in the configuration file. If present, comment it out or remove it.
    - If the master has a firewall or IP filtering configuration, ensure that the network port being used for MySQL is not being filtered.
    - Check that you can reach the master by using `ping` or `traceroute`/`tracert` to reach the host.

- If the slave was running previously but has stopped, the reason usually is that some statement that succeeded on the master failed on the slave. This should never happen if you have taken a proper snapshot of the master, and never modified the data on the slave outside of the slave thread. If the slave stops unexpectedly, it is a bug or you have encountered one of the known replication limitations described in Section 4.1, “Replication Features and Issues”. If it is a bug, see Section 4.5, “How to Report Replication Bugs or Problems”, for instructions on how to report it.

- If a statement that succeeded on the master refuses to run on the slave, try the following procedure if it is not feasible to do a full database resynchronization by deleting the slave's databases and copying a new snapshot from the master:

  1. Determine whether the affected table on the slave is different from the master table. Try to understand how this happened. Then make the slave's table identical to the master's and run `START SLAVE`.

  2. If the preceding step does not work or does not apply, try to understand whether it would be safe to make the update manually (if needed) and then ignore the next statement from the master.

  3. If you decide that the slave can skip the next statement from the master, issue the following statements:

     ```
     mysql> SET GLOBAL sql_slave_skip_counter = N;
     mysql> START SLAVE;
     ```

     The value of *`N`* should be 1 if the next statement from the master does not use `AUTO_INCREMENT` or `LAST_INSERT_ID()`. Otherwise, the value should be 2. The reason for using a value of 2 for statements that use `AUTO_INCREMENT` or `LAST_INSERT_ID()` is that they take two events in the binary log of the master.

     See also SET GLOBAL sql_slave_skip_counter Syntax.

  4. If you are sure that the slave started out perfectly synchronized with the master, and that no one has updated the tables involved outside of the slave thread, then presumably the discrepancy is the result of a bug. If you are running the most recent version of MySQL, please report the problem. If you are running an older version, try upgrading to the latest production release to determine whether the problem persists.

4.5 How to Report Replication Bugs or Problems

When you have determined that there is no user error involved, and replication still either does not work at all or is unstable, it is time to send us a bug report. We need to obtain as much information as possible from you to be able to track down the bug. Please spend some time and effort in preparing a good bug report.

If you have a repeatable test case that demonstrates the bug, please enter it into our bugs database using the instructions given in How to Report Bugs or Problems. If you have a “phantom” problem (one that you cannot duplicate at will), use the following procedure:

1. Verify that no user error is involved. For example, if you update the slave outside of the slave thread, the data goes out of synchrony, and you can have unique key violations on updates. In this case, the slave thread stops and waits for you to clean up the tables manually to bring them into synchrony. *This is not a replication problem. It is a problem of outside interference causing replication to fail.*

2. Run the slave with the `--log-slave-updates` and `--log-bin` options. These options cause the slave to log the updates that it receives from the master into its own binary logs.

3. Save all evidence before resetting the replication state. If we have no information or only sketchy information, it becomes difficult or impossible for us to track down the problem. The evidence you should collect is:

   - All binary log files from the master
   - All binary log files from the slave
   - The output of `SHOW MASTER STATUS` from the master at the time you discovered the problem
   - The output of `SHOW SLAVE STATUS` from the slave at the time you discovered the problem
   - Error logs from the master and the slave

4. Use `mysqlbinlog` to examine the binary logs. The following should be helpful to find the problem statement. *`log_file`* and *`log_pos`* are the `Master_Log_File` and `Read_Master_Log_Pos` values from `SHOW SLAVE STATUS`.

   ```
   shell> mysqlbinlog --start-position=log_pos log_file | head
   ```

After you have collected the evidence for the problem, try to isolate it as a separate test case first. Then enter the problem with as much information as possible into our bugs database using the instructions at How to Report Bugs or Problems.

Chapter 5 Replication Implementation

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Replication is based on the master server keeping track of all changes to its databases (updates, deletes, and so on) in its binary log. The binary log serves as a written record of all events that modify database structure or content (data) from the moment the server was started. Typically, `SELECT` statements are not recorded because they modify neither database structure nor content.

Each slave that connects to the master requests a copy of the binary log. That is, it pulls the data from the master, rather than the master pushing the data to the slave. The slave also executes the events from the binary log that it receives. This has the effect of repeating the original changes just as they were made on the master. Tables are created or their structure modified, and data is inserted, deleted, and updated according to the changes that were originally made on the master.

Because each slave is independent, the replaying of the changes from the master's binary log occurs independently on each slave that is connected to the master. In addition, because each slave receives a copy of the binary log only by requesting it from the master, the slave is able to read and update the copy of the database at its own pace and can start and stop the replication process at will without affecting the ability to update to the latest database status on either the master or slave side.

For more information on the specifics of the replication implementation, see Section 5.2, “Replication Implementation Details”.

Masters and slaves report their status in respect of the replication process regularly so that you can monitor them. See Examining Thread Information, for descriptions of all replicated-related states.

The master binary log is written to a local relay log on the slave before it is processed. The slave also records information about the current position with the master's binary log and the local relay log. See Section 5.4, “Replication Relay and Status Logs”.

Database changes are filtered on the slave according to a set of rules that are applied according to the various configuration options and variables that control event evaluation. For details on how these rules are applied, see Section 5.5, “How Servers Evaluate Replication Filtering Rules”.

5.1 Replication Formats

Replication works because events written to the binary log are read from the master and then processed on the slave. The events are recorded within the binary log in different formats according to the type of event. The different replication formats used correspond to the binary logging format used when the events were recorded in the master's binary log. The correlation between binary logging formats and the terms used during replication are:

- When using statement-based binary logging, the master writes SQL statements to the binary log. Replication of the master to the slave works by executing the SQL statements on the slave. This is called *statement-based replication* (often abbreviated as *SBR*), which corresponds to the standard MySQL statement-based binary logging format. Replication capabilities in MySQL version 5.1.4 and earlier used this format exclusively.
- When using row-based logging, the master writes *events* to the binary log that indicate how individual table rows are changed. Replication of the master to the slave works by copying the events representing the changes to the table rows to the slave. This is called *row-based replication* (often abbreviated as *RBR*).
- You can also configure MySQL to use a mix of both statement-based and row-based logging, depending on which is most appropriate for the change to be logged. This is called *mixed-format logging*. When using mixed-format logging, a statement-based log is used by default. Depending on certain statements, and also the storage engine being used, the log is automatically switched to row-based in particular cases. Replication using the mixed format is often referred to as *mixed-based replication* or *mixed-format replication*. For more information, see Mixed Binary Logging Format.

Prior to MySQL 5.7.7, statement-based format was the default. In MySQL 5.7.7 and later, row-based format is the default.

MySQL Cluster. The default binary logging format in MySQL Cluster NDB 7.5 is `MIXED`. You should note that MySQL Cluster Replication always uses row-based replication, and that the `NDB` storage engine is incompatible with statement-based replication. See General Requirements for MySQL Cluster Replication, for more information.

When using `MIXED` format, the binary logging format is determined in part by the storage engine being used and the statement being executed. For more information on mixed-format logging and the rules governing the support of different logging formats, see Mixed Binary Logging Format.

The logging format in a running MySQL server is controlled by setting the `binlog_format` server system variable. This variable can be set with session or global scope. The rules governing when and how the new setting takes effect are the same as for other MySQL server system variables—setting the variable for the current session lasts only until the end of that session, and the change is not visible to other sessions; setting the variable globally requires a restart of the server to take effect. For more information, see SET Syntax for Variable Assignment.

There are conditions under which you cannot change the binary logging format at runtime or doing so causes replication to fail. See Setting The Binary Log Format.

You must have the `SUPER` privilege to set either the global or session `binlog_format` value.

The statement-based and row-based replication formats have different issues and limitations. For a comparison of their relative advantages and disadvantages, see Section 5.1.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

With statement-based replication, you may encounter issues with replicating stored routines or triggers. You can avoid these issues by using row-based replication instead. For more information, see Binary Logging of Stored Programs.

5.1.1 Advantages and Disadvantages of Statement-Based and Row-Based Replication

Each binary logging format has advantages and disadvantages. For most users, the mixed replication format should provide the best combination of data integrity and performance. If, however, you want to take advantage of the features specific to the statement-based or row-based replication format when performing certain tasks, you can use the information in this section, which provides a summary of their relative advantages and disadvantages, to determine which is best for your needs.

- Advantages of statement-based replication
- Disadvantages of statement-based replication
- Advantages of row-based replication
- Disadvantages of row-based replication

Advantages of statement-based replication

- Proven technology that has existed in MySQL since 3.23.
- Less data written to log files. When updates or deletes affect many rows, this results in *much* less storage space required for log files. This also means that taking and restoring from backups can be accomplished more quickly.
- Log files contain all statements that made any changes, so they can be used to audit the database.

Disadvantages of statement-based replication

- **Statements that are unsafe for SBR.**
  Not all statements which modify data (such as `INSERT` `DELETE`, `UPDATE`, and `REPLACE` statements) can be replicated using statement-based replication. Any nondeterministic behavior is difficult to replicate when using statement-based replication. Examples of such Data Modification Language (DML) statements include the following:
  - A statement that depends on a UDF or stored program that is nondeterministic, since the value returned by such a UDF or stored program or depends on factors other than the parameters supplied to it. (Row-based replication, however, simply replicates the value returned by the UDF or stored program, so its effect on table rows and data is the same on both the master and slave.) See Section 4.1.12, “Replication of Invoked Features”, for more information.
  - `DELETE` and `UPDATE` statements that use a `LIMIT` clause without an `ORDER BY` are nondeterministic. See Section 4.1.17, “Replication and LIMIT”.
  - Deterministic UDFs must be applied on the slaves.
  - Statements using any of the following functions cannot be replicated properly using statement-based replication:
    - `LOAD_FILE()`
    - `UUID()`, `UUID_SHORT()`
    - `USER()`
    - `FOUND_ROWS()`

  - `SYSDATE()` (unless both the master and the slave are started with the `--sysdate-is-now` option)
  - `GET_LOCK()`
  - `IS_FREE_LOCK()`
  - `IS_USED_LOCK()`
  - `MASTER_POS_WAIT()`
  - `RAND()`
  - `RELEASE_LOCK()`
  - `SLEEP()`
  - `VERSION()`

  However, all other functions are replicated correctly using statement-based replication, including `NOW()` and so forth.

  For more information, see Section 4.1.16, “Replication and System Functions”.

  Statements that cannot be replicated correctly using statement-based replication are logged with a warning like the one shown here:

```
[Warning] Statement is not safe to log in statement format.
```

  A similar warning is also issued to the client in such cases. The client can display it using `SHOW WARNINGS`.

- `INSERT ... SELECT` requires a greater number of row-level locks than with row-based replication.
- `UPDATE` statements that require a table scan (because no index is used in the `WHERE` clause) must lock a greater number of rows than with row-based replication.
- For `InnoDB`: An `INSERT` statement that uses `AUTO_INCREMENT` blocks other nonconflicting `INSERT` statements.
- For complex statements, the statement must be evaluated and executed on the slave before the rows are updated or inserted. With row-based replication, the slave only has to modify the affected rows, not execute the full statement.
- If there is an error in evaluation on the slave, particularly when executing complex statements, statement-based replication may slowly increase the margin of error across the affected rows over time. See Section 4.1.28, “Slave Errors During Replication”.
- Stored functions execute with the same `NOW()` value as the calling statement. However, this is not true of stored procedures.
- Deterministic UDFs must be applied on the slaves.
- Table definitions must be (nearly) identical on master and slave. See Section 4.1.10, “Replication with Differing Table Definitions on Master and Slave”, for more information.

Advantages of row-based replication

- All changes can be replicated. This is the safest form of replication.

  > **Note**
  >
  > Statements that update the information in the `mysql` database—such as `GRANT`, `REVOKE` and the manipulation of triggers, stored routines (including stored procedures), and views—are all replicated to slaves using statement-based replication.
  >
  > For statements such as `CREATE TABLE ... SELECT`, a `CREATE` statement is generated from the table definition and replicated using statement-based format, while the row insertions are replicated using row-based format.

- Fewer row locks are required on the master, which thus achieves higher concurrency, for the following types of statements:
  - `INSERT ... SELECT`
  - `INSERT` statements with `AUTO_INCREMENT`
  - `UPDATE` or `DELETE` statements with `WHERE` clauses that do not use keys or do not change most of the examined rows.
- Fewer row locks are required on the slave for any `INSERT`, `UPDATE`, or `DELETE` statement.

Disadvantages of row-based replication

- RBR can generate more data that must be logged. To replicate a DML statement (such as an `UPDATE` or `DELETE` statement), statement-based replication writes only the statement to the binary log. By contrast, row-based replication writes each changed row to the binary log. If the statement changes many rows, row-based replication may write significantly more data to the binary log; this is true even for statements that are rolled back. This also means that making and restoring a backup can require more time. In addition, the binary log is locked for a longer time to write the data, which may cause concurrency problems. Use `binlog_row_image=minimal` to reduce the disadvantage considerably.
- Deterministic UDFs that generate large `BLOB` values take longer to replicate with row-based replication than with statement-based replication. This is because the `BLOB` column value is logged, rather than the statement generating the data.
- You cannot see on the slave what statements were received from the master and executed. However, you can see what data was changed using `mysqlbinlog` with the options `--base64-output=DECODE-ROWS` and `--verbose`.

  Alternatively, use the `binlog_rows_query_log_events` variable, which if enabled adds a `Rows_query` event with the statement to `mysqlbinlog` output when the `-vv` option is used.
- For tables using the `MyISAM` storage engine, a stronger lock is required on the slave for `INSERT` statements when applying them as row-based events to the binary log than when applying them as statements. This means that concurrent inserts on `MyISAM` tables are not supported when using row-based replication.

5.1.2 Usage of Row-Based Logging and Replication

MySQL uses statement-based logging (SBL), row-based logging (RBL) or mixed-format logging. The type of binary log used impacts the size and efficiency of logging.Therefore the choice between row-based replication (RBR) or statement-based replication (SBR) depends on your application and environment. This section describes known issues when using a row-based format log, and describes some best practices using it in replication.

For additional information, see Section 5.1, “Replication Formats”, and Section 5.1.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

For information about issues specific to MySQL Cluster Replication (which depends on row-based replication), see Known Issues in MySQL Cluster Replication.

- **Row-based logging of temporary tables.** As noted in Section 4.1.24, “Replication and Temporary Tables”, temporary tables are not replicated when using row-based format. When using mixed format logging, “safe” statements involving temporary tables are logged using statement-based format. For more information, see Section 5.1.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

  Temporary tables are not replicated when using row-based format because there is no need. In addition, because temporary tables can be read only from the thread which created them, there is seldom if ever any benefit obtained from replicating them, even when using statement-based format.

  In MySQL 5.7, you can switch from statement-based to row-based binary logging mode even when temporary tables have been created. However, while using the row-based format, the MySQL server cannot determine the logging mode that was in effect when a given temporary table was created. For this reason, the server in such cases logs a `DROP TEMPORARY TABLE IF EXISTS` statement for each temporary table that still exists for a given client session when that session ends. While this means that it is possible that an unnecessary `DROP TEMPORARY TABLE` statement might be logged in some cases, the statement is harmless, and does not cause an error even if the table does not exist, due to the presence of the `IF EXISTS` option.

  Nontransactional DML statements involving temporary tables are allowed when using `binlog_format=ROW`, as long as any nontransactional tables affected by the statements are temporary tables (Bug #14272672).

- **RBL and synchronization of nontransactional tables.** When many rows are affected, the set of changes is split into several events; when the statement commits, all of these events are written to the binary log. When executing on the slave, a table lock is taken on all tables involved, and then the rows are applied in batch mode. Depending on the engine used for the slave's copy of the table, this may or may not be effective.

- **Latency and binary log size.** RBL writes changes for each row to the binary log and so its size can increase quite rapidly. This can significantly increase the time required to make changes on the slave that match those on the master. You should be aware of the potential for this delay in your applications.

- **Reading the binary log.** `mysqlbinlog` displays row-based events in the binary log using the `BINLOG` statement (see BINLOG Syntax). This statement displays an event as a base 64-encoded string, the meaning of which is not evident. When invoked with the `--base64-output=DECODE-ROWS` and `--verbose` options, `mysqlbinlog` formats the contents of the binary log to be human readable. When binary log events were written in row-based format and you want to read or recover from a replication or database failure you can use this command to read contents of the binary log. For more information, see mysqlbinlog Row Event Display.

- **Binary log execution errors and slave_exec_mode.** If `slave_exec_mode` is `IDEMPOTENT`, a failure to apply changes from RBL because the original row cannot be found does not trigger an error or cause replication to fail. This means that it is possible that updates are not applied on the slave, so that the master and slave are no longer synchronized. Latency issues and use of nontransactional tables with RBR when `slave_exec_mode` is `IDEMPOTENT` can cause the master and slave to diverge even further. For more information about `slave_exec_mode`, see Server System Variables.

> **Note**
>
> `slave_exec_mode=IDEMPOTENT` is generally useful only for circular replication or multi-master replication with MySQL Cluster, for which `IDEMPOTENT` is the default value.

For other scenarios, setting `slave_exec_mode` to `STRICT` is normally sufficient; this is the default value for storage engines other than `NDB`.

- **Lack of binary log checksums.** RBL does not use checksums, so network, disk, and other errors may not be identified when processing the binary log. To ensure that data is transmitted without network corruption use SSL for replication connections. The `CHANGE MASTER TO` statement has options to enable replication over SSL. See also CHANGE MASTER TO Syntax, for general information about setting up MySQL with SSL.

- **Filtering based on server ID not supported.** In MySQL 5.7, you can filter based on server ID by using the `IGNORE_SERVER_IDS` option for the `CHANGE MASTER TO` statement. This option works with statement-based and row-based logging formats. Another method to filter out changes on some slaves is to use a `WHERE` clause that includes the relation `@@server_id <> *id_value*` clause with `UPDATE` and `DELETE` statements. For example, `WHERE @@server_id <> 1`. However, this does not work correctly with row-based logging. To use the `server_id` system variable for statement filtering, use statement-based logging.

- **Database-level replication options.** The effects of the `--replicate-do-db`, `--replicate-ignore-db`, and `--replicate-rewrite-db` options differ considerably depending on whether row-based or statement-based logging is used. Therefore, it is recommended to avoid database-level options and instead use table-level options such as `--replicate-do-table` and `--replicate-ignore-table`. For more information about these options and the impact replication format has on how they operate, see Section 2.6, "Replication and Binary Logging Options and Variables".

- **RBL, nontransactional tables, and stopped slaves.** When using row-based logging, if the slave server is stopped while a slave thread is updating a nontransactional table, the slave database can reach an inconsistent state. For this reason, it is recommended that you use a transactional storage engine such as `InnoDB` for all tables replicated using the row-based format. Use of `STOP SLAVE` or `STOP SLAVE SQL_THREAD` prior to shutting down the slave MySQL server helps prevent issues from occurring, and is always recommended regardless of the logging format or storage engine you use.

5.1.3 Determination of Safe and Unsafe Statements in Binary Logging

The "safeness" of a statement in MySQL Replication, refers to whether the statement and its effects can be replicated correctly using statement-based format. If this is true of the statement, we refer to the statement as *safe*; otherwise, we refer to it as *unsafe*.

In general, a statement is safe if it deterministic, and unsafe if it is not. However, certain nondeterministic functions are *not* considered unsafe (see Nondeterministic functions not considered unsafe, later in this section). In addition, statements using results from floating-point math functions—which are hardware-dependent—are always considered unsafe (see Section 4.1.13, "Replication and Floating-Point Values").

Handling of safe and unsafe statements. A statement is treated differently depending on whether the statement is considered safe, and with respect to the binary logging format (that is, the current value of `binlog_format`).

- When using row-based logging, no distinction is made in the treatment of safe and unsafe statements.

- When using mixed-format logging, statements flagged as unsafe are logged using the row-based format; statements regarded as safe are logged using the statement-based format.

- When using statement-based logging, statements flagged as being unsafe generate a warning to this effect. Safe statements are logged normally.

Each statement flagged as unsafe generates a warning. Formerly, if a large number of such statements were executed on the master, this could lead to excessively large error log files. To prevent this, MySQL 5.7 provides a warning suppression mechanism, which behaves as follows: Whenever the 50 most recent `ER_BINLOG_UNSAFE_STATEMENT` warnings have been generated more than 50 times in any 50-second period, warning suppression is enabled. When activated, this causes such warnings not to be written to the error log; instead, for each 50 warnings of this type, a note `The last warning was repeated N times in last S seconds` is written to the error log. This continues as long as the 50 most recent such warnings were issued in 50 seconds or less; once the rate has decreased below this threshold, the warnings are once again logged normally. Warning suppression has no effect on how the safety of statements for statement-based logging is determined, nor on how warnings are sent to the client. MySQL clients still receive one warning for each such statement.

For more information, see Section 5.1, “Replication Formats”.

Statements considered unsafe.
Statements with the following characteristics are considered unsafe:

- **Statements containing system functions that may return a different value on slave.** These functions include `FOUND_ROWS()`, `GET_LOCK()`, `IS_FREE_LOCK()`, `IS_USED_LOCK()`, `LOAD_FILE()`, `MASTER_POS_WAIT()`, `PASSWORD()`, `RAND()`, `RELEASE_LOCK()`, `ROW_COUNT()`, `SESSION_USER()`, `SLEEP()`, `SYSDATE()`, `SYSTEM_USER()`, `USER()`, `UUID()`, and `UUID_SHORT()`.

  Nondeterministic functions not considered unsafe. Although these functions are not deterministic, they are treated as safe for purposes of logging and replication: `CONNECTION_ID()`, `CURDATE()`, `CURRENT_DATE()`, `CURRENT_TIME()`, `CURRENT_TIMESTAMP()`, `CURTIME()`,, `LAST_INSERT_ID()`, `LOCALTIME()`, `LOCALTIMESTAMP()`, `NOW()`, `UNIX_TIMESTAMP()`, `UTC_DATE()`, `UTC_TIME()`, and `UTC_TIMESTAMP()`.

  For more information, see Section 4.1.16, “Replication and System Functions”.

- **References to system variables.** Most system variables are not replicated correctly using the statement-based format. See Section 4.1.38, “Replication and Variables”. For exceptions, see Mixed Binary Logging Format.

- **UDFs.** Since we have no control over what a UDF does, we must assume that it is executing unsafe statements.

- **Fulltext plugin.** This plugin may behave differently on different MySQL servers; therefore, statements depending on it could have different results. For this reason, all statements relying on the fulltext plugin are treated as unsafe in MySQL 5.7.1 and later. (Bug #11756280, Bug #48183)

- **Trigger or stored program updates a table having an AUTO_INCREMENT column.** This is unsafe because the order in which the rows are updated may differ on the master and the slave.

  In addition, an `INSERT` into a table that has a composite primary key containing an `AUTO_INCREMENT` column that is not the first column of this composite key is unsafe.

  For more information, see Section 4.1.1, “Replication and AUTO_INCREMENT”.

- **INSERT ... ON DUPLICATE KEY UPDATE statements on tables with multiple primary or unique keys.** When executed against a table that contains more than one primary or unique key, this statement is considered unsafe, being sensitive to the order in which the storage engine checks the keys, which is not deterministic, and on which the choice of rows updated by the MySQL Server depends.

An `INSERT ... ON DUPLICATE KEY UPDATE` statement against a table having more than one unique or primary key is marked as unsafe for statement-based replication. (Bug #11765650, Bug #58637)

- **Updates using LIMIT.** The order in which rows are retrieved is not specified, and is therefore considered unsafe. See Section 4.1.17, “Replication and LIMIT”.
- **Accesses or references log tables.** The contents of the system log table may differ between master and slave.
- **Nontransactional operations after transactional operations.** Within a transaction, allowing any nontransactional reads or writes to execute after any transactional reads or writes is considered unsafe.

  For more information, see Section 4.1.33, “Replication and Transactions”.
- **Accesses or references self-logging tables.** All reads and writes to self-logging tables are considered unsafe. Within a transaction, any statement following a read or write to self-logging tables is also considered unsafe.
- **LOAD DATA INFILE statements.** `LOAD DATA INFILE` is considered unsafe, it causes a warning in statement-based mode, and a switch to row-based format when using mixed-format logging. See Section 4.1.18, “Replication and LOAD DATA INFILE”.

For additional information, see Section 4.1, “Replication Features and Issues”.

5.2 Replication Implementation Details

MySQL replication capabilities are implemented using three threads, one on the master server and two on the slave:

- **Binlog dump thread.** The master creates a thread to send the binary log contents to a slave when the slave connects. This thread can be identified in the output of `SHOW PROCESSLIST` on the master as the `Binlog Dump` thread.

  The binary log dump thread acquires a lock on the master's binary log for reading each event that is to be sent to the slave. As soon as the event has been read, the lock is released, even before the event is sent to the slave.
- **Slave I/O thread.** When a `START SLAVE` statement is issued on a slave server, the slave creates an I/O thread, which connects to the master and asks it to send the updates recorded in its binary logs.

  The slave I/O thread reads the updates that the master's `Binlog Dump` thread sends (see previous item) and copies them to local files that comprise the slave's relay log.

  The state of this thread is shown as `Slave_IO_running` in the output of `SHOW SLAVE STATUS` or as `Slave_running` in the output of `SHOW STATUS`.
- **Slave SQL thread.** The slave creates an SQL thread to read the relay log that is written by the slave I/O thread and execute the events contained therein.

In the preceding description, there are three threads per master/slave connection. A master that has multiple slaves creates one binary log dump thread for each currently connected slave, and each slave has its own I/O and SQL threads.

A slave uses two threads to separate reading updates from the master and executing them into independent tasks. Thus, the task of reading statements is not slowed down if statement execution is slow.

For example, if the slave server has not been running for a while, its I/O thread can quickly fetch all the binary log contents from the master when the slave starts, even if the SQL thread lags far behind. If the slave stops before the SQL thread has executed all the fetched statements, the I/O thread has at least fetched everything so that a safe copy of the statements is stored locally in the slave's relay logs, ready for execution the next time that the slave starts.

The `SHOW PROCESSLIST` statement provides information that tells you what is happening on the master and on the slave regarding replication. For information on master states, see Replication Master Thread States. For slave states, see Replication Slave I/O Thread States, and Replication Slave SQL Thread States.

The following example illustrates how the three threads show up in the output from `SHOW PROCESSLIST`.

On the master server, the output from `SHOW PROCESSLIST` looks like this:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
     Id: 2
   User: root
   Host: localhost:32931
     db: NULL
Command: Binlog Dump
   Time: 94
  State: Has sent all binlog to slave; waiting for binlog to
         be updated
   Info: NULL
```

Here, thread 2 is a `Binlog Dump` replication thread that services a connected slave. The `State` information indicates that all outstanding updates have been sent to the slave and that the master is waiting for more updates to occur. If you see no `Binlog Dump` threads on a master server, this means that replication is not running; that is, no slaves are currently connected.

On a slave server, the output from `SHOW PROCESSLIST` looks like this:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
     Id: 10
   User: system user
   Host:
     db: NULL
Command: Connect
   Time: 11
  State: Waiting for master to send event
   Info: NULL
*************************** 2. row ***************************
     Id: 11
   User: system user
   Host:
     db: NULL
Command: Connect
   Time: 11
  State: Has read all relay log; waiting for the slave I/O
         thread to update it
   Info: NULL
```

The `State` information indicates that thread 10 is the I/O thread that is communicating with the master server, and thread 11 is the SQL thread that is processing the updates stored in the relay logs. At the time that `SHOW PROCESSLIST` was run, both threads were idle, waiting for further updates.

The value in the `Time` column can show how late the slave is compared to the master. See MySQL 5.7 FAQ: Replication. If sufficient time elapses on the master side without activity on the `Binlog Dump` thread, the master determines that the slave is no longer connected. As for any other client connection, the timeouts for this depend on the values of `net_write_timeout` and `net_retry_count`; for more information about these, see Server System Variables.

The `SHOW SLAVE STATUS` statement provides additional information about replication processing on a slave server. See Section 2.7.1, “Checking Replication Status”.

5.3 Replication Channels

MySQL 5.7.6 introduces the concept of a replication channel, which represents the path of transactions flowing from a master to a slave. This section describes how channels can be used in a replication topology, and the impact they have on single-source replication.

To provide compatibity with previous versions, the MySQL server automatically creates on startup a default channel whose name is the empty string (`""`). This channel is always present; it cannot be created or destroyed by the user. If no other channels (having nonempty names) have been created, replication statements act on the default channel only, so that all replication statements from older slaves function as expected (see Section 5.3.2, “Compatibility with Previous Replication Statements”. Statements applying to replication channels as described in this section can be used only when there is at least one named channel.

A replication channel encompasses the path of transactions transmitted from a master to a slave. In multi-source replication a slave opens multiple channels, one per master, and each channel has its own relay log and applier (SQL) threads. Once transactions are received by a replication channel's receiver (I/O) thread, they are added to the channel's relay log file and passed through to an applier thread. This enables channels to function independently.

A replication channel is also associated with a host name and port. You can assign multiple channels to the same combination of host name and port; in MySQL 5.7, the maximum number of channels that can be added to one slave in a multi-source replication topology is 256. Each replication channel must have a unique (nonempty) name (see Section 5.3.4, “Replication Channel Naming Conventions”). Channels can be configured independently.

5.3.1 Commands for Operations on a Single Channel

To enable existing MySQL replication statements to act on individual replication channels, MySQL 5.7.6 introduces the `FOR CHANNEL` *`channel_name`* option for use with the following replication statements in managing a replication channel independently of other channels:

- `CHANGE MASTER TO`
- `START SLAVE`
- `STOP SLAVE`
- `SHOW RELAYLOG EVENTS`
- `FLUSH RELAY LOGS`
- `SHOW SLAVE STATUS`
- `RESET SLAVE`

Similarly, an additional `channel_name` parameter is introduced for the following functions:

- `MASTER_POS_WAIT()`
- `WAIT_UNTIL_SQL_THREAD_AFTER_GTIDS()`

Beginning with MySQL 5.7.9, the following statements are disallowed for the `group_replication_recovery` channel.

- `START SLAVE`
- `STOP SLAVE`

5.3.2 Compatibility with Previous Replication Statements

When a replication slave has multiple channels and a `FOR CHANNEL` *`channel_name`* option is not specified, a valid statement generally acts on all available channels.

For example, the following statements behave as expected:

- `START SLAVE` starts replication threads for all channels. (In MySQL 5.7.9 and later, this does not include the `group_replication_recovery` channel.)
- `STOP SLAVE` stops replication threads for all the channels. (In MySQL 5.7.9 and later, this does not include the `group_replication_recovery` channel.)
- `SHOW SLAVE STATUS` reports the status for all channels.
- `FLUSH RELAY LOGS` flushes the relay logs for all channels.
- `RESET SLAVE` resets all channels.

> **Warning**
>
> Use `RESET SLAVE` with caution as this statement deletes all existing channels, purges their relay log files, and recreates only the default channel.

Some replication statements cannot operate on all channels. In this case, error 1964 `Multiple channels exist on the slave. Please provide channel name as an argument.` is generated. The following statements and functions generate this error when used in a multi-source replication topology and a `FOR CHANNEL` *`channel_name`* option is not used to specify which channel to act on:

- `SHOW RELAYLOG EVENTS`
- `CHANGE MASTER TO`
- `MASTER_POS_WAIT()`
- `WAIT_UNTIL_SQL_THREAD_AFTER_GTIDS()`
- `WAIT_FOR_EXECUTED_GTID_SET()`

Note that a default channel always exists in a single source replication topology, where statements and functions behave as in previous versions of MySQL.

5.3.3 Startup Options and Replication Channels

This section describes startup options which are impacted by the addition of replication channels.

The following startup options *must* be configured correctly to use multi-source replication.

- `--relay-log-info-repository`

  This must be set to `TABLE`. If this option is set to `FILE`, attempting to add more sources to a slave fails with **`ER_SLAVE_NEW_CHANNEL_WRONG_REPOSITORY`**.

- `--master-info-repository`

  This must be set to `TABLE`. If this option is set to `FILE`, attempting to add more sources to a slave fails with **`ER_SLAVE_NEW_CHANNEL_WRONG_REPOSITORY`**.

The following startup options now affect *all* channels in a replication topology.

- `--log-slave-updates`

  All transactions received by the slave (even from multiple sources) are written in the binary log.

- `--relay-log-purge`

  When set, each channel purges its own relay log automatically.

- `--slave_transaction_retries`

  Applier threads of all channels retry transactions.

- `--skip-slave-start`

  No replication threads start on any channels.

- `--slave-skip-errors`

  Execution continues and errors are skipped for all channels.

The values set for the following startup options apply on each channel; since these are `mysqld` startup options, they are applied on every channel.

- `--max-relay-log-size=size`

  Maximum size of the individual relay log file for each channel; after reaching this limit, the file is rotated.

- `--relay-log-space-limit=size`

  Upper limit for the total size of all relay logs combined, for each individual channel. For *`N`* channels, the combined size of these logs is limited to `relay_log_space_limit * N`.

- `--slave-parallel-workers=value`

  Number of slave parallel workers per channel.

- `--slave-checkpoint-group`

  Waiting time by an I/O thread for each source.

- `--relay-log-index=filename`

  Base name for each channel's relay log index file. See Section 5.3.4, “Replication Channel Naming Conventions”.

- `--relay-log=filename`

  Denotes the base name of each channel's relay log file. See Section 5.3.4, “Replication Channel Naming Conventions”.

- `--slave_net-timeout=N`

  This value is set per channel, so that each channel waits for *`N`* seconds to check for a broken connection.

- `--slave-skip-counter=N`

  This value is set per channel, so that each channel skips *`N`* events from its master.

5.3.4 Replication Channel Naming Conventions

This section describes how naming conventions are impacted by replication channels.

Each replication channel has a unique name which is a string with a maximum length of 64 characters and is case insensitive. Because channel names are used in slave tables, the character set used for these is always UTF-8. Although you are generally free to use any name for channels, the following names are reserved:

- `group_replication_applier`
- `group_replication_recovery`

The name you choose for a replication channel also influences the file names used by a multi-source replication slave. The relay log files and index files for each channel are named `base_name-relay-bin-channel_name.0000x`, where *`base_name`* is generally a host name (if not specified using `--log-bin`) and *`channel_name`* is the name of the channel logged to this file.

5.4 Replication Relay and Status Logs

During replication, a slave server creates several logs that hold the binary log events relayed from the master to the slave, and to record information about the current status and location within the relay log. There are three types of logs used in the process, listed here:

- The *master info log* contains status and current configuration information for the slave's connection to the master. This log holds information on the master host name, login credentials, and coordinates indicating how far the slave has read from the master's binary log.

  This log can be written to the `mysql.slave_master_info` table instead of a file, by starting the slave with `--master-info-repository=TABLE`.

- The *relay log* consists of the events read from the binary log of the master and written by the slave I/O thread. Events in the relay log are executed on the slave as part of the SQL thread.

- The *relay log info log* holds status information about the execution point within the slave's relay log.

  This log can be written to the `mysql.slave_relay_log_info` table instead of a file by starting the slave with `--relay-log-info-repository=TABLE`.

In MySQL 5.7, setting `relay_log_info_repository` and `master_info_repository` to `TABLE` can improve resilience to unexpected halts (crash-safe replication). See Section 3.2, “Handling an Unexpected Halt of a Replication Slave”. When using this configuration, a warning is given if `mysqld` is unable to initialize the replication logging tables, but the slave is allowed to continue starting. This situation is most likely to occur when upgrading from a version of MySQL that does not support slave logging tables to one in which they are supported.

> **Important**
>
> Do not attempt to update or insert rows in the `slave_master_info` or `slave_relay_log_info` table manually. Doing so can cause undefined behavior, and is not supported.

Execution of any statement requiring a write lock on either or both of the `slave_master_info` and `slave_relay_log_info` tables is disallowed while replication is ongoing, while statements that perform only reads are permitted at any time.

5.4.1 The Slave Relay Log

The relay log, like the binary log, consists of a set of numbered files containing events that describe database changes, and an index file that contains the names of all used relay log files.

The term “relay log file” generally denotes an individual numbered file containing database events. The term “relay log” collectively denotes the set of numbered relay log files plus the index file.

Relay log files have the same format as binary log files and can be read using `mysqlbinlog` (see `mysqlbinlog` — Utility for Processing Binary Log Files).

By default, relay log file names have the form `*host_name*-relay-bin.*nnnnnn*` in the data directory, where `*host_name*` is the name of the slave server host and `*nnnnnn*` is a sequence number. Successive relay log files are created using successive sequence numbers, beginning with `000001`. The slave uses an index file to track the relay log files currently in use. The default relay log index file name is `*host_name*-relay-bin.index` in the data directory.

The default relay log file and relay log index file names can be overridden with, respectively, the `--relay-log` and `--relay-log-index` server options (see Section 2.6, “Replication and Binary Logging Options and Variables”).

If a slave uses the default host-based relay log file names, changing a slave's host name after replication has been set up can cause replication to fail with the errors `Failed to open the relay log` and `Could not find target log during relay log initialization`. This is a known issue (see Bug #2122). If you anticipate that a slave's host name might change in the future (for example, if networking is set up on the slave such that its host name can be modified using DHCP), you can avoid this issue entirely by using the `--relay-log` and `--relay-log-index` options to specify relay log file names explicitly when you initially set up the slave. This will make the names independent of server host name changes.

If you encounter the issue after replication has already begun, one way to work around it is to stop the slave server, prepend the contents of the old relay log index file to the new one, and then restart the slave. On a Unix system, this can be done as shown here:

```
shell> cat new_relay_log_name.index >> old_relay_log_name.index
shell> mv old_relay_log_name.index new_relay_log_name.index
```

A slave server creates a new relay log file under the following conditions:

- Each time the I/O thread starts.
- When the logs are flushed; for example, with `FLUSH LOGS` or `mysqladmin flush-logs`.
- When the size of the current relay log file becomes “too large,” determined as follows:
  - If the value of `max_relay_log_size` is greater than 0, that is the maximum relay log file size.
  - If the value of `max_relay_log_size` is 0, `max_binlog_size` determines the maximum relay log file size.

The SQL thread automatically deletes each relay log file as soon as it has executed all events in the file and no longer needs it. There is no explicit mechanism for deleting relay logs because the SQL thread takes care of doing so. However, `FLUSH LOGS` rotates relay logs, which influences when the SQL thread deletes them.

5.4.2 Slave Status Logs

A replication slave server creates two logs. By default, these logs are files named `master.info` and `relay-log.info` and created in the data directory. The names and locations of these files can be changed by using the `--master-info-file` and `--relay-log-info-file` options, respectively. In MySQL 5.7, either or both of these logs can also be written to tables in the `mysql` database by starting the server with the appropriate option: use `--master-info-repository` to have the master info log written to the `mysql.slave_master_info` table, and use `--relay-log-info-repository` to have the relay log info log written to the `mysql.slave_relay_log_info` table. See Section 2.6, "Replication and Binary Logging Options and Variables".

The two status logs contain information like that shown in the output of the `SHOW SLAVE STATUS` statement, which is discussed in SQL Statements for Controlling Slave Servers. Because the status logs are stored on disk, they survive a slave server's shutdown. The next time the slave starts up, it reads the two logs to determine how far it has proceeded in reading binary logs from the master and in processing its own relay logs.

The master info log file or table should be protected because it contains the password for connecting to the master. See Passwords and Logging.

The slave I/O thread updates the master info log. The following table shows the correspondence between the lines in the `master.info` file, the columns in the `mysql.slave_master_info` table, and the columns displayed by `SHOW SLAVE STATUS`.

Line in `master.info` File	**`slave_master_info` Table Column**	**`SHOW SLAVE STATUS` Column**	**Description**
1	`Number_of_lines`	[None]	Number of lines in the file, or columns in the table
2	`Master_log_name`	`Master_Log_File`	The name of the master binary log currently being read from the master
3	`Master_log_pos`	`Read_Master_Log_Pos`	The current position within the master binary log that have been read from the master
4	`Host`	`Master_Host`	The host name of the master
5	`User_name`	`Master_User`	The user name used to connect to the master
6	`User_password`	Password (not shown by `SHOW SLAVE STATUS`)	The password used to connect to the master

Line in `master.info` File	**`slave_master_info` Table Column**	**`SHOW SLAVE STATUS` Column**	**Description**
7	`Port`	`Master_Port`	The network port used to connect to the master
8	`Connect_retry`	`Connect_Retry`	The period (in seconds) that the slave will wait before trying to reconnect to the master
9	`Enabled_ssl`	`Master_SSL_Allowed`	Indicates whether the server supports SSL connections
10	`Ssl_ca`	`Master_SSL_CA_File`	The file used for the Certificate Authority (CA) certificate
11	`Ssl_capath`	`Master_SSL_CA_Path`	The path to the Certificate Authority (CA) certificates
12	`Ssl_cert`	`Master_SSL_Cert`	The name of the SSL certificate file
13	`Ssl_cipher`	`Master_SSL_Cipher`	The list of possible ciphers used in the handshake for the SSL connection
14	`Ssl_key`	`Master_SSL_Key`	The name of the SSL key file
15	`Ssl_verify_server_cert`	`Master_SSL_Verify_Server_Cert`	Whether to verify the server certificate
16	`Heartbeat`	[None]	Interval between replication heartbeats, in seconds
17	`Bind`	`Master_Bind`	Which of the slave's network interfaces should be used for connecting to the master

Line in `master.info` File	`slave_master_info` Table Column	`SHOW SLAVE STATUS` Column	Description
18	`Ignored_server_ids`	`Replicate_Ignore_Server_Ids`	The list of server IDs to be ignored. Note that for `Ignored_server_ids` the list of server IDs is preceded by the total number of server IDs to ignore.
19	`Uuid`	`Master_UUID`	The master's unique ID
20	`Retry_count`	`Master_Retry_Count`	Maximum number of reconnection attempts permitted
21	`Ssl_crl`	[None]	Path to an ssl certificate revocation list file
22	`Ssl_crl_path`	[None]	Path to a directory containing ssl certificate revocation list files
23	`Enabled_auto_position`	`Auto_position`	If autopositioning is in use or not
24	`Channel_name`	`Channel_name`	The name of the replication channel

The slave SQL thread updates the relay log info log. In MySQL 5.7, the `relay-log.info` file includes a line count and a replication delay value. The following table shows the correspondence between the lines in the `relay-log.info` file, the columns in the `mysql.slave_relay_log_info` table, and the columns displayed by `SHOW SLAVE STATUS`.

Line in `relay-log.info`	`slave_relay_log_info` Table Column	`SHOW SLAVE STATUS` Column	Description
1	`Number_of_lines`	[None]	Number of lines in the file or columns in the table
2	`Relay_log_name`	`Relay_Log_File`	The name of the current relay log file

Line in `relay-log.info`	**`slave_relay_log_info` Table Column**	**`SHOW SLAVE STATUS` Column**	**Description**
3	`Relay_log_pos`	`Relay_Log_Pos`	The current position within the relay log file; events up to this position have been executed on the slave database
4	`Master_log_name`	`Relay_Master_Log_File`	The name of the master binary log file from which the events in the relay log file were read
5	`Master_log_pos`	`Exec_Master_Log_Pos`	The equivalent position within the master's binary log file of events that have already been executed
6	`Sql_delay`	`SQL_Delay`	The number of seconds that the slave must lag the master
7	`Number_of_workers`	[None]	The number of slave worker threads for executing replication events (transactions) in parallel
8	`Id`	[None]	ID used for internal purposes; currently this is always 1
9	`Channel_name`	Channel_name	The name of the replication channel

In older versions of MySQL (prior to MySQL 5.6), the `relay-log.info` file does not include a line count or a delay value (and the `slave_relay_log_info` table is not available).

Line	**Status Column**	**Description**
1	`Relay_Log_File`	The name of the current relay log file
2	`Relay_Log_Pos`	The current position within the relay log file; events up to this position have been executed on the slave database
3	`Relay_Master_Log_File`	The name of the master binary log file from which the events in the relay log file were read
4	`Exec_Master_Log_Pos`	The equivalent position within the master's binary log file of events that have already been executed

> **Note**
>
> If you downgrade a slave server to a version older than MySQL 5.6, the older server does not read the `relay-log.info` file correctly. To address this, modify the file in a text editor by deleting the initial line containing the number of lines.

The contents of the `relay-log.info` file and the states shown by the `SHOW SLAVE STATUS` statement might not match if the `relay-log.info` file has not been flushed to disk. Ideally, you should only view `relay-log.info` on a slave that is offline (that is, `mysqld` is not running). For a running system, you can use `SHOW SLAVE STATUS`, or query the `slave_master_info` and `slave_relay_log_info` tables if you are writing the status logs to tables.

When you back up the slave's data, you should back up these two status logs, along with the relay log files. The status logs are needed to resume replication after you restore the data from the slave. If you lose the relay logs but still have the relay log info log, you can check it to determine how far the SQL thread has executed in the master binary logs. Then you can use `CHANGE MASTER TO` with the `MASTER_LOG_FILE` and `MASTER_LOG_POS` options to tell the slave to re-read the binary logs from that point. Of course, this requires that the binary logs still exist on the master.

5.5 How Servers Evaluate Replication Filtering Rules

If a master server does not write a statement to its binary log, the statement is not replicated. If the server does log the statement, the statement is sent to all slaves and each slave determines whether to execute it or ignore it.

On the master, you can control which databases to log changes for by using the `--binlog-do-db` and `--binlog-ignore-db` options to control binary logging. For a description of the rules that servers use in evaluating these options, see Section 5.5.1, “Evaluation of Database-Level Replication and Binary Logging Options”. You should not use these options to control which databases and tables are replicated. Instead, use filtering on the slave to control the events that are executed on the slave.

On the slave side, decisions about whether to execute or ignore statements received from the master are made according to the `--replicate-*` options that the slave was started with. (See Section 2.6, “Replication and Binary Logging Options and Variables”.) In MySQL 5.7.3 and later, the filters governed by these options can also be set dynamically using the `CHANGE REPLICATION FILTER` statement. The rules governing such filters are the same whether they are created on startup using `--replicate-*` options or while the slave server is running by `CHANGE REPLICATION FILTER`.

In the simplest case, when there are no `--replicate-*` options, the slave executes all statements that it receives from the master. Otherwise, the result depends on the particular options given.

Database-level options (`--replicate-do-db`, `--replicate-ignore-db`) are checked first; see Section 5.5.1, “Evaluation of Database-Level Replication and Binary Logging Options”, for a description of this process. If no database-level options are used, option checking proceeds to any table-level options that may be in use (see Section 5.5.2, “Evaluation of Table-Level Replication Options”, for a discussion of these). If one or more database-level options are used but none are matched, the statement is not replicated.

For statements affecting databases only (that is, `CREATE DATABASE`, `DROP DATABASE`, and `ALTER DATABASE`), database-level options always take precedence over any `--replicate-wild-do-table` options. In other words, for such statements, `--replicate-wild-do-table` options are checked if and only if there are no database-level options that apply. This is a change in behavior from previous versions of MySQL, where the statement `CREATE DATABASE dbx` was not replicated if the slave had been started with `--replicate-do-db=dbx --replicate-wild-do-table=db%.t1`. (Bug #46110)

To make it easier to determine what effect an option set will have, it is recommended that you avoid mixing “do” and “ignore” options, or wildcard and nonwildcard options.

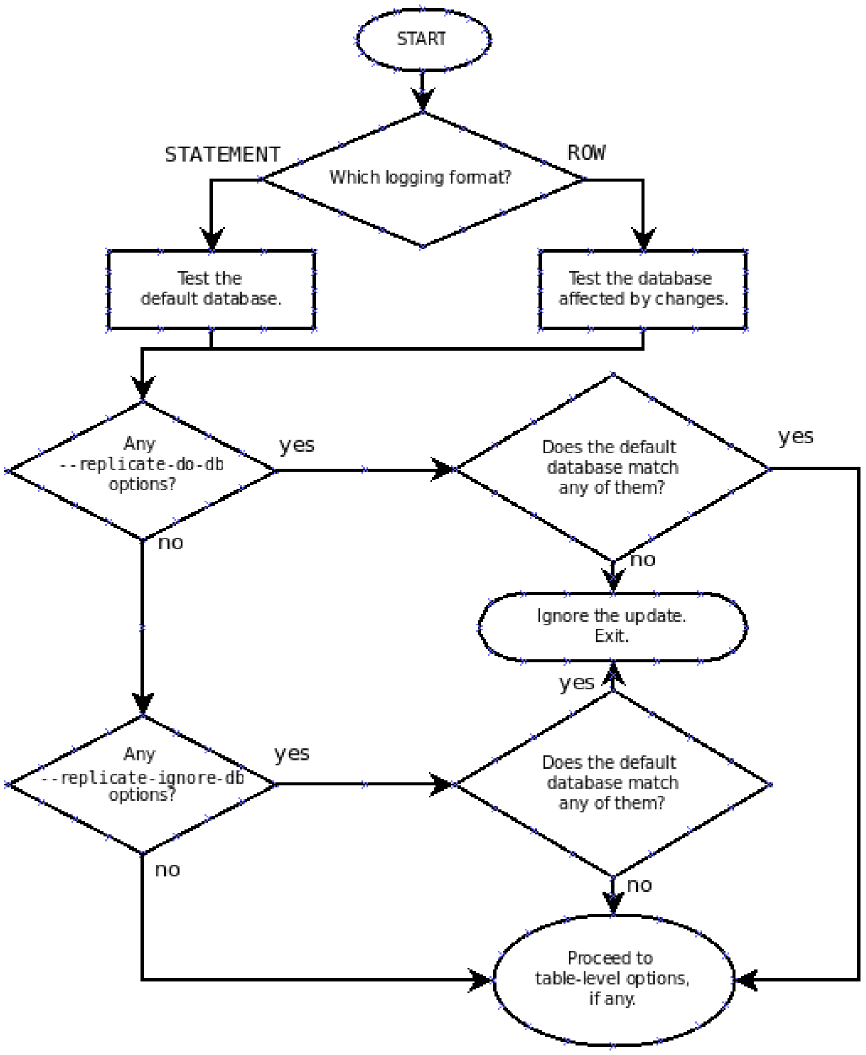
If any `--replicate-rewrite-db` options were specified, they are applied before the `--replicate-*` filtering rules are tested.

> **Note**
>
> In MySQL 5.7, all replication filtering options follow the same rules for case sensitivity that apply to names of databases and tables elsewhere in the MySQL server, including the effects of the `lower_case_table_names` system variable.
>
> This is a change from previous versions of MySQL. (Bug #51639)

5.5.1 Evaluation of Database-Level Replication and Binary Logging Options

When evaluating replication options, the slave begins by checking to see whether there are any `--replicate-do-db` or `--replicate-ignore-db` options that apply. When using `--binlog-do-db` or `--binlog-ignore-db`, the process is similar, but the options are checked on the master.

With statement-based replication, the default database is checked for a match. With row-based replication, the database where data is to be changed is the database that is checked. Regardless of the binary logging format, checking of database-level options proceeds as shown in the following diagram.


START
Which logging format?
STATEMENT
ROW
Test the default database.
Test the database affected by changes.
Any --replicate-do-db options?
yes
no
Does the default database match any of them?
yes
no
Ignore the update. Exit.
yes
Any --replicate-ignore-db options?
yes
no
Does the default database match any of them?
no
Proceed to table-level options, if any.

The steps involved are listed here:

1. Are there any `--replicate-do-db` options?
   - **Yes.** Do any of them match the database?
     - **Yes.** Execute the statement and exit.
     - **No.** Ignore the statement and exit.
   - **No.** Continue to step 2.
2. Are there any `--replicate-ignore-db` options?
   - **Yes.** Do any of them match the database?
     - **Yes.** Ignore the statement and exit.
     - **No.** Continue to step 3.
   - **No.** Continue to step 3.

3. Proceed to checking the table-level replication options, if there are any. For a description of how these options are checked, see Section 5.5.2, “Evaluation of Table-Level Replication Options”.

> **Important**
>
> A statement that is still permitted at this stage is not yet actually executed. The statement is not executed until all table-level options (if any) have also been checked, and the outcome of that process permits execution of the statement.

For binary logging, the steps involved are listed here:

1. Are there any `--binlog-do-db` or `--binlog-ignore-db` options?
   - **Yes.** Continue to step 2.
   - **No.** Log the statement and exit.
2. Is there a default database (has any database been selected by `USE`)?
   - **Yes.** Continue to step 3.
   - **No.** Ignore the statement and exit.
3. There is a default database. Are there any `--binlog-do-db` options?
   - **Yes.** Do any of them match the database?
     - **Yes.** Log the statement and exit.
     - **No.** Ignore the statement and exit.
   - **No.** Continue to step 4.
4. Do any of the `--binlog-ignore-db` options match the database?
   - **Yes.** Ignore the statement and exit.
   - **No.** Log the statement and exit.

> **Important**
>
> For statement-based logging, an exception is made in the rules just given for the `CREATE DATABASE`, `ALTER DATABASE`, and `DROP DATABASE` statements. In those cases, the database being *created, altered, or dropped* replaces the default database when determining whether to log or ignore updates.

`--binlog-do-db` can sometimes mean “ignore other databases”. For example, when using statement-based logging, a server running with only `--binlog-do-db=sales` does not write to the binary log statements for which the default database differs from `sales`. When using row-based logging with the same option, the server logs only those updates that change data in `sales`.

5.5.2 Evaluation of Table-Level Replication Options

The slave checks for and evaluates table options only if either of the following two conditions is true:

- No matching database options were found.

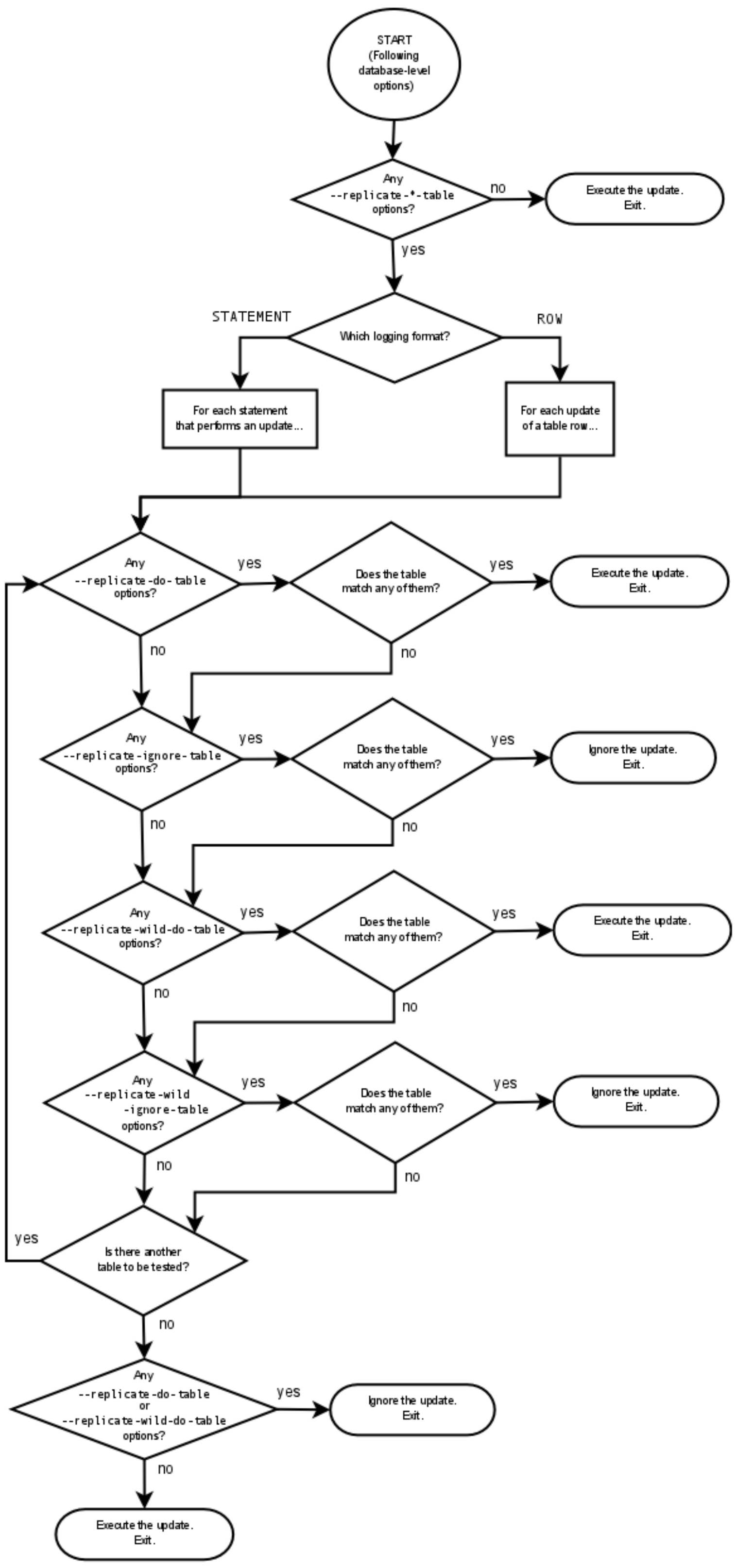
- One or more database options were found, and were evaluated to arrive at an “execute” condition according to the rules described in the previous section (see Section 5.5.1, “Evaluation of Database-Level Replication and Binary Logging Options”).

First, as a preliminary condition, the slave checks whether statement-based replication is enabled. If so, and the statement occurs within a stored function, the slave executes the statement and exits. If row-based replication is enabled, the slave does not know whether a statement occurred within a stored function on the master, so this condition does not apply.

Note

For statement-based replication, replication events represent statements (all changes making up a given event are associated with a single SQL statement); for row-based replication, each event represents a change in a single table row (thus a single statement such as `UPDATE mytable SET mycol = 1` may yield many row-based events). When viewed in terms of events, the process of checking table options is the same for both row-based and statement-based replication.

Having reached this point, if there are no table options, the slave simply executes all events. If there are any `--replicate-do-table` or `--replicate-wild-do-table` options, the event must match one of these if it is to be executed; otherwise, it is ignored. If there are any `--replicate-ignore-table` or `--replicate-wild-ignore-table` options, all events are executed except those that match any of these options. This process is illustrated in the following diagram.


START (Following database-level options)
Any --replicate-*-table options?
no
Execute the update. Exit.
yes
Which logging format?
STATEMENT
ROW
For each statement that performs an update...
For each update of a table row...
Any --replicate-do-table options?
yes
Does the table match any of them?
yes
Execute the update. Exit.
no
no
Any --replicate-ignore-table options?
yes
Does the table match any of them?
yes
Ignore the update. Exit.
no
no
Any --replicate-wild-do-table options?
yes
Does the table match any of them?
yes
Execute the update. Exit.
no
no
Any --replicate-wild -ignore-table options?
yes
Does the table match any of them?
yes
Ignore the update. Exit.
no
no
Is there another table to be tested?
yes
no
Any --replicate-do-table or --replicate-wild-do-table options?
yes
Ignore the update. Exit.
no
Execute the update. Exit.

The following steps describe this evaluation in more detail:

1. Are there any table options?
   - **Yes.** Continue to step 2.
   - **No.** Execute the event and exit.
2. Are there any `--replicate-do-table` options?
   - **Yes.** Does the table match any of them?
     - **Yes.** Execute the event and exit.
     - **No.** Continue to step 3.
   - **No.** Continue to step 3.
3. Are there any `--replicate-ignore-table` options?
   - **Yes.** Does the table match any of them?
     - **Yes.** Ignore the event and exit.
     - **No.** Continue to step 4.
   - **No.** Continue to step 4.
4. Are there any `--replicate-wild-do-table` options?
   - **Yes.** Does the table match any of them?
     - **Yes.** Execute the event and exit.
     - **No.** Continue to step 5.
   - **No.** Continue to step 5.
5. Are there any `--replicate-wild-ignore-table` options?
   - **Yes.** Does the table match any of them?
     - **Yes.** Ignore the event and exit.
     - **No.** Continue to step 6.
   - **No.** Continue to step 6.
6. Are there any `--replicate-do-table` or `--replicate-wild-do-table` options?
   - **Yes.** Ignore the event and exit.
   - **No.** Execute the event and exit.

5.5.3 Replication Rule Application

This section provides additional explanation and examples of usage for different combinations of replication filtering options.

Some typical combinations of replication filter rule types are given in the following table:

Condition (Types of Options)	Outcome
No `--replicate-*` options at all:	The slave executes all events that it receives from the master.
`--replicate-*-db` options, but no table options:	The slave accepts or ignores events using the database options. It executes all events permitted by those options because there are no table restrictions.
`--replicate-*-table` options, but no database options:	All events are accepted at the database-checking stage because there are no database conditions. The slave executes or ignores events based solely on the table options.
A combination of database and table options:	The slave accepts or ignores events using the database options. Then it evaluates all events permitted by those options according to the table options. This can sometimes lead to results that seem counterintuitive, and that may be different depending on whether you are using statement-based or row-based replication; see the text for an example.

A more complex example follows, in which we examine the outcomes for both statement-based and row-based settings.

Suppose that we have two tables `mytbl1` in database `db1` and `mytbl2` in database `db2` on the master, and the slave is running with the following options (and no other replication filtering options):

```
replicate-ignore-db = db1
replicate-do-table  = db2.tbl2
```

Now we execute the following statements on the master:

```
USE db1;
INSERT INTO db2.tbl2 VALUES (1);
```

The results on the slave vary considerably depending on the binary log format, and may not match initial expectations in either case.

Statement-based replication. The `USE` statement causes `db1` to be the default database. Thus the `--replicate-ignore-db` option matches, *and the `INSERT` statement is ignored*. The table options are not checked.

Row-based replication. The default database has no effect on how the slave reads database options when using row-based replication. Thus, the `USE` statement makes no difference in how the `--replicate-ignore-db` option is handled: the database specified by this option does not match the database where the `INSERT` statement changes data, so the slave proceeds to check the table options. The table specified by `--replicate-do-table` matches the table to be updated, *and the row is inserted*.