Oracle Linux 7

Managing Core System Configuration

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Contents

Preface

Oracle® Linux 7: Managing Core System Configuration provides information about configuring Oracle Linux 7 systems, including the boot loader configuration and processes, system devices, services and settings, as well as kernel parameters.

Conventions

The following text conventions are used in this document:

Convention	Meaning
boldface	Boldface type indicates graphical user interface elements associated with an action, or terms defined in text or the glossary.
italic	Italic type indicates book titles, emphasis, or placeholder variables for which you supply particular values.
`monospace`	Monospace type indicates commands within a paragraph, URLs, code in examples, text that appears on the screen, or text that you enter.

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1 Working With the GRUB 2 Bootloader and Configuring Boot Services

This chapter describes the Oracle Linux boot process and how to configure and use the GRUB 2 bootloader and other boot-related kernel parameters.

About the Boot Process

Understanding the Oracle Linux boot process can help you troubleshoot problems while booting a system. The boot process involves several files and errors in these files are the usual cause of boot problems.

When an Oracle Linux system boots, it performs the following operations:

1. The computer's BIOS performs a power-on self-test (POST), and then locates and initializes any peripheral devices including the hard disk.
2. The BIOS reads the Master Boot Record (MBR) into memory from the boot device. (For GUID Partition Table (GPT) disks, this MBR is the *protective MBR* on the first sector of the disk.) The MBR stores information about the organization of partitions on that device. On a computer with x86 architecture, the MBR occupies the first 512 bytes of the boot device. The first 446 bytes contain boot code that points to the boot loader program, which can be on the same device or on another device. The next 64 bytes contain the partition table. The final two bytes are the boot signature, which is used for error detection.

   The default boot loader program that is used in Oracle Linux is the GRand Unified Bootloader version 2 (GRUB 2).
3. The boot loader loads the `vmlinuz` kernel image file into memory and extracts the contents of the `initramfs` image file into a temporary, memory-based file system (`tmpfs`).
4. The kernel loads the driver modules from the `initramfs` file system that are needed to access the root file system.
5. The kernel starts the `systemd` process with a process ID of 1 (PID 1). `systemd` is the ancestor of all processes on a system. `systemd` reads its configuration from files in the `/etc/systemd` directory. The `/etc/systemd/system.conf` file controls how `systemd` handles system initialization.

   `systemd` reads the file linked by `/etc/systemd/system/default.target`, for example `/usr/lib/systemd/system/multi-user.target`, to determine the default system target.

   > **Note:**
   >
   > You can use a kernel boot parameter to override the default system target. See Kernel Boot Parameters.

The system target file defines the services that `systemd` starts.

`systemd` brings the system to the state defined by the system target, performing system initialization tasks such as:

- Setting the host name.
- Initializing the network.
- Initializing SELinux based on its configuration.
- Printing a welcome banner.
- Initializing the system hardware based on kernel boot arguments.
- Mounting the file systems, including virtual file systems such as the `/proc` file system.
- Cleaning up directories in `/var`.
- Starting swapping.

See About System-State Targets.

6. If you have made `/etc/rc.local` executable and you have copied `/usr/lib/systemd/system/rc-local.service` to `/etc/systemd/system`, `systemd` runs any actions that you have defined in `/etc/rc.local`. However, the preferred way of running such local actions is to define your own `systemd` unit.

For information about `systemd` and on how to write `systemd` units, see the `systemd(1)`, `systemd-system.conf(5)`, and `systemd.unit(5)` manual pages.

Working With the GRUB 2 Bootloader

The GRUB 2 bootloader can load many operating systems in addition to Oracle Linux and it can chain-load proprietary operating systems. GRUB 2 understands the formats of file systems and kernel executables, which allows it to load an arbitrary operating system without needing to know the exact location of the kernel on the boot device. GRUB 2 requires only the file name and drive partitions to load a kernel.

Customizing GRUB 2 Configuration

You can manage GRUB 2 configuration by using the GRUB 2 menu or by using the command line.

> **Note:**
>
> Do not edit the GRUB 2 configuration file directly. On BIOS-based systems, the configuration file is `/boot/grub2/grub.cfg`. On UEFI-based systems, the configuration file is `/boot/efi/EFI/redhat/grub.cfg`.
>
> The `grub2-mkconfig` command generates the configuration file by using the template scripts in the `/etc/grub.d` file and menu configuration settings are taken from the `/etc/default/grub` configuration file.

The default menu entry is determined by the value of the `GRUB_DEFAULT` parameter in `/etc/default/grub`. The value `saved` allows you to use the `grub2-set-default` and `grub2-reboot` commands to specify the default entry. `grub2-set-default` sets the default entry for all subsequent reboots and `grub2-reboot` sets the default entry for the next reboot only.

If you specify a numeric value as the value of `GRUB_DEFAULT` or as an argument to either `grub2-reboot` or `grub2-set-default`, GRUB 2 counts the menu entries in the configuration file starting at 0 for the first entry.

Using the GRUB 2 Bootloader to Set the Default Boot Kernel

To set the UEK as the default boot kernel:

1. Display the menu entries that are defined in the configuration file, for example:

   ```
   grep '^menuentry' /boot/grub2/grub.cfg


   menuentry 'Oracle Linux Everything, with Linux 3.10.0-123.el7.x86_64' ... {
   menuentry 'Oracle Linux Everything, with Linux 3.8.13-35.2.1.el7uek.x86_64' ... {
   menuentry 'Oracle Linux Everything, with Linux 0-
   rescue-052e316f566e4a45a3391cff21b4174b' ... {
   ```

   In this example for a BIOS-based system, the configuration file is `/boot/grub2/grub.cfg`, which contains menu entries 0, 1, and 2 that correspond to the RHCK, UEK, and the rescue kernel respectively.

2. Enter the following commands to make the UEK (entry 1) the default boot kernel:

   ```
   sudo grub2-set-default 1
   sudo grub2-mkconfig -o /boot/grub2/grub.cfg
   ```

   Alternatively, you can specify the value of the text of the entry as a string enclosed in quotes.

   ```
   sudo grub2-set-default 'Oracle Linux Everything, with Linux
   3.8.13-35.2.1.el7uek.x86_64'
   sudo grub2-mkconfig -o /boot/grub2/grub.cfg
   ```

For more information about using, configuring, and customizing GRUB 2, see the GNU GRUB Manual, which is also installed as `/usr/share/doc/grub2-tools-2.00/grub.html`.

Kernel Boot Parameters

There are several kernel boot parameters that you can set. The following table lists some of the more commonly used parameters.

Option	Description
`0`, `1`, `2`, `3`, `4`, `5`, or `6`, or `systemd.unit=runlevel`*N*`.target`	Specifies the nearest `systemd`-equivalent system-state target to an Oracle Linux 6 run level. *N* can take an integer value between 0 and 6. For a description of system-state targets, see About System-State Targets.

Option	Description
`1`, `s`, `S`, `single`, or `systemd.unit=rescue.target`	Specifies the rescue shell. The system boots to single-user mode prompts for the `root` password.
`3` or `systemd.unit=multi-user.target`	Specifies the `systemd` target for multi-user, non-graphical login.
`5` or `systemd.unit=graphical.target`	Specifies the `systemd` target for multi-user, graphical login.
`-b`, `emergency`, or `systemd.unit=emergency.target`	Specifies emergency mode. The system boots to single-user mode and prompts for the `root` password. Fewer services are started than when in rescue mode.
`KEYBOARDTYPE=`*`kbtype`*	Specifies the keyboard type, which is written to `/etc/sysconfig/keyboard` in the `initramfs`.
`KEYTABLE=`*`kbtype`*	Specifies the keyboard layout, which is written to `/etc/sysconfig/keyboard` in the `initramfs`.
`LANG=`*`language_territory.codeset`*	Specifies the system language and code set, which is written to `/etc/sysconfig/i18n` in the `initramfs`.
`max_loop=`*`N`*	Specifies the number of loop devices (`/dev/loop*`) that are available for accessing files as block devices. The default and maximum values of *N* are 8 and 255.
`nouptrack`	Disables Ksplice Uptrack updates from being applied to the kernel.
`quiet`	Reduces debugging output.
`rd_LUKS_UUID=`*`UUID`*	Activates an encrypted Linux Unified Key Setup (LUKS) partition with the specified UUID.
`rd_LVM_VG=`*`vg`*`/lv_`*`vol`*	Specifies an LVM volume group and volume to be activated.
`rd_NO_LUKS`	Disables detection of an encrypted LUKS partition.
`rhgb`	Specifies that the Red Hat graphical boot display should be used to indicate the progress of booting.
`rn_NO_DM`	Disables Device-Mapper (DM) RAID detection.
`rn_NO_MD`	Disables Multiple Device (MD) RAID detection.
`ro root=/dev/mapper/`*`vg`*`-lv_root`	Specifies that the root file system is to be mounted read only, and specifies the root file system by the device path of its LVM volume (where *vg* is the name of the volume group).
`rw root=UUID=`*`UUID`*	Specifies that the root (`/`) file system is to be mounted read-writable at boot time, and specifies the root partition by its UUID.
`selinux=0`	Disables SELinux.

Option	Description
`SYSFONT=`*`font`*	Specifies the console font, which is written to `/etc/sysconfig/i18n` in the `initramfs`.

The kernel boot parameters that were last used to boot a system are recorded in `/proc/cmdline`, as shown in the following example:

```
cat /proc/cmdline

BOOT_IMAGE=/vmlinuz-3.10.0-123.el7.x86_64
root=UUID=52c1cab6-969f-4872-958d-47f8518267de
ro rootflags=subvol=root vconsole.font=latarcyrheb-sun16 crashkernel=auto
vconsole.keymap=uk
rhgb quiet LANG=en_GB.UTF-8
```

For more information, see the `kernel-command-line(7)` manual page.

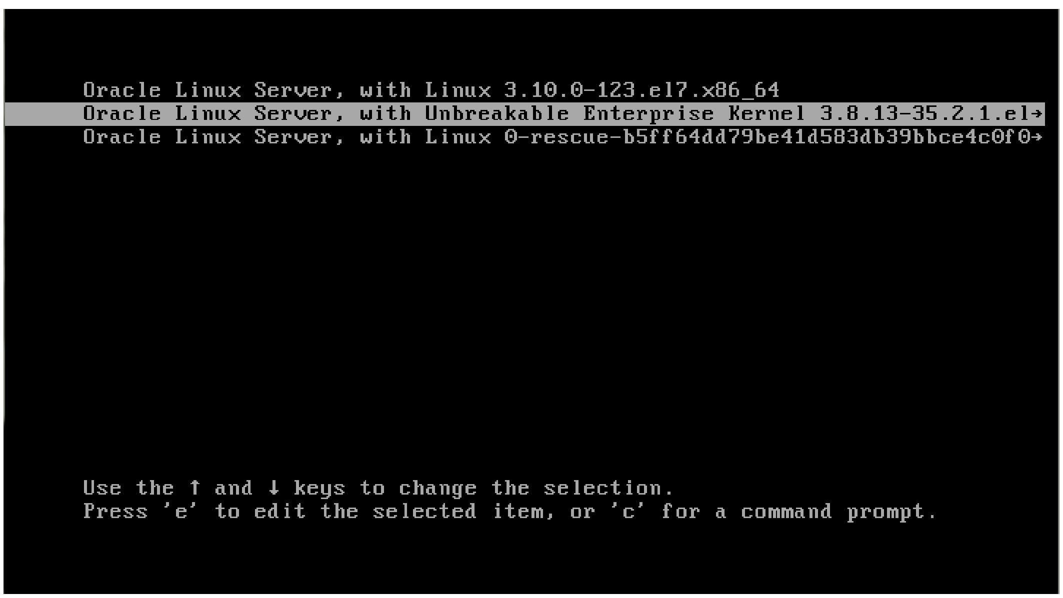
Modifying Kernel Boot Parameters Before Booting

To modify boot parameters before booting a kerne, follow these stepsl:

1. When presented with the GRUB boot menu, use the arrow keys to highlight the required kernel and then press the space bar.

   The following figure shows the GRUB menu with the Unbreakable Enterprise Kernel (UEK) boot entry selected.

   Figure 1-1 GRUB Menu with UEK boot entry selected

2. Press `E` to edit the boot configuration for the kernel.
3. Using the arrow keys, scroll down the screen until the cursor is at the start of the boot configuration line for the kernel (which starts `linux16`).
4. Edit this line to change the boot parameters.

For example, press `End` to go to the end of the line and enter an additional boot parameter.

The following figure shows the kernel boot line with the additional parameter `systemd.target=runlevel1.target`, which starts the rescue shell.

Figure 1-2 Kernel Boot Line with an Additional Parameter to Select the Rescue Shell

5. Press `Ctrl+X` to boot the system.

Modifying Kernel Boot Parameters in GRUB 2 Configuration

To modify boot parameters in the GRUB 2 configuration so that they are applied by default at every reboot, follow these steps:

1. Edit the `/etc/default/grub` file and modify the parameters in the `GRUB_CMDLINE_LINUX` definition, for example:

   ```
   GRUB_CMDLINE_LINUX="vconsole.font=latarcyrheb-sun16 vconsole.keymap=uk
   crashkernel=auto  rd.lvm.lv=ol/swap rd.lvm.lv=ol/root biosdevname=0
   rhgb quiet systemd.unit=runlevel3.target"
   ```

   The previous example adds the `systemd.unit=runlevel3.target` parameter so that the system boots into multi-user, non-graphical mode by default.

2. Rebuild the `/boot/grub2/grub.cfg` file as follows:

   ```
   sudo grub2-mkconfig -o /boot/grub2/grub.cfg
   ```

   This change takes effect for subsequent system reboots of all configured kernels.

2

Working With System Services

This chapter describes how to manage system processes, services, and resources on a running Oracle Linux system. Information about how to change the `systemd` target for a system, as well as how to configure the services that are available for a target is also provided.

About the systemd Service Manager

The `systemd` service manager replaces the Upstart `init` daemon in Oracle Linux 7, while also providing backward compatibility for legacy Oracle Linux 6 service scripts. The `systemd` service manager offers the following benefits over the `init` daemon:

- Services are started in parallel wherever possible by using socket-based activation and D-Bus.
- Daemons can be started on demand.
- Processes are tracked by using control groups (*cgroups*).
- Snapshotting of the system state and restoration of the system state from a snapshot is supported.
- mount points can be configured as `systemd` targets.

The `systemd` process is the first process that starts after the system boots and is the final process that is running when the system shuts down. `systemd` controls the final stages of booting and prepares the system for use. `systemd` also speeds up booting by loading services concurrently.

`systemd` enables you to manage various types of units on a system, including services (*name* `.service`) and targets (*name* `.target`), devices (*name* `.device`), file system mount points (*name* `.mount`), and sockets (*name* `.socket`).

For example, the following command instructs the system to mount the temporary file system (`tmpfs`) on `/tmp` at boot time:

```
sudo systemctl enable tmp.mount
```

About System-State Targets

The `systemd` service manager defines system-state targets that allow you to start a system with only those services that are required for a specific purpose. For example, a server can run more efficiently with `multi-user.target`, because it does not run the X Window System at that run level. You should perform diagnostics, backups, and upgrades with `rescue.target` only when `root` can use the system. Each run level defines the services that `systemd` stops or starts. For example, `systemd` starts network services for `multi-user.target` and the X Window System for `graphical.target`; whereas, it stops both of these services for `rescue.target`.

The following table describes commonly used system-state targets and their equivalent run-level targets, where compatibility with Oracle Linux 6 run levels is required.

Table 2-1 System-State Targets and Equivalent Run-Level Targets

System-State Targets	Equivalent Run-Level Targets	Description
`graphical.target`	`runlevel5.target`	Set up a multi-user system with networking and display manager.

`multi-user.target`	`runlevel2.target`
	`runlevel3.target`
	`runlevel4.target`
		Set up a non-graphical multi-user system with networking.

`poweroff.target`	`runlevel0.target`	Shut down and power off the system.
`reboot.target`	`runlevel6.target`	Shut down and reboot the system.
`rescue.target`	`runlevel1.target`	Set up a rescue shell.

The `runlevel*` targets are implemented as symbolic links.

The nearest equivalent `systemd` target to the Oracle Linux 6 run levels 2, 3, and 4 is `multi-user.target`.

For more information, see the `systemd.target(5)` manual page.

Displaying the Default and Active System-State Targets

To display the default system-state target, use the `systemctl get-default` command:

```
sudo systemctl get-default

graphical.target
```

To display the currently active targets on a system, use the `systemctl list-units` command:

```
sudo systemctl list-units --type target

UNIT                 LOAD   ACTIVE SUB    DESCRIPTION
basic.target         loaded active active Basic System
cryptsetup.target    loaded active active Encrypted Volumes
getty.target         loaded active active Login Prompts
graphical.target     loaded active active Graphical Interface
local-fs-pre.target  loaded active active Local File Systems (Pre)
local-fs.target      loaded active active Local File Systems
multi-user.target    loaded active active Multi-User System
network.target       loaded active active Network
nfs.target           loaded active active Network File System Server
paths.target         loaded active active Paths
remote-fs.target     loaded active active Remote File Systems
slices.target        loaded active active Slices
sockets.target       loaded active active Sockets
```

```
sound.target        loaded active active Sound Card
swap.target         loaded active active Swap
sysinit.target      loaded active active System Initialization
timers.target       loaded active active Timers

LOAD   = Reflects whether the unit definition was properly loaded.
ACTIVE = The high-level unit activation state, i.e. generalization of SUB.
SUB    = The low-level unit activation state, values depend on unit type.

17 loaded units listed. Pass --all to see loaded but inactive units, too.
To show all installed unit files use 'systemctl list-unit-files'.
```

The previous example output for a system with the `graphical` target active shows that this target depends on 16 other active targets, including `network` and `sound` to support networking and sound.

To display the status of all targets on the system, specify the `--all` option:

```
sudo systemctl list-units --type target --all

UNIT                      LOAD   ACTIVE   SUB    DESCRIPTION
basic.target              loaded active   active Basic System
cryptsetup.target         loaded active   active Encrypted Volumes
emergency.target          loaded inactive dead   Emergency Mode
final.target              loaded inactive dead   Final Step
getty.target              loaded active   active Login Prompts
graphical.target          loaded active   active Graphical Interface
local-fs-pre.target       loaded active   active Local File Systems (Pre)
local-fs.target           loaded active   active Local File Systems
multi-user.target         loaded active   active Multi-User System
network-online.target     loaded inactive dead   Network is Online
network.target            loaded active   active Network
nfs.target                loaded active   active Network File System Server
nss-lookup.target         loaded inactive dead   Host and Network Name Lookups
nss-user-lookup.target    loaded inactive dead   User and Group Name Lookups
paths.target              loaded active   active Paths
remote-fs-pre.target      loaded inactive dead   Remote File Systems (Pre)
remote-fs.target          loaded active   active Remote File Systems
rescue.target             loaded inactive dead   Rescue Mode
shutdown.target           loaded inactive dead   Shutdown
slices.target             loaded active   active Slices
sockets.target            loaded active   active Sockets
sound.target              loaded active   active Sound Card
swap.target               loaded active   active Swap
sysinit.target            loaded active   active System Initialization
syslog.target             not-found inactive dead   syslog.target
time-sync.target          loaded inactive dead   System Time Synchronized
timers.target             loaded active   active Timers
umount.target             loaded inactive dead   Unmount All Filesystems

LOAD   = Reflects whether the unit definition was properly loaded.
ACTIVE = The high-level unit activation state, i.e. generalization of SUB.
SUB    = The low-level unit activation state, values depend on unit type.

28 loaded units listed.
To show all installed unit files use 'systemctl list-unit-files'.
```

For more information, see the `systemctl(1)` and `systemd.target(5)` manual pages.

Changing the Default and Active System-State Targets

Use the `systemctl set-default` command to change the default system-state target:

```
sudo systemctl set-default multi-user.target
sudo rm '/etc/systemd/system/default.target'
sudo ln -s '/usr/lib/systemd/system/multi-user.target' '/etc/systemd/system/
default.target'
```

> **Note:**
>
> This command changes the target to which the default target is linked, but does not change the state of the system.

To change the currently active system target, use the `systemctl isolate` command:

```
sudo systemctl isolate multi-user.target
```

Listing all of the targets shows that the `graphical` and `sound` targets are not active:

```
sudo systemctl list-units --type target --all

UNIT                      LOAD   ACTIVE   SUB    DESCRIPTION
basic.target              loaded active   active Basic System
cryptsetup.target         loaded active   active Encrypted Volumes
emergency.target          loaded inactive dead   Emergency Mode
final.target              loaded inactive dead   Final Step
getty.target              loaded active   active Login Prompts
graphical.target          loaded inactive dead   Graphical Interface
local-fs-pre.target       loaded active   active Local File Systems (Pre)
local-fs.target           loaded active   active Local File Systems
multi-user.target         loaded active   active Multi-User System
network-online.target     loaded inactive dead   Network is Online
network.target            loaded active   active Network
nfs.target                loaded active   active Network File System Server
nss-lookup.target         loaded inactive dead   Host and Network Name Lookups
nss-user-lookup.target    loaded inactive dead   User and Group Name Lookups
paths.target              loaded active   active Paths
remote-fs-pre.target      loaded inactive dead   Remote File Systems (Pre)
remote-fs.target          loaded active   active Remote File Systems
rescue.target             loaded inactive dead   Rescue Mode
shutdown.target           loaded inactive dead   Shutdown
slices.target             loaded active   active Slices
sockets.target            loaded active   active Sockets
sound.target              loaded inactive dead   Sound Card
swap.target               loaded active   active Swap
sysinit.target            loaded active   active System Initialization
syslog.target             not-found inactive dead   syslog.target
time-sync.target          loaded inactive dead   System Time Synchronized
timers.target             loaded active   active Timers
umount.target             loaded inactive dead   Unmount All Filesystems

LOAD   = Reflects whether the unit definition was properly loaded.
ACTIVE = The high-level unit activation state, i.e. generalization of SUB.
```

```
SUB    = The low-level unit activation state, values depend on unit type.

28 loaded units listed.
To show all installed unit files use 'systemctl list-unit-files'.
```

For more information, see the `systemctl(1)` manual page.

Shutting Down, Suspending, and Rebooting the System

The following list describes the `systemctl` commands that are used to shut down, reboot, or otherwise suspend the operation of a system:

- `systemctl halt`: Halt the system.
- `systemctl hibernate`: Put the system into hibernation.
- `systemctl hybrid-sleep`: Put the system into hibernation and suspend its operration.
- `systemctl poweroff`: Halt and power off the system.
- `systemctl reboot`: Reboot the system.
- `systemctl suspend`: Suspend the system.

For more information, see the `systemctl(1)` manual page.

Starting and Stopping Services

To start a service, use the `systemctl` command with the `start` argument:

```
sudo systemctl start sshd
```

For legacy scripts in the `/etc/init.d` file that have not been ported as `systemd` services, you can run the script directly with the `start` argument, for example:

```
/etc/init.d/yum-cron start
```

To stop a service, use the `stop` argument to `systemctl`:

```
sudo systemctl stop sshd
```

> **Note:**
>
> Changing the state of a service only lasts as long as the system remains at the same state. If you stop a service and then change the system-state target to one in which the service is configured to run (for example, by rebooting the system), the service restarts. Similarly, starting a service does not enable the service to start following a reboot. See Enabling and Disabling Services for details.

The `systemctl` service manager supports the `disable`, `enable`, `reload`, `restart`, `start`, `status`, and `stop` actions for services. For other actions, you must either run the script that the service provides to support these actions; or, for legacy scripts, the `/etc/init.d` script with the required action argument. For legacy scripts, omitting the argument to the script displays a usage message, for example:

```
/etc/init.d/yum-cron
```

```
Usage: /etc/init.d/yum-cron {start|stop|status|restart|reload|force-reload|
condrestart}
```

For more information, see the `systemctl(1)` manual page.

Enabling and Disabling Services

You can use the `systemctl` command to enable or disable a service from starting when the system starts, for example:

```
sudo systemctl enable httpd
sudo ln -s '/usr/lib/systemd/system/httpd.service' '/etc/systemd/system/multi-
user.target.wants/httpd.service'
```

The previous command enables a service by creating a symbolic link for the lowest-level system-state target at which the service should start. In the example, the command creates the symbolic link `httpd.service` for the `multi-user` target.

Disabling a service removes the symbolic link, for example:

```
sudo systemctl disable httpd
sudo rm '/etc/systemd/system/multi-user.target.wants/httpd.service'
```

You can use the `is-enabled` subcommand to check whether a service is enabled:

```
sudo systemctl is-enabled httpd

disabled

sudo systemctl is-enabled nfs

enabled
```

After running the `systemctl disable` command, the service can still be started or stopped by user accounts, scripts and other processes. If that is not your desired behavior, use the `systemctl mask` command to disable the service completely:

```
sudo systemctl mask httpd

Created symlink from '/etc/systemd/system/multi-user.target.wants/httpd.service'
to '/dev/null'
```

If you try to run the service, you will see an error message stating that the unit has been masked because the service reference was changed to `/dev/null`:

```
sudo systemctl start httpd

Failed to start httpd.service: Unit is masked.
```

To re-link the service reference back to the matching service unit configuration file, use the `systemctl unmask` command:

```
sudo systemctl unmask httpd
```

For more information, see the `systemctl(1)` manual page.

Displaying the Status of Services

You can use the `is-active` subcommand to check whether a service is running (*active*) or not running (*inactive*):

```
sudo systemctl is-active httpd

active

sudo systemctl is-active nfs

inactive
```

You can use the `status` action to view a detailed summary of the status of a service, including a tree of all the tasks in the *control group* (cgroup) that the service implements:

```
sudo systemctl status httpd

httpd.service - The Apache HTTP Server
   Loaded: loaded (/usr/lib/systemd/system/httpd.service; enabled)
   Active: active (running) since Mon 2014-04-28 15:02:40 BST; 1s ago
 Main PID: 6452 (httpd)
   Status: "Processing requests..."
   CGroup: /system.slice/httpd.service
           ├─6452 /usr/sbin/httpd -DFOREGROUND
           ├─6453 /usr/sbin/httpd -DFOREGROUND
           ├─6454 /usr/sbin/httpd -DFOREGROUND
           ├─6455 /usr/sbin/httpd -DFOREGROUND
           ├─6456 /usr/sbin/httpd -DFOREGROUND
           └─6457 /usr/sbin/httpd -DFOREGROUND

Apr 28 15:02:40 localhost.localdomain systemd[1]: Started The Apache HTTP Ser...
Hint: Some lines were ellipsized, use -l to show in full.
```

A cgroup is a collection of processes that are bound together so that you can control their access to system resources. In the previous example, the cgroup for the `httpd` service is `httpd.service`, which is in the `system` *slice*.

Slices divide the cgroups on a system into different categories. To display the slice and cgroup hierarchy, use the `systemd-cgls` command:

```
sudo systemd-cgls

├─1 /usr/lib/systemd/systemd --system --deserialize 17
├─user.slice
│ ├─user-0.slice
│ │ └─session-3.scope
│ │   └─9313 /usr/sbin/anacron -s
│ └─user-1000.slice
│   └─session-5.scope
│     ├─15980 sshd: root [priv]
│     ├─15983 sshd: root@pts/1
│     ├─15984 -bash
│     ├─17605 sudo systemd-cgls
│     ├─17607 systemd-cgls
│     └─17608 less
└─system.slice
  ├─rngd.service
  │ └─1042 /sbin/rngd -f
```

```
├─irqbalance.service
│ └─1067 /usr/sbin/irqbalance --foreground
├─libstoragemgmt.service
│ └─1057 /usr/bin/lsmd -d
├─systemd-udevd.service
│ └─24714 /usr/lib/systemd/systemd-udevd
├─polkit.service
│ └─1064 /usr/lib/polkit-1/polkitd --no-debug
├─chronyd.service
│ └─1078 /usr/sbin/chronyd
├─auditd.service
│ └─1012 /sbin/auditd
├─tuned.service
│ └─2405 /usr/bin/python2 -Es /usr/sbin/tuned -l -P
├─systemd-journald.service
│ └─820 /usr/lib/systemd/systemd-journald
├─atd.service
│ └─1824 /usr/sbin/atd -f
├─sshd.service
```

`system.slice` contains services and other system processes, while `user.slice` contains user processes, which run within transient cgroups called *scopes*. In the example, the processes for the user with ID 1000 are running in the `session-5.scope` scope, under the `/user.slice/user-1000.slice` slice.

You can use the `systemctl` command to limit the CPU, I/O, memory, and other resources that are available to the processes in service and scope cgroups. See Controlling Access to System Resources.

For more information, see the `systemctl(1)` and `systemd-cgls(1)` manual pages.

Controlling Access to System Resources

You use the `systemctl` command to control a cgroup's access to system resources, for example:

```
sudo systemctl set-property httpd.service CPUShares=512 MemoryLimit=1G
```

`CPUShare` controls access to CPU resources. As the default value is 1024, a value of 512 halves the access that the processes in the cgroup have to CPU time. Similarly, `MemoryLimit` controls the maximum amount of memory that the cgroup can use.

> **Note:**
>
> You do not need to specify the `.service` extension to the name of a service.

If you specify the `--runtime` option, the setting does not persist across system reboots.

```
sudo systemctl --runtime set-property httpd CPUShares=512 MemoryLimit=1G
```

Alternatively, you can change the resource settings for a service under the `[Service]` heading in the service's configuration file in `/usr/lib/systemd/system`. After editing the file, direct `systemd` to reload its configuration files and then restart the service, as shown in the following example:

```
sudo systemctl daemon-reload
sudo systemctl restart service
```

You can run general commands within scopes and use the `systemctl` command to control the access that these transient cgroups have to system resources.

To run a command within in a scope, use the `systemd-run` command:

```
sudo systemd-run --scope --unit=group_name [--slice=slice_name] command
```

If you do not want to create the group under the default `system` slice, you can specify another slice or the name of a new slice.

> **Note:**
>
> If you do not specify the `--scope` option, the control group is a created as a service rather than as a scope.

For example, run a command named `mymonitor` in `mymon.scope` under `myslice.slice`:

```
sudo systemd-run --scope --unit=mymon --slice=myslice mymonitor

Running as unit mymon.scope.
```

You can then use the `systemctl` command to control the access that a scope has to system resources in the same way as for a service. However, unlike a service, you must specify the `.scope` extension, for example:

```
sudo systemctl --runtime set-property mymon.scope CPUShares=256
```

For more information see the `systemctl(1)`, `systemd-cgls(1)`, and `systemd.resource-control(5)` manual pages.

Modifying systemd Configuration Files

If you want to change the configuration of `systemd`, copy the `service`, `target`, `mount`, `socket` or other file from `/usr/lib/systemd/system` to `/etc/systemd/system` and edit this copy of the original file. Note that the version of the file in `/etc/systemd/system` takes precedence over the version in `/usr/lib/systemd/system` and is not overwritten when you update a package that touches files in `/usr/lib/systemd/system`. To make `systemd` revert to using the original version of the file, either rename or delete the modified copy of the file in `/etc/systemd/system`.

Running systemctl on a Remote System

If the `sshd` service is running on a remote Oracle Linux 7 system, you can use the `-H` option with `systemctl` to control the system remotely, as shown in the following example:

```
sudo systemctl -H root@10.0.0.2 status sshd

root@10.0.0.2's password: password
sshd.service - OpenSSH server daemon
   Loaded: loaded (/usr/lib/systemd/system/sshd.service; enabled)
   Active: active (running) since Fri 2014-05-23 09:27:22 BST; 5h 43min ago
```

```
  Process: 1498 ExecStartPre=/usr/sbin/sshd-keygen (code=exited, status=0/
SUCCESS)
 Main PID: 1524 (sshd)
   CGroup: /system.slice/sshd.service
```

For more information see the `systemctl(1)` manual page.

3
Configuring System Settings

This chapter describes the files and virtual file systems that you can use to change configuration settings for your system.

About the /etc/sysconfig Files

The `/etc/sysconfig` directory contains files that control your system's configuration. The contents of this directory depend on the packages that you have installed on your system.

Some of the files that you might find in the `/etc/sysconfig` directory include:

`atd`
Specifies additional command line arguments for the `atd` daemon.

`authconfig`
Specifies whether various authentication mechanisms and options may be used. For example, the entry `USEMKHOMEDIR=no` disables the creation of a home directory for a user when he or she first logs in.

`autofs`
Defines custom options for automatically mounting devices and controlling the operation of the automounter.

`crond`
Passes arguments to the `crond` daemon at boot time.

`firewalld`
Passes arguments to the firewall daemon (`firewalld`) at boot time.

`grub`
Specifies default settings for the GRUB 2 boot loader. This file is a symbolic link to `/etc/default/grub`. For more information, see Working With the GRUB 2 Bootloader.

`init`
Controls how the system appears and functions during the boot process.

`keyboard`
Specifies the keyboard.

`modules` (directory)
Contains scripts that the kernel runs to load additional modules at boot time. A script in the `modules` directory must have the extension `.modules` and it must have 755 executable permissions. For an example, see the `bluez-uinput.modules` script that loads the `uinput` module. For more information, see Specifying Modules To Be Loaded at Boot Time.

`named`
Passes arguments to the name service daemon at boot time. The `named` daemon is a Domain Name System (DNS) server that is part of the Berkeley Internet Name Domain

(BIND) distribution. This server maintains a table that associates host names with IP addresses on the network.

nfs
Controls which ports remote procedure call (RPC) services use for NFS v2 and v3. This file allows you to set up firewall rules for NFS v2 and v3. Firewall configuration for NFS v4 does not require you to edit this file.

ntpd
Passes arguments to the network time protocol (NTP) daemon at boot time.

samba
Passes arguments to the `smbd`, `nmbd`, and `winbindd` daemons at boot time to support file-sharing connectivity for Windows clients, NetBIOS-over-IP naming service, and connection management to domain controllers.

selinux
Controls the state of SELinux on the system. This file is a symbolic link to `/etc/selinux/config`. For more information, see Oracle® Linux: Administering SELinux.

snapper
Defines a list of btrfs file systems and thinly-provisioned LVM volumes whose contents can be recorded as snapshots by the `snapper` utility. For more information, see Oracle Linux 7: Managing File Systems.

sysstat
Configures logging parameters for system activity data collector utilities such as `sadc`.

For more information, see `/usr/share/doc/initscripts*/sysconfig.txt`.

> **Note:**
>
> In previous releases of Oracle Linux, the host name of the system was defined in `/etc/sysconfig/network`. The host name is now defined in `/etc/hostname` and can be changed by using the `hostnamectl` command. The host name must be a fully qualified domain name (FQDN), for example, `host20.mydomain.com`, instead of a simple short name.
>
> Additionally, system-wide default localization settings such as the default language, keyboard, and console font were defined in `/etc/sysconfig/i18n`. These settings are now defined in `/etc/locale.conf` and `/etc/vconsole.conf`.
>
> For more information, see the `hostname(5)`, `hostnamectl(1)`, `locale.conf(5)`, and `vconsole.conf(5)` manual pages.

About the /proc Virtual File System

The files in the `/proc` directory hierarchy contain information about your system hardware and the processes that are running on the system. You can change the configuration of the kernel by writing to certain files that have write permission.

The name of the `proc` file system stems from its original purpose on the Oracle Solaris operating system, which was to allow access by debugging tools to the data structures inside running processes. Linux added this interface and extended it to allow access to data structures in the kernel. Over time, `/proc` became quite disordered and the `sysfs` file system was created in an attempt to tidy it up. For more information, see About the /sys Virtual File System.

Files under the `/proc` directory are virtual files that the kernel creates on demand to present a browsable view of the underlying data structures and system information. As such, `/proc` is an example of a virtual file system. Most virtual files are listed as zero bytes in size, but they contain a large amount of information when viewed.

Virtual files such as `/proc/interrupts`, `/proc/meminfo`, `/proc/mounts`, and `/proc/partitions` provide a view of the system's hardware. Others, such as `/proc/filesystems` and the files under `/proc/sys` provide information about the system's configuration and allow this configuration to be modified.

Files that contain information about related topics are grouped into virtual directories. For example, a separate directory exists in `/proc` for each process that is currently running on the system, and the directory's name corresponds to the numeric process ID. `/proc/1` corresponds to the `systemd` process, which has a PID of 1.

You can use commands such as `cat`, `less`, and `view` to examine virtual files within `/proc`. For example, `/proc/cpuinfo` contains information about the system's CPUs:

```
sudo cat /proc/cpuinfo
```

```
processor         : 0
vendor_id         : GenuineIntel
cpu family        : 6
model             : 42
model name        : Intel(R) Core(TM) i5-2520M CPU @ 2.50GHz
stepping          : 7
cpu MHz           : 2393.714
cache size        : 6144 KB
physical id       : 0
siblings          : 2
core id           : 0
cpu cores         : 2
apicid            : 0
initial apicid    : 0
fpu               : yes
fpu_exception     : yes
cpuid level       : 5
wp                : yes
...
```

Certain files under `/proc` require `root` privileges for access or contain information that is not human-readable. You can use utilities such as `lspci`, `free`, and `top` to access the information in these files. For example, `lspci` lists all PCI devices on a system:

```
sudo lspci
```

```
00:00.0 Host bridge: Intel Corporation 440FX - 82441FX PMC [Natoma] (rev 02)
00:01.0 ISA bridge: Intel Corporation 82371SB PIIX3 ISA [Natoma/Triton II]
00:01.1 IDE interface: Intel Corporation 82371AB/EB/MB PIIX4 IDE (rev 01)
00:02.0 VGA compatible controller: InnoTek Systemberatung GmbH VirtualBox Graphics
Adapter
```

```
00:03.0 Ethernet controller: Intel Corporation 82540EM Gigabit Ethernet
Controller (rev 02)
00:04.0 System peripheral: InnoTek Systemberatung GmbH VirtualBox Guest Service
00:05.0 Multimedia audio controller: Intel Corporation 82801AA AC'97 Audio
Controller (rev 01)
00:06.0 USB controller: Apple Inc. KeyLargo/Intrepid USB
00:07.0 Bridge: Intel Corporation 82371AB/EB/MB PIIX4 ACPI (rev 08)
00:0b.0 USB controller: Intel Corporation 82801FB/FBM/FR/FW/FRW (ICH6 Family)
USB2 EHCI Controller
00:0d.0 SATA controller: Intel Corporation 82801HM/HEM (ICH8M/ICH8M-E) SATA
Controller [AHCI mode]
        (rev 02)
...
```

Virtual Files and Directories Under /proc

The following table lists the most useful virtual files and directories under the `/proc` directory hierarchy.

Table 3-1 Useful Virtual Files and Directories Under `/proc`

Virtual File or Directory	Description
`PID` (Directory)	Provides information about the process with the process ID (*PID*). The directory's owner and group is same as the process's. Useful files under the directory include: **`cmdline`** Command path. **`cwd`** Symbolic link to the process's current working directory. **`environ`** Environment variables. **`exe`** Symbolic link to the command executable. **`fd/N`** File descriptors. **`maps`** Memory maps to executable and library files. **`root`** Symbolic link to the effective root directory for the process. **`stack`** The contents of the kernel stack. **`status`** Run state and memory usage.

Table 3-1 (Cont.) Useful Virtual Files and Directories Under `/proc`

Virtual File or Directory	Description
`buddyinfo`	Provides information for diagnosing memory fragmentation.
`bus` (directory)	Contains information about the various buses (such as `pci` and `usb`) that are available on the system. You can use commands such as `lspci`, `lspcmcia`, and `lsusb` to display information for such devices.
`cgroups`	Provides information about the resource control groups that are in use on the system.
`cmdline`	Lists parameters passed to the kernel at boot time.
`cpuinfo`	Provides information about the system's CPUs.
`crypto`	Provides information about all installed cryptographic cyphers.
`devices`	Lists the names and major device numbers of all currently configured characters and block devices.
`dma`	Lists the direct memory access (DMA) channels that are currently in use.
`driver` (directory)	Contains information about drivers used by the kernel, such as those for non-volatile RAM (`nvram`), the real-time clock (`rtc`), and memory allocation for sound (`snd-page-alloc`).
`execdomains`	Lists the execution domains for binaries that the Oracle Linux kernel supports.
`filesystems`	Lists the file system types that the kernel supports. Entries marked with `nodev` are not in use.
`fs` (directory)	Contains information about mounted file systems, organized by file system type.
`interrupts`	Records the number of interrupts per interrupt request queue (IRQ) for each CPU since system startup.
`iomem`	Lists the system memory map for each physical device.
`ioports`	Lists the range of I/O port addresses that the kernel uses with devices.
`irq` (directory)	Contains information about each IRQ. You can configure the affinity between each IRQ and the system CPUs.

Table 3-1 (Cont.) Useful Virtual Files and Directories Under `/proc`

Virtual File or Directory	Description
`kcore`	Presents the system's physical memory in `core` file format that you can examine using a debugger such as `crash` or `gdb`. This file is not human-readable.
`kmsg`	Records kernel-generated messages, which are picked up by programs such as `dmesg`.
`loadavg`	Displays the system load averages (number of queued processes) for the past 1, 5, and 15 minutes, the number of running processes, the total number of processes, and the PID of the process that is running.
`locks`	Displays information about the file locks that the kernel is currently holding on behalf of processes. The information provided includes: • lock class (`FLOCK` or `POSIX`) • lock type (`ADVISORY` or `MANDATORY`) • access type (`READ` or `WRITE`) • process ID • major device, minor device, and inode numbers • bounds of the locked region
`mdstat`	Lists information about multiple-disk RAID devices.
`meminfo`	Reports the system's usage of memory in more detail than is available using the `free` or `top` commands.
`modules`	Displays information about the modules that are currently loaded into the kernel. The `lsmod` command formats and displays the same information, excluding the kernel memory offset of a module.
`mounts`	Lists information about all mounted file systems.
`net` (directory)	Provides information about networking protocol, parameters, and statistics. Each directory and virtual file describes aspects of the configuration of the system's network.
`partitions`	Lists the major and minor device numbers, number of blocks, and name of partitions mounted by the system.
`scsi/device_info`	Provides information about supported SCSI devices.
`scsi/scsi` and `scsi/sg/*`	Provide information about configured SCSI devices, including vendor, model, channel, ID, and LUN data .

Table 3-1 (Cont.) Useful Virtual Files and Directories Under `/proc`

Virtual File or Directory	Description
`self`	Symbolic link to the process that is examining `/proc`.
`slabinfo`	Provides detailed information about slab memory usage.
`softirqs`	Displays information about software interrupts (*softirqs*). A softirq is similar to a hardware interrupt (*hardirq*) and allow the kernel to perform asynchronous processing that would take too long during a hardware interrupt.
`stat`	Records information about the system since it was started, including: **`cpu`** Total CPU time (measured in *jiffies*) spent in user mode, low-priority user mode, system mode, idle, waiting for I/O, handling hardirq events, and handling softirq events. **`cpu`*`N`*** Times for CPU *N*.
`swaps`	Provides information about swap devices. The units of size and usage are kilobytes.
`sys` (directory)	Provides information about the system and also allows you to enable, disable, or modify kernel features. You can write new settings to any file that has write permission. See Changing Kernel Parameters. The following subdirectory hierarchies of `/proc/sys` contain virtual files, some of whose values you can usefully alter: **`dev`** Device parameters. **`fs`** File system parameters. **`kernel`** Kernel configuration parameters. **`net`** Networking parameters.

Table 3-1 (Cont.) Useful Virtual Files and Directories Under /proc

Virtual File or Directory	Description
`sysvipc` (directory)	Provides information about the usage of System V Interprocess Communication (IPC) resources for messages (`msg`), semaphores (`sem`), and shared memory (`shm`).
`tty` (directory)	Provides information about the available and currently used terminal devices on the system. The `drivers` virtual file lists the devices that are currently configured.
`vmstat`	Provides information about virtual memory usage.

For more information, see the `proc(5)` manual page.

Changing Kernel Parameters

Some virtual files under `/proc`, and under `/proc/sys` in particular, are writable and you can use them to adjust settings in the kernel. For example, to change the host name, you can write a new value to `/proc/sys/kernel/hostname`:

```
echo www.mydomain.com > /proc/sys/kernel/hostname
```

Other files take value that take binary or Boolean values. For example, the value of `/proc/sys/net/ipv4/ip_forward` determines whether the kernel forwards IPv4 network packets.

```
cat /proc/sys/net/ipv4/ip_forward

0

echo 1 > /proc/sys/net/ipv4/ip_forward
cat /proc/sys/net/ipv4/ip_forward

1
```

You can use the `sysctl` command to view or modify values under the `/proc/sys` directory.

> **Note:**
>
> Even `root` cannot bypass the file access permissions of virtual file entries under `/proc`. If you attempt to change the value of a read-only entry such as `/proc/partitions`, there is no kernel code to service the `write()` system call.

To display all of the current kernel settings:

```
sudo sysctl -a
```

```
kernel.sched_child_runs_first = 0
kernel.sched_min_granularity_ns = 2000000
kernel.sched_latency_ns = 10000000
kernel.sched_wakeup_granularity_ns = 2000000
kernel.sched_shares_ratelimit = 500000
...
```

> **Note:**
>
> The delimiter character in the name of a setting is a period (`.`) rather than a slash (`/`) in a path relative to `/proc/sys`. For example, `net.ipv4.ip_forward` represents `net/ipv4/ip_forward` and `kernel.msgmax` represents `kernel/msgmax`.

To display an individual setting, specify its name as the argument to `sysctl`:

```
sudo sysctl net.ipv4.ip_forward
```

```
net.ipv4.ip_forward = 0
```

To change the value of a setting, use the following form of the command:

```
sudo sysctl -w net.ipv4.ip_forward=1
```

```
net.ipv4.ip_forward = 1
```

Changes that you make in this way remain in force only until the system is rebooted. To make configuration changes persist after the system is rebooted, you must add them to the `/etc/sysctl.d` directory as a configuration file. Any changes that you make to the files in this directory take effect when the system reboots or if you run the `sysctl --system` command, for example:

```
echo 'net.ipv4.ip_forward=1' > /etc/sysctl.d/ip_forward.conf
grep -r ip_forward /etc/sysctl.d
```

```
/etc/sysctl.d/ip_forward.conf:net.ipv4.ip_forward=1
```

```
sudo sysctl net.ipv4.ip_forward
```

```
net.ipv4.ip_forward = 0
```

```
sudo sysctl --system
```

```
* Applying /usr/lib/sysctl.d/00-system.conf ...
net.bridge.bridge-nf-call-ip6tables = 0
net.bridge.bridge-nf-call-iptables = 0
net.bridge.bridge-nf-call-arptables = 0
* Applying /usr/lib/sysctl.d/50-default.conf ...
kernel.sysrq = 16
kernel.core_uses_pid = 1
net.ipv4.conf.default.rp_filter = 1
net.ipv4.conf.all.rp_filter = 1
net.ipv4.conf.default.accept_source_route = 0
net.ipv4.conf.all.accept_source_route = 0
net.ipv4.conf.default.promote_secondaries = 1
net.ipv4.conf.all.promote_secondaries = 1
fs.protected_hardlinks = 1
fs.protected_symlinks = 1
```

```
* Applying /etc/sysctl.d/99-sysctl.conf ...
* Applying /etc/sysctl.d/ip_forward.conf ...
net.ipv4.ip_forward = 1
* Applying /etc/sysctl.conf ...
# sysctl net.ipv4.ip_forward
net.ipv4.ip_forward = 1
```

For more information, see the `sysctl(8)` and `sysctl.d(5)` manual pages.

Parameters That Control System Performance

The following parameters control aspects of system performance:

`fs.file-max`
Specifies the maximum number of open files for all processes. Increase the value of this parameter if you see messages about running out of file handles.

`net.core.netdev_max_backlog`
Specifies the size of the receiver backlog queue, which is used if an interface receives packets faster than the kernel can process them. If this queue is too small, packets are lost at the receiver, rather than on the network.

`net.core.rmem_max`
Specifies the maximum read socket buffer size. To minimize network packet loss, this buffer must be large enough to handle incoming network packets.

`net.core.wmem_max`
Specifies the maximum write socket buffer size. To minimize network packet loss, this buffer must be large enough to handle outgoing network packets.

`net.ipv4.tcp_available_congestion_control`
Displays the TCP congestion avoidance algorithms that are available for use. Use the `modprobe` command if you need to load additional modules such as `tcp_htcp` to implement the `htcp` algorithm.

`net.ipv4.tcp_congestion_control`
Specifies which TCP congestion avoidance algorithm is used.

`net.ipv4.tcp_max_syn_backlog`
Specifies the number of outstanding `SYN` requests that are allowed. Increase the value of this parameter if you see `synflood` warnings in your logs, and investigation shows that they are occurring because the server is overloaded by legitimate connection attempts.

`net.ipv4.tcp_rmem`
Specifies minimum, default, and maximum receive buffer sizes that are used for a TCP socket. The maximum value cannot be larger than `net.core.rmem_max`.

`net.ipv4.tcp_wmem`
Specifies minimum, default, and maximum send buffer sizes that are used for a TCP socket. The maximum value cannot be larger than `net.core.wmem_max`.

`vm.swappiness`
Specifies how likely the kernel is to write loaded pages to swap rather than drop pages from the system page cache. When set to 0, swapping only occurs to avoid an

out of memory condition. When set to 100, the kernel swaps aggressively. For a desktop system, setting a lower value can improve system responsiveness by decreasing latency. The default value is 60.

> **Caution:**
>
> This parameter is intended for use with laptops to reduce power consumption by the hard disk. Do not adjust this value on server systems.

Parameters That Control Kernel Panics

The following parameters control the circumstances under which a kernel panic can occur:

`kernel.hung_task_panic`
(UEK R3 only) If set to 1, the kernel panics if any kernel or user thread sleeps in the `TASK_UNINTERRUPTIBLE` state (*D state*) for more than `kernel.hung_task_timeout_secs` seconds. A process remains in D state while waiting for I/O to complete. You cannot kill or interrupt a process in this state.
The default value is 0, which disables the panic.

> **Tip:**
>
> To diagnose a hung thread, you can examine `/proc/`*`PID`*`/stack`, which displays the kernel stack for both kernel and user threads.

`kernel.hung_task_timeout_secs`
(UEK R3 only) Specifies how long a user or kernel thread can remain in D state before a warning message is generated or the kernel panics (if the value of `kernel.hung_task_panic` is 1). The default value is 120 seconds. A value of 0 disables the timeout.

`kernel.nmi_watchdog`
If set to 1 (default), enables the non-maskable interrupt (NMI) watchdog thread in the kernel. If you want to use the NMI switch or the OProfile system profiler to generate an undefined NMI, set the value of `kernel.nmi_watchdog` to 0.

`kernel.panic`
Specifies the number of seconds after a panic before a system will automatically reset itself. If the value is 0, the system hangs, which allows you to collect detailed information about the panic for troubleshooting. This is the default value.
To enable automatic reset, set a non-zero value. If you require a memory image (`vmcore`), allow enough time for Kdump to create this image. The suggested value is 30 seconds, although large systems will require a longer time.

`kernel.panic_on_io_nmi`
If set to 0 (default), the system tries to continue operations if the kernel detects an I/O channel check (IOCHK) NMI that usually indicates a uncorrectable hardware error. If set to 1, the system panics.

kernel.panic_on_oops
If set to 0, the system tries to continue operations if the kernel encounters an oops or BUG condition. If set to 1 (default), the system delays a few seconds to give the kernel log daemon, `klogd`, time to record the oops output before the panic occurs.
In an OCFS2 cluster. set the value to 1 to specify that a system must panic if a kernel oops occurs. If a kernel thread required for cluster operation crashes, the system must reset itself. Otherwise, another node might not be able to tell whether a node is slow to respond or unable to respond, causing cluster operations to hang.

kernel.panic_on_stackoverflow
(RHCK only) If set to 0 (default), the system tries to continue operations if the kernel detects an overflow in a kernel stack. If set to 1, the system panics.

kernel.panic_on_unrecovered_nmi
If set to 0 (default), the system tries to continue operations if the kernel detects an NMI that usually indicates an uncorrectable parity or ECC memory error. If set to 1, the system panics.

kernel.softlockup_panic
If set to 0 (default), the system tries to continue operations if the kernel detects a *soft-lockup* error that causes the NMI watchdog thread to fail to update its time stamp for more than twice the value of `kernel.watchdog_thresh` seconds. If set to 1, the system panics.

kernel.unknown_nmi_panic
If set to 1, the system panics if the kernel detects an undefined NMI. You would usually generate an undefined NMI by manually pressing an NMI switch. As the NMI watchdog thread also uses the undefined NMI, set the value of `kernel.unknown_nmi_panic` to 0 if you set `kernel.nmi_watchdog` to 1.

kernel.watchdog_thresh
Specifies the interval between generating an NMI performance monitoring interrupt that the kernel uses to check for *hard-lockup* and *soft-lockup* errors. A hard-lockup error is assumed if a CPU is unresponsive to the interrupt for more than `kernel.watchdog_thresh` seconds. The default value is 10 seconds. A value of 0 disables the detection of lockup errors.

vm.panic_on_oom
If set to 0 (default), the kernel's OOM-killer scans through the entire task list and attempts to kill a memory-hogging process to avoid a panic. If set to 1, the kernel panics but can survive under certain conditions. If a process limits allocations to certain nodes by using memory policies or cpusets, and those nodes reach memory exhaustion status, the OOM-killer can kill one process. No panic occurs in this case because other nodes' memory might be free and the system as a whole might not yet be out of memory. If set to 2, the kernel always panics when an OOM condition occurs. Settings of 1 and 2 are for intended for use with clusters, depending on your preferred failover policy.

About the /sys Virtual File System

In addition to `/proc`, the kernel exports information to the `/sys` virtual file system (`sysfs`). Programs such as the dynamic device manager, `udev`, use `/sys` to access device and device driver information. The implementation of `/sys` has helped to tidy up the `/proc` file system as most hardware information has been moved to `/sys`.

> **Note:**
>
> `/sys` exposes kernel data structures and control points, which implies that it might contain circular references, where a directory links to an ancestor directory. As a result, a `find` command used on `/sys` might never terminate.

The following list identifies useful virtual directories under the `/sys` directory hierarchy.

- `block`

  Contains subdirectories for block devices. For example: `/sys/block/sda`.

- `bus`

  Contains subdirectories for each supported physical bus type, such as `pci`, `pcmcia`, `scsi`, or `usb`. Under each bus type, the `devices` directory lists discovered devices, and the `drivers` directory contains directories for each device driver.

- `class`

  Contains subdirectories for every class of device that is registered with the kernel.

- `devices`

  Contains the global device hierarchy of all devices on the system. The platform directory contains peripheral devices such as device controllers that are specific to a particular platform. The `system` directory contains non-peripheral devices such as CPUs and APICs. The `virtual` directory contains virtual and pseudo devices. See Device Management.

- `firmware`

  Contains subdirectories for firmware objects.

- `module`

  Contains subdirectories for each module loaded into the kernel. You can alter some parameter values for loaded modules. See About Module Parameters.

- `power`

  Contains attributes that control the system's power state.

For more information, see https://www.kernel.org/doc/Documentation/filesystems/sysfs.txt.

Configuring System Date and Time Settings

System time is based on the POSIX time standard, where time is measured as the number of seconds that have elapsed since 00:00:00 Coordinated Universal Time (UTC), Thursday, 1 January 1970. A day is defined as 86400 seconds and leap seconds are subtracted automatically.

Date and time representation on a system can be set to match a specific timezone. To list all of the available timezones, run:

```
sudo timedatectl list-timezones
```

To set the system timezone to match a value returned from the available timezones, you can run:

```
sudo timedatectl set-timezone America/Los_Angeles
```

Substitute *America/Los_Angeles* with a valid timezone entry.

This command sets a symbolic link from `/etc/localtime` to point to the appropriate zone information file in `/usr/share/zoneinfo/`. The setting takes effect immediately. Some long running processes that might use `/etc/localtime` to detect the current system timezone, may not detect a subsequent change in system timezone until the process is restarted.

Note that timezones are largely used for display purposes or to handle user input. Changing timezone does not change the time for the system clock. You can change the presentation for system time in any console by setting the `TZ` environment variable. For example, to see the current time in Tokyo, you can run:

```
TZ="Asia/Tokyo" date
```

You can check your system's current date and time configuration by running the `timedatectl` command on its own:

```
sudo timedatectl

      Local time: Thu 2018-10-25 13:11:30 BST
  Universal time: Thu 2018-10-25 12:11:30 UTC
        RTC time: Thu 2018-10-25 12:11:17
       Time zone: Europe/London (BST, +0100)
     NTP enabled: yes
NTP synchronized: yes
 RTC in local TZ: no
      DST active: yes
 Last DST change: DST began at
                  Sun 2018-03-25 00:59:59 GMT
                  Sun 2018-03-25 02:00:00 BST
 Next DST change: DST ends (the clock jumps one hour backwards) at
                  Sun 2018-10-28 01:59:59 BST
                  Sun 2018-10-28 01:00:00 GMT
```

To set system time manually, you can use the `timedatectl set-time` command. For example. you can run:

```
sudo timedatectl set-time "2018-10-28 01:59:59"
```

This command sets the current system time based on the time specified assuming the currently set system timezone. The command also updates the system Real Time Clock (RTC).

Consider configuring your system to use network time synchronization for accurate time-keeping. This can be particularly important when setting up high-availability or when using network-based file systems.

If you configure an NTP service, you can enable NTP by running the following command:

```
sudo timedatectl set-ntp true
```

This command enables and starts the `chronyd` service, if available.

4
Device Management

This chapter describes how the system uses device files and how the udev device manager dynamically creates or removes device node files.

About Device Files

The `/dev` directory contains *device files* (also sometimes known as *device special files* and *device nodes*) that provide access to peripheral devices such as hard disks, to resources on peripheral devices such as disk partitions, and pseudo devices such as a random number generator.

The `/dev` directory has several subdirectory hierarchies, each of which holds device files that relate to a certain type of device. For example, the `/dev/disk/id-by-uuid` directory contains device files for hard disks named according to the universally unique identifier (UUID) for the disk. The device files in subdirectories such as these are actually implemented as symbolic links to device files in `/dev`. You can access the same device using the file in `/dev` or the corresponding link to the file listed in `/dev/disk/id-by-uuid`.

If you use the `ls -l` command to list the files under `/dev`, you see that some device files are shown as being either type `b` for *block* or type `c` for *character*. These devices have a pair of numbers associated with them instead of a file size. These *major* and *minor* numbers identify the device to the system.

```
ls -l /dev

total 0
crw-rw----. 1 root    root     10,  56 Mar 17 08:17 autofs
drwxr-xr-x. 2 root    root         640 Mar 17 08:17 block
drwxr-xr-x. 2 root    root          80 Mar 17 08:16 bsg
drwxr-xr-x. 3 root    root          60 Mar 17 08:16 bus
lrwxrwxrwx. 1 root    root           3 Mar 17 08:17 cdrom -> sr0
drwxr-xr-x. 2 root    root        2880 Mar 17 08:17 char
crw-------. 1 root    root      5,   1 Mar 17 08:17 console
lrwxrwxrwx. 1 root    root          11 Mar 17 08:17 core -> /proc/kcore
drwxr-xr-x. 4 root    root         100 Mar 17 08:17 cpu
crw-rw----. 1 root    root     10,  61 Mar 17 08:17 cpu_dma_latency
drwxr-xr-x. 6 root    root         120 Mar 17 08:16 disk
brw-rw----. 1 root    disk    253,   0 Mar 17 08:17 dm-0
brw-rw----. 1 root    disk    253,   1 Mar 17 08:17 dm-1
...
crw-rw-rw-. 1 root    root      1,   3 Mar 17 08:17 /dev/null
...
drwxr-xr-x. 2 root     root          0 Mar 17 08:16 pts
...
crw-rw-rw-. 1 root     root     1,   8 Mar 17 08:17 random
...
brw-rw----. 1 root     disk     8,   0 Mar 17 08:17 sda
brw-rw----. 1 root     disk     8,   1 Mar 17 08:17 sda1
brw-rw----. 1 root     disk     8,   2 Mar 17 08:17 sda2
...
lrwxrwxrwx. 1 root     root         15 Mar 17 08:17 stderr -> /proc/self/fd/2
```

```
lrwxrwxrwx. 1 root     root         15 Mar 17 08:17 stdin -> /proc/self/fd/0
lrwxrwxrwx. 1 root     root         15 Mar 17 08:17 stdout -> /proc/self/fd/1
...
crw--w----. 1 root     tty      4,   0 Mar 17 08:17 tty0
crw--w----. 1 root     tty      4,   1 Mar 17 08:17 tty1
...
crw-rw-rw-. 1 root     root     1,   9 Mar 17 08:17 urandom
...
crw-rw-rw-. 1 root     root     1,   5 Mar 17 08:17 zero
```

Block devices support random access to data, seeking media for data, and usually allow data to be buffered while it is being written or read. Examples of block devices include hard disks, CD-ROM drives, flash memory, and other addressable memory devices. The kernel writes data to or reads data from a block device in blocks of a certain number of bytes. In the sample output, `sda` is the block device file that corresponds to the hard disk, and it has a major number of 8 and a minor number of 0. `sda1` and `sda2` are partitions of this disk, and they have the same major number as `sda` (8), but their minor numbers are 1 and 2.

Character devices support streaming of data to or from a device, and data is not usually buffered nor is random access permitted to data on a device. The kernel writes data to or reads data from a character device one byte at a time. Examples of character devices include keyboards, mice, terminals, pseudo-terminals, and tape drives. `tty0` and `tty1` are character device files that correspond to terminal devices that allow users to log in from serial terminals or terminal emulators. These files have major number 4 and minor numbers 0 and 1.

Pseudo-terminals worker or secondary (slave) devices emulate real terminal devices to interact with software. For example, a user might log in on a terminal device such as `/dev/tty1`, which then uses the pseudo-terminal primary (master) device `/dev/pts/ptmx` to interact with an underlying pseudo-terminal device. The character device files for worker and primary pseudo-terminals are located in the `/dev/pts` directory:

```
ls -l /dev/pts

total 0
crw--w----. 1 guest tty  136, 0 Mar 17 10:11 0
crw--w----. 1 guest tty  136, 1 Mar 17 10:53 1
crw--w----. 1 guest tty  136, 2 Mar 17 10:11 2
c---------. 1 root  root   5, 2 Mar 17 08:16 ptmx
```

Some device entries, such as `stdin` for the standard input, are symbolically linked via the `self` subdirectory of the `proc` file system. The pseudo-terminal device file to which they actually point depends on the context of the process.

```
ls -l /proc/self/fd/[012]

total 0
lrwx------. 1 root root 64 Mar 17 10:02 0 -> /dev/pts/1
lrwx------. 1 root root 64 Mar 17 10:02 1 -> /dev/pts/1
lrwx------. 1 root root 64 Mar 17 10:02 2 -> /dev/pts/1
```

Character devices such as `null`, `random`, `urandom`, and `zero` are examples of pseudo-devices that provide access to virtual functionality implemented in software rather than to physical hardware.

`/dev/null` is a data sink. Data that you write to `/dev/null` effectively disappears but the write operation succeeds. Reading from `/dev/null` returns `EOF` (end-of-file).

/dev/zero is a data source of an unlimited number of zero-value bytes.

/dev/random and /dev/urandom are data sources of streams of pseudo-random bytes. To maintain high-entropy output, /dev/random blocks if its entropy pool does not contains sufficient bits of noise. /dev/urandom does not block and, as a result, the entropy of its output might not be as consistently high as that of /dev/random. However, neither /dev/random nor /dev/urandom are considered to be truly random enough for the purposes of secure cryptography such as military-grade encryption.

You can find out the size of the entropy pool and the entropy value for /dev/random from virtual files under /proc/sys/kernel/random:

```
cat /proc/sys/kernel/random/poolsize

4096

cat /proc/sys/kernel/random/entropy_avail

3467
```

For more information, see the null(4), pts(4), and random(4) manual pages.

About the Udev Device Manager

The udev device manager dynamically creates or removes device node files at boot time or if you add a device to or remove a device from the system with a 2.6 version kernel or later. When creating a device node, udev reads the device's /sys directory for attributes such as the label, serial number, and bus device number.

Udev can use persistent device names to guarantee consistent naming of devices across reboots, regardless of their order of discovery. Persistent device names are especially important when using external storage devices.

The configuration file for udev is /etc/udev/udev.conf. The file contains the variable udev_log which indicates the logging priority. The variable can be set to err, info and debug. The default value is err.

For more information, see the udev(7) manual page.

About Udev Rules

Udev uses rules files that determine how it identifies devices and creates device names. The udev service (systemd-udevd) reads the rules files at system startup and stores the rules in memory. If the kernel discovers a new device or an existing device goes offline, the kernel sends an event action (*uevent*) notification to udev, which matches the in-memory rules against the device attributes in /sys to identify the device. As part of device event handling, rules can specify additional programs that should run to configure a device. Rules files, which have the file extension .rules, are located in the following directories:

/lib/udev/rules.d
Contains default rules files. Do not edit these files.

/etc/udev/rules.d/*.rules
Contains customized rules files. You can modify these files.

/dev/.udev/rules.d/*.rules
Contains temporary rules files. Do not edit these files.

Udev processes the rules files in lexical order, regardless of which directory they are located. Rules files in `/etc/udev/rules.d` override files of the same name in `/lib/udev/rules.d`.

The following rules are extracted from the file `/lib/udev/rules.d/50-udev-default.rules` and illustrate the syntax of udev rules.

```
# do not edit this file, it will be overwritten on update

SUBSYSTEM=="block", SYMLINK{unique}+="block/%M:%m"
SUBSYSTEM!="block", SYMLINK{unique}+="char/%M:%m"

KERNEL=="pty[pqrstuvwxyzabcdef][0123456789abcdef]", GROUP="tty", MODE="0660"
KERNEL=="tty[pqrstuvwxyzabcdef][0123456789abcdef]", GROUP="tty", MODE="0660"
...
# mem
KERNEL=="null|zero|full|random|urandom", MODE="0666"
KERNEL=="mem|kmem|port|nvram",  GROUP="kmem", MODE="0640"
...
# block
SUBSYSTEM=="block", GROUP="disk"
...
# network
KERNEL=="tun",                  MODE="0666"
KERNEL=="rfkill",               MODE="0644"

# CPU
KERNEL=="cpu[0-9]*",            MODE="0444"
...
# do not delete static device nodes
ACTION=="remove", NAME=="", TEST=="/lib/udev/devices/%k", \
    OPTIONS+="ignore_remove"
ACTION=="remove", NAME=="?*", TEST=="/lib/udev/devices/$name", \
    OPTIONS+="ignore_remove"
```

Comment lines begin with a `#` character. All other non-blank lines define a rule, which is a list of one or more comma-separated key-value pairs. A rule either assigns a value to a key or it tries to find a match for a key by comparing its current value with the specified value. The following list shows the assignment and comparison operators that you can use:

- `=`: Assign a value to a key, overwriting any previous value.
- `+=`: Assign a value by appending it to the key's current list of values.
- `:=`: Assign a value to a key. This value cannot be changed by any further rules.
- `==`: Match the key's current value against the specified value for equality.
- `!=`: Match the key's current value against the specified value for equality.

You can use the following shell-style pattern matching characters in values:

- `?`: Matches a single character.
- `*`: Matches any number of characters, including zero.
- `[]`: Matches any single character or character from a range of characters specified within the brackets. For example, `tty[sS][0-9]` would match `ttys7` or `ttyS7`.

The following list shows commonly used match keys in rules.

- `ACTION`

  Matches the name of the action that led to an event. For example, `ACTION="add"` or `ACTION="remove"`.

- `ENV{`*`key`*`}`

  Matches a value for the device property *key*. For example, `ENV{DEVTYPE}=="disk"`.

- `KERNEL`

  Matches the name of the device that is affected by an event. For example, `KERNEL=="dm-*"` for disk media.

- `NAME`

  Matches the name of a device file or network interface. For example, `NAME="?*"` for any name that consists of one or more characters.

- `SUBSYSTEM`

  Matches the subsystem of the device that is affected by an event. For example, `SUBSYSTEM=="tty"`.

- `TEST`

  Tests if the specified file or path exists. For example, `TEST=="/lib/udev/devices/$name"`, where `$name` is the name of the currently matched device file.

Other match keys include `ATTR{`*`filename`*`}`, `ATTRS{`*`filename`*`}`, `DEVPATH`, `DRIVER`, `DRIVERS`, `KERNELS`, `PROGRAM`, `RESULT`, `SUBSYSTEMS`, and `SYMLINK`.

The following list shows commonly used assignment keys in rules.

- `ENV{`*`key`*`}`

  Specifies a value for the device property *key*. For example, `GROUP="disk"`.

- `GROUP`

  Specifies the group for a device file. For example, `GROUP="disk"`.

- `IMPORT{`*`type`*`}`:

  Specifies a set of variables for the device property, depending on *type*:

  - **`cmdline`**: Import a single property from the boot `kernel` command line. For simple flags, udev sets the value of the property to 1. For example, `IMPORT{cmdline}="nodmraid"`.
  - **`db`**: Interpret the specified value as an index into the device database and import a single property, which must have already been set by an earlier event. For example, `IMPORT{db}="DM_UDEV_LOW_PRIORITY_FLAG"`.
  - **`file`**: Interpret the specified value as the name of a text file and import its contents, which must be in environmental key format. For example, `IMPORT{file}="keyfile"`.
  - **`parent`**: Interpret the specified value as a key-name filter and import the stored keys from the database entry for the parent device. For example `IMPORT{parent}="ID_*"`.
  - **`program`**: Run the specified value as an external program and imports its result, which must be in environmental key format. For example `IMPORT{program}="usb_id --export %p"`.

- `MODE`

  Specifies the permissions for a device file. For example, `MODE="0640"`.

- `NAME`

  Specifies the name of a device file. For example, `NAME="em1"`.

- `OPTIONS`

  Specifies rule and device options. For example, `OPTIONS+="ignore_remove"`, which means that the device file is not removed if the device is removed.

- `OWNER`

  Specifies the owner for a device file. For example, `GROUP="root"`.

- `RUN`

  Specifies a command to be run after the device file has been created. For example, `RUN+="/usr/bin/eject $kernel"`, where `$kernel` is the kernel name of the device.

- `SYMLINK`

  Specifies the name of a symbolic link to a device file. For example, `SYMLINK+="disk/by-uuid/$env{ID_FS_UUID_ENC}"`, where `$env{}` is substituted with the specified device property.

Other assignment keys include `ATTR{`*`key`*`}`, `GOTO`, `LABEL`, `RUN`, and `WAIT_FOR`.

The following list shows string substitutions that are commonly used with the `GROUP`, `MODE`, `NAME`, `OWNER`, `PROGRAM`, `RUN`, and `SYMLINK` keys:

- `$attr{`*`file`*`}` or `%s{`*`file`*`}`

  Specifies the value of a device attribute from a file under `/sys`. For example, `ENV{MATCHADDR}="$attr{address}"`.

- `$devpath` or `%p`

  The device path of the device in the `sysfs` file system under `/sys`. For example, `RUN+="keyboard-force-release.sh $devpath common-volume-keys"`.

- `$env{`*`key`*`}` or `%E{`*`key`*`}`

  Specifies the value of a device property. For example, `SYMLINK+="disk/by-id/md-name-$env{MD_NAME}-part%n"`.

- `$kernel` or `%k`

  The kernel name for the device.

- `$major` or `%M`

  Specifies the major number of a device. For example, `IMPORT{program}="udisks-dm-export %M %m"`.

- `$minor` or `%m`

  Specifies the minor number of a device. For example, `RUN+="$env{LVM_SBIN_PATH}/lvm pvscan --cache --major $major --minor $minor"`.

- `$name`

Specifies the device file of the current device. For example, `TEST=="/lib/udev/devices/$name"`.

Udev expands the strings specified for `RUN` immediately before its program is executed, which is after udev has finished processing all other rules for the device. For the other keys, udev expands the strings while it is processing the rules.

For more information, see the `udev(7)` manual page.

Querying Udev and Sysfs

You can use the `udevadm` command to query the udev database and `sysfs`.

For example, to query the `sysfs` device path relative to `/sys` that corresponds to the device file `/dev/sda`:

```
sudo udevadm info --query=path --name=/dev/sda

/devices/pci0000:00/0000:00:0d.0/host0/target0:0:0/0:0:0:0/block/sda
```

To query the symbolic links that point to `/dev/sda`:

```
sudo udevadm info --query=symlink --name=/dev/sda

block/8:0
disk/by-id/ata-VBOX_HARDDISK_VB6ad0115d-356e4c09
disk/by-id/scsi-SATA_VBOX_HARDDISK_VB6ad0115d-356e4c09
disk/by-path/pci-0000:00:0d.0-scsi-0:0:0:0
```

To query the properties of `/dev/sda`:

```
sudo udevadm info --query=property --name=/dev/sda

UDEV_LOG=3
DEVPATH=/devices/pci0000:00/0000:00:0d.0/host0/target0:0:0/0:0:0:0/block/sda
MAJOR=8
MINOR=0
DEVNAME=/dev/sda
DEVTYPE=disk
SUBSYSTEM=block
ID_ATA=1
ID_TYPE=disk
ID_BUS=ata
ID_MODEL=VBOX_HARDDISK
ID_MODEL_ENC=VBOX\x20HARDDISK\x20\x20\x20\x20\x20\x20\x20\x20\x20\x20\x20\x20...
ID_REVISION=1.0
ID_SERIAL=VBOX_HARDDISK_VB579a85b0-bf6debae
ID_SERIAL_SHORT=VB579a85b0-bf6debae
ID_ATA_WRITE_CACHE=1
ID_ATA_WRITE_CACHE_ENABLED=1
ID_ATA_FEATURE_SET_PM=1
ID_ATA_FEATURE_SET_PM_ENABLED=1
ID_ATA_SATA=1
ID_ATA_SATA_SIGNAL_RATE_GEN2=1
ID_SCSI_COMPAT=SATA_VBOX_HARDDISK_VB579a85b0-bf6debae
ID_PATH=pci-0000:00:0d.0-scsi-0:0:0:0
ID_PART_TABLE_TYPE=dos
LVM_SBIN_PATH=/sbin
UDISKS_PRESENTATION_NOPOLICY=0
UDISKS_PARTITION_TABLE=1
```

```
UDISKS_PARTITION_TABLE_SCHEME=mbr
UDISKS_PARTITION_TABLE_COUNT=2
UDISKS_ATA_SMART_IS_AVAILABLE=0
DEVLINKS=/dev/block/8:0 /dev/disk/by-id/ata-VBOX_HARDDISK_VB579a85b0-bf6debae ...
```

To query all information for `/dev/sda`:

```
sudo udevadm info --query=all --name=/dev/sda

P: /devices/pci0000:00/0000:00:0d.0/host0/target0:0:0/0:0:0:0/block/sda
N: sda
W: 37
S: block/8:0
S: disk/by-id/ata-VBOX_HARDDISK_VB579a85b0-bf6debae
S: disk/by-id/scsi-SATA_VBOX_HARDDISK_VB579a85b0-bf6debae
S: disk/by-path/pci-0000:00:0d.0-scsi-0:0:0:0
E: UDEV_LOG=3
E: DEVPATH=/devices/pci0000:00/0000:00:0d.0/host0/target0:0:0/0:0:0:0/block/sda
E: MAJOR=8
E: MINOR=0
E: DEVNAME=/dev/sda
E: DEVTYPE=disk
E: SUBSYSTEM=block
E: ID_ATA=1
E: ID_TYPE=disk
E: ID_BUS=ata
E: ID_MODEL=VBOX_HARDDISK
E: 
ID_MODEL_ENC=VBOX\x20HARDDISK\x20\x20\x20\x20\x20\x20\x20\x20\x20\x20\x20\x20...
E: ID_SERIAL=VBOX_HARDDISK_VB579a85b0-bf6debae
E: ID_SERIAL_SHORT=VB579a85b0-bf6debae
E: ID_ATA_WRITE_CACHE=1
E: ID_ATA_WRITE_CACHE_ENABLED=1
E: ID_ATA_FEATURE_SET_PM=1
E: ID_ATA_FEATURE_SET_PM_ENABLED=1
E: ID_ATA_SATA=1
E: ID_ATA_SATA_SIGNAL_RATE_GEN2=1
E: ID_SCSI_COMPAT=SATA_VBOX_HARDDISK_VB579a85b0-bf6debae
E: ID_PATH=pci-0000:00:0d.0-scsi-0:0:0:0
E: ID_PART_TABLE_TYPE=dos
E: LVM_SBIN_PATH=/sbin
E: UDISKS_PRESENTATION_NOPOLICY=0
E: UDISKS_PARTITION_TABLE=1
E: UDISKS_PARTITION_TABLE_SCHEME=mbr
E: UDISKS_PARTITION_TABLE_COUNT=2
E: UDISKS_ATA_SMART_IS_AVAILABLE=0
E: DEVLINKS=/dev/block/8:0 /dev/disk/by-id/ata-VBOX_HARDDISK_VB579a85b0-
bf6debae ...
```

To display all properties of `/dev/sda` and its parent devices that udev has found in `/sys`:

```
sudo udevadm info --attribute-walk --name=/dev/sda

...
  looking at device '/devices/pci0000:00/0000:00:0d.0/host0/target0:0:0/0:0:0:0/
block/sda':
    KERNEL=="sda"
    SUBSYSTEM=="block"
    DRIVER==""
    ATTR{range}=="16"
```

```
    ATTR{ext_range}=="256"
    ATTR{removable}=="0"
    ATTR{ro}=="0"
    ATTR{size}=="83886080"
    ATTR{alignment_offset}=="0"
    ATTR{capability}=="52"
    ATTR{stat}=="   20884    15437  1254282   338919     5743     8644   103994
109005 ...
    ATTR{inflight}=="       0        0"

  looking at parent device '/devices/pci0000:00/0000:00:0d.0/host0/
target0:0:0/0:0:0:0':
    KERNELS=="0:0:0:0"
    SUBSYSTEMS=="scsi"
    DRIVERS=="sd"
    ATTRS{device_blocked}=="0"
    ATTRS{type}=="0"
    ATTRS{scsi_level}=="6"
    ATTRS{vendor}=="ATA     "
    ATTRS{model}=="VBOX HARDDISK   "
    ATTRS{rev}=="1.0 "
    ATTRS{state}=="running"
    ATTRS{timeout}=="30"
    ATTRS{iocounterbits}=="32"
    ATTRS{iorequest_cnt}=="0x6830"
    ATTRS{iodone_cnt}=="0x6826"
    ATTRS{ioerr_cnt}=="0x3"
    ATTRS{modalias}=="scsi:t-0x00"
    ATTRS{evt_media_change}=="0"
    ATTRS{dh_state}=="detached"
    ATTRS{queue_depth}=="31"
    ATTRS{queue_ramp_up_period}=="120000"
    ATTRS{queue_type}=="simple"

  looking at parent device '/devices/pci0000:00/0000:00:0d.0/host0/target0:0:0':
    KERNELS=="target0:0:0"
    SUBSYSTEMS=="scsi"
    DRIVERS==""

  looking at parent device '/devices/pci0000:00/0000:00:0d.0/host0':
    KERNELS=="host0"
    SUBSYSTEMS=="scsi"
    DRIVERS==""

  looking at parent device '/devices/pci0000:00/0000:00:0d.0':
    KERNELS=="0000:00:0d.0"
    SUBSYSTEMS=="pci"
    DRIVERS=="ahci"
    ATTRS{vendor}=="0x8086"
    ATTRS{device}=="0x2829"
    ATTRS{subsystem_vendor}=="0x0000"
    ATTRS{subsystem_device}=="0x0000"
    ATTRS{class}=="0x010601"
    ATTRS{irq}=="21"

ATTRS{local_cpus}=="00000000,00000000,00000000,00000000,00000000,00000000,00000000,0000
0003"
    ATTRS{local_cpulist}=="0-1"
    ATTRS{modalias}=="pci:v00008086d00002829sv00000000sd00000000bc01sc06i01"
    ATTRS{numa_node}=="-1"
    ATTRS{enable}=="1"
```

```
    ATTRS{broken_parity_status}=="0"
    ATTRS{msi_bus}==""
    ATTRS{msi_irqs}==""

  looking at parent device '/devices/pci0000:00':
    KERNELS=="pci0000:00"
    SUBSYSTEMS==""
    DRIVERS==""
```

The command starts at the device specified by its device path and walks up the chain of parent devices. For every device that it finds, it displays all possible attributes for the device and its parent devices in the match key format for udev rules.

For more information, see the `udevadm(8)` manual page.

Modifying Udev Rules

The order in which rules are evaluated is important. Udev processes rules in lexical order. If you want to add your own rules, you need udev to find and evaluate these rules before the default rules.

The following example illustrates how to implement a udev rules file that adds a symbolic link to the disk device `/dev/sdb`.

1. Create a rule file under `/etc/udev/rules.d` with a file name such as `10-local.rules` that udev will read before any other rules file.

   For example, the following rule in `10-local.rules` creates the symbolic link `/dev/my_disk`, which points to `/dev/sdb`:

   ```
   KERNEL=="sdb", ACTION=="add", SYMLINK="my_disk"
   ```

   Listing the device files in `/dev` shows that udev has not yet applied the rule:

   ```
   sudo ls /dev/sd* /dev/my_disk

   ls: cannot access /dev/my_disk: No such file or directory
   /dev/sda  /dev/sda1  /dev/sda2  /dev/sdb
   ```

2. To simulate how udev applies its rules to create a device, you can use the `udevadm test` command with the device path of `sdb` listed under the `/sys/class/block` hierarchy, for example:

   ```
   sudo udevadm test /sys/class/block/sdb

   calling: test
   version ...
   This program is for debugging only, it does not run any program
   specified by a RUN key. It may show incorrect results, because
   some values may be different, or not available at a simulation run.
   ...
   LINK 'my_disk' /etc/udev/rules.d/10-local.rules:1
   ...
   creating link '/dev/my_disk' to '/dev/sdb'
   creating symlink '/dev/my_disk' to 'sdb
   ...
   ACTION=add
   DEVLINKS=/dev/disk/by-id/ata-VBOX_HARDDISK_VB186e4ce2-f80f170d
     /dev/disk/by-uuid/a7dc508d-5bcc-4112-b96e-f40b19e369fe
   ```

```
  /dev/my_disk
...
```

3. Restart the `systemd-udevd` service:

   ```
   sudo systemctl restart systemd-udevd
   ```

   After udev processes the rules files, the symbolic link `/dev/my_disk` has been added:

   ```
   sudo ls -F /dev/sd* /dev/my_disk
   ```

   ```
   /dev/my_disk@  /dev/sda  /dev/sda1  /dev/sda2  /dev/sdb
   ```

To undo the changes, remove `/etc/udev/rules.d/10-local.rules` and `/dev/my_disk` and run `systemctl restart systemd-udevd` again.

5 Kernel Modules

This chapter describes how to load, unload, and modify the behavior of kernel modules.

About Kernel Modules

The boot loader loads the kernel into memory. You can add new code to the kernel by including the source files in the kernel source tree and recompiling the kernel. Kernel modules, which can be dynamically loaded and unloaded on demand, provide device drivers that allow the kernel to access new hardware, support different file system types, and extend its functionality in other ways. To avoid wasting memory on unused device drivers, Oracle Linux supports loadable kernel modules (LKMs), which allow a system to run with only the device drivers and kernel code that it requires loaded into memory.

Listing Information about Loaded Modules

Use the `lsmod` command to list the modules that are currently loaded into the kernel.

```
sudo lsmod

Module                  Size  Used by
nls_utf8                1405  1
fuse                   59164  0
tun                    12079  0
autofs4                22739  3
...
ppdev                   7901  0
parport_pc             21262  0
parport                33812  2 ppdev,parport_pc
...
```

> **Note:**
>
> This command produces its output by reading the `/proc/modules` file.

The output shows the module name, the amount of memory it uses, the number of processes using the module and the names of other modules on which it depends. In the sample output, the module `parport` depends on the modules `ppdev` and `parport_pc`, which are loaded in advance of `parport`. Two processes are currently using all three modules.

To display detailed information about a module, use the `modinfo` command, for example:

```
sudo modinfo ahci

filename:       /lib/modules/2.6.32-300.27.1.el6uek.x86_64/kernel/drivers/ata/ahci.ko
version:        3.0
license:        GPL
description:    AHCI SATA low-level driver
```

```
author:         Jeff Garzik
srcversion:     AC5EC885397BF332DE16389
alias:          pci:v*d*sv*sd*bc01sc06i01*
...
depends:
vermagic:       2.6.32-300.27.1.el6uek.x86_64 SMP mod_unload modversions
parm:           skip_host_reset:skip global host reset (0=don't skip, 1=skip)
(int)
parm:           ignore_sss:Ignore staggered spinup flag (0=don't ignore,
1=ignore) (int)
...
```

The output includes the following information:

filename
Absolute path of the kernel object file.

version
Version number of the module.

description
Short description of the module.

srcversion
Hash of the source code used to create the module.

alias
Internal alias names for the module.

depends
Comma-separated list of any modules on which this module depends.

vermagic
Kernel version that was used to compile the module, which is checked against the current kernel when the module is loaded.

parm
Module parameters and descriptions.

Modules are loaded into the kernel from kernel object (`ko`) files in the `/lib/modules/`*`kernel_version`*`/kernel` directory. To display the absolute path of a kernel object file, specify the -n option, for example:

```
sudo modinfo -n parport

/lib/modules/2.6.32-300.27.1.el6uek.x86_64/kernel/drivers/parport/parport.ko
```

For more information, see the `lsmod(5)` and `modinfo(8)` manual pages.

Loading and Unloading Modules

The `modprobe` command loads kernel modules, for example:

```
sudo modprobe nfs
sudo lsmod | grep nfs

nfs                    266415  0
lockd                   66530  1 nfs
```

```
fscache                 41704  1 nfs
nfs_acl                  2477  1 nfs
auth_rpcgss             38976  1 nfs
sunrpc                 204268  5 nfs,lockd,nfs_acl,auth_rpcgss
```

Use the `-v` verbose option to show if any additional modules are loaded to resolve dependencies.

```
sudo modprobe -v nfs

insmod /lib/modules/2.6.32-300.27.1.el6uek.x86_64/kernel/net/sunrpc/auth_gss/
auth_rpcgss.ko
insmod /lib/modules/2.6.32-300.27.1.el6uek.x86_64/kernel/fs/nfs_common/nfs_acl.ko
insmod /lib/modules/2.6.32-300.27.1.el6uek.x86_64/kernel/fs/fscache/fscache.ko
...
```

To determine the dependencies, the `modprobe` command queries the `/lib/modules/`*`kernel_version`*`/modules.dep` file, which the `depmod` utility creates when you install kernel modules.

> **Note:**
>
> `modprobe` does not reload modules that are already loaded. You must first unload a module before you can load it again.

Use the `-r` option to unload kernel modules, for example:

```
sudo modprobe -rv nfs

rmmod /lib/modules/2.6.32-300.27.1.el6uek.x86_64/kernel/fs/nfs/nfs.ko
rmmod /lib/modules/2.6.32-300.27.1.el6uek.x86_64/kernel/fs/lockd/lockd.ko
rmmod /lib/modules/2.6.32-300.27.1.el6uek.x86_64/kernel/fs/fscache/fscache.ko
...
```

Modules are unloaded in the reverse order that they were loaded. Modules are not unloaded if a process or another loaded module requires them.

> **Note:**
>
> `modprobe` uses the `insmod` and `rmmod` utilities to load and unload modules. As `insmod` and `rmmod` do not resolve module dependencies, do not use these utilities.

For more information, see the `modprobe(8)` and `modules.dep(5)` manual pages.

About Module Parameters

Modules accept parameters that you can specify using `modprobe` to modify a module's behavior:

```
sudo modprobe module_name parameter=value ...
```

Use spaces to separate multiple parameter/value pairs. Array values are represented by a comma-separated list, for example:

```
sudo modprobe foo arrayparm=1,2,3,4
```

You can also change the values of some parameters for loaded modules and built-in drivers by writing the new value to a file under `/sys/module/`*`module_name`*`/parameters`, for example:

```
echo 0 > /sys/module/ahci/parameters/skip_host_reset
```

The `/etc/modprobe.d` directory contains `.conf` configuration files specify module options, create module aliases, and override the usual behavior of `modprobe` for modules with special requirements. The `/etc/modprobe.conf` file that was used with earlier versions of `modprobe` is also valid if it exists. Entries in the `/etc/modprobe.conf` and `/etc/modprobe.d/*.conf` files use the same syntax.

The following are commonly used commands in `modprobe` configuration files:

`alias`
Creates an alternate name for a module. The alias can include shell wildcards. For example, create an alias for the `sd-mod` module:

```
alias block-major-8-* sd_mod
```

As a result, a command such as `modprobe block-major-8-0` has the same effect as `modprobe sd_mod`.

`blacklist`
Ignore a module's internal alias that is displayed by the `modinfo` command. This command is typically used if the associated hardware is not required, if two or more modules both support the same devices, or if a module invalidly claims to support a device. For example, to blocklist the alias for the frame-buffer driver `cirrusfb`:

```
blacklist cirrusfb
```

The `/etc/modprobe.d/blacklist.conf` file prevents hotplug scripts from loading a module, usually so that a different driver binds the module instead, regardless of which driver happens to be probed first.

`install`
Runs a shell command instead of loading a module into the kernel. For example, load the module `snd-emu10k1-synth` instead of `snd-emu10k1`:

```
install snd-emu10k1 /sbin/modprobe --ignore-install snd-emu10k1 && \
/sbin/modprobe snd-emu10k1-synth
```

`options`
Defines options for a module,. For example, define the `nohwcrypt` and `qos` options for the `b43` module:

```
options b43 nohwcrypt=1 qos=0
```

`remove`
Runs a shell command instead of unloading a module. For example, unmount `/proc/fs/nfsd` before unloading the `nfsd` module:

```
remove nfsd { /bin/umount /proc/fs/nfsd > /dev/null 2>&1 || :; } ; \
/sbin/modprobe -r --first-time --ignore-remove nfsd
```

For more information, see the `modprobe.conf(5)` manual page.

Specifying Modules To Be Loaded at Boot Time

The system loads most modules automatically at boot time. If necessary, you can specify an additional module that should be loaded.

To specify a module to be loaded at boot time:

1. Create a file in the `/etc/sysconfig/modules` directory. The file name must have the extension `.modules`, for example `foo.modules`.
2. Edit the file to create the script that loads the module.

   The script to load a module can be a simple `modprobe` call, for example:

   ```
   #!/bin/sh
   modprobe foo
   ```

   or more complex to include error handling:

   ```
   #!/bin/sh
   if [ ! -c /dev/foo ] ; then
     exec /sbin/modprobe foo > /dev/null 2>&1
   fi
   ```

3. Use the following command to make the script executable:

   ```
   sudo chmod 755 /etc/sysconfig/modules/foo.modules
   ```

About Weak Update Modules

External modules, such as drivers installed using a driver update disk, are usually installed into `/lib/modules/`*`kernel-version`*`/extra`. Modules stored in this directory are given preference over matching modules included with the kernel, itself, when you attempt to load them. This means that external drivers and modules can be installed to override kernel modules where hardware issues may need resolution. For each subsequent kernel update, it is important that the external module is made available to each compatible kernel to avoid potential boot issues resulting from driver incompatibilities with the affected hardware.

Since the requirement to load the external module with each compatible kernel update is system critical, a mechanism is in place so that external modules can be loaded as weak update modules for compatible kernels. Weak update modules are made available by creating symbolic links to compatible modules in the `/lib/modules/`*`kernel-version`*`/weak-updates` directory. The package manager handles this process automatically when it detects driver modules installed in any `/lib/modules/`*`kernel-version`*`/extra` directories for compatible kernels. For example, installation of the `kmod-megaraid_sas-uek` driver update package on the Driver Update Disk (DUD) for the Oracle Linux 7.4 might install the following:

```
/lib/modules/4.1.12-61.1.18.el7uek.x86_64/extra/megaraid_sas
/lib/modules/4.1.12-61.1.18.el7uek.x86_64/extra/megaraid_sas/megaraid_sas.ko
```

The new driver module is installed into the `extra` directory for the `4.1.12-61.1.18.el7uek.x86_64`, which was the kernel version that was originally used to build the module.

A subsequent kernel update means that the system is now running the `4.1.12-112.14.13.el7uek.x86_64` version of the kernel. This kernel is compatible with the module installed for the previous kernel, so the external module is automatically added, as a symbolic link, in the `weak-updates` directory as part of the installation process:

```
ls -l /lib/modules/4.1.12-112.14.13.el7uek.x86_64/weak-updates/megaraid_sas/*.ko

lrwxrwxrwx. 1 root root 76 Jan 30 04:52 /lib/modules/
4.1.12-112.14.13.el7uek.x86_64\
    /weak-updates/megaraid_sas/megaraid_sas.ko \
     -> /lib/modules/4.1.12-61.1.18.el7uek.x86_64/extra/megaraid_sas/
megaraid_sas.ko
```

The output means that the external module is loaded for subsequent kernel updates.

In most cases, weak updates make sense and ensure that no extra work must be done to carry an external module through subsequent kernel updates. This prevents possible driver related boot issues after kernel upgrades and maintains the predictable running of a system and its hardware.

In some cases you may wish to remove weak update modules for a newer kernel. For instance, if an issue has been resolved for a driver that is shipped in the newer kernel and you would prefer to use this driver over the external module that you installed as part of a driver update.

You can remove weak update modules by removing the symbolic links for each kernel, manually. For example:

```
sudo rm -rf /lib/modules/4.1.12-112.14.13.el7uek.x86_64/weak-updates/
megaraid_sas/
```

For more information about external driver modules and driver update disks, see Oracle Linux 7: Installation Guide.