Managing Integrated Peripherals

Special Files

In a PC, peripherals are connected to a **controler** which communicates with the processor via a **bus**. The controller and associated peripherals require specific drivers. Under Linux, these drivers are normally supplied as kernel **modules**. Each peripheral is represented by a special file in the **/dev** directory. Each special file contains the information required by the system in order for it to use the driver.

<note important> Peripherals that require the system to be halted prior to plugging or unplugging them are refered to as **Cold Plug Devices**. Peripherals that can be plugged/unplugged whilst the system is running are refered to as **Hot Plug Devices**. </note>

The following output shows the typical content of the /dev directory:

```
[root@centos ~]# ls -l /dev
total 0
crw-rw----. 1 root     root     10,  55 Apr  9 09:08 autofs
drwxr-xr-x. 2 root     root         620 Apr  9 09:07 block
drwxr-xr-x. 2 root     root          80 Apr  9 09:07 bsg
drwxr-xr-x. 3 root     root          60 Apr  9 09:07 bus
lrwxrwxrwx. 1 root     root           3 Apr  9 09:07 cdrom -> sr0
drwxr-xr-x. 2 root     root        2740 Apr  9 09:08 char
crw-------. 1 root     root      5,   1 Apr  9 09:07 console
lrwxrwxrwx. 1 root     root          11 Apr  9 09:07 core -> /proc/kcore
drwxr-xr-x. 3 root     root          80 Apr  9 09:07 cpu
crw-rw----. 1 root     root     10,  61 Apr  9 09:07 cpu_dma_latency
crw-rw----. 1 root     root     10,  62 Apr  9 09:07 crash
drwxr-xr-x. 5 root     root         100 Apr  9 09:07 disk
lrwxrwxrwx. 1 root     root           3 Apr  9 09:07 dvd -> sr0
lrwxrwxrwx. 1 root     root           3 Apr  9 09:07 fb -> fb0
crw-rw----. 1 root     root     29,   0 Apr  9 09:07 fb0
lrwxrwxrwx. 1 root     root          13 Apr  9 09:07 fd -> /proc/self/fd
```

```
crw-rw-rw-. 1 root     root      1,   7 Apr  9 09:07 full
crw-rw-rw-. 1 root     root     10, 229 Apr  9 09:08 fuse
crw-rw----. 1 root     root     10, 228 Apr  9 09:07 hpet
drwxr-xr-x. 2 root     root         40 Apr  9 09:07 hugepages
crw-------. 1 root     root    229,   0 Apr  9 09:07 hvc0
drwxr-xr-x. 3 root     root        240 Apr  9 09:07 input
crw-rw----. 1 root     root      1,  11 Apr  9 09:07 kmsg
srw-rw-rw-. 1 root     root          0 Apr  9 09:07 log
brw-rw----. 1 root     disk      7,   0 Apr  9 09:07 loop0
brw-rw----. 1 root     disk      7,   1 Apr  9 09:07 loop1
brw-rw----. 1 root     disk      7,   2 Apr  9 09:07 loop2
brw-rw----. 1 root     disk      7,   3 Apr  9 09:07 loop3
brw-rw----. 1 root     disk      7,   4 Apr  9 09:07 loop4
brw-rw----. 1 root     disk      7,   5 Apr  9 09:07 loop5
brw-rw----. 1 root     disk      7,   6 Apr  9 09:07 loop6
brw-rw----. 1 root     disk      7,   7 Apr  9 09:07 loop7
crw-rw----. 1 root     lp        6,   0 Apr  9 09:07 lp0
crw-rw----. 1 root     lp        6,   1 Apr  9 09:07 lp1
crw-rw----. 1 root     lp        6,   2 Apr  9 09:07 lp2
crw-rw----. 1 root     lp        6,   3 Apr  9 09:07 lp3
lrwxrwxrwx. 1 root     root         13 Apr  9 09:07 MAKEDEV -> /sbin/MAKEDEV
drwxr-xr-x. 2 root     root         60 Apr  9 09:07 mapper
crw-rw----. 1 root     root     10, 227 Apr  9 09:07 mcelog
crw-r-----. 1 root     kmem      1,   1 Apr  9 09:07 mem
drwxr-xr-x. 2 root     root         60 Apr  9 09:07 net
crw-rw----. 1 root     root     10,  60 Apr  9 09:07 network_latency
crw-rw----. 1 root     root     10,  59 Apr  9 09:07 network_throughput
crw-rw-rw-. 1 root     root      1,   3 Apr  9 09:07 null
crw-r-----. 1 root     kmem     10, 144 Apr  9 09:07 nvram
crw-rw----. 1 root     root      1,  12 Apr  9 09:07 oldmem
crw-r-----. 1 root     kmem      1,   4 Apr  9 09:07 port
crw-------. 1 root     root    108,   0 Apr  9 09:07 ppp
crw-rw-rw-. 1 root     tty       5,   2 Jun 16 05:19 ptmx
drwxr-xr-x. 2 root     root          0 Apr  9 09:07 pts
```

```
brw-rw----. 1 root     disk      1,    0 Apr  9 09:07 ram0
brw-rw----. 1 root     disk      1,    1 Apr  9 09:07 ram1
brw-rw----. 1 root     disk      1,   10 Apr  9 09:07 ram10
brw-rw----. 1 root     disk      1,   11 Apr  9 09:07 ram11
brw-rw----. 1 root     disk      1,   12 Apr  9 09:07 ram12
brw-rw----. 1 root     disk      1,   13 Apr  9 09:07 ram13
brw-rw----. 1 root     disk      1,   14 Apr  9 09:07 ram14
brw-rw----. 1 root     disk      1,   15 Apr  9 09:07 ram15
brw-rw----. 1 root     disk      1,    2 Apr  9 09:07 ram2
brw-rw----. 1 root     disk      1,    3 Apr  9 09:07 ram3
brw-rw----. 1 root     disk      1,    4 Apr  9 09:07 ram4
brw-rw----. 1 root     disk      1,    5 Apr  9 09:07 ram5
brw-rw----. 1 root     disk      1,    6 Apr  9 09:07 ram6
brw-rw----. 1 root     disk      1,    7 Apr  9 09:07 ram7
brw-rw----. 1 root     disk      1,    8 Apr  9 09:07 ram8
brw-rw----. 1 root     disk      1,    9 Apr  9 09:07 ram9
crw-rw-rw-. 1 root     root      1,    8 Apr  9 09:07 random
drwxr-xr-x. 2 root     root           60 Apr  9 09:07 raw
lrwxrwxrwx. 1 root     root            4 Apr  9 09:07 root -> sda2
lrwxrwxrwx. 1 root     root            4 Apr  9 09:07 rtc -> rtc0
crw-rw----. 1 root     root    254,    0 Apr  9 09:07 rtc0
lrwxrwxrwx. 1 root     root            3 Apr  9 09:07 scd0 -> sr0
brw-rw----. 1 root     disk      8,    0 Apr  9 09:07 sda
brw-rw----. 1 root     disk      8,    1 Apr  9 09:07 sda1
brw-rw----. 1 root     disk      8,    2 Apr  9 09:07 sda2
brw-rw----. 1 root     disk      8,    3 Apr  9 09:07 sda3
crw-rw----. 1 root     cdrom    21,    0 Apr  9 09:07 sg0
crw-rw----. 1 root     disk     21,    1 Apr  9 09:07 sg1
drwxrwxrwt. 2 root     root          160 Jun 11 15:47 shm
crw-rw----. 1 root     root     10, 231 Apr  9 09:07 snapshot
drwxr-xr-x. 3 root     root          180 Apr  9 09:07 snd
brw-rw----+ 1 root     cdrom    11,    0 Apr  9 09:07 sr0
lrwxrwxrwx. 1 root     root           15 Apr  9 09:07 stderr -> /proc/self/fd/2
lrwxrwxrwx. 1 root     root           15 Apr  9 09:07 stdin -> /proc/self/fd/0
```

```
lrwxrwxrwx. 1 root     root          15 Apr  9 09:07 stdout -> /proc/self/fd/1
lrwxrwxrwx. 1 root     root           4 Apr  9 09:07 systty -> tty0
crw-rw-rw-. 1 root     tty       5,   0 Apr  9 09:07 tty
crw--w----. 1 root     tty       4,   0 Apr  9 09:07 tty0
crw--w----. 1 root     tty       4,   1 Apr  9 09:08 tty1
crw--w----. 1 root     tty       4,  10 Apr  9 09:07 tty10
crw--w----. 1 root     tty       4,  11 Apr  9 09:07 tty11
crw--w----. 1 root     tty       4,  12 Apr  9 09:07 tty12
crw--w----. 1 root     tty       4,  13 Apr  9 09:07 tty13
crw--w----. 1 root     tty       4,  14 Apr  9 09:07 tty14
crw--w----. 1 root     tty       4,  15 Apr  9 09:07 tty15
crw--w----. 1 root     tty       4,  16 Apr  9 09:07 tty16
crw--w----. 1 root     tty       4,  17 Apr  9 09:07 tty17
crw--w----. 1 root     tty       4,  18 Apr  9 09:07 tty18
crw--w----. 1 root     tty       4,  19 Apr  9 09:07 tty19
crw-------. 1 root     root      4,   2 Apr  9 09:08 tty2
crw--w----. 1 root     tty       4,  20 Apr  9 09:07 tty20
crw--w----. 1 root     tty       4,  21 Apr  9 09:07 tty21
crw--w----. 1 root     tty       4,  22 Apr  9 09:07 tty22
crw--w----. 1 root     tty       4,  23 Apr  9 09:07 tty23
crw--w----. 1 root     tty       4,  24 Apr  9 09:07 tty24
crw--w----. 1 root     tty       4,  25 Apr  9 09:07 tty25
crw--w----. 1 root     tty       4,  26 Apr  9 09:07 tty26
crw--w----. 1 root     tty       4,  27 Apr  9 09:07 tty27
crw--w----. 1 root     tty       4,  28 Apr  9 09:07 tty28
crw--w----. 1 root     tty       4,  29 Apr  9 09:07 tty29
crw-------. 1 root     root      4,   3 Apr  9 09:08 tty3
crw--w----. 1 root     tty       4,  30 Apr  9 09:07 tty30
crw--w----. 1 root     tty       4,  31 Apr  9 09:07 tty31
crw--w----. 1 root     tty       4,  32 Apr  9 09:07 tty32
crw--w----. 1 root     tty       4,  33 Apr  9 09:07 tty33
crw--w----. 1 root     tty       4,  34 Apr  9 09:07 tty34
crw--w----. 1 root     tty       4,  35 Apr  9 09:07 tty35
crw--w----. 1 root     tty       4,  36 Apr  9 09:07 tty36
```

```
crw--w----. 1 root     tty       4,  37 Apr  9 09:07 tty37
crw--w----. 1 root     tty       4,  38 Apr  9 09:07 tty38
crw--w----. 1 root     tty       4,  39 Apr  9 09:07 tty39
crw-------. 1 root     root      4,   4 Apr  9 09:08 tty4
crw--w----. 1 root     tty       4,  40 Apr  9 09:07 tty40
crw--w----. 1 root     tty       4,  41 Apr  9 09:07 tty41
crw--w----. 1 root     tty       4,  42 Apr  9 09:07 tty42
crw--w----. 1 root     tty       4,  43 Apr  9 09:07 tty43
crw--w----. 1 root     tty       4,  44 Apr  9 09:07 tty44
crw--w----. 1 root     tty       4,  45 Apr  9 09:07 tty45
crw--w----. 1 root     tty       4,  46 Apr  9 09:07 tty46
crw--w----. 1 root     tty       4,  47 Apr  9 09:07 tty47
crw--w----. 1 root     tty       4,  48 Apr  9 09:07 tty48
crw--w----. 1 root     tty       4,  49 Apr  9 09:07 tty49
crw-------. 1 root     root      4,   5 Apr  9 09:08 tty5
crw--w----. 1 root     tty       4,  50 Apr  9 09:07 tty50
crw--w----. 1 root     tty       4,  51 Apr  9 09:07 tty51
crw--w----. 1 root     tty       4,  52 Apr  9 09:07 tty52
crw--w----. 1 root     tty       4,  53 Apr  9 09:07 tty53
crw--w----. 1 root     tty       4,  54 Apr  9 09:07 tty54
crw--w----. 1 root     tty       4,  55 Apr  9 09:07 tty55
crw--w----. 1 root     tty       4,  56 Apr  9 09:07 tty56
crw--w----. 1 root     tty       4,  57 Apr  9 09:07 tty57
crw--w----. 1 root     tty       4,  58 Apr  9 09:07 tty58
crw--w----. 1 root     tty       4,  59 Apr  9 09:07 tty59
crw-------. 1 root     root      4,   6 Apr  9 09:08 tty6
crw--w----. 1 root     tty       4,  60 Apr  9 09:07 tty60
crw--w----. 1 root     tty       4,  61 Apr  9 09:07 tty61
crw--w----. 1 root     tty       4,  62 Apr  9 09:07 tty62
crw--w----. 1 root     tty       4,  63 Apr  9 09:07 tty63
crw--w----. 1 root     tty       4,   7 Apr  9 09:07 tty7
crw--w----. 1 root     tty       4,   8 Apr  9 09:07 tty8
crw--w----. 1 root     tty       4,   9 Apr  9 09:07 tty9
crw-rw----. 1 root     dialout   4,  64 Apr  9 09:07 ttyS0
```

```
crw-rw----. 1 root     dialout   4,  65 Apr  9 09:07 ttyS1
crw-rw----. 1 root     dialout   4,  66 Apr  9 09:07 ttyS2
crw-rw----. 1 root     dialout   4,  67 Apr  9 09:07 ttyS3
crw-rw-rw-. 1 root     root      1,   9 Apr  9 09:07 urandom
crw-rw----. 1 root     root    250,   0 Apr  9 09:07 usbmon0
crw-rw----. 1 root     root    250,   1 Apr  9 09:07 usbmon1
crw-rw----. 1 vboxadd  root     10,  57 Apr  9 09:07 vboxguest
crw-rw-rw-. 1 vboxadd  root     10,  56 Apr  9 09:07 vboxuser
crw-rw----. 1 vcsa     tty       7,   0 Apr  9 09:07 vcs
crw-rw----. 1 vcsa     tty       7,   1 Apr  9 09:07 vcs1
crw-rw----. 1 vcsa     tty       7,   2 Apr  9 09:08 vcs2
crw-rw----. 1 vcsa     tty       7,   3 Apr  9 09:08 vcs3
crw-rw----. 1 vcsa     tty       7,   4 Apr  9 09:08 vcs4
crw-rw----. 1 vcsa     tty       7,   5 Apr  9 09:08 vcs5
crw-rw----. 1 vcsa     tty       7,   6 Apr  9 09:08 vcs6
crw-rw----. 1 vcsa     tty       7, 128 Apr  9 09:07 vcsa
crw-rw----. 1 vcsa     tty       7, 129 Apr  9 09:07 vcsa1
crw-rw----. 1 vcsa     tty       7, 130 Apr  9 09:08 vcsa2
crw-rw----. 1 vcsa     tty       7, 131 Apr  9 09:08 vcsa3
crw-rw----. 1 vcsa     tty       7, 132 Apr  9 09:08 vcsa4
crw-rw----. 1 vcsa     tty       7, 133 Apr  9 09:08 vcsa5
crw-rw----. 1 vcsa     tty       7, 134 Apr  9 09:08 vcsa6
crw-rw----. 1 root     root     10,  63 Apr  9 09:07 vga_arbiter
crw-rw-rw-. 1 root     root      1,   5 Apr  9 09:07 zero
```

As you can see, certain files refer to **block** devices whilst others refer to **character** devices:

```
...
brw-rw----. 1 root     disk      8,   1 Apr  9 09:07 sda1
...
crw-rw-rw-. 1 root     tty       5,   0 Apr  9 09:07 tty
...
```

The major difference between these two types lies in the way that the communication between the system and the peripheral takes place. In the case

of a block file, that communication uses a buffer whilst in the case of a character file the communication takes place directly byte by byte.

The figures that can be seen immediately before the date of the special file are called respectively the **major** and the **minor** :

- the **major** identifies the peripheral's driver,
- the **minor** identifies the peripheral. For instance 8,1 indicates the first partition of the **sda** disk.

Commands

The lspci Command

This command show a list of the peripherals connected to the PCI, AGP and PCI express buses:

```
[root@centos ~]# 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)
00:0d.0 SATA controller: Intel Corporation 82801HM/HEM (ICH8M/ICH8M-E) SATA Controller [AHCI mode] (rev 02)
```

To obtain peripheral specific information, use the **-v** or **-vv** switches whilst specifying the peripheral ID:

```
[root@centos ~]# lspci -v -s 00:03.0
00:03.0 Ethernet controller: Intel Corporation 82540EM Gigabit Ethernet Controller (rev 02)
    Subsystem: Intel Corporation PRO/1000 MT Desktop Adapter
    Flags: bus master, 66MHz, medium devsel, latency 64, IRQ 10
    Memory at f0000000 (32-bit, non-prefetchable) [size=128K]
```

```
        I/O ports at d010 [size=8]
        Capabilities: [dc] Power Management version 2
        Capabilities: [e4] PCI-X non-bridge device
        Kernel driver in use: e1000
        Kernel modules: e1000

[root@centos ~]# lspci -vv -s 00:03.0
00:03.0 Ethernet controller: Intel Corporation 82540EM Gigabit Ethernet Controller (rev 02)
        Subsystem: Intel Corporation PRO/1000 MT Desktop Adapter
        Control: I/O+ Mem+ BusMaster+ SpecCycle- MemWINV- VGASnoop- ParErr- Stepping- SERR- FastB2B- DisINTx-
        Status: Cap+ 66MHz+ UDF- FastB2B- ParErr- DEVSEL=medium >TAbort- <TAbort- <MAbort- >SERR- <PERR- INTx-
        Latency: 64 (63750ns min)
        Interrupt: pin A routed to IRQ 10
        Region 0: Memory at f0000000 (32-bit, non-prefetchable) [size=128K]
        Region 2: I/O ports at d010 [size=8]
        Capabilities: [dc] Power Management version 2
            Flags: PMEClk- DSI+ D1- D2- AuxCurrent=0mA PME(D0-,D1-,D2-,D3hot-,D3cold-)
            Status: D0 NoSoftRst- PME-Enable- DSel=0 DScale=0 PME-
        Capabilities: [e4] PCI-X non-bridge device
            Command: DPERE- ERO+ RBC=512 OST=1
            Status: Dev=ff:1f.0 64bit- 133MHz- SCD- USC- DC=simple DMMRBC=2048 DMOST=1 DMCRS=8 RSCEM- 266MHz- 533MHz-
        Kernel driver in use: e1000
        Kernel modules: e1000
```

Command Line Switches

The command line switches of this command are:

```
[root@centos ~]# lspci --help
lspci: invalid option -- '-'
Usage: lspci [<switches>]

Basic display modes:
```

```
-mm      Produce machine-readable output (single -m for an obsolete format)
-t       Show bus tree

Display options:
-v       Be verbose (-vv for very verbose)
-k       Show kernel drivers handling each device
-x       Show hex-dump of the standard part of the config space
-xxx        Show hex-dump of the whole config space (dangerous; root only)
-xxxx       Show hex-dump of the 4096-byte extended config space (root only)
-b       Bus-centric view (addresses and IRQ's as seen by the bus)
-D       Always show domain numbers

Resolving of device ID's to names:
-n       Show numeric ID's
-nn      Show both textual and numeric ID's (names & numbers)
-q       Query the PCI ID database for unknown ID's via DNS
-qq      As above, but re-query locally cached entries
-Q       Query the PCI ID database for all ID's via DNS

Selection of devices:
-s [[[[<domain>]:]<bus>]:][<slot>][.[<func>]]   Show only devices in selected slots
-d [<vendor>]:[<device>]             Show only devices with specified ID's

Other options:
-i <file> Use specified ID database instead of /usr/share/hwdata/pci.ids
-p <file> Look up kernel modules in a given file instead of default modules.pcimap
-M       Enable `bus mapping' mode (dangerous; root only)

PCI access options:
-A <method>   Use the specified PCI access method (see `-A help' for a list)
-O <par>=<val>  Set PCI access parameter (see `-O help' for a list)
-G       Enable PCI access debugging
-H <mode> Use direct hardware access (<mode> = 1 or 2)
-F <file> Read PCI configuration dump from a given file
```

The lsusb Command

This command show a list of the peripherals connected to the USB bus:

```
[root@centos ~]# lsusb
Bus 001 Device 001: ID 1d6b:0001 Linux Foundation 1.1 root hub
```

To obtain peripheral specific information, use the **-d** switch whilst specifying the peripheral ID:

Command Line Switches

The command line switches of this command are:

```
[root@centos ~]# lsusb --help
lsusb: unrecognized option '--help'
Usage: lsusb [options]...
List USB devices
  -v, --verbose
      Increase verbosity (show descriptors)
  -s [[bus]:][devnum]
      Show only devices with specified device and/or
      bus numbers (in decimal)
  -d vendor:[product]
      Show only devices with the specified vendor and
      product ID numbers (in hexadecimal)
  -D device
      Selects which device lsusb will examine
  -t
      Dump the physical USB device hierarchy as a tree
  -V, --version
      Show version of program
```

The dmidecode Command

The **dmidecode** Command reads the **DMI** (*Desktop Management Interface*) table, also called the **SMBIOS** (*System Management BIOS*) and provides information on:

- the current status of each peripheral,
- possible extensions.

```
[root@centos ~]# dmidecode
# dmidecode 2.11
SMBIOS 2.5 present.
10 structures occupying 448 bytes.
Table at 0x000E1000.

Handle 0x0000, DMI type 0, 20 bytes
BIOS Information
    Vendor: innotek GmbH
    Version: VirtualBox
    Release Date: 12/01/2006
    Address: 0xE0000
    Runtime Size: 128 kB
    ROM Size: 128 kB
    Characteristics:
        ISA is supported
        PCI is supported
        Boot from CD is supported
        Selectable boot is supported
        8042 keyboard services are supported (int 9h)
        CGA/mono video services are supported (int 10h)
        ACPI is supported

Handle 0x0001, DMI type 1, 27 bytes
System Information
    Manufacturer: innotek GmbH
```

```
    Product Name: VirtualBox
    Version: 1.2
    Serial Number: 0
    UUID: Not Settable
    Wake-up Type: Power Switch
    SKU Number: Not Specified
    Family: Virtual Machine

Handle 0x0008, DMI type 2, 15 bytes
Base Board Information
    Manufacturer: Oracle Corporation
    Product Name: VirtualBox
    Version: 1.2
    Serial Number: 0
    Asset Tag: Not Specified
    Features:
        Board is a hosting board
    Location In Chassis: Not Specified
    Chassis Handle: 0x0003
    Type: Motherboard
    Contained Object Handles: 0

Handle 0x0003, DMI type 3, 13 bytes
Chassis Information
    Manufacturer: Oracle Corporation
    Type: Other
    Lock: Not Present
    Version: Not Specified
    Serial Number: Not Specified
    Asset Tag: Not Specified
    Boot-up State: Safe
    Power Supply State: Safe
    Thermal State: Safe
    Security Status: None
```

```
Handle 0x0007, DMI type 126, 42 bytes
Inactive


Handle 0x0005, DMI type 126, 15 bytes
Inactive


Handle 0x0006, DMI type 126, 28 bytes
Inactive


Handle 0x0002, DMI type 11, 7 bytes
OEM Strings
        String 1: vboxVer_4.3.0
        String 2: vboxRev_89960


Handle 0x0008, DMI type 128, 8 bytes
OEM-specific Type
        Header and Data:
                80 08 08 00 B5 F9 22 00


Handle 0xFEFF, DMI type 127, 4 bytes
End Of Table
```

Command Line Switches

The command line switches of this command are:

```
[root@centos ~]# dmidecode --help
Usage: dmidecode [OPTIONS]
Options are:
 -d, --dev-mem FILE     Read memory from device FILE (default: /dev/mem)
 -h, --help             Display this help text and exit
 -q, --quiet            Less verbose output
 -s, --string KEYWORD   Only display the value of the given DMI string
```

```
 -t, --type TYPE        Only display the entries of given type
 -u, --dump             Do not decode the entries
    --dump-bin FILE     Dump the DMI data to a binary file
    --from-dump FILE    Read the DMI data from a binary file
 -V, --version          Display the version and exit
```

The /proc Directory

The /proc directory contains virtual files and directories wich are created dynamically when consulted. Only root can consult all of the information in /proc.

```
[root@centos ~]# ls /proc
1      1355   1492   1755   1829   1922   2052   2114   2139   2206   27     3      38     8          cpuinfo     interrupts
kpagecount  mtrr          stat            vmallocinfo
10     1393   15     1771   1831   1931   2057   2115   2140   23     27466  30     388    9          crypto      iomem
kpageflags  net           swaps           vmstat
11     1397   1512   1779   1838   1939   2060   2117   2141   2363   27467  300    39     971        devices     ioports
loadavg     pagetypeinfo  sys             zoneinfo
1188   14     1574   1787   1839   1961   2085   2126   2142   2371   27468  31     4      972        diskstats   ipmi
locks       partitions    sysrq-trigger
12     1403   1586   1798   1840   1970   2093   2127   2144   2372   27482  31548  433    acpi       dma         irq
mdstat      sched_debug   sysvipc
1230   1413   16     18     1855   1978   2098   2129   2147   2373   27488  31644  5      asound     driver      kallsyms
meminfo     schedstat     timer_list
13     1438   1658   1811   1857   1979   21     2131   2151   2385   28     339    577    buddyinfo  execdomains kcore
misc        scsi          timer_stats
1325   1447   1666   1818   1875   2      2106   2133   2156   24     29     340    6      bus        fb          keys
modules     self          tty
1336   1448   17     1825   1881   20     2110   2134   22     25     290    36     69     cgroups    filesystems key-users
mounts      slabinfo      uptime
1340   1479   1747   1827   19     2045   2111   2137   2202   26     291    377    7      cmdline    fs          kmsg
mtd         softirqs      version
```

Sub-directories

ide/scsi

This sub-directory contains disk capacity, disk type and disk geometry information.

acpi

This sub-directory contains information on energy management, temperatures, fan speeds and battery levels.

bus

This sub-directory contains a sub-directory for each bus.

net

This sub-directory contains information concerning the network.

sys

This sub-directory contains files used by root to configure the kernel. For instance, the following command configiresthe kernel to ignore incoming pings:

```
# echo 1 > /proc/sys/net/ipv4/icmp_echo_ignore_all [Entrée]
```

The sysctl Command

Files in the **/proc/sys** can be administered by using the **sysctl** command.

The **sysctl** command applies rules at system boot that are defined in the **/etc/sysctl.conf** file:

```
[root@centos ~]# cat /etc/sysctl.conf
# Kernel sysctl configuration file for Red Hat Linux
#
# For binary values, 0 is disabled, 1 is enabled.  See sysctl(8) and
# sysctl.conf(5) for more details.

# Controls IP packet forwarding
net.ipv4.ip_forward = 0

# Controls source route verification
net.ipv4.conf.default.rp_filter = 1

# Do not accept source routing
net.ipv4.conf.default.accept_source_route = 0

# Controls the System Request debugging functionality of the kernel
kernel.sysrq = 0

# Controls whether core dumps will append the PID to the core filename.
# Useful for debugging multi-threaded applications.
kernel.core_uses_pid = 1

# Controls the use of TCP syncookies
net.ipv4.tcp_syncookies = 1

# Disable netfilter on bridges.
net.bridge.bridge-nf-call-ip6tables = 0
```

```
net.bridge.bridge-nf-call-iptables = 0
net.bridge.bridge-nf-call-arptables = 0

# Controls the default maxmimum size of a mesage queue
kernel.msgmnb = 65536

# Controls the maximum size of a message, in bytes
kernel.msgmax = 65536

# Controls the maximum shared segment size, in bytes
kernel.shmmax = 4294967295

# Controls the maximum number of shared memory segments, in pages
kernel.shmall = 268435456
```

Command Line Switches

The command line switches of this command are:

```
[root@centos ~]# sysctl --help
usage:  sysctl [-n] [-e] variable ...
        sysctl [-n] [-e] [-q] -w variable=value ...
        sysctl [-n] [-e] -a
        sysctl [-n] [-e] [-q] -p <file>   (default /etc/sysctl.conf)
        sysctl [-n] [-e] -A
```

Files

/proc/cpuinfo

```
[root@centos ~]# cat /proc/cpuinfo
```

```
processor     : 0
vendor_id     : GenuineIntel
cpu family    : 6
model         : 37
model name    : Intel(R) Core(TM) i5 CPU       M 480  @ 2.67GHz
stepping      : 5
cpu MHz       : 2647.112
cache size    : 6144 KB
fdiv_bug      : no
hlt_bug       : no
f00f_bug      : no
coma_bug      : no
fpu       : yes
fpu_exception   : yes
cpuid level : 5
wp        : yes
flags         : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush mmx fxsr sse sse2
syscall nx lm constant_tsc up pni monitor ssse3 lahf_lm
bogomips      : 5294.22
clflush size    : 64
cache_alignment : 64
address sizes   : 36 bits physical, 48 bits virtual
power management:
```

/proc/interrupts

```
[root@centos ~]# cat /proc/interrupts
          CPU0
  0:       122    XT-PIC-XT        timer
  1:       974    XT-PIC-XT        i8042
  2:         0    XT-PIC-XT        cascade
  8:         0    XT-PIC-XT        rtc0
  9:     38140    XT-PIC-XT        acpi, vboxguest
```

```
 10:     102335    XT-PIC-XT          eth0
 11:      51228    XT-PIC-XT          ohci_hcd:usb1, ahci, Intel 82801AA-ICH
 12:       1340    XT-PIC-XT          i8042
 14:          0    XT-PIC-XT          ata_piix
 15:     307485    XT-PIC-XT          ata_piix
NMI:          0    Non-maskable interrupts
LOC:    3953311    Local timer interrupts
SPU:          0    Spurious interrupts
PMI:          0    Performance monitoring interrupts
IWI:          0    IRQ work interrupts
RES:          0    Rescheduling interrupts
CAL:          0    Function call interrupts
TLB:          0    TLB shootdowns
TRM:          0    Thermal event interrupts
THR:          0    Threshold APIC interrupts
MCE:          0    Machine check exceptions
MCP:        171    Machine check polls
ERR:          0
MIS:          0
```

/proc/dma

```
[root@centos ~]# cat /proc/dma
 4: cascade
```

/proc/ioports

```
[root@centos ~]# cat /proc/ioports
0000-001f : dma1
0020-0021 : pic1
0040-0043 : timer0
```

```
0050-0053 : timer1
0060-0060 : keyboard
0064-0064 : keyboard
0070-0071 : rtc_cmos
  0070-0071 : rtc0
0080-008f : dma page reg
00a0-00a1 : pic2
00c0-00df : dma2
00f0-00ff : fpu
0170-0177 : 0000:00:01.1
  0170-0177 : ata_piix
01f0-01f7 : 0000:00:01.1
  01f0-01f7 : ata_piix
0376-0376 : 0000:00:01.1
  0376-0376 : ata_piix
03c0-03df : vga+
03f6-03f6 : 0000:00:01.1
  03f6-03f6 : ata_piix
0cf8-0cff : PCI conf1
4000-4003 : ACPI PM1a_EVT_BLK
4004-4005 : ACPI PM1a_CNT_BLK
4008-400b : ACPI PM_TMR
4020-4021 : ACPI GPE0_BLK
d000-d00f : 0000:00:01.1
  d000-d00f : ata_piix
d010-d017 : 0000:00:03.0
  d010-d017 : e1000
d020-d03f : 0000:00:04.0
d100-d1ff : 0000:00:05.0
  d100-d1ff : Intel 82801AA-ICH
d200-d23f : 0000:00:05.0
  d200-d23f : Intel 82801AA-ICH
d240-d247 : 0000:00:0d.0
  d240-d247 : ahci
```

```
d250-d257 : 0000:00:0d.0
  d250-d257 : ahci
d260-d26f : 0000:00:0d.0
  d260-d26f : ahci
```

<note warning> If two peripherals have the same port, **both** peripherals will be unusable. </note>

/proc/devices

```
[root@centos ~]# cat /proc/devices
Character devices:
  1 mem
  4 /dev/vc/0
  4 tty
  4 ttyS
  5 /dev/tty
  5 /dev/console
  5 /dev/ptmx
  7 vcs
 10 misc
 13 input
 14 sound
 21 sg
 29 fb
 99 ppdev
116 alsa
128 ptm
136 pts
162 raw
180 usb
189 usb_device
202 cpu/msr
203 cpu/cpuid
```

```
226 drm
250 hidraw
251 usbmon
252 bsg
253 pcmcia
254 rtc

Block devices:
  1 ramdisk
259 blkext
  7 loop
  8 sd
  9 md
 11 sr
 65 sd
 66 sd
 67 sd
 68 sd
 69 sd
 70 sd
 71 sd
128 sd
129 sd
130 sd
131 sd
132 sd
133 sd
134 sd
135 sd
253 device-mapper
254 mdp
```

/proc/modules

```
[root@centos ~]# cat /proc/modules
fuse 59447 0 - Live 0xf7f05000
vboxsf 35841 0 - Live 0xf7ffd000
autofs4 20373 3 - Live 0xf7eca000
sunrpc 212455 1 - Live 0xf8031000
8021q 20323 0 - Live 0xf7e5c000
garp 5703 1 8021q, Live 0xf7e48000
stp 1626 1 garp, Live 0xf7e3f000
llc 4258 2 garp,stp, Live 0xf7e1a000
ipt_REJECT 1867 2 - Live 0xf82b0000
nf_conntrack_ipv4 7694 2 - Live 0xf82a7000
nf_defrag_ipv4 1039 1 nf_conntrack_ipv4, Live 0xf829d000
iptable_filter 2173 1 - Live 0xf8295000
ip_tables 9567 1 iptable_filter, Live 0xf828c000
ip6t_REJECT 3987 2 - Live 0xf827e000
nf_conntrack_ipv6 7207 2 - Live 0xf8275000
nf_defrag_ipv6 8897 1 nf_conntrack_ipv6, Live 0xf826a000
xt_state 1064 4 - Live 0xf8260000
nf_conntrack 65620 3 nf_conntrack_ipv4,nf_conntrack_ipv6,xt_state, Live 0xf8243000
ip6table_filter 2245 1 - Live 0xf8224000
ip6_tables 10867 1 ip6table_filter, Live 0xf821a000
ipv6 264187 35 ip6t_REJECT,nf_conntrack_ipv6,nf_defrag_ipv6, Live 0xf81c2000
ppdev 7297 0 - Live 0xf80d8000
parport_pc 19086 0 - Live 0xf808f000
parport 29925 2 ppdev,parport_pc, Live 0xf8077000
microcode 12216 0 - Live 0xf802d000
sg 24038 0 - Live 0xf801c000
i2c_piix4 11156 0 - Live 0xf7ed9000
i2c_core 25632 1 i2c_piix4, Live 0xf7f19000
snd_intel8x0 24281 2 - Live 0xf7efa000
snd_ac97_codec 95611 1 snd_intel8x0, Live 0xf7f84000
```

```
ac97_bus 968 1 snd_ac97_codec, Live 0xf7e87000
snd_seq 44709 0 - Live 0xf7edf000
snd_seq_device 5124 1 snd_seq, Live 0xf7e54000
snd_pcm 67800 2 snd_intel8x0,snd_ac97_codec, Live 0xf7e8e000
snd_timer 17152 2 snd_seq,snd_pcm, Live 0xf7e27000
snd 51792 10 snd_intel8x0,snd_ac97_codec,snd_seq,snd_seq_device,snd_pcm,snd_timer, Live 0xf7e6a000
soundcore 6390 1 snd, Live 0xf7e21000
snd_page_alloc 6882 2 snd_intel8x0,snd_pcm, Live 0xf7e17000
vboxguest 195019 7 vboxsf, Live 0xf8bff000
e1000 149778 0 - Live 0xf8743000
ext4 328781 2 - Live 0xf7fab000
jbd2 75154 1 ext4, Live 0xf7f24000
mbcache 6017 1 ext4, Live 0xf7f02000
sd_mod 34923 4 - Live 0xf7ef0000
crc_t10dif 1217 1 sd_mod, Live 0xf7edd000
sr_mod 13282 0 - Live 0xf7ed4000
cdrom 33416 1 sr_mod, Live 0xf7ec0000
ahci 34601 3 - Live 0xf7ea1000
pata_acpi 2513 0 - Live 0xf7e8c000
ata_generic 2805 0 - Live 0xf7e85000
ata_piix 20413 0 - Live 0xf7e78000
dm_mirror 11774 0 - Live 0xf7e66000
dm_region_hash 9644 1 dm_mirror, Live 0xf7e58000
dm_log 8322 2 dm_mirror,dm_region_hash, Live 0xf7e4c000
dm_mod 68819 2 dm_mirror,dm_log, Live 0xf7e2d000
```

/proc/diskstats

```
[root@centos ~]# cat /proc/diskstats
   1       0 ram0 0 0 0 0 0 0 0 0 0 0 0
   1       1 ram1 0 0 0 0 0 0 0 0 0 0 0
   1       2 ram2 0 0 0 0 0 0 0 0 0 0 0
   1       3 ram3 0 0 0 0 0 0 0 0 0 0 0
```

```
   1        4 ram4 0 0 0 0 0 0 0 0 0 0 0
   1        5 ram5 0 0 0 0 0 0 0 0 0 0 0
   1        6 ram6 0 0 0 0 0 0 0 0 0 0 0
   1        7 ram7 0 0 0 0 0 0 0 0 0 0 0
   1        8 ram8 0 0 0 0 0 0 0 0 0 0 0
   1        9 ram9 0 0 0 0 0 0 0 0 0 0 0
   1       10 ram10 0 0 0 0 0 0 0 0 0 0 0
   1       11 ram11 0 0 0 0 0 0 0 0 0 0 0
   1       12 ram12 0 0 0 0 0 0 0 0 0 0 0
   1       13 ram13 0 0 0 0 0 0 0 0 0 0 0
   1       14 ram14 0 0 0 0 0 0 0 0 0 0 0
   1       15 ram15 0 0 0 0 0 0 0 0 0 0 0
   7        0 loop0 0 0 0 0 0 0 0 0 0 0 0
   7        1 loop1 0 0 0 0 0 0 0 0 0 0 0
   7        2 loop2 0 0 0 0 0 0 0 0 0 0 0
   7        3 loop3 0 0 0 0 0 0 0 0 0 0 0
   7        4 loop4 0 0 0 0 0 0 0 0 0 0 0
   7        5 loop5 0 0 0 0 0 0 0 0 0 0 0
   7        6 loop6 0 0 0 0 0 0 0 0 0 0 0
   7        7 loop7 0 0 0 0 0 0 0 0 0 0 0
  11        0 sr0 0 0 0 0 0 0 0 0 0 0 0
   8        0 sda 33391 5791 1232722 251998 19357 267987 2298676 1462247 0 268156 1714173
   8        1 sda1 783 351 49488 1249 22 6 68 141 0 975 1379
   8        2 sda2 32102 5408 1178930 250304 19285 267981 2298608 1461984 0 267063 1712228
   8        3 sda3 332 31 2904 333 0 0 0 0 0 333 333
```

/proc/partitions

```
[root@centos ~]# cat /proc/partitions
major minor  #blocks  name

   8        0   20971520 sda
   8        1     102400 sda1
```

```
8        2    5120000 sda2
8        3    2096128 sda3
```

/proc/swaps

```
[root@centos ~]# cat /proc/swaps
Filename                 Type          Size     Used    Priority
/dev/sda3                            partition  2096120   0     -1
```

/proc/loadavg

```
[root@centos ~]# cat /proc/loadavg
0.00 0.00 0.00 1/231 32129
```

/proc/meminfo

```
[root@centos ~]# cat /proc/meminfo
MemTotal:        1915472 kB
MemFree:          662856 kB
Buffers:           88732 kB
Cached:           959116 kB
SwapCached:            0 kB
Active:           656708 kB
Inactive:         483352 kB
Active(anon):      92268 kB
Inactive(anon):     4316 kB
Active(file):     564440 kB
Inactive(file):   479036 kB
Unevictable:           0 kB
Mlocked:               0 kB
```

```
HighTotal:       1165256 kB
HighFree:         109244 kB
LowTotal:         750216 kB
LowFree:          553612 kB
SwapTotal:       2096120 kB
SwapFree:        2096120 kB
Dirty:                 0 kB
Writeback:             0 kB
AnonPages:         92228 kB
Mapped:            53416 kB
Shmem:              4376 kB
Slab:              91496 kB
SReclaimable:      58008 kB
SUnreclaim:        33488 kB
KernelStack:        1840 kB
PageTables:         5908 kB
NFS_Unstable:          0 kB
Bounce:                0 kB
WritebackTmp:          0 kB
CommitLimit:     3053856 kB
Committed_AS:     453216 kB
VmallocTotal:     122880 kB
VmallocUsed:       25776 kB
VmallocChunk:      83448 kB
HugePages_Total:       0
HugePages_Free:        0
HugePages_Rsvd:        0
HugePages_Surp:        0
Hugepagesize:       2048 kB
DirectMap4k:       14328 kB
DirectMap2M:      892928 kB
```

/proc/version

```
[root@centos ~]# cat /proc/version
Linux version 2.6.32-358.23.2.el6.i686 (mockbuild@c6b9.bsys.dev.centos.org) (gcc version 4.4.7 20120313 (Red Hat
4.4.7-3) (GCC) ) #1 SMP Wed Oct 16 17:21:31 UTC 2013
```

Interpreting Information in /proc

The information found in files in the /proc filesystem can be interpreted using the following commands:

- free,
- uptime et w,
- iostat,
- vmstat,
- mpstat,
- sar.

Commands

free

The **free** command shows total, used, free, shared, buffered, cached and swapped memory:

```
[root@centos ~]# free -m
             total       used       free     shared    buffers     cached
Mem:          1007        617        389          0         37        359
-/+ buffers/cache:        220        787
Swap:         1999          0       1999
```

In the above example, you can see:

- 1007 MB of total physical memory,
- 617 MB of used physical memory and 389MB of free physical memory,
- 1999 MB of swap space with 0MB being used.

The **-/+ buffers/cache:** line indicates that applications are using 220 MB and that they have 787 MB of free memory (37+359+389).

The command line switches of this command are:

```
[root@centos ~]# free -h
free: invalid option -- 'h'
usage: free [-b|-k|-m|-g] [-l] [-o] [-t] [-s delay] [-c count] [-V]
  -b,-k,-m,-g show output in bytes, KB, MB, or GB
  -l show detailed low and high memory statistics
  -o use old format (no -/+buffers/cache line)
  -t display total for RAM + swap
  -s update every [delay] seconds
  -c update [count] times
  -V display version information and exit
```

uptime or w

Each of these commands show the load average over the past 1, 5 and 15 minutes:

```
[root@centos ~]# uptime
 17:19:49 up 2 min,  2 users,  load average: 0.35, 0.21, 0.08
[root@centos ~]# w
 17:19:51 up 2 min,  2 users,  load average: 0.35, 0.21, 0.08
USER     TTY      FROM             LOGIN@   IDLE   JCPU   PCPU WHAT
trainee  tty1     :0               17:18    1:56   2.25s  0.14s pam: gdm-password
trainee  pts/0    :0.0             17:18    0.00s  0.16s  0.64s gnome-terminal
```

The **load average** indicates the number of processes being executed and waiting to be executed for the period concerned.

If the load average of a single-core system was **3.48 4.00 3.85** this would indicate a bottleneck since, on average:

- 2.48 processes would have been waiting to be executed over the last minute,
- 3.00 processes would have been waiting to be executed over the last 5 minutes,
- 2.85 processes would have been waiting to be executed over the last 15 minutes,

The command line switches of these commands are:

```
[root@centos ~]# uptime --help
usage: uptime [-V]
    -V    display version
[root@centos ~]# w --help
w : option invalide -- '-'
usage: w -hlsufV [user]
    -h    skip header
    -l    long listing (default)
    -s    short listing
    -u    ignore uid of processes
    -f    toggle FROM field (default on)
    -V    display version
```

iostat

The **iostat** command show disk, terminal and streamer statistics:

```
[root@centos ~]# iostat
Linux 2.6.32-358.23.2.el6.i686 (centos.fenestros.loc)   06/16/2014    _i686_    (1 CPU)

avg-cpu:  %user   %nice %system %iowait  %steal   %idle
           9.04    0.00   17.92   31.19    0.00   41.85


Device:            tps   Blk_read/s   Blk_wrtn/s   Blk_read   Blk_wrtn
```

| sda | 87.65 | 4300.73 | 297.09 | 331500 | 22900 |

The command line switches of this command are:

```
[root@centos ~]# iostat --help
Usage: iostat [ options ] [ <interval> [ <count> ] ]
Options are:
[ -c ] [ -d ] [ -N ] [ -n ] [ -h ] [ -k | -m ] [ -t ] [ -V ] [ -x ] [ -z ]
[ <device> [...] | ALL ] [ -p [ <device> [,...] | ALL ] ]
```

vmstat

The **vmstat** commands shows memory, pagination and processor statistics:

```
[root@centos ~]# vmstat 1 10
procs -----------memory---------- ---swap-- -----io---- --system-- -----cpu-----
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 0  0      0 1601536  26936 139004    0    0  2102    59  254  585  4  7 77 12  0
 0  0      0 1601528  26936 139028    0    0     0     0   95  183  0  0 100  0  0
 0  0      0 1601528  26936 139028    0    0     0     0   70  138  0  0 100  0  0
 0  0      0 1601528  26936 139028    0    0     0     0   94  173  0  1 99  0  0
 0  0      0 1601536  26936 139028    0    0     0     0   82  171  0  0 100  0  0
 0  0      0 1601536  26944 139036    0    0     0    36   98  183  0  1 99  0  0
 0  0      0 1601536  26944 139036    0    0     0     0   78  144  0  0 100  0  0
 0  0      0 1601528  26944 139036    0    0     0     0   92  174  0  0 100  0  0
 0  0      0 1601272  26944 139040    0    0     0     0   89  144  1  1 98  0  0
 0  0      0 1601272  26944 139040    0    0     0     0  123  212  1  1 98  0  0
```

The command line switches of this command are:

```
[root@centos ~]# vmstat --help
usage: vmstat [-V] [-n] [delay [count]]
```

```
            -V prints version.
            -n causes the headers not to be reprinted regularly.
            -a print inactive/active page stats.
            -d prints disk statistics
            -D prints disk table
            -p prints disk partition statistics
            -s prints vm table
            -m prints slabinfo
            -t add timestamp to output
            -S unit size
            delay is the delay between updates in seconds.
            unit size k:1000 K:1024 m:1000000 M:1048576 (default is K)
            count is the number of updates.
```

By default vmstat shows statistics from boot until current time.

mpstat

The **mpstat** command shows detailed statistics concerning CPUs :

```
[root@centos ~]# mpstat
Linux 2.6.32-358.23.2.el6.i686 (centos.fenestros.loc)   06/16/2014      _i686_    (1 CPU)

05:24:40 PM  CPU    %usr   %nice    %sys %iowait    %irq   %soft  %steal  %guest   %idle
05:24:40 PM  all    2.31    0.00    3.76    6.70    0.19    0.03    0.00    0.00   87.01
```

If there are several CPU's in the system, statistics can be viewed by core and as an average:

```
[root@centos ~]# mpstat -P ALL
Linux 2.6.32-358.23.2.el6.i686 (centos.fenestros.loc)   06/16/2014      _i686_    (1 CPU)

05:24:52 PM  CPU    %usr   %nice    %sys %iowait    %irq   %soft  %steal  %guest   %idle
```

```
05:24:52 PM  all    2.26    0.00    3.67    6.52    0.19    0.03    0.00    0.00   87.34
05:24:52 PM    0    2.26    0.00    3.67    6.52    0.19    0.03    0.00    0.00   87.34
```

Finally, mpstat is capable of showing statistics over time. In the following example you can see 5 data sets, one taken every 2 seconds:

```
[root@centos ~]# mpstat -P ALL 2 5
Linux 2.6.32-358.23.2.el6.i686 (centos.fenestros.loc)   06/16/2014     _i686_    (1 CPU)

05:25:20 PM  CPU    %usr   %nice    %sys %iowait    %irq   %soft  %steal  %guest   %idle
05:25:22 PM  all    0.51    0.00    0.51    0.00    0.00    0.00    0.00    0.00   98.99
05:25:22 PM    0    0.51    0.00    0.00    0.00    0.00    0.00    0.00    0.00   99.49

05:25:22 PM  CPU    %usr   %nice    %sys %iowait    %irq   %soft  %steal  %guest   %idle
05:25:24 PM  all    0.51    0.00    0.51    0.00    0.00    0.00    0.00    0.00   98.99
05:25:24 PM    0    0.51    0.00    0.51    0.00    0.00    0.00    0.00    0.00   98.99

05:25:24 PM  CPU    %usr   %nice    %sys %iowait    %irq   %soft  %steal  %guest   %idle
05:25:26 PM  all    1.01    0.00    0.51    0.00    0.00    0.00    0.00    0.00   98.48
05:25:26 PM    0    1.01    0.00    0.51    0.00    0.00    0.00    0.00    0.00   98.48

05:25:26 PM  CPU    %usr   %nice    %sys %iowait    %irq   %soft  %steal  %guest   %idle
05:25:28 PM  all    0.51    0.00    0.51    0.00    0.00    0.00    0.00    0.00   98.99
05:25:28 PM    0    0.51    0.00    0.51    0.00    0.00    0.00    0.00    0.00   98.99

05:25:28 PM  CPU    %usr   %nice    %sys %iowait    %irq   %soft  %steal  %guest   %idle
05:25:30 PM  all    0.51    0.00    0.00    0.00    0.00    0.00    0.00    0.00   99.49
05:25:30 PM    0    0.51    0.00    0.00    0.00    0.00    0.00    0.00    0.00   99.49

Average:     CPU    %usr   %nice    %sys %iowait    %irq   %soft  %steal  %guest   %idle
Average:     all    0.61    0.00    0.40    0.00    0.00    0.00    0.00    0.00   98.99
Average:       0    0.61    0.00    0.30    0.00    0.00    0.00    0.00    0.00   99.09
```

The command line switches of this command are:

```
[root@centos ~]# mpstat --help
Usage: mpstat [ options ] [ <interval> [ <count> ] ]
Options are:
[ -A ] [ -I { SUM | CPU | ALL } ] [ -u ]
[ -P { <cpu> [,...] | ON | ALL } ] [ -V ]
```

sar

The **sar** command can survey all system resources dependant upon the switch that is used. Several important switches are:

Switch	Description
-u	CPU usage in %
-q	Number of processes in the process queue
-r	Memory usage
-w	Swap usage
-p	Pagination usage
-b	Buffer usage
-d	Disk usage

The **/usr/lib/sa/sadc** command is used to collect data:

```
[root@centos ~]# ls /usr/lib/sa
sa1   sa2   sadc
```

The **/usr/lib/sa/sa1** script calls the **/usr/lib/sa/sadc** command and can use two switches:

Switch	Description
-t	Interval
-n	Count

The **/usr/lib/sa/sa2** script also creates a log at **/var/log/sa/sar<dd>**, where <dd> is the day of the month.

Both of these scripts should ideally be called by cron or anacron.

To see how these scripts work, use the following command:

```
[root@centos ~]# /usr/lib/sa/sa1 5 5
```

Once the script has completed, use the following commands:

```
[root@centos ~]# sar
Linux 2.6.32-358.23.2.el6.i686 (centos.fenestros.loc)   06/17/2014    _i686_    (1 CPU)

07:40:01 AM     CPU     %user     %nice   %system    %iowait    %steal     %idle
07:50:02 AM     all      0.22      0.00      0.24       0.09      0.00     99.45
07:52:51 AM     all      0.26      0.00      0.30       0.33      0.00     99.11
07:52:56 AM     all      0.20      0.00      0.40       0.20      0.00     99.19
07:53:01 AM     all      0.00      0.00      0.40       0.20      0.00     99.39
07:53:06 AM     all      0.20      0.00      0.20       0.00      0.00     99.60
07:53:11 AM     all      0.00      0.00      0.40       0.00      0.00     99.60
Average:        all      0.23      0.00      0.26       0.14      0.00     99.37
[root@centos ~]# sar -u 5 3
Linux 2.6.32-358.23.2.el6.i686 (centos.fenestros.loc)   06/17/2014    _i686_    (1 CPU)

07:54:16 AM     CPU     %user     %nice   %system    %iowait    %steal     %idle
07:54:21 AM     all      0.20      0.00      0.40       0.00      0.00     99.39
07:54:26 AM     all      0.40      0.00      0.60       0.00      0.00     98.99
07:54:31 AM     all      0.20      0.00      0.20       0.00      0.00     99.60
Average:        all      0.27      0.00      0.40       0.00      0.00     99.33
[root@centos ~]# sar -r 5 3
Linux 2.6.32-358.23.2.el6.i686 (centos.fenestros.loc)   06/17/2014    _i686_    (1 CPU)

07:54:50 AM kbmemfree kbmemused  %memused kbbuffers  kbcached  kbcommit   %commit
07:54:55 AM   1595940    319532     16.68     27428    140012    423960     10.57
07:55:00 AM   1595956    319516     16.68     27428    140012    423960     10.57
07:55:05 AM   1595940    319532     16.68     27428    140012    423960     10.57
```

```
Average:      1595945    319527     16.68     27428     140012     423960      10.57
[root@centos ~]# sar -w 5 3
Linux 2.6.32-358.23.2.el6.i686 (centos.fenestros.loc)    06/17/2014     _i686_    (1 CPU)

07:55:31 AM    proc/s    cswch/s
07:55:36 AM     0.00      198.38
07:55:41 AM     0.00      170.56
07:55:46 AM     0.00      211.74
Average:        0.00      193.54
[root@centos ~]# sar -b 5 3
Linux 2.6.32-358.23.2.el6.i686 (centos.fenestros.loc)    06/17/2014     _i686_    (1 CPU)

07:55:50 AM       tps      rtps      wtps    bread/s    bwrtn/s
07:55:55 AM      0.20      0.00      0.20      0.00       1.61
07:56:00 AM      0.81      0.00      0.81      0.00       9.70
07:56:05 AM      0.00      0.00      0.00      0.00       0.00
Average:         0.34      0.00      0.34      0.00       3.77
[root@centos ~]# sar -d 5 3
Linux 2.6.32-358.23.2.el6.i686 (centos.fenestros.loc)    06/17/2014     _i686_    (1 CPU)

07:56:39 AM       DEV       tps   rd_sec/s  wr_sec/s  avgrq-sz  avgqu-sz     await     svctm     %util
07:56:44 AM     dev8-0      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

07:56:44 AM       DEV       tps   rd_sec/s  wr_sec/s  avgrq-sz  avgqu-sz     await     svctm     %util
07:56:49 AM     dev8-0      0.81      0.00      9.72     12.00      0.00      1.25      0.75      0.06

07:56:49 AM       DEV       tps   rd_sec/s  wr_sec/s  avgrq-sz  avgqu-sz     await     svctm     %util
07:56:54 AM     dev8-0      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00

Average:          DEV       tps   rd_sec/s  wr_sec/s  avgrq-sz  avgqu-sz     await     svctm     %util
Average:        dev8-0      0.27      0.00      3.23     12.00      0.00      1.25      0.75      0.02
[root@centos ~]# sar -p 5 3
Linux 2.6.32-358.23.2.el6.i686 (centos.fenestros.loc)    06/17/2014     _i686_    (1 CPU)
```

```
07:57:12 AM     CPU    %user    %nice   %system   %iowait   %steal     %idle
07:57:17 AM     all     0.20     0.00      0.40      0.00     0.00     99.39
07:57:22 AM     all     0.40     0.00      0.60      0.20     0.00     98.79
07:57:27 AM     all     0.20     0.00      0.40      0.00     0.00     99.39
Average:        all     0.27     0.00      0.47      0.07     0.00     99.19
[root@centos ~]# sar -v 5 3
Linux 2.6.32-358.23.2.el6.i686 (centos.fenestros.loc)   06/17/2014      _i686_     (1 CPU)


07:57:53 AM dentunusd   file-nr  inode-nr    pty-nr
07:57:58 AM      8284      4352     13857         4
07:58:03 AM      8284      4352     13857         4
07:58:08 AM      8284      4352     13857         4
Average:         8284      4352     13857         4
```

The command line switches of this command are:

```
[root@centos ~]# sar --help
Usage: sar [ options ] [ <interval> [ <count> ] ]
Options are:
[ -A ] [ -b ] [ -B ] [ -C ] [ -d ] [ -h ] [ -m ] [ -p ] [ -q ] [ -r ] [ -R ]
[ -S ] [ -t ] [ -u [ ALL ] ] [ -v ] [ -V ] [ -w ] [ -W ] [ -y ]
[ -I { <int> [,...] | SUM | ALL | XALL } ] [ -P { <cpu> [,...] | ALL } ]
[ -n { <keyword> [,...] | ALL } ]
[ -o [ <filename> ] | -f [ <filename> ] ]
[ -i <interval> ] [ -s [ <hh:mm:ss> ] ] [ -e [ <hh:mm:ss> ] ]
```

Production Environements

Identifying a System with a CPU Bottleneck

The use of the following commands should clearly show CPU bottlenecks:

- uptime or w
- vmstat
- mpstat -P ALL
- sar -u
- iostat -c

Identifying a Memory Problem

The use of the following commands should clearly show memory problems:

- free
- sar -B

Identifying I/O Bottlenecks

The use of the following command should clearly show I/O bottlenecks:

- iostat -d -x

USB Modules

The Universal Serial Bus can offer data transfer speeds of upto 480Mb/s for version 2.0 and upto 4.8 Gb/s for version 3.0. Under Linux the USB modules are:

USB Version	Module	Name
1.0\1.1	**UHCI**	Universal Controller Host Interface
	OHCI	Open Controller Host Interface
2.0	**EHCI**	Enhanced Host Controller Interface
3.0	**XHCI**	Extensible Host Controller Interface

The following table shows a list of commonly used USB modules:

Module	Peripheral
usb_storage	Block devices
usbhid	Human Interface Device
snd-usb-audio	Sound cards
usbvidéo	Video acquisition cards
irda-usb	IR peripherals
usbnet	NICs

These modules can be loaded by any one of the following:

- Initramfs,
- The init process,
- kmod by using the **/lib/modules/2.6.32-358.23.2.el6.i686/modules.usbmap** file,
- udev,
- manually.

<note> Insert a USB stick and configure VirtualBox to mount it in your VM. </note>

udev

The 2.6 Kernel series is capable of **hotplugging**. Linux uses three componants to manage hotplugging:

- Udev,
- HAL,
- Dbus.

The roles of each componant are as follows:

- Udev dynamically creates/deletes nodes in the **/dev** directory,
- HAL obtains information from udev, creates a files in XML format representing the peripheral and then informs Nautilus by using Dbus,

- Dbus acts as a system bus and is used for inter-process communication.

When Linux is booted, udev plays an important role:

- at boot **tmpfs** is mounted on /dev,
- udev copies any statically configured nodes from **/lib/udev/devices** to /dev,
- the **udevd** daemon collects **uevents** from the kernel and looks for anappropriate rule in the **/lib/udev/rules.d/** directory,
- udev creates the nodes and any required symbolic links specified in the rule previously identified,
- udev stores in RAM the rules from **/lib/udev/rules.d/*.rules**,
- when a change occurs udev updates the the rules in the RAM.

udev uses the **sysfs** filesystem mounted on /sys which renders the peripherals visible to udev in user space. For example when a USB stick is inserted, udev creates **/dev/sdb1** automatically:

```
[root@centos ~]# ls /dev | grep sdb
sdb
sdb1
[root@centos ~]# ls /dev/.udev/db | grep sdb
block:sdb
block:sdb1
[root@centos ~]# ls /sys/block/sdb
alignment_offset   capability   device           ext_range   inflight   queue   removable   sdb1   slaves   subsystem
uevent
bdi                dev          discard_alignment  holders     power      range   ro          size   stat     trace
```

and then uses the information found in the **/lib/modules/`uname -r`/modules.alias** file to find the appropriate driver:

```
[root@centos ~]# more /lib/modules/`uname -r`/modules.alias
# Aliases extracted from modules themselves.
alias acpi acpi_cpufreq
alias char-major-10-184 microcode
alias aes-asm aes_i586
alias aes aes_i586
alias twofish-asm twofish_i586
```

```
alias twofish twofish_i586
alias salsa20-asm salsa20_i586
alias salsa20 salsa20_i586
alias crc32c-intel crc32c_intel
alias crc32c crc32c_intel
alias nls_tis-620 nls_cp874
alias nls_sjis nls_cp932
alias nls_gb2312 nls_cp936
alias nls_euc-kr nls_cp949
alias nls_big5 nls_cp950
alias nls_iso8859-8 nls_cp1255
alias nfs-layouttype4-1 nfs_layout_nfsv41_files
alias char-major-10-229 fuse
alias devname:btrfs-control btrfs
alias char-major-10-234 btrfs
alias cipher_null crypto_null
alias digest_null crypto_null
alias compress_null crypto_null
alias sha256 sha256_generic
alias sha224 sha256_generic
alias sha512 sha512_generic
alias sha384 sha512_generic
alias wp256 wp512
alias wp384 wp512
alias tgr128 tgr192
alias tgr160 tgr192
alias rfc3686 ctr
--More--(0%)
```

The contents of the **/dev/.udev/db/block:sdb1** file is:

```
[root@centos ~]# cat /dev/.udev/db/block:sdb1
N:sdb1
S:block/8:17
```

```
S:disk/by-id/usb-_USB_DISK_2.0_0710433A0D8D6A52-0:0-part1
S:disk/by-path/pci-0000:00:06.0-usb-0:1:1.0-scsi-0:0:0:0-part1
S:disk/by-uuid/2B1E-1434
S:disk/by-label/USB\x20DISK
W:45
E:ID_VENDOR_ENC=\x20\x20\x20\x20\x20\x20\x20\x20
E:ID_VENDOR_ID=13fe
E:ID_MODEL=USB_DISK_2.0
E:ID_MODEL_ENC=USB\x20DISK\x202.0\x20\x20\x20\x20
E:ID_MODEL_ID=4200
E:ID_REVISION=PMAP
E:ID_SERIAL=_USB_DISK_2.0_0710433A0D8D6A52-0:0
E:ID_SERIAL_SHORT=0710433A0D8D6A52
E:ID_TYPE=disk
E:ID_INSTANCE=0:0
E:ID_BUS=usb
E:ID_USB_INTERFACES=:080650:
E:ID_USB_INTERFACE_NUM=00
E:ID_USB_DRIVER=usb-storage
E:ID_PATH=pci-0000:00:06.0-usb-0:1:1.0-scsi-0:0:0:0
E:ID_PART_TABLE_TYPE=dos
E:ID_FS_LABEL=USB_DISK
E:ID_FS_LABEL_ENC=USB\x20DISK
E:ID_FS_UUID=2B1E-1434
E:ID_FS_UUID_ENC=2B1E-1434
E:ID_FS_VERSION=FAT32
E:ID_FS_TYPE=vfat
E:ID_FS_USAGE=filesystem
E:LVM_SBIN_PATH=/sbin
E:UDISKS_PRESENTATION_NOPOLICY=0
E:UDISKS_PARTITION=1
E:UDISKS_PARTITION_SCHEME=mbr
E:UDISKS_PARTITION_NUMBER=1
E:UDISKS_PARTITION_TYPE=0x0c
```

```
E:UDISKS_PARTITION_SIZE=8011186176
E:UDISKS_PARTITION_SLAVE=/sys/devices/pci0000:00/0000:00:06.0/usb1/1-1/1-1:1.0/host3/target3:0:0/3:0:0:0/block/sd
b
E:UDISKS_PARTITION_OFFSET=4128768
E:UDISKS_PARTITION_ALIGNMENT_OFFSET=0
```

This is the content of /dev:

```
[root@centos ~]# ls -lR /dev/disk
/dev/disk:
total 0
drwxr-xr-x. 2 root root 240 Jun 17 08:49 by-id
drwxr-xr-x. 2 root root  60 Jun 17 08:49 by-label
drwxr-xr-x. 2 root root 180 Jun 17 08:49 by-path
drwxr-xr-x. 2 root root 120 Jun 17 08:49 by-uuid

/dev/disk/by-id:
total 0
lrwxrwxrwx. 1 root root  9 Jun 16 17:17 ata-VBOX_HARDDISK_VBc95fcb92-63983501 -> ../../sda
lrwxrwxrwx. 1 root root 10 Jun 16 17:18 ata-VBOX_HARDDISK_VBc95fcb92-63983501-part1 -> ../../sda1
lrwxrwxrwx. 1 root root 10 Jun 16 17:18 ata-VBOX_HARDDISK_VBc95fcb92-63983501-part2 -> ../../sda2
lrwxrwxrwx. 1 root root 10 Jun 16 17:17 ata-VBOX_HARDDISK_VBc95fcb92-63983501-part3 -> ../../sda3
lrwxrwxrwx. 1 root root  9 Jun 16 17:17 scsi-SATA_VBOX_HARDDISK_VBc95fcb92-63983501 -> ../../sda
lrwxrwxrwx. 1 root root 10 Jun 16 17:18 scsi-SATA_VBOX_HARDDISK_VBc95fcb92-63983501-part1 -> ../../sda1
lrwxrwxrwx. 1 root root 10 Jun 16 17:18 scsi-SATA_VBOX_HARDDISK_VBc95fcb92-63983501-part2 -> ../../sda2
lrwxrwxrwx. 1 root root 10 Jun 16 17:17 scsi-SATA_VBOX_HARDDISK_VBc95fcb92-63983501-part3 -> ../../sda3
lrwxrwxrwx. 1 root root  9 Jun 17 08:49 usb-_USB_DISK_2.0_0710433A0D8D6A52-0:0 -> ../../sdb
lrwxrwxrwx. 1 root root 10 Jun 17 08:49 usb-_USB_DISK_2.0_0710433A0D8D6A52-0:0-part1 -> ../../sdb1

/dev/disk/by-label:
total 0
lrwxrwxrwx. 1 root root 10 Jun 17 08:49 USB\x20DISK -> ../../sdb1

/dev/disk/by-path:
```

```
total 0
lrwxrwxrwx. 1 root root  9 Jun 16 17:17 pci-0000:00:01.1-scsi-1:0:0:0 -> ../../sr0
lrwxrwxrwx. 1 root root  9 Jun 17 08:49 pci-0000:00:06.0-usb-0:1:1.0-scsi-0:0:0:0 -> ../../sdb
lrwxrwxrwx. 1 root root 10 Jun 17 08:49 pci-0000:00:06.0-usb-0:1:1.0-scsi-0:0:0:0-part1 -> ../../sdb1
lrwxrwxrwx. 1 root root  9 Jun 16 17:17 pci-0000:00:0d.0-scsi-0:0:0:0 -> ../../sda
lrwxrwxrwx. 1 root root 10 Jun 16 17:18 pci-0000:00:0d.0-scsi-0:0:0:0-part1 -> ../../sda1
lrwxrwxrwx. 1 root root 10 Jun 16 17:18 pci-0000:00:0d.0-scsi-0:0:0:0-part2 -> ../../sda2
lrwxrwxrwx. 1 root root 10 Jun 16 17:17 pci-0000:00:0d.0-scsi-0:0:0:0-part3 -> ../../sda3


/dev/disk/by-uuid:
total 0
lrwxrwxrwx. 1 root root 10 Jun 17 08:49 2B1E-1434 -> ../../sdb1
lrwxrwxrwx. 1 root root 10 Jun 16 17:17 a1d6a043-6f10-4f60-bb9c-aaaac9632c57 -> ../../sda3
lrwxrwxrwx. 1 root root 10 Jun 16 17:18 c7b1d3e8-6471-4cba-947b-430db974e774 -> ../../sda2
lrwxrwxrwx. 1 root root 10 Jun 16 17:18 d8988475-7dc7-4a61-8081-6153b7c9551b -> ../../sda1
```

The main configuration file for udev is **/etc/udev/udev.conf**:

```
[root@centos ~]# cat /etc/udev/udev.conf
# The initial syslog(3) priority: "err", "info", "debug" or its
# numerical equivalent. For runtime debugging, the daemons internal
# state can be changed with: "udevadm control --log-priority=<value>".
udev_log="err"
```

Rules files can be foud in **/lib/udev/rules.d/** :

```
[root@centos ~]# ls /lib/udev/rules.d/
10-console.rules              60-persistent-v4l.rules       75-cd-aliases-generator.rules        85-
regulatory.rules
10-dm.rules                   60-wacom.rules                75-net-description.rules             88-
clock.rules
11-dm-lvm.rules              61-mobile-action.rules        75-persistent-net-generator.rules    89-
microcode.rules
13-dm-disk.rules             61-option-modem-modeswitch.rules 75-tty-description.rules            90-
```

```
pulseaudio.rules
40-isdn.rules                      61-persistent-storage-edd.rules   77-mm-ericsson-mbm.rules              91-
drm-modeset.rules
40-libgphoto2.rules                61-uinput-stddev.rules            77-mm-longcheer-port-types.rules     95-
devkit-power-battery-recall-dell.rules
40-redhat.rules                    61-uinput-wacom.rules             77-mm-pcmcia-device-blacklist.rules  95-
devkit-power-battery-recall-fujitsu.rules
42-qemu-usb.rules                  64-device-mapper.rules            77-mm-platform-serial-whitelist.rules 95-
devkit-power-battery-recall-gateway.rules
50-firmware.rules                  64-md-raid.rules                  77-mm-simtech-port-types.rules       95-
devkit-power-battery-recall-ibm.rules
50-udev-default.rules              65-libsane.rules                  77-mm-usb-device-blacklist.rules     95-
devkit-power-battery-recall-lenovo.rules
60-alias-kmsg.rules                65-libwacom.rules                 77-mm-zte-port-types.rules           95-
devkit-power-battery-recall-toshiba.rules
60-cdrom_id.rules                  65-md-incremental.rules           77-nm-olpc-mesh.rules                95-
devkit-power-csr.rules
60-net.rules                       69-dm-lvm-metad.rules             78-sound-card.rules                  95-
devkit-power-hid.rules
60-persistent-alsa.rules           70-acl.rules                      79-fstab_import.rules                95-
devkit-power-wup.rules
60-persistent-input.rules          70-cups-libusb.rules              80-drivers.rules                     95-dm-
notify.rules
60-persistent-serial.rules         70-hid2hci.rules                  80-iosched.rules                     95-
keyboard-force-release.rules
60-persistent-storage.rules        70-printers.rules                 80-mpath-iosched.rules               95-
keymap.rules
60-persistent-storage-tape.rules   71-biosdevname.rules              80-udisks.rules                      95-
udev-late.rules
```

<note important> You can create your own rules by putting them in the **99-local.rules** file. </note>

The default udev rule file is **50-udev-default.rules**:

```
[root@centos ~]# cat /lib/udev/rules.d/50-udev-default.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"
KERNEL=="ptmx",             GROUP="tty", MODE="0666"
KERNEL=="tty",             GROUP="tty", MODE="0666"
KERNEL=="tty[0-9]*",        GROUP="tty", MODE="0620"
KERNEL=="console",         MODE="0600"
KERNEL=="vcs|vcs[0-9]*|vcsa|vcsa[0-9]*", GROUP="tty"


# serial
KERNEL=="tty[A-Z]*[0-9]|pppox[0-9]*|ircomm[0-9]*|noz[0-9]*|rfcomm[0-9]*", GROUP="dialout"
KERNEL=="ppp",             MODE="0600"
KERNEL=="mwave",      GROUP="dialout"
KERNEL=="hvc*|hvsi*",     GROUP="dialout"


# virtio serial / console ports
KERNEL=="vport*", ATTR{name}=="?*", SYMLINK+="virtio-ports/$attr{name}"


# mem
KERNEL=="null|zero|full|random|urandom", MODE="0666"
KERNEL=="mem|kmem|port|nvram",    GROUP="kmem", MODE="0640"


# input
KERNEL=="mouse*|mice|event*", MODE="0640"
KERNEL=="ts[0-9]*|uinput",    MODE="0640"
KERNEL=="js[0-9]*",       MODE="0644"


# video4linux
SUBSYSTEM=="video4linux", GROUP="video"
```

```
KERNEL=="vttuner*",         GROUP="video"
KERNEL=="vtx*|vbi*",        GROUP="video"
KERNEL=="winradio*",        GROUP="video"


# graphics
KERNEL=="agpgart",          MODE="0600", GROUP="video"
KERNEL=="pmu",              GROUP="video"
KERNEL=="nvidia*|nvidiactl*", GROUP="video"
SUBSYSTEM=="graphics",          GROUP="video"
SUBSYSTEM=="drm",       GROUP="video"


# sound
SUBSYSTEM=="sound",         GROUP="audio"
KERNEL=="mixer0",       SYMLINK+="mixer"


# DVB (video)
SUBSYSTEM=="dvb", GROUP="video"


# FireWire (firewire-core driver: IIDC devices, AV/C devices)
SUBSYSTEM=="firewire", ATTR{units}=="*0x00a02d:0x00010*", GROUP="video"
SUBSYSTEM=="firewire", ATTR{units}=="*0x00a02d:0x010001*", GROUP="video"


# FireWire (deprecated dv1394 and video1394 drivers)
KERNEL=="dv1394-[0-9]*",  NAME="dv1394/%n", GROUP="video"
KERNEL=="video1394-[0-9]*",   NAME="video1394/%n", GROUP="video"


# libusb device nodes
SUBSYSTEM=="usb", ENV{DEVTYPE}=="usb_device", MODE="0664"


# printer
KERNEL=="parport[0-9]*",  GROUP="lp"
SUBSYSTEM=="printer",     KERNEL=="lp*", GROUP="lp"
SUBSYSTEM=="ppdev",         GROUP="lp"
SUBSYSTEM=="usb",       KERNEL=="lp*", SYMLINK+="usb%k", GROUP="lp"
```

```
KERNEL=="lp[0-9]*",          GROUP="lp"
KERNEL=="irlpt[0-9]*",          GROUP="lp"
# hplip and cups 1.4+ use raw USB devices, so permissions should be similar to
# the ones from the old usblp kernel module
SUBSYSTEM=="usb", ENV{DEVTYPE}=="usb_device", ENV{ID_USB_INTERFACES}=="", IMPORT{program}="usb_id --export %p"
SUBSYSTEM=="usb", ENV{DEVTYPE}=="usb_device", ENV{ID_USB_INTERFACES}==":0701*:", GROUP="lp", MODE="0664"


# block
SUBSYSTEM=="block", GROUP="disk"


# floppy
KERNEL=="fd[0-9]", GROUP="floppy"
KERNEL=="fd[0-9]", ACTION=="add", ATTRS{cmos}=="?*", RUN+="create_floppy_devices -c -t $attr{cmos} -m %M -M 0640
-G floppy $root/%k"
KERNEL=="hd*", SUBSYSTEMS=="ide", ATTRS{media}=="floppy", OPTIONS+="all_partitions"


# cdrom
SUBSYSTEM=="block", KERNEL=="sr[0-9]*", SYMLINK+="scd%n", GROUP="cdrom"
SUBSYSTEM=="block", KERNEL=="hd*", SUBSYSTEMS=="ide", ATTRS{media}=="cdrom", GROUP="cdrom"
SUBSYSTEM=="scsi_generic", SUBSYSTEMS=="scsi", ATTRS{type}=="4|5", GROUP="cdrom"
KERNEL=="pktcdvd[0-9]*", GROUP="cdrom"
KERNEL=="pktcdvd", GROUP="cdrom"


# tape
KERNEL=="ht[0-9]*|nht[0-9]*", GROUP="tape"
KERNEL=="pt[0-9]*|npt[0-9]*|pht[0-9]*", GROUP="tape"
SUBSYSTEM=="scsi_generic|scsi_tape", SUBSYSTEMS=="scsi", ATTRS{type}=="1|8", GROUP="tape"


# block-related
KERNEL=="sch[0-9]*", GROUP="disk"
SUBSYSTEM=="scsi_generic", SUBSYSTEMS=="scsi", ATTRS{type}=="0", GROUP="disk"
KERNEL=="pg[0-9]*", GROUP="disk"
KERNEL=="qft[0-9]*|nqft[0-9]*|zqft[0-9]*|nzqft[0-9]*|rawqft[0-9]*|nrawqft[0-9]*", GROUP="disk"
KERNEL=="rawctl", GROUP="disk"
```

```
SUBSYSTEM=="raw", KERNEL=="raw[0-9]*", GROUP="disk"
SUBSYSTEM=="aoe", GROUP="disk", MODE="0220"
SUBSYSTEM=="aoe", KERNEL=="err", MODE="0440"

# network
KERNEL=="tun",          MODE="0666"
KERNEL=="rfkill",     MODE="0644"

# CPU
KERNEL=="cpu[0-9]*",      MODE="0444"

# miscellaneous
KERNEL=="fuse",          MODE="0666"
SUBSYSTEM=="rtc", DRIVERS=="rtc_cmos", SYMLINK+="rtc"
KERNEL=="mmtimer",       MODE="0644"
KERNEL=="rflash[0-9]*",       MODE="0400"
KERNEL=="rrom[0-9]*",     MODE="0400"

# 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"
```

Each rule has the following format:

KEY, [KEY, …] NAME [, SYMLINK]

The Key is a **type=value** pair which uniquely identifies a peripheral. The **type** can be one of the following:

Type	Description	Examples
BUS	Bus type	usb, scsi, ide
KERNEL	The default name given to the peripheral by the kernel	hda, ttyUSB0, lp0
SUBSYSTEM	The default sub-system name given by the Kernel, generally identical to the BUS value	usb, scsi
DRIVER	The name of the module used by the peripheral	usb-storage
ID	The position of the peripheral on its bus	PCI bus id, USB id

Type	Description	Examples
PLACE	The topological position of a USB oeripheral on its bus.	S/O
SYSFS{filename}	The name of the peripheral file in /sys. This file contains the manufacturer's name, the label, the serial number and the UUID of the peripheral. Each rule can contains upto five references to files.	S/O
PROGRAM	An eventual external program to be called in order to identify the peripheral	S/O
RESULT	Value expected from PROGRAM	S/O

NAME and SYMLINK are used to tell udev what to do with the peripheral:

Type	Description
NAME	The name of the peripheral in /dev
SYMLINK	The eventual symbolic links that point to NAME

The udevadm Command

To obtain information from udev on a particular peripheral, you can use the **udevadm** command which has replaced the **udevinfo** command available in Red Hat/CentOS 5:

```
[root@centos ~]# udevadm info --query=all -n /dev/sda
P: /devices/pci0000:00/0000:00:0d.0/host2/target2:0:0/2:0:0:0/block/sda
N: sda
W: 38
S: block/8:0
S: disk/by-id/ata-VBOX_HARDDISK_VBc95fcb92-63983501
S: disk/by-id/scsi-SATA_VBOX_HARDDISK_VBc95fcb92-63983501
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/host2/target2:0:0/2:0:0:0/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\x20\x20\x20\x20\x20\x20\x20\x20\x20
\x20\x20\x20\x20\x20\x20
E: ID_REVISION=1.0
E: ID_SERIAL=VBOX_HARDDISK_VBc95fcb92-63983501
E: ID_SERIAL_SHORT=VBc95fcb92-63983501
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_VBc95fcb92-63983501
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=3
E: UDISKS_ATA_SMART_IS_AVAILABLE=0
E: DEVLINKS=/dev/block/8:0 /dev/disk/by-id/ata-VBOX_HARDDISK_VBc95fcb92-63983501 /dev/disk/by-id/scsi-
SATA_VBOX_HARDDISK_VBc95fcb92-63983501 /dev/disk/by-path/pci-0000:00:0d.0-scsi-0:0:0:0
```

This caommand can also be used to obtain all information known to sys concerning specific peripheral:

```
[root@centos ~]# udevadm info -a -p /sys/class/input/mouse0/

Udevadm info starts with the device specified by the devpath and then
walks up the chain of parent devices. It prints for every device
```

```
found, all possible attributes in the udev rules key format.
A rule to match, can be composed by the attributes of the device
and the attributes from one single parent device.

  looking at device '/devices/virtual/input/input2/mouse0':
    KERNEL=="mouse0"
    SUBSYSTEM=="input"
    DRIVER==""

  looking at parent device '/devices/virtual/input/input2':
    KERNELS=="input2"
    SUBSYSTEMS=="input"
    DRIVERS==""
    ATTRS{name}=="Macintosh mouse button emulation"
    ATTRS{phys}==""
    ATTRS{uniq}==""
    ATTRS{modalias}=="input:b0017v0001p0001e0100-e0,1,2,k110,111,112,r0,1,amlsfw"
```

The command line switches of this command are:

```
[root@centos ~]# udevadm --help
Usage: udevadm [--help] [--version] [--debug] COMMAND [COMMAND OPTIONS]
  info         query sysfs or the udev database
  trigger      request events from the kernel
  settle       wait for the event queue to finish
  control      control the udev daemon
  monitor      listen to kernel and udev events
  test         simulation run

[root@centos ~]# udevadm info --help
Usage: udevadm info OPTIONS
  --query=<type>               query device information:
      name                       name of device node
      symlink                    pointing to node
```

```
        path                        sys device path
        property                    the device properties
        all                         all values
  --path=<syspath>              sys device path used for query or attribute walk
  --name=<name>                 node or symlink name used for query or attribute walk
  --root                        prepend dev directory to path names
  --attribute-walk              print all key matches while walking along the chain
                                of parent devices
  --device-id-of-file=<file> print major:minor of device containing this file
  --export-db                   export the content of the udev database
  --help
```

The **/sys** Filesystem

The virtual filesystem **/sys** was introduced with the 2.6 Kernel. Its role is to identify and describe peripherals for udev:

```
[root@centos ~]# ls -l /sys
total 0
drwxr-xr-x.   2 root root 0 Jun 17 08:49 block
drwxr-xr-x.  17 root root 0 Jun 16 17:17 bus
drwxr-xr-x.  40 root root 0 Jun 16 17:17 class
drwxr-xr-x.   4 root root 0 Jun 16 17:17 dev
drwxr-xr-x.  12 root root 0 Jun 16 17:17 devices
drwxr-xr-x.   4 root root 0 Jun 16 17:17 firmware
drwxr-xr-x.   4 root root 0 Jun 16 17:18 fs
drwxr-xr-x.   2 root root 0 Jun 16 17:18 hypervisor
drwxr-xr-x.   5 root root 0 Jun 16 17:17 kernel
drwxr-xr-x. 102 root root 0 Jun 17 08:49 module
drwxr-xr-x.   2 root root 0 Jun 16 17:18 power
```

Each directory contains specific information:

- **block**
  - information concerning block devices
- **bus**
  - information concerning buses
- **class**
  - information concerning classes
- **devices**
  - information concerning the posiion of devices on their bus
- **firmware**
  - information concerning APCI
- **module**
  - information concerning kernel modules
- **power**
  - information concerning power management
- **fs**
  - information concerning file systems

For example:

```
[root@centos ~]# cat /sys/block/sda/sda1/size
204800
```

The figure returned is in sectors.

Limiting Resources

Resources available to users can be limited by using the **ulimit** command.

The **ulimit** command manages two limits:

- a *hard* hard limit by specifying the **-H** switch,
- a *soft* soft limit by specifying the **-S** switch,

<note important> Only root can position a hard limit and only if the limit does not exceed real resource levels. </note>

The soft limit is the limit imposed on the user whilst the hard limit is the limit that a user can obtain once he has gone over the soft limit.

Root can define limits by editing the **/etc/security/limits.conf** file:

```
[root@centos ~]# cat /etc/security/limits.conf
# /etc/security/limits.conf
#
#Each line describes a limit for a user in the form:
#
#<domain>        <type>  <item>  <value>
#
#Where:
#<domain> can be:
#        - an user name
#        - a group name, with @group syntax
#        - the wildcard *, for default entry
#        - the wildcard %, can be also used with %group syntax,
#                for maxlogin limit
#
#<type> can have the two values:
#        - "soft" for enforcing the soft limits
#        - "hard" for enforcing hard limits
#
#<item> can be one of the following:
#        - core - limits the core file size (KB)
#        - data - max data size (KB)
#        - fsize - maximum filesize (KB)
#        - memlock - max locked-in-memory address space (KB)
#        - nofile - max number of open files
#        - rss - max resident set size (KB)
#        - stack - max stack size (KB)
#        - cpu - max CPU time (MIN)
```

```
#              - nproc - max number of processes
#              - as - address space limit (KB)
#              - maxlogins - max number of logins for this user
#              - maxsyslogins - max number of logins on the system
#              - priority - the priority to run user process with
#              - locks - max number of file locks the user can hold
#              - sigpending - max number of pending signals
#              - msgqueue - max memory used by POSIX message queues (bytes)
#              - nice - max nice priority allowed to raise to values: [-20, 19]
#              - rtprio - max realtime priority
#
#<domain>        <type>   <item>           <value>
#


#*                   soft    core             0
#*                   hard    rss              10000
#@student            hard    nproc            20
#@faculty            soft    nproc            20
#@faculty            hard    nproc            50
#ftp                 hard    nproc            0
#@student            -       maxlogins        4


# End of file
```

<note important> The limit can be a number or the word **unlimited**. </note>

For example if root adds the two following lines to /etc/security/limits.conf:

```
...
trainee                 soft       nofile          1024
trainee                 hard       nofile          4096
...
```

the number of open files for trainee is limited to 1024. However trainee can increase this limit to 4 096 by using the following command:

```
$ ulimit -n 4096
```

To see the list of the current limits use the **-a** switch:

```
[root@centos ~]# ulimit -a
core file size          (blocks, -c) 0
data seg size           (kbytes, -d) unlimited
scheduling priority             (-e) 0
file size               (blocks, -f) unlimited
pending signals                 (-i) 14843
max locked memory       (kbytes, -l) 64
max memory size         (kbytes, -m) unlimited
open files                      (-n) 1024
pipe size            (512 bytes, -p) 8
POSIX message queues     (bytes, -q) 819200
real-time priority              (-r) 0
stack size              (kbytes, -s) 10240
cpu time               (seconds, -t) unlimited
max user processes              (-u) 14843
virtual memory          (kbytes, -v) unlimited
file locks                      (-x) unlimited
```

The command line switches of this command are:

```
[root@centos ~]# help ulimit
ulimit: ulimit [-SHacdefilmnpqrstuvx] [limit]
    Modify shell resource limits.
    Provides control over the resources available to the shell and processes
    it creates, on systems that allow such control.
    Options:
      -S    use the `soft' resource limit
      -H    use the `hard' resource limit
      -a    all current limits are reported
      -b    the socket buffer size
```

```
     -c     the maximum size of core files created
     -d     the maximum size of a process's data segment
     -e     the maximum scheduling priority (`nice')
     -f     the maximum size of files written by the shell and its children
     -i     the maximum number of pending signals
     -l     the maximum size a process may lock into memory
     -m     the maximum resident set size
     -n     the maximum number of open file descriptors
     -p     the pipe buffer size
     -q     the maximum number of bytes in POSIX message queues
     -r     the maximum real-time scheduling priority
     -s     the maximum stack size
     -t     the maximum amount of cpu time in seconds
     -u     the maximum number of user processes
     -v     the size of virtual memory
     -x     the maximum number of file locks
    If LIMIT is given, it is the new value of the specified resource; the
    special LIMIT values `soft', `hard', and `unlimited' stand for the
    current soft limit, the current hard limit, and no limit, respectively.
    Otherwise, the current value of the specified resource is printed.  If
    no option is given, then -f is assumed.
    Values are in 1024-byte increments, except for -t, which is in seconds,
    -p, which is in increments of 512 bytes, and -u, which is an unscaled
    number of processes.
    Exit Status:
    Returns success unless an invalid option is supplied or an error occurs.
```

~~DISCUSSION:off~~

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