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# LPI exam 102 prep: Kernel

## Junior Level Administration (LPIC-1) topic 105

Skill Level: Intermediate

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In this tutorial, Ian Shields begins preparing you to take the Linux Professional Institute® Junior Level Administration (LPIC-1) Exam 102. In this first in a [series of nine tutorials](#), Ian introduces you to the kernel on Linux®. By the end of this tutorial, you will know how to build, install, and query a Linux kernel and its kernel modules.

## Section 1. Before you start

Learn what these tutorials can teach you and how you can get the most from them.

### About this series

The [Linux Professional Institute](#) (LPI) certifies Linux system administrators at two levels: *junior level* (also called "certification level 1") and *intermediate level* (also called "certification level 2"). To attain certification level 1, you must pass exams 101 and 102; to attain certification level 2, you must pass exams 201 and 202.

developerWorks offers tutorials to help you prepare for each of the four exams. Each exam covers several topics, and each topic has a corresponding self-study tutorial on developerWorks. For LPI exam 102, the nine topics and corresponding developerWorks tutorials are:

Table 1. LPI exam 102: Tutorials and topics

LPI exam 102 topic	developerWorks tutorial	Tutorial summary
Topic 105	LPI exam 102 prep: Kernel	(This tutorial). Learn how to install and maintain Linux kernels and kernel modules. See detailed <a href="#">objectives</a> below.
Topic 106	LPI exam 102 prep: Boot, initialization, shutdown, and runlevels	Coming soon.
Topic 107	LPI exam 102 prep: Printing	Coming soon.
Topic 108	LPI exam 102 prep: Documentation	Coming soon.
Topic 109	LPI exam 102 prep: Shells, scripting, programming and compiling	Coming soon.
Topic 111	LPI exam 102 prep: Administrative tasks	Coming soon.
Topic 112	LPI exam 102 prep: Networking fundamentals	Coming soon.
Topic 113	LPI exam 102 prep: Networking services	Coming soon.
Topic 114	LPI exam 102 prep: Security	Coming soon.

To pass exams 101 and 102 (and attain certification level 1), you should be able to:

- Work at the Linux command line
- Perform easy maintenance tasks: help out users, add users to a larger system, back up and restore, and shut down and reboot
- Install and configure a workstation (including X) and connect it to a LAN, or connect a stand-alone PC via modem to the Internet

To continue preparing for certification level 1, see the [developerWorks tutorials for LPI exams 101 and 102](#), as well as the [entire set of developerWorks LPI tutorials](#).

The Linux Professional Institute does not endorse any third-party exam preparation material or techniques in particular. For details, please contact [info@lpi.org](mailto:info@lpi.org).

## About this tutorial

Welcome to "Kernel," the first of nine tutorials designed to prepare you for LPI exam

102. In this tutorial, you learn how to build, install, and query a Linux kernel and its kernel modules.

This tutorial is organized according to the LPI objectives for this topic. Very roughly, expect more questions on the exam for objectives with higher weight.

LPI exam objective	Objective weight	Objective summary
1.105.1 <a href="#">Manage and query kernel and kernel modules at runtime</a>	Weight 4	Learn to query and manage a kernel and kernel-loadable modules.
1.105.2 <a href="#">Reconfigure, build, and install a custom kernel and kernel modules</a>	Weight 3	Learn to customize, build, and install a kernel and kernel-loadable modules from source.

## Prerequisites

To get the most from this tutorial, you should have a basic knowledge of Linux and a working Linux system on which to practice the commands covered in this tutorial.

This tutorial builds on content covered in previous tutorials in this LPI series, so you may want to first review the [tutorials for exam 101](#). In particular, you should be very familiar with the material from [LPI exam 101 prep: Hardware and architecture](#) tutorial.

Different versions of a program may format output differently, so your results may not look exactly like the listings and figures in this tutorial.

## Section 2. Runtime kernel management

This section covers material for topic 1.105.1 for the Junior Level Administration (LPIC-1) exam 102. The topic has a weight of 4.

In this section, learn how to:

- Use command-line utilities to get information about the currently running kernel and kernel modules
- Manually load and unload kernel modules

- Determine when modules can be unloaded
- Configure the system to load modules by names other than their file name

Technically, Linux is the kernel of your system. The kernel provides a framework for applications to run and use various hardware devices. It is low-level code that deals with hardware interfaces, scheduling, and memory management among other things. Many people refer to a whole system as GNU/Linux because many of the tools that make most distributions usable come from the GNU project of the Free Software Foundation. Nevertheless, you will often just see "Linux" instead of "GNU/Linux."

## uname

The `uname` command prints information about your system and its kernel. Listing 1 shows the various options for `uname` and the resulting information; each option is defined in Table 3.

### Listing 1. The `uname` command

```

ian@pinguino:~$ uname
Linux
ian@pinguino:~$ uname -s
Linux
ian@pinguino:~$ uname -n
pinguino
ian@pinguino:~$ uname -r
2.6.12-10-386
ian@pinguino:~$ uname -v
#1 Mon Jan 16 17:18:08 UTC 2006
ian@pinguino:~$ uname -m
i686
ian@pinguino:~$ uname -o
GNU/Linux
ian@pinguino:~$ uname -a
Linux pinguino 2.6.12-10-386 #1 Mon Jan 16 17:18:08 UTC 2006 i686 GNU/Linux
    
```

Table 3. Options for <code>uname</code>	
Option	Description
-s	Print the kernel name. This is the default if no option is specified.
-n	Print the nodename or hostname.
-r	Print the release of the kernel. This option is often used with module-handling commands.

-v	Print the version of the kernel.
-m	Print the machine's hardware (CPU) name.
-o	Print the operating system name.
-a	Print all of the above information.

Listing 1 is from an Ubuntu system running on an Intel® CPU. The `uname` command is available on most UNIX® and UNIX-like systems as well as Linux. The information printed will vary by Linux distribution and version as well as by the type of machine you are running on. Listing 2 shows the output from an AMD Athlon 64 system running Fedora Core 4 and, for comparison, an Apple PowerBook.

### Listing 2. Using `uname` with another system

```
Linux attic4 2.6.14-1.1656_FC4 #1 Thu Jan 5 22:13:55 EST 2006 x86_64
x86_64 x86_64 GNU/Linuxfilesystem

Darwin Ian-Shields-Computer.local 7.9.0 Darwin Kernel Version 7.9.0:
Wed Mar 30 20:11:17 PST 2005; root:xnu/xnu-517.12.7.obj~1/RELEASE_PPC
Power Macintosh powerpc
```

## Kernel modules

The kernel manages many of the low-level aspects of your system, including hardware and interfaces. With a large variety of possible hardware and several different file systems, a kernel that supported everything would be rather large. Fortunately, *kernel modules* allow you to load support software such as hardware drivers or file systems when needed, so you can start your system with a small kernel and then load other modules as needed. Often the loading is automatic, such as when USB devices are plugged in.

The remainder of this section looks at the commands and configuration for kernel modules.

The commands for tasks such as loading or unloading modules require root authority. The commands for displaying information about modules can usually be run by general users. However, since they reside in `/sbin`, they are not usually on a non-root user's path, so you will probably have to use full path names if you are not root.

## lsmod

Use the `lsmod` command to display the modules that are currently loaded on your system, as shown in Listing 3. Your output is likely to be different, although you should see some common entries.

### Listing 3. Displaying kernel modules with `lsmod`

```
[ian@attic4 ~]$ /sbin/lsmod
Module                Size Used by
nvnet                  74148 0
nvidia                4092336 12
forcedeth             24129 0
md5                   4161 1
ipv6                  268737 12
parport_pc            29189 1
lp                   13129 0
parport               40969 2 parport_pc,lp
autofs4               29637 1
sunrpc                168453 1
ipt_REJECT            5825 1
ipt_state              1985 3
ip_conntrack          42009 1 ipt_state
iptables_filter       3137 1
ip_tables             19521 3 ipt_REJECT,ipt_state,iptables_filter
dm_mod                58613 0
video                 16069 0
button                4161 0
battery               9541 0
ac                    4933 0
ohci_hcd              26977 0
ehci_hcd              41165 0
i2c_nforce2           7105 0
i2c_core              21825 1 i2c_nforce2
shpchp                94661 0
snd_intel8x0          34945 1
snd_ac97_codec        76217 1 snd_intel8x0
snd_seq_dummy         3781 0
snd_seq_oss           37569 0
snd_seq_midi_event    9409 1 snd_seq_oss
snd_seq               62801 5 snd_seq_dummy,snd_seq_oss,snd_seq_midi_event
snd_seq_device        9037 3 snd_seq_dummy,snd_seq_oss,snd_seq
snd_pcm_oss           51569 0
snd_mixer_oss         18113 1 snd_pcm_oss
snd_pcm               100553 3 snd_intel8x0,snd_ac97_codec,snd_pcm_oss
snd_timer             33733 2 snd_seq,snd_pcm
snd                   57669 11 snd_intel8x0,snd_ac97_codec,snd_seq_oss,snd_seq,
snd_seq_device,snd_pcm_oss,snd_mixer_oss,snd_pcm,snd_timer
soundcore             11169 1 snd
snd_page_alloc        9925 2 snd_intel8x0,snd_pcm
floppy                65397 0
ext3                  132681 3
jbd                   86233 1 ext3
sata_nv               9541 0
libata                47301 1 sata_nv
sd_mod                20545 0
scsi_mod              147977 2 libata,sd_mod
[ian@attic4 ~]$
```

You can see that this system has many loaded modules. Most of these are supplied with the kernel. However, some, such as the `nvnet`, `nvidia`, and `sata_nv` modules from NVIDIA Corporation include proprietary code and are not supplied as part of a standard kernel. In this way, the modular approach allows proprietary code to be plugged in to an open source kernel. Assuming the vendor license permits it, a Linux

distributor may add proprietary modules to a distribution, saving you the effort of getting them directly from a vendor and helping to ensure that you have the appropriate levels.

From Listing 3, you can also see that modular support extends to devices such as video, SATA and SCSI hard drives, floppy disks, and sound cards, as well as to networking features such as IPV6, file system support such as ext3, and Sun remote procedure call (RPC).

In addition to the module name, `lsmod` also shows the module size and the number of users of the module. If the module is used by any other modules, these are listed. So, for example, the `soundcore` module is used by the `snd` module, which in turn is used by several other sound modules.

## modinfo

The `modinfo` command displays information about one or more modules. As shown in Listing 4, the information includes the full path to the file, the author, license, any parameters that the module might accept, version, dependencies, and other information.

### Listing 4. Basic module information

```
[ian@attic4 ~]$ /sbin/modinfo floppy
filename:      /lib/modules/2.6.12-1.1456_FC4/kernel/drivers/block/floppy.ko
author:       Alain L. Knaff
license:      GPL
alias:        block-major-2-*
vermagic:     2.6.12-1.1456_FC4 686 REGPARM 4KSTACKS gcc-4.0
depends:
srcversion:   2633BC999A0747D8D215F1F
parm:         FLOPPY_DMA:int
parm:         FLOPPY_IRQ:int
parm:         floppy:charp
[ian@attic4 ~]$ /sbin/modinfo sata_nv
filename:      /lib/modules/2.6.12-1.1456_FC4/kernel/drivers/scsi/sata_nv.ko
author:       NVIDIA
description:  low-level driver for NVIDIA nForce SATA controller
license:      GPL
version:      0.6
vermagic:     2.6.12-1.1456_FC4 686 REGPARM 4KSTACKS gcc-4.0
depends:       libata
alias:        pci:v000010DEd00000008Esv*sd*bc*sc*i*
alias:        pci:v000010DEd000000E3sv*sd*bc*sc*i*
alias:        pci:v000010DEd000000EEsv*sd*bc*sc*i*
alias:        pci:v000010DEd00000054sv*sd*bc*sc*i*
alias:        pci:v000010DEd00000055sv*sd*bc*sc*i*
alias:        pci:v000010DEd00000036sv*sd*bc*sc*i*
alias:        pci:v000010DEd0000003Esv*sd*bc*sc*i*
alias:        pci:v000010DEd*sv*sd*bc01sc01i*
srcversion:   3094AD48C1B869BCC301E9F
```

In Listing 4, notice in the lines giving the module filenames that these filenames end in a `.ko` suffix. This distinguishes modules for 2.6 kernels from other object files and

from modules for 2.4 and earlier kernels, which used the same .o suffix as other object files.

You will also notice that the module path include the kernel version. For example, `/lib/modules/2.6.12-1.1456_FC4/kernel/drivers/block/floppy.ko` includes `2.6.12-1.1456_FC4` as a path element. This is the same value emitted by `uname -r`. Kernel modules are specific to a given kernel, and this structure manages that relationship.

On 2.6 kernels you can also use `modinfo` to limit requests to specific information about a module. Use the `-F` option to extract a single information type, such as `parm`, `description`, `license`, `filename`, or `alias`. Use the command multiple times with different options if you need different types of information. On 2.4 kernels, parameters such as `-p` extracted parameter information. The current `modinfo` command also supports the older parameters. Listing 5 shows some examples.

### Listing 5. Specific module information

```
[ian@attic4 ~]$ /sbin/modinfo -F parm snd
cards_limit:Count of auto-loadable soundcards.
major:Major # for sound driver.
[ian@attic4 ~]$ /sbin/modinfo -F license nvidia floppy
NVIDIA
GPL
[ian@attic4 ~]$ /sbin/modinfo -p snd
major:Major # for sound driver.
cards_limit:Count of auto-loadable soundcards.
```

## Using your Linux skills

You may use some of the techniques covered in the tutorial "[LPI exam 101 prep \(topic 103\): GNU and UNIX commands](#)" to extract information such as the number of parameters accepted by any module that accepts parameters. Listing 6 shows an example.

### Listing 6. Number of parameters per module

```
[ian@attic4 ~]$ for n in `/sbin/lsmmod | tail +2 | cut -d " " -f1`;
> do echo "$n $(/sbin/modinfo -p $n | wc -l )" | grep -v " 0$"; done
nvnet 12
forcedeth 1
parport_pc 5
dm_mod 1
ohci_hcd 2
ehci_hcd 2
shpchp 3
snd_intel8x0 7
snd_ac97_codec 1
snd_seq_dummy 2
snd_seq_oss 2
snd_seq 7
snd_pcm_oss 3
snd_pcm 2
snd_timer 1
snd 2
```



```
snd_page_alloc 1
scsi_mod 6
```

## rmmod

If a module's use count is 0, you may safely remove it. For example, you might do this in preparation for loading an updated version. This is a great feature of a modular kernel because you do not always have to reboot just to update support for one or another particular device. To remove a mod, use the `rmmod` command along with the module name as shown in Listing 7.

### Listing 7. Removing a module for a running system

```
[root@attic4 ~]# rmmod floppy
```

Consult the man pages for other options available with `rmmod`.

## insmod and modprobe

Once you have removed a module, you may need to reload it. You can do this using the `insmod` command, which takes the full path name of the module to be reloaded, along with any module options that may be required. If you use this command, you will probably want to use command substitution for generating the filename. Two ways of doing this are shown in Listing 8.

### Listing 8. Loading a module using insmod

```
[root@attic4 ~]# insmod /lib/modules/`uname
-r`/kernel/drivers/block/floppy.ko
[root@attic4 ~]# rmmod floppy
[root@attic4 ~]# insmod $(modinfo -F filename floppy)
```

The second form above saves you the need to remember which subdirectory (drivers/block in this case) a module is located in, but there is an even better way to load a module. The `modprobe` command provides a higher-level interface that operates with the module name instead of file path. It also handles loading additional modules upon which a module depends, and can remove modules as well as load them.

Listing 9 shows how to use `modprobe` to remove the `vfat` module, along with the `fat` module that uses it. It then shows what the system would do if the module were reloaded, and finally the result of reloading the module. Note that the `-v` option is specified to obtain verbose output; otherwise, `modprobe` (and the underlying `insmod` command) will display only error messages from the module itself. Between

each step, the output of `lsmod` is piped through `grep` to show whether either the `vfat` or `fat` module is loaded or not.

### Listing 9. Loading a module using `modprobe`

```
[root@lyrebird root]# modprobe -r vfat
vfat: Device or resource busy
[root@lyrebird root]# lsmod | grep fat
vfat          13132    1
fat           38744    0 [vfat]
[root@lyrebird root]# umount /windows/D
[root@lyrebird root]# modprobe -r vfat
[root@lyrebird root]# modprobe -v --show vfat
/sbin/insmod /lib/modules/2.4.21-37.0.1.EL/kernel/fs/fat/fat.o
/sbin/insmod /lib/modules/2.4.21-37.0.1.EL/kernel/fs/vfat/vfat.o
[root@lyrebird root]# lsmod | grep fat
[root@lyrebird root]# modprobe -v vfat
/sbin/insmod /lib/modules/2.4.21-37.0.1.EL/kernel/fs/fat/fat.o
Using /lib/modules/2.4.21-37.0.1.EL/kernel/fs/fat/fat.o
Symbol version prefix ''
/sbin/insmod /lib/modules/2.4.21-37.0.1.EL/kernel/fs/vfat/vfat.o
Using /lib/modules/2.4.21-37.0.1.EL/kernel/fs/vfat/vfat.o
[root@lyrebird root]# lsmod | grep fat
vfat          13132    0 (unused)
fat           38744    0 [vfat]
```

## depmod

You have just seen that `modprobe` can handle the automatic loading of multiple modules when some are dependent on others. The dependencies are kept in the `modules.dep` file in the `/lib/modules` subdirectory for the appropriate kernel, as given by the `uname -r` command. This file, along with several map files, is generated by the `depmod` command. The `-a` (for *all*) is now optional.

The `depmod` command scans the modules in the subdirectories of `/lib/modules` for the kernel you are working on and freshens the dependency information. An example, along with the resulting changed files, is shown in Listing 10.

### Listing 10. Using `depmod` to rebuild `modules.dep`

```
[root@lyrebird root]# date
Thu Mar 16 10:41:05 EST 2006
[root@lyrebird root]# depmod
[root@lyrebird root]# cd /lib/modules/`uname -r`
[root@lyrebird 2.4.21-37.0.1.EL]# ls -l mod*
-rw-rw-r-- 1 root root          54194 Mar 16 10:41 modules.dep
-rw-rw-r-- 1 root root           31 Mar 16 10:41 modules.generic_string
-rw-rw-r-- 1 root root           73 Mar 16 10:41 modules.ieee1394map
-rw-rw-r-- 1 root root          1614 Mar 16 10:41 modules.isapnpmap
-rw-rw-r-- 1 root root           29 Mar 16 10:41 modules.parpportmap
-rw-rw-r-- 1 root root         65171 Mar 16 10:41 modules.pcimmap
-rw-rw-r-- 1 root root           24 Mar 16 10:41 modules.pnpbiosmap
-rw-rw-r-- 1 root root         122953 Mar 16 10:41 modules.usbmap
[root@lyrebird 2.4.21-37.0.1.EL]# cd -
/root
```

You can customize the behavior of `modprobe` and `depmod` using the configuration file `/etc/modules.conf`. This is commonly used to alias module names and to specify commands that should be run after a module is loaded or before it is unloaded. However, an extensive range of other configuration can be done. Listing 11 shows an example of `/etc/modules.conf`. Consult the man page for `modules.conf` for more details.

### Listing 11. Example `/etc/modules` file

```
[root@lyrebird root]# cat /etc/modules.conf
alias eth0 e100
alias usb-controller usb-uhci
alias usb-controller1 ehci-hcd
alias sound-slot-0 i810_audio
post-install sound-slot-0 /bin/aumix-minimal -f /etc/.aumixrc -L >/dev/null 2>&1 || :
pre-remove sound-slot-0 /bin/aumix-minimal -f /etc/.aumixrc -S >/dev/null 2>&1 || :
```

You should also be aware that some systems use another configuration file called `modprobe.conf`, while others store module configuration information in the `/etc/modules.d` directory. You may also find a file called `/etc/modules` on some systems; this file contains the names of kernel modules that should be loaded at boot time.

## USB modules

When you hot plug a USB device into your Linux system, the kernel must determine which modules to load to handle the device. This is usually done for you by a hot plug script that uses the `usbmodules` command to find the appropriate module. You can also run `usbmodules` (as root) to see for yourself. Listing 12 shows an example.

### Listing 12. USB modules

```
root@pinguino:~# lsusb
Bus 005 Device 004: ID 1058:0401 Western Digital Technologies, Inc.
Bus 005 Device 003: ID 054c:0220 Sony Corp.
Bus 005 Device 001: ID 0000:0000
Bus 004 Device 001: ID 0000:0000
Bus 003 Device 001: ID 0000:0000
Bus 002 Device 001: ID 0000:0000
Bus 001 Device 003: ID 04b3:310b IBM Corp. Red Wheel Mouse
Bus 001 Device 001: ID 0000:0000
root@pinguino:~# usbmodules --device /proc/bus/usb/005/003
usb-storage
root@pinguino:~# usbmodules --device /proc/bus/usb/001/003
usbmouse
usbhid
```

The next section shows you how to build and configure a custom kernel.

---

## Section 3. Customize and build kernels and kernel modules

This section covers material for topic 1.105.2 for the Junior Level Administration (LPIC-1) exam 102. The topic has a weight of 3.

In this section, learn how to:

- Customize the current kernel configuration
- Build a new kernel and appropriate kernel modules
- Install a new kernel and any modules
- Ensure that the boot manager can locate the new kernel and associated files

As you learned in the previous section, [Runtime kernel management](#), the kernel provides the low-level support for your system hardware and file systems. A modern kernel image usually contains only essential functions, but is configured to support additional functions that you might need through the use of *kernel modules*. The additional support is loaded only when needed, for example when a device is plugged in or otherwise enabled.

The modular code becomes an integral part of the kernel, dynamically extending the kernel functions. If the functions of a loaded kernel module have not been used for several minutes, the kernel can voluntarily disassociate it from the rest of the kernel and unload it from memory through a process known as *autocleaning*.

Without kernel modules, your running kernel, which is loaded from disk as a single binary file, would have to contain all the functionality you might possibly ever need. You would also need to build a completely new kernel every time you wanted to add functionality to your system.

You cannot put *everything* in a module, however. At a bare minimum, the kernel image that is loaded must be able to mount your root file system. But, as you learned in the tutorial "[LPI exam 101 prep \(topic 102\): Linux installation and package management](#)," your boot loader can load an *initial RAM disk* (or *initrd*), which may contain the modules necessary to mount the root file system. Nevertheless, the kernel image must at least contain support for the RAM file system used in the initial RAM disk. If it does not, your system will not boot.

Once your system has bootstrapped itself this far, it proceeds to mount the root file system and then start the other initialization processes. After a few seconds, the

system is up and ready for you to use. The kernel, however, remains in control awaiting requests to perform work for user processes and scheduling the system resources among the tasks that require them.

Modular kernels work well in modern systems with plenty of RAM and disk space. However, you may have a new piece of hardware, such as a video card or storage system, that is not supported by the kernel that came with your distribution. Indeed, some drivers contain proprietary code that is said to *taint* a pure Linux kernel, so some distributors will not include it, even if the vendor license terms permit it to be distributed by your chosen distributor. In this case, you will need to at least build new modules, and possibly even build a new kernel.

Linux can be used in many environments, from embedded systems such as mobile phones, to networking devices such as routers, to set-top boxes as well as more traditional computing environments. Some of these devices use a kernel that is customized to support only those functions that the system is intended to support. For example, a system intended to be a diskless firewall probably does not need support for any file system other than the read-only file system from which it loaded, yet it may need support for advanced networking hardware that is not part of a standard kernel. Again, a custom kernel will be required.

## Source packages

The ultimate source for the Linux kernel is the Linux Kernel Archives (see [Resources](#) for a link). Unless you already know what you are doing, you should use a kernel package from your Linux distribution, because your distributor may have added custom patches. If you are already familiar with obtaining and extracting source packages, review the tutorial "[LPI exam 101 prep \(topic 102\): Linux installation and package management](#)." As with anything that may change your system, make backups first so that you can recover if things go wrong.

If you download source from the public kernel archives, you will download a compressed file, and you will need to decompress it using `gzip` or `bzip2`, according to whether you download the `.gz` or the `.bz2` version of the kernel source. The `pub/linux/kernel/` directory on the download server has a directory for each kernel version, such as 2.4, 2.5, or 2.6. At the date of this writing, the latest `bzip2` version of the 2.6 kernel is `linux-2.6.15.tar.bz2`.

In that kernel directory, you will also see a corresponding `ChangeLog-2.6.15.6` file that describes changes in this version, and a `patch-2.6.15.bz2`, which is a smaller file that allows you to patch the prior version of source to bring it up to 2.6.15 level. You will also notice signature files that you may use to verify that your downloaded file was not corrupted, either accidentally or maliciously.

The compressed source is normally uncompressed in `/usr/src`, and it creates a new

subdirectory for the kernel version, such as `linux-2.6.15`, containing the tree of files needed to build your kernel. If you already have such a directory, you may want to back it up or rename it before unpacking the new kernel source. This will ensure that you can go back if you need to, and also that you will not have stray files that should not be in your kernel source tree. You need about 40MB of disk space for the tarball and about 350MB for the expanded source code.

Some distributors, notably Red Hat, now distribute the kernel headers and source necessary for building kernel modules as a kernel development package. Documentation may be in a separate kernel documentation package. These are designed for and sufficient for building modules, such as a proprietary vendor graphics card module, but they are not sufficient for rebuilding a custom kernel. Your distribution should have information about how to rebuild a kernel and how the source can be obtained. Check for documentation such as release notes.

Suppose you use FTP or HTTP to download the `kernel-2.6.15-1.1833_FC4.src.rpm` source RPM from the `pub/fedora/linux/core/updates/4/SRPMS/` at `download.fedora.redhat.com`, and the file is in the `/root` directory. Note that version numbers used here will probably be different for your system, so make sure you get the updated version of source corresponding to your installed kernel. Now, for Fedora, you must install the source RPM, then switch to the `/usr/src/redhat/SPECS` directory, and finally build the source RPM in order to create the Linux kernel source tree as shown in Listing 13.

### Listing 13. Creating the kernel source tree for Fedora Core

```
[root@attic4 ~]# uname -r
2.6.15-1.1833_FC4
[root@attic4 ~]# rpm -Uvh kernel-2.6.15-1.1833_FC4.src.rpm
 1:kernel ##### [100%]
[root@attic4 ~]# cd /usr/src/redhat/SPECS
[root@attic4 SPECS]# rpmbuild -bp --target $(arch) kernel-2.6.spec
Building target platforms: x86_64
Building for target x86_64
Executing(%prep): /bin/sh -e /var/tmp/rpm-tmp.23188
+ umask 022
+ cd /usr/src/redhat/BUILD
+ LANG=C
+ export LANG
+ unset DISPLAY
+ '[' '!' -d kernel-2.6.15/vanilla ']'
+ cd /usr/src/redhat/BUILD
+ rm -rf kernel-2.6.15
+ /bin/mkdir -p kernel-2.6.15
+ cd kernel-2.6.15
+ /usr/bin/bzip2 -dc /usr/src/redhat/SOURCES/linux-2.6.15.tar.bz2
+ tar -xf -
+ . . .
+ echo '# x86_64'
+ cat .config
+ perl -p -i -e 's/^\SUBLEVEL.*\/SUBLEVEL = 15/' Makefile
+ perl -p -i -e 's/^\EXTRAVERSION.*\/EXTRAVERSION = -prep/' Makefile
+ find . -name '*.orig' -o -name '*~' -exec rm -f '{}' ';'
+ exit 0
```

The Linux kernel source for Fedora is now located in `/usr/src/redhat/BUILD/kernel-2.6.15/linux-2.6.15`. By convention, the `/linux-2.6.15` tree is often moved to `/usr/src` and symbolically linked to `/usr/src/linux`, as shown in Listing 14. This is not strictly necessary, but it's easier to follow along with references that assume the kernel source tree will be in `.usr./src/linux`.

#### Listing 14. Moving the source tree to `/usr/src`

```
[root@attic4 SPECS]# mv ../BUILD/kernel-2.6.15/linux-2.6.15 /usr/src
[root@attic4 SPECS]# cd /usr/src
[root@attic4 src]# ln -s linux-2.6.15 linux
[root@attic4 src]# ls -ld lin*
lrwxrwxrwx  1 root root  12 Mar 20 18:23 linux -> linux-2.6.15
drwxr-xr-x 20 root root 4096 Mar 20 18:13 linux-2.6.15
```

Before you attempt to build anything, review the `Changes` file that is located in the `Documentation` directory. Among other things, it lists the minimum levels of various software packages that you need to build a kernel. Make sure that you have these packages installed.

You may notice `Makefile` and `.config` among the files shown in Listing 13. The `make` file contains several `make` targets for tasks such as configuring the kernel options, building the kernel and its modules, and installing the modules and building RPM or deb packages. More recent kernel sources allow you to use `make help` for brief help on each target. For older systems, you may need to consult the documentation or examine the `make` file. Listing 15 shows partial output for `make help`.

#### Listing 15. Help for kernel building `make` file

```
[ian@attic4 linux-2.6.15]$ make help
Cleaning targets:
  clean          - remove most generated files but keep the config
  mrproper       - remove all generated files + config + various backup files

Configuration targets:
  config         - Update current config utilising a line-oriented program
  menuconfig     - Update current config utilising a menu based program
  xconfig        - Update current config utilising a QT based front-end
  gconfig        - Update current config utilising a GTK based front-end
  oldconfig      - Update current config utilising a provided .config as base
  randconfig     - New config with random answer to all options
  defconfig      - New config with default answer to all options
  allmodconfig   - New config selecting modules when possible
  allyesconfig   - New config where all options are accepted with yes
  allnoconfig    - New minimal config

Other generic targets:
  all            - Build all targets marked with [*]
  * vmlinux      - Build the bare kernel
  * modules      - Build all modules
  modules_install - Install all modules
  dir/           - Build all files in dir and below
  dir/file.[ois] - Build specified target only
  ...
```

## Configuration

The `.config` file in your kernel build directory contains configuration information for your kernel, including the target machine environment, the features to be included, and whether a feature should be compiled into the kernel or built as a module. Creating a `.config` file is the first step to building or rebuilding a kernel. You create it using one of the configuration targets in the make file.

The main configuration options are:

### **config**

The `config` target uses a command-line interface to obtain answers to many questions to either build or update your `.config` file. With the advent of the menu-based configuration targets, this command-line interface is rarely used today.

### **menuconfig**

The `menuconfig` target uses an ncurses-based, menu-based program to create or update your `.config` file. You need only answer questions for items you want to change. This approach has superseded the older `config` target. You run this in a terminal window either remotely or locally.

### **xconfig**

The `xconfig` target uses a graphical menu system based on a QT front-end, like the one used with the KDE desktop.

### **gconfig**

The `gconfig` target uses a graphical menu system based on a GTK front-end, like the one used with the GNOME desktop.

### **oldconfig**

The `oldconfig` target allows you to build a configuration using an existing `.config` file, such as you might have from a previous build or another system. For example, if you installed the kernel source for Fedora as described above, you may copy the configuration file for your running system from `/lib/modules/$(uname -r)/build/.config` to `/usr/src/linux`. Once you've built it, you may use one of the menu configuration targets to modify it if necessary.

Figure 1 shows what you might see if you run `make menuconfig` for a 2.4 series kernel. Press **Enter** to descend into lower-level menus, and press **Esc** to return. Help is available for most items. Either tab to the **< Help >** button and press **Enter**, or simply type **h**. Press **Esc** to return to configuring.

### **Figure 1. Running make menuconfig on a 2.4 kernel**



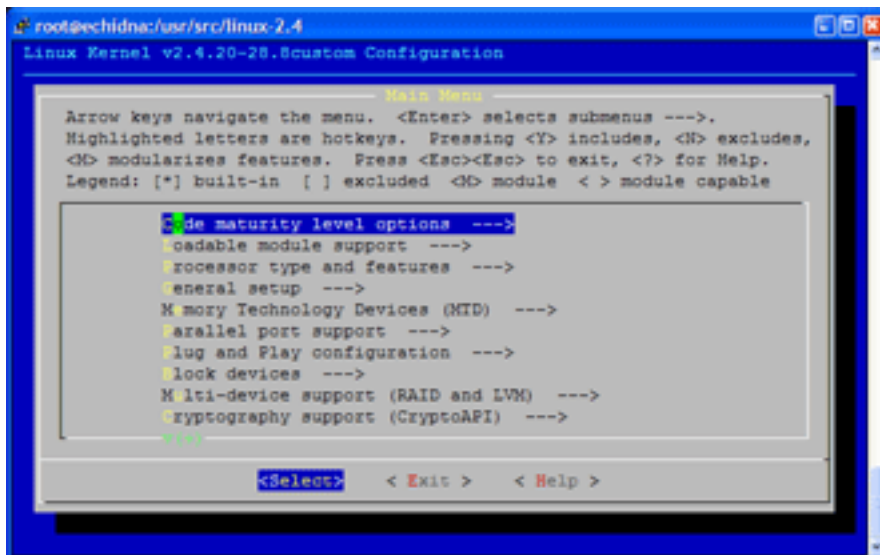
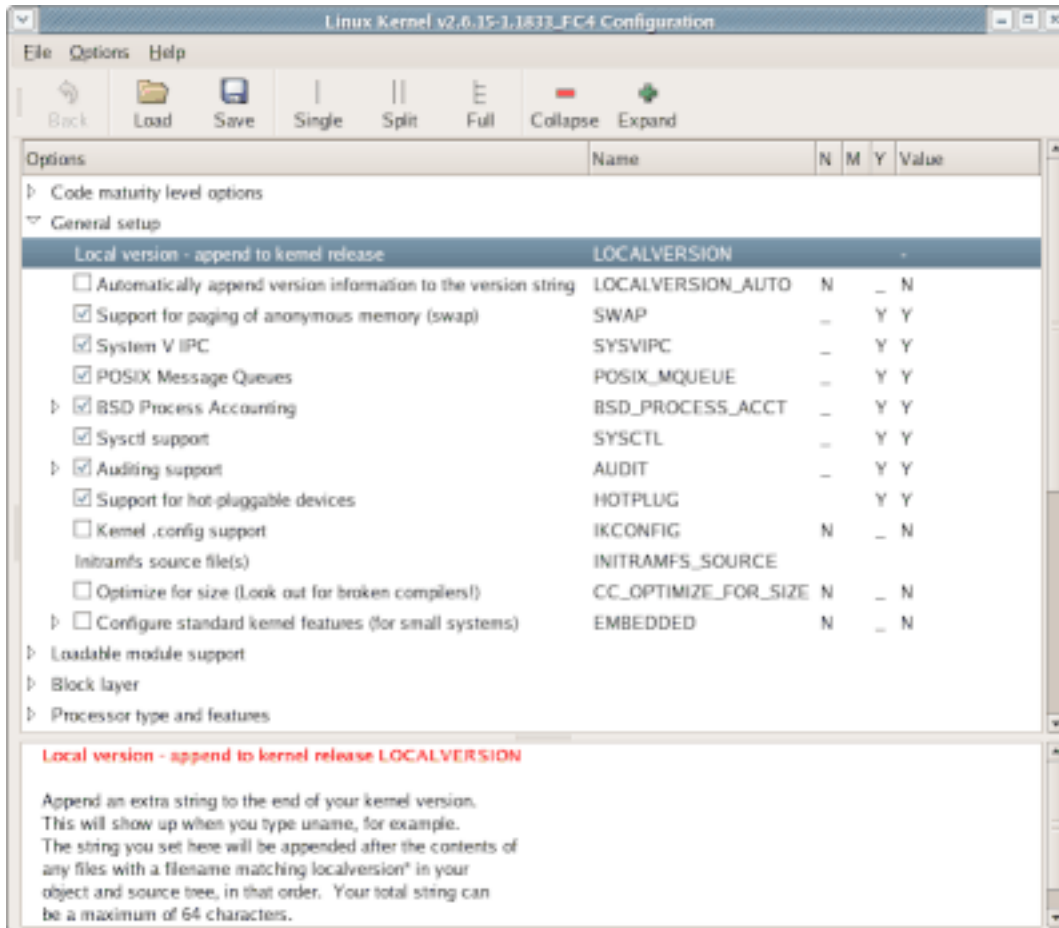


Table 4 shows the various options for including features in the kernel, either built in or as modules. When an option is highlighted, press the space bar to toggle between the allowable choices for that feature. You can also press **y** to enable an option, **n** to disable it, or **m** to have it compiled as a module if possible.

Table 4. Options for menuconfig	
Option	Description
[*]	Feature will be built into the kernel.
[]	Feature will not be included in the kernel.
<M>	Feature will be built as a kernel module.
< >	Feature will not be included in the kernel but is capable of being built as a module.

Figure 2 shows what you might see if you run `make gconfig` for a 2.6 series kernel. Click the arrows to expand or collapse menu items. Help is displayed in a lower pane.

**Figure 2. Running make gconfig on a 2.6 kernel**



The major configuration sections for a 2.6 kernel are described below. You may not find all of these with 2.4 and earlier kernels, but this list gives you an overview of where to find what.

### Code maturity level options

This section contains an option that determines whether remaining options give you a choice for code that is considered experimental. If you do not select this option, then you will be able to select only options that are considered stable. Be warned that functions you choose may or may not work at the current code level on your system, so you might have a chance to help with debugging.

### General setup

This section lets you include an identification string with your new kernel, along with options for several kernel attributes that do not belong elsewhere but that you must specify.

### Loadable module support

This section contains an option that determines whether your kernel will support modules and whether they may be automatically loaded and unloaded. You should enable module support.

## Block layer

This section contains support for disks larger than 2TB, and allows you to choose the type of disk scheduling that you would like.

## Processor type and features

This section contains CPU-specific configuration options. Here you choose the processor or processor family that your kernel will support, as well as whether or not to enable access to various processor features. Be sure to enable symmetric multi-processing support if you have more than one CPU or a hyperthreaded CPU. Generally, you should enable the MTRR option to allow better graphic performance with AGP or PCI video cards.

## Power management options

This section contains several power management options. These are particularly useful on laptops. Besides controlling power states, you will find options here to control and monitor such things as temperatures or fan states.

## Bus options (PCI etc.)

This section contains options for buses supported by your system, such as PCI, PCI Express, and PC Card buses. You can also enable the `/proc/pci` file system here, although you should generally use `lspci` instead.

## Executable file formats / Emulations

This section contains options for supporting various binary file formats. You should enable ELF binary support. You may also enable support for DOS binaries to run under DOSEMU, as well as wrapper-driven binaries such as Java™, Python, Emacs-Lisp, and so on. Finally, for a 64-bit system that supports 32-bit emulation, you probably want to enable 32-bit binary support.

## Networking

The networking section is large. Here you can enable basic sockets and TCP/IP networking, as well as packet filtering, bridging, routing, and support for a variety of protocols such as IPV6, IPX, Appletalk, and X.25. You can also enable wireless, infrared, and amateur radio support here.

## Device drivers

This section is also very large. Here you enable support for most of your hardware devices, including IDE/ATAPI or SCSI hard drives and flash memory devices. Enable DMA for your IDE devices; otherwise, they will work in the slower PIO mode. If you want support for multiple devices such as RAID or LVM, this is where you enable it. You can also configure parallel port support here if you want parallel printer support. This is also where you configure a vast range of possible networking devices to support the networking protocols you configured above. You will also find support here for audio and video capture devices, USB and IEEE 1384 (Firewire) devices, as well as a variety of hardware monitoring devices. Under the character devices subsection, you will

probably want to enable parallel print support and direct rendering support.

### **Firmware drivers**

This section contains a few options related to BIOS setting and updating, such as using the Dell System Management functions on certain Dell systems.

### **File systems**

This section is for configuring the file systems that you want your kernel to support, either compiled in or as modules. You will also find file systems here for removable media such as diskettes and CD or DVD devices, along with support for networked file systems such as NFS, SMB, or CIFS. Support for a variety of partitions and Native Language Support is found here too.

### **Instrumentation support**

This section allows you to enable experimental profiling support for profiling your system's activity.

### **Kernel hacking**

This section allows you to enable kernel debugging and choose which features will be enabled.

### **Security options**

This section allows you to configure several security options and to enable and configure SELinux (Security Enhanced Linux).

### **Cryptographic options**

This section allows you to configure several cryptographic algorithms, such as MD4, DES, and SHA256.

### **Library routines**

This section allows you to decide whether certain CRC algorithms should be compiled in or built as modules.

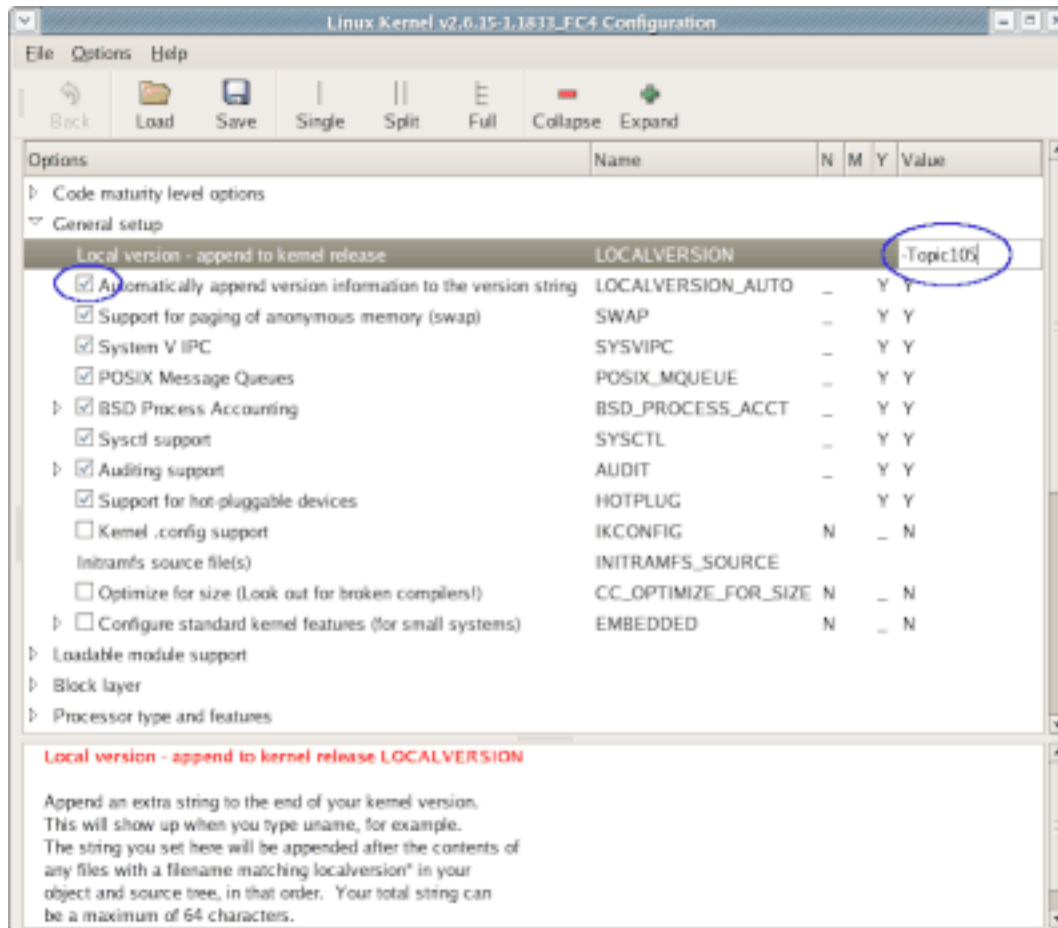
## **Building**

Now that you've seen the major aspects of configuring a kernel, you're ready to build one. If you are not sure of the state of your build tree, run `make clean` before configuring your new kernel. For an even more extreme cleanup target, run `make mrproper`; this will remove your `.config` file as well as some other files used by the build process. If you do this and then need to restore a backed up `.config` file, you will need to run `make oldconfig` before configuring.

While you are experimenting, you should give your new kernel a custom name so you can easily identify it. Do this by setting a local version value and enabling the option to automatically append version information to the version string under the

General setup section as shown in Figure 3.

**Figure 3. Configuring a custom kernel**



In the spirit of taking small steps, the examples in the remainder of this tutorial are based on building a kernel with just the two changes shown in Figure 3.

In principle, the kernel does not require root authority to build, although you will need root authority to install your new kernel. However, if you are using the package installed by your distribution, you will probably have to run as root because of the file and directory permissions that have been set up. You can practice in user mode by downloading a kernel source tarball from the Linux kernel archives and unpacking it in your home directory, or by making a copy of your kernel build tree and changing the permissions to your userid.

To start building a 2.6 kernel, type `make`.

To start building a 2.4 kernel, run these three commands:

```
make dep
make bzImage
make modules
```

The first makes necessary dependency files. The second builds the kernel. And the last builds your modules.

Running `make` on my AMD Athlon 3500+ system takes about a half hour to complete the build from a clean start. Slower systems may take a couple of hours to complete the job, so take a break or do something else while you wait. You will see progress messages such as those in Listing 16 while the build is running.

### Listing 16. Running make

```
[root@attic4 linux]# make
CHK      include/linux/version.h
HOSTCC   scripts/basic/fixdep
HOSTCC   scripts/basic/split-include
HOSTCC   scripts/basic/docproc
SPLIT    include/linux/autoconf.h -> include/config/*
CC       arch/x86_64/kernel/asm-offsets.s
GEN      include/asm-x86_64/asm-offsets.h
...
LD [M]   sound/usb/snd-usb-lib.ko
CC       sound/usb/usx2y/snd-usb-usx2y.mod.o
LD [M]   sound/usb/usx2y/snd-usb-usx2y.ko
```

## Installing

When you have completed building your kernel, you still have a couple of steps to go. First, you need to run `make modules_install` to install your kernel modules in a new subdirectory of `./lib/modules`.

If you need proprietary modules for a video card or network driver, as I need for my nVidia graphics card and nForce 4 motherboard chipset, now is a good time to build those modules using the vendor-supplied tools.

Finally, you need to run `make install` to install the new kernel and initial RAM disk in `/boot` and update your boot loader configuration. These steps are illustrated in Listing 17.

### Listing 17. Installing the kernel and modules

```
[root@attic4 linux]# make modules_install
INSTALL arch/x86_64/crypto/aes-x86_64.ko
INSTALL arch/x86_64/kernel/cpufreq/acpi-cpufreq.ko
INSTALL arch/x86_64/kernel/microcode.ko
INSTALL arch/x86_64/oprofile/oprofile.ko
INSTALL crypto/aes.ko
INSTALL crypto/anubis.ko
INSTALL crypto/arc4.ko
...
[root@attic4 linux]# ls -lrt /lib/modules | tail -n 3
drwxr-xr-x  5 root root 4096 Mar  4 14:48 2.6.15-1.1831_FC4
drwxr-xr-x  5 root root 4096 Mar 20 18:52 2.6.15-1.1833_FC4
drwxr-xr-x  3 root root 4096 Mar 20 21:38 2.6.15-prep-Topic105
[root@attic4 linux]# sh /root/NFORCE-Linux-x86_64-1.0-0310-pkg1.run -a \
> -n -K -k 2.6.15-prep-Topic105
```

```

Verifying archive integrity...OK
Uncompressing NVIDIA nForce drivers for Linux-x86_64 1.0-0310.....
[root@attic4 linux]# sh /root/NVIDIA-Linux-x86_64-1.0-8178-pkg2.run -a \
> -n -K -k 2.6.15-prep-Topic105
Verifying archive integrity... OK
Uncompressing NVIDIA Accelerated Graphics Driver for Linux-x86_64 1.0-8178.....
[root@attic4 linux]# make install
CHK include/linux/version.h
CHK include/linux/compile.h
CHK usr/initramfs_list
Kernel: arch/x86_64/boot/bzImage is ready (#2)
sh /usr/src/linux-2.6.15/arch/x86_64/boot/install.sh 2.6.15-prep-Topic105
arch/x86_64/boot/bzImage System.map "/boot"
[root@attic4 linux]# ls -lrt /boot | tail -n 6
-rw-r--r-- 1 root root 1743149 Mar 20 21:45 vmlinuz-2.6.15-prep-Topic105
lrwxrwxrwx 1 root root 28 Mar 20 21:45 vmlinuz -> vmlinuz-2.6.15-prep-Topic105
-rw-r--r-- 1 root root 980796 Mar 20 21:45 System.map-2.6.15-prep-Topic105
lrwxrwxrwx 1 root root 31 Mar 20 21:45 System.map -> System.map-2.6.15-prep-Topic105
-rw-r--r-- 1 root root 1318741 Mar 20 21:45 initrd-2.6.15-prep-Topic105.img
drwxr-xr-x 2 root root 4096 Mar 20 21:45 grub

```

## Initial RAM disk

Notice that the build process automatically created the necessary initial RAM disk (initrd) for you. If you ever need to create one manually, you do so using the `mkinitrd` command. See the man pages for details.

## Boot loaders

If everything worked correctly, the `make install` step should have also updated your boot loader configuration. Some lines from mine are shown in Listing 18.

### Listing 18. Updated GRUB configuration file

```

                                default=1
timeout=10
splashimage=(hd0,5)/boot/grub/splash.xpm.gz
password --md5 $1$y.uQRs1W$Sqs30hDB3GtE957PoidWO.
title Fedora Core (2.6.15-prep-Topic105)
    root (hd0,11)
    kernel /boot/vmlinuz-2.6.15-prep-Topic105 ro root=LABEL=FC4-64 rhgb quiet
    initrd /boot/initrd-2.6.15-prep-Topic105.img
title Fedora Core -x86-64 (2.6.15-1.1833_FC4)

```

The entry for the newly built kernel has been placed at the top, but the default entry has been adjusted to remain as the previous default. If you use LILO instead, then the `grubby` command that is used in the build script should have updated your LILO configuration. If the configuration was not updated correctly for any reason, refer to the tutorial "[LPI exam 101 prep \(topic 102\): Linux installation and package management](#)," where you will find full instructions on setting up your boot loader.

One final note. You may wonder why the sample configuration added `-Topic105`, yet the created files all had `-prep-Topic105` instead. This is a Fedora safety measure to prevent you from inadvertently destroying your live kernel. This is

controlled by the `EXTRAVERSION` variable set near the top of the main make file, as shown in Listing 19. Edit the file if you need to remove this.

### Listing 19. Updated GRUB configuration file

```
[root@attic4 linux]# head -n 6 Makefile
VERSION = 2
PATCHLEVEL = 6
SUBLEVEL = 15
EXTRAVERSION = -prep
NAME=Sliding Snow Leopard
```

## Rebooting

If all is well, you should now be able to boot your new system. You will need to select the configuration entry for the new kernel because it is not (yet) the default. After you are happy with it, you can make it the default. When you reboot, use the `uname` command to check your system's kernel as shown in Listing 20.

### Listing 20. Checking your new system

```
[ian@attic4 ~]$ uname -rv
2.6.15-prep-Topic105 #2 Mon Mar 20 21:13:20 EST 2006
```



# Resources

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- Review the entire [LPI exam prep tutorial series](#) on developerWorks to learn Linux fundamentals and prepare for system administrator certification.
- At the [LPIC Program](#), find task lists, sample questions, and detailed objectives for the three levels of the Linux Professional Institute's Linux system administration certification.
- In "[Basic tasks for new Linux developers](#)" (developerWorks, March 2005), learn how to open a terminal window or shell prompt and much more.
- The [Linux Documentation Project](#) has a variety of useful documents, especially its HOWTOs.
- [The Linux Kernel Archives](#) is the ultimate resource for the Linux kernel. Check for your nearest mirror before you download.
- The [kernelnewbies project](#) has lots of information for those new to kernels and building them.
- The [Kernel Rebuild Guide](#) shows you how to configure, build, and install a new kernel.
- The [Linux Kernel Module Programming Guide](#) from [Linuxtopia](#) is an online book about kernel modules for Linux.
- *[LPI Linux Certification in a Nutshell](#)* (O'Reilly, 2001) and *[LPIC I Exam Cram 2: Linux Professional Institute Certification Exams 101 and 102 \(Exam Cram 2\)](#)* (Que, 2004) are references for readers who prefer book format.
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Ian Shields works on a multitude of Linux projects for the developerWorks Linux zone. He is a Senior Programmer at IBM at the Research Triangle Park, NC. He joined IBM in Canberra, Australia, as a Systems Engineer in 1973, and has since worked on communications systems and pervasive computing in Montreal, Canada, and RTP, NC. He has several patents. His undergraduate degree is in pure mathematics and philosophy from the Australian National University. He has an M.S. and Ph.D. in computer science from North Carolina State University. You can contact Ian at [ishields@us.ibm.com](mailto:ishields@us.ibm.com).

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