Embedded Linux kernel usage

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Latest update: Feb 21, 2011,
Document sources, updates and translations:
http://free-electrons.com/docs/kernel-usage
Corrections, suggestions, contributions and translations are welcome!

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Linux kernel sources

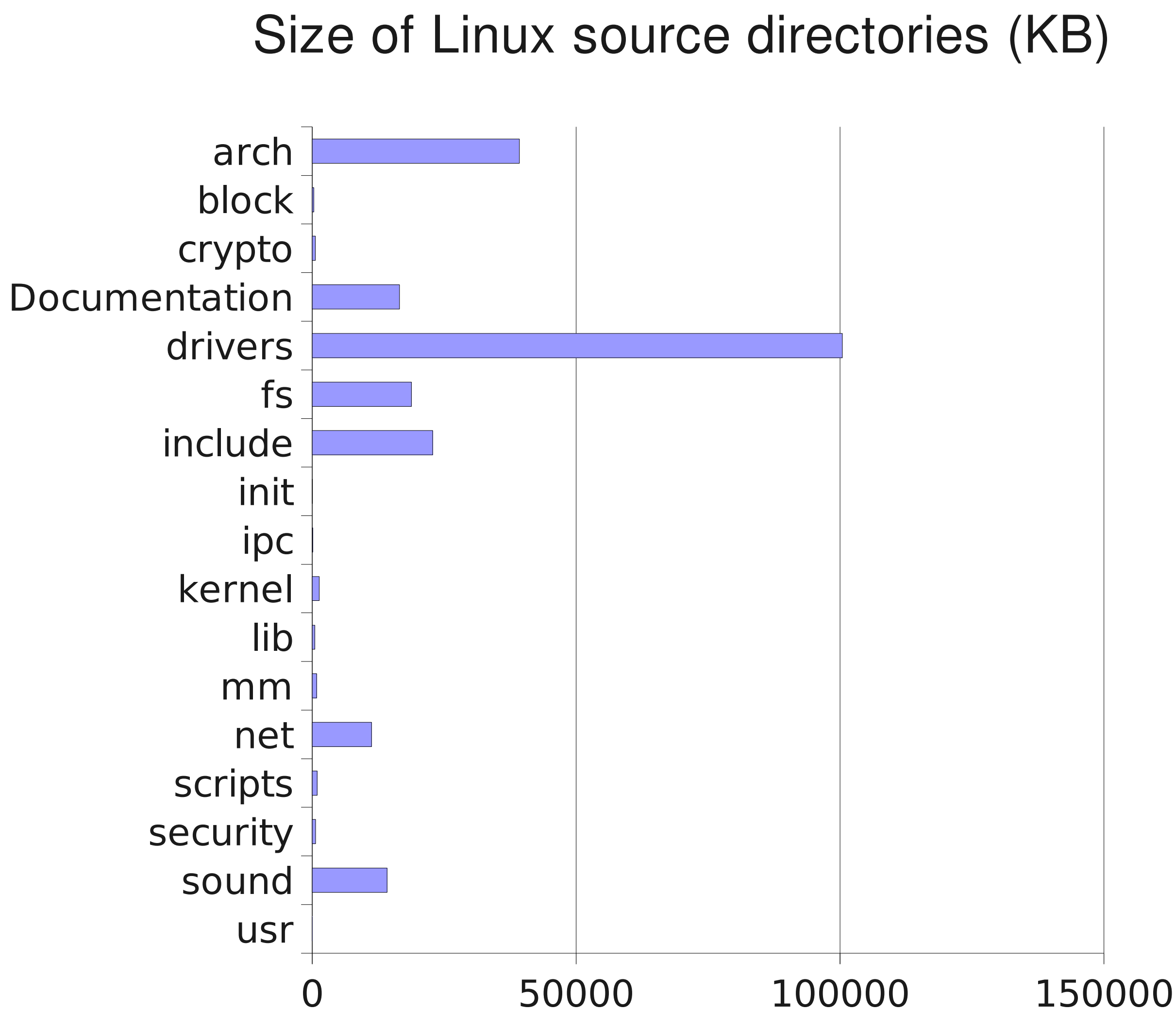
Location of kernel sources

- The official version of the Linux kernel, as released by Linus Torvalds is available at http://www.kernel.org
  - This version follows the well-defined development model of the kernel
  - However, it may not contain the latest development from a specific area, due to the organization of the development model and because features in development might not be ready for mainline inclusion
- Many kernel sub-communities maintain their own kernel, with usually newer but less stable features
  - Architecture communities (ARM, MIPS, PowerPC, etc.), device drivers communities (I2C, SPI, USB, PCI, network, etc.), other communities (real-time, etc.)
  - They generally don't release official versions, only development trees are available

Linux kernel size (1)

- Linux 2.6.37 sources:
  Raw size: 412 MB (37,300 files, approx 14,000,000 lines)
  `gzip` compressed tar archive: 89 MB
  `bzip2` compressed tar archive: 71 MB (better)
  `lzma` compressed tar archive: 61 MB (best)
- Minimum Linux 2.6.29 compiled kernel size with `CONFIG_EMBEDDED`, for a kernel that boots a QEMU PC (IDE hard drive, ext2 filesystem, ELF executable support):
  532 KB (compressed), 1325 KB (raw)
- Why are these sources so big?
  Because they include thousands of device drivers, many network protocols, support many architectures and filesystems...
- The Linux core (scheduler, memory management...) is pretty small!

Linux kernel size (2)



Linux 2.6.17

Measured with:

`du -s --apparent-size`

Getting Linux sources

- Full tarballs
  - Contain the complete kernel sources
  - Long to download and uncompress, but must be done at least once
  - Example:
    http://kernel.org/pub/linux/kernel/v2.6/linux-2.6.14.7.tar.bz2
- Incremental patches between versions
  - It assumes you already have a base version and you apply the correct patches in the right order
  - Quick to download and apply
  - Examples
    http://kernel.org/pub/linux/kernel/v2.6/patch-2.6.14.bz2 (2.6.13 to 2.6.14)
    http://kernel.org/pub/linux/kernel/v2.6/patch-2.6.14.7.bz2 (2.6.14 to 2.6.14.7)
- All previous kernel versions are available in
  http://kernel.org/pub/linux/kernel/

Using the patch command

The patch command applies changes to files in the current directory:

- Making changes to existing files
- Creating or deleting files and directories

patch usage examples:

- patch -p<n> < diff_file
- cat diff_file | patch -p<n>
- bzcat diff_file.bz2 | patch -p<n>
- zcat diff_file.gz | patch -p<n>

n: number of directory levels to skip in the file paths

You can reverse a patch with the -R option

You can test a patch with the --dry-run option

Anatomy of a patch file

A patch file is the output of the `diff` command

```
diff -Nru a/Makefile b/Makefile
--- a/Makefile  2005-03-04 09:27:15 -08:00
+++ b/Makefile  2005-03-04 09:27:15 -08:00
@@ -1,7 +1,7 @@
 VERSION = 2
 PATCHLEVEL = 6
 SUBLEVEL = 11
-EXTRAVERSION =
+EXTRAVERSION = .1
 NAME=Woozy Numbat

 # *DOCUMENTATION*
```

- `diff` command line
- File date info
- Line numbers in files
- Context info: 3 lines before the change
  Useful to apply a patch when line numbers changed
- Removed line(s) if any
- Added line(s) if any
- Context info: 3 lines after the change

Applying a Linux patch

Linux patches...

- Always to apply to the `x.y.<z-1>` version
  Downloadable in `gzip`
  and `bzip2` (much smaller) compressed files.
- Always produced for `n=1`
  (that's what everybody does... do it too!)
- Linux patch command line example:

```
cd linux-2.6.13
bzcat ../patch-2.6.14.bz2 | patch -p1
bzcat ../patch-2.6.14.7.bz2 | patch -p1
cd ..; mv linux-2.6.13 linux-2.6.14.7
```

- Keep patch files compressed: useful to check their signature later.
  You can still view (or even edit) the uncompressed data with `vim`:
  `vim patch-2.6.14.bz2` (on the fly (un)compression)

> You can make `patch` 30% faster by using `-sp1` instead of `-p1` (**s**ilent)
>
> Tested on patch-2.6.23.bz2

Ketchup - Easy access to kernel sources

http://www.selenic.com/ketchup/

- Makes it easy to download a specific version.
  Takes care of downloading and applying patches
- Example: downloading the latest kernel version

```
> mkdir linux-2.6.31
> cd linux-2.6.31
> ketchup -G 2.6.31.6
None -> 2.6.31.6
Downloading linux-2.6.31.6.tar.bz2
Unpacking linux-2.6.31.6.tar.bz2
```

- Now getting back to an older version (from the same directory)

```
> ketchup -G 2.6.29
2.6.31.6 -> 2.6.29
Applying patch-2.6.31.6.bz2 -R
Applying patch-2.6.31.bz2 -R
Downloading patch-2.6.30.bz2
Applying patch-2.6.30.bz2 -R
```

The `-G` option of ketchup disables source signature checking.

See http://kernel.org/signature.html for details about enabling kernel source integrity checking.

Practical lab – Kernel sources

- Get the sources
- Apply patches

Compiling and booting Linux

Kernel configuration

Kernel configuration (1)

- The kernel contains thousands of device drivers, filesystem drivers, network protocols and other configurable items
- Thousands of options are available, that are used to selectively compile parts of the kernel source code
- The kernel configuration is the process of defining the set of options with which you want your kernel to be compiled
- The set of options depends
  - On your hardware
  - On the capabilities you would like to give to your kernel

Kernel configuration (2)

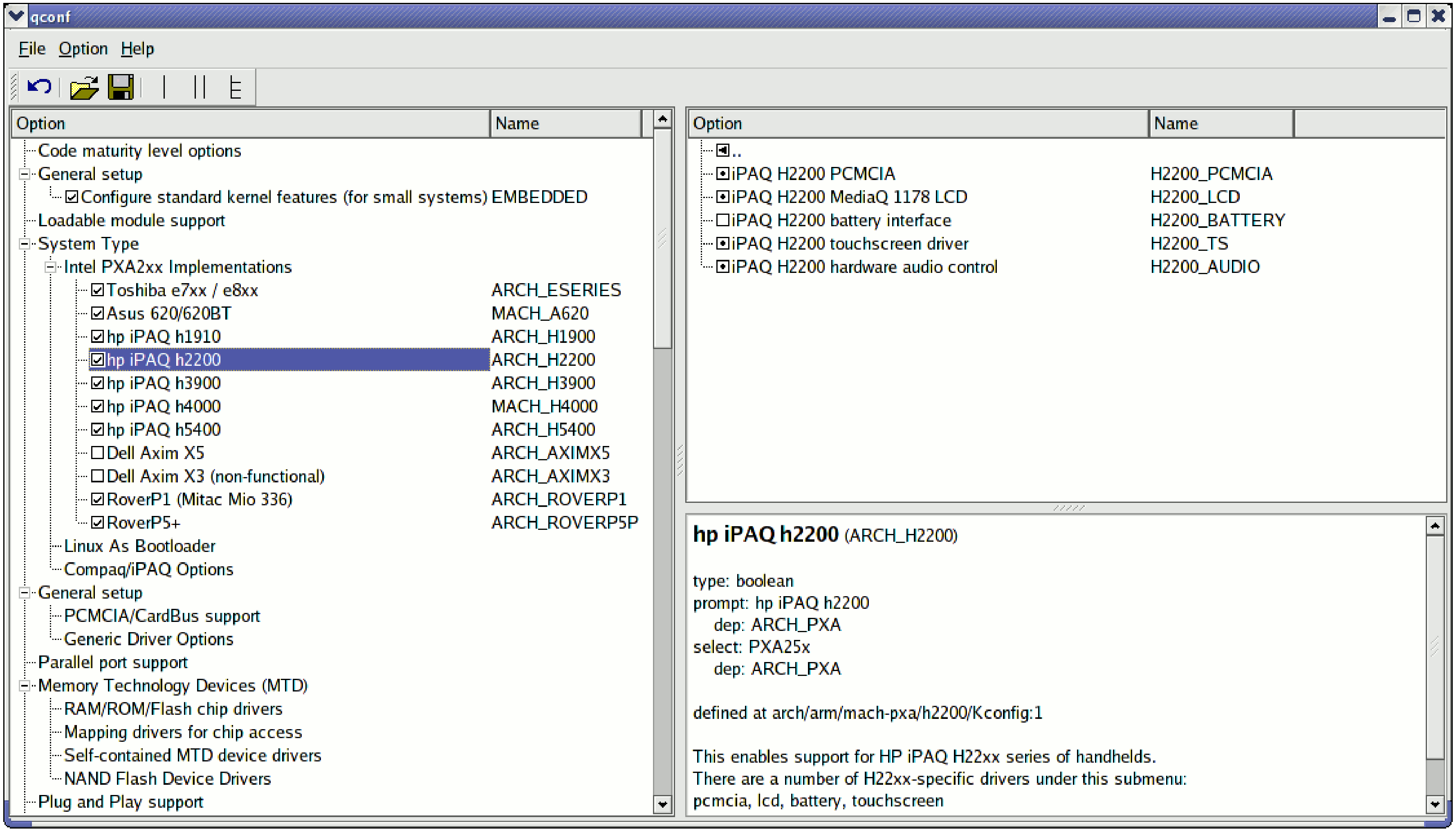
- The configuration is stored in the `.config` file at the root of kernel sources
  - Simple text file, `key=value` style
- As options have dependencies, typically never edited by hand, but through graphical interfaces :
  - `make [xconfig|gconfig|menuconfig|oldconfig]`
  - These are targets from the main kernel Makefile. Run `make help` to get a list of all available targets.
- To modify a kernel in a GNU/Linux distribution:
  the configuration files are usually released in `/boot/`, together with kernel images: `/boot/config-2.6.17-11-generic`

make xconfig

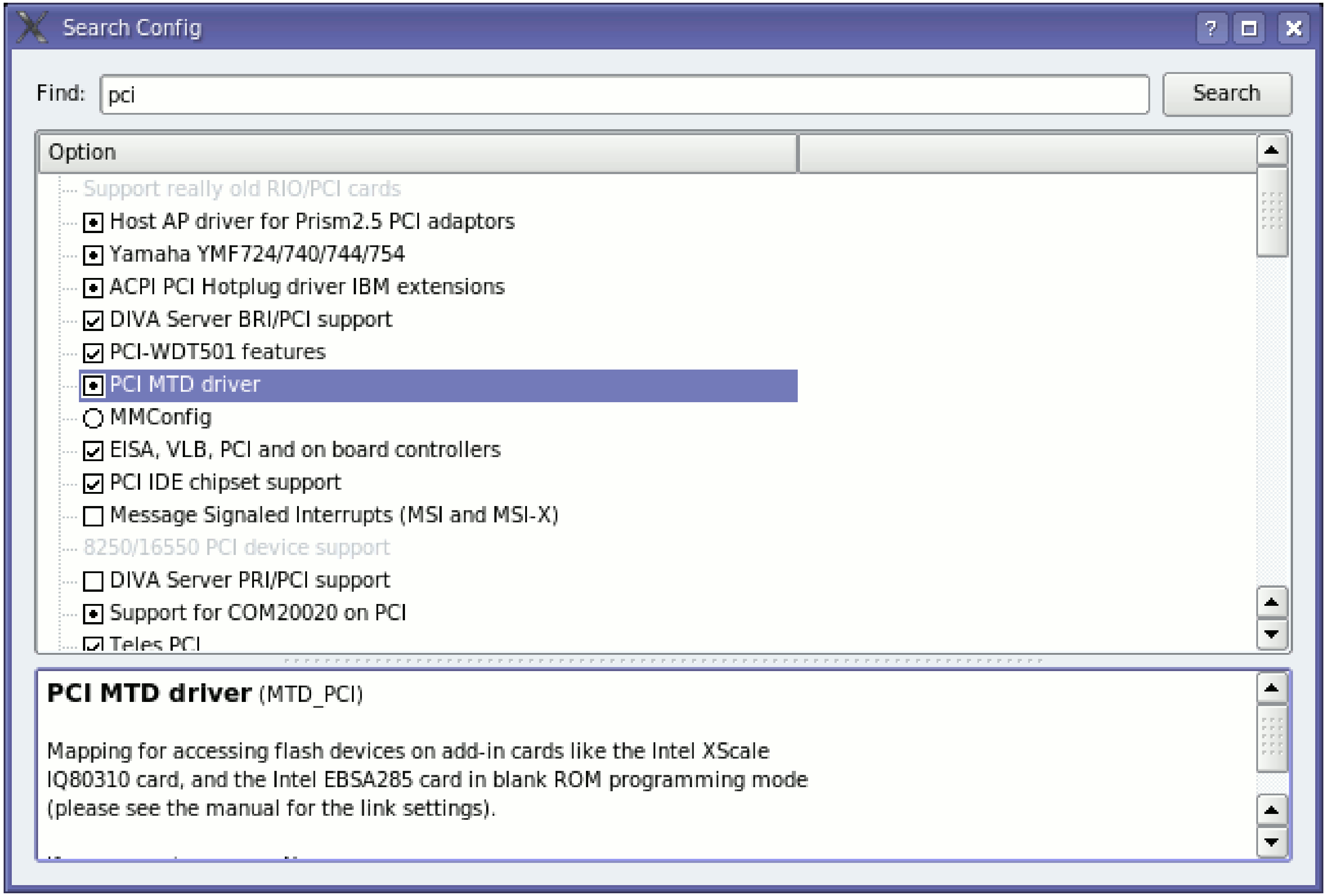
`make xconfig`

- The most common graphical interface to configure the kernel.
- Make sure you read `help -> introduction: useful options!`
- File browser: easier to load configuration files
- New search interface to look for parameters
- Required Debian / Ubuntu packages: `libqt3-mt-dev`, `g++`

make xconfig screenshot



make xconfig search interface

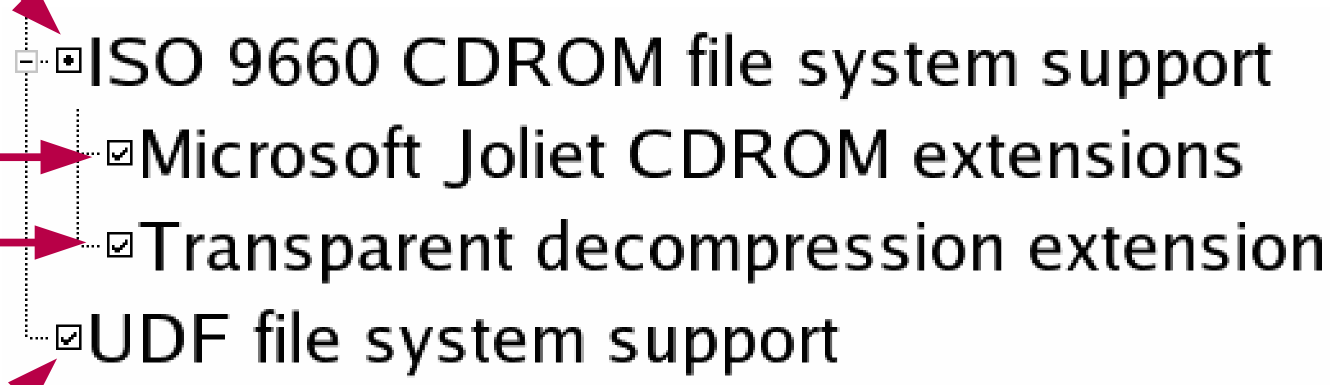


Looks for a keyword in the description string

Allows to select or unselect found parameters.

Compiled as a module (separate file)
`CONFIG_ISO9660_FS=m`

Driver options
`CONFIG_JOLIET=y`
`CONFIG_ZISOFS=y`



Compiled statically into the kernel
`CONFIG_UDF_FS=y`

Corresponding .config file excerpt

```
#
# CD-ROM/DVD Filesystems
#
CONFIG_ISO9660_FS=m
CONFIG_JOLIET=y
CONFIG_ZISOFS=y
CONFIG_UDF_FS=y
CONFIG_UDF_NLS=y

#
# DOS/FAT/NT Filesystems
#
# CONFIG_MSDOS_FS is not set
# CONFIG_VFAT_FS is not set
CONFIG_NTFS_FS=m
# CONFIG_NTFS_DEBUG is not set
CONFIG_NTFS_RW=y
```

Section name
(helps to locate settings in the interface)

All parameters are prefixed
with `CONFIG_`

Kernel option dependencies

- There are dependencies between kernel options
- For example, enabling a network driver requires the network stack to be enabled
- Two types of dependencies
  - *depends on* dependencies. In this case, option A that depends on option B is not visible until option B is enabled
  - *select* dependencies. In this case, with option A depending on option B, when option A is enabled, option B is automatically enabled
  - *make xconfig* allows to see all options, even those that cannot be selected because of missing dependencies. In this case, they are displayed in gray

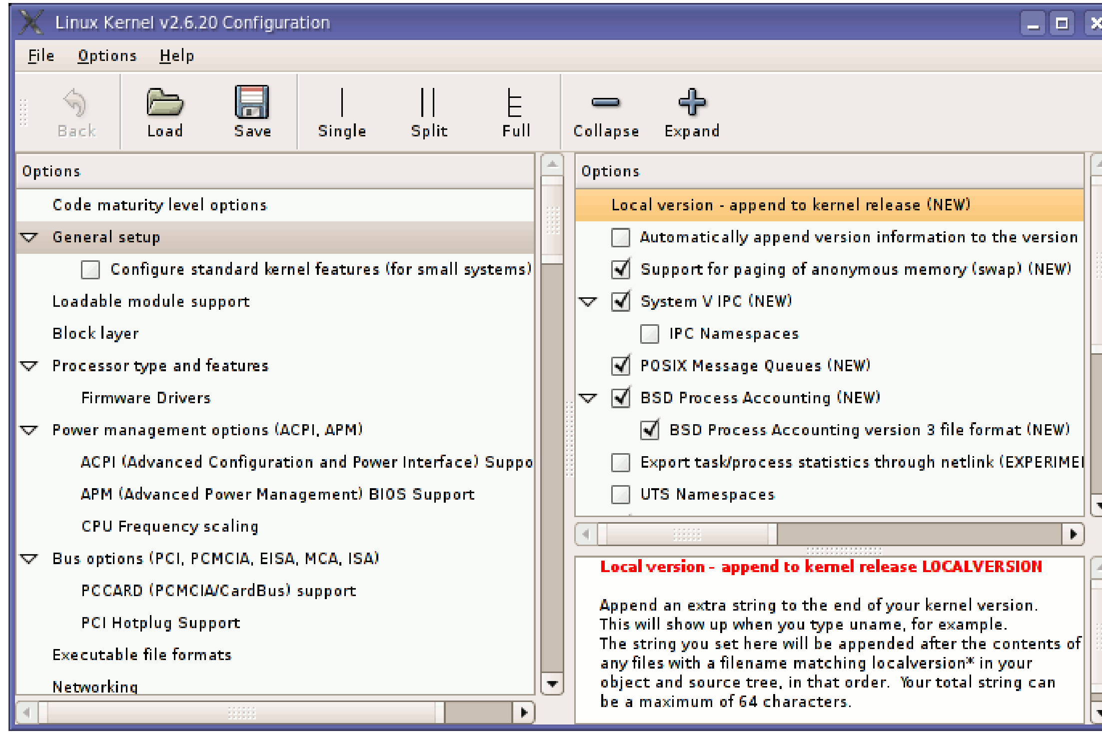
make gconfig

`make gconfig`

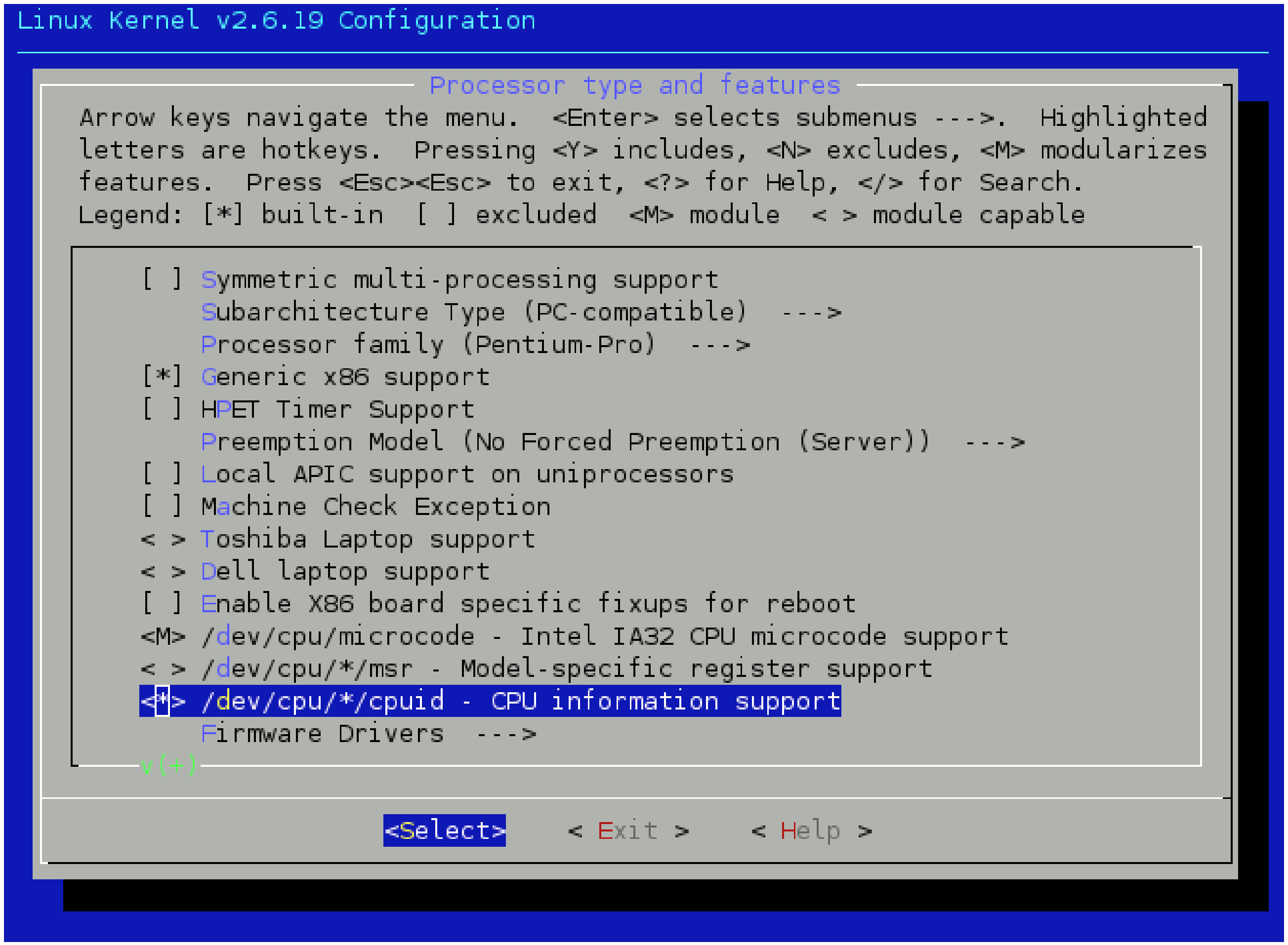
New GTK based graphical configuration interface. Functionality similar to that of `make xconfig`.

Just lacking a search functionality.

Required Debian packages: `libglade2-dev`



make menuconfig



`make menuconfig`

Useful when no graphics are available. Pretty convenient too!

Same interface found in other tools: BusyBox, buildroot...

Required Debian packages: `libncurses-dev`

make oldconfig

`make oldconfig`

- Needed very often!
- Useful to upgrade a `.config` file from an earlier kernel release
- Issues warnings for configuration parameters that no longer exist in the new kernel.
- Asks for values for new parameters

If you edit a `.config` file by hand, it's strongly recommended to run `make oldconfig` afterwards!

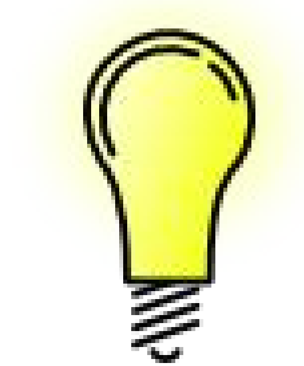
`make allnoconfig`

- Only sets strongly recommended settings to `y`.
- Sets all other settings to `n`.
- Very useful in embedded systems to select only the minimum required set of features and drivers.
- Much more convenient than unselecting hundreds of features one by one!

Undoing configuration changes

A frequent problem:

- After changing several kernel configuration settings, your kernel no longer works.
- If you don't remember all the changes you made, you can get back to your previous configuration:
  `> cp .config.old .config`
- All the configuration interfaces of the kernel (`xconfig`, `menuconfig`, `allnoconfig`...) keep this `.config.old` backup copy.



Configuration per architecture

- The set of configuration options is architecture dependent
  - Some configuration options are very architecture-specific
  - Most of the configuration options (global kernel options, network subsystem, filesystems, most of the device drivers) are visible in all-architecture
- By default, the kernel build system assumes that the kernel is being built for the host architecture, i.e native compilation
- The architecture is not defined inside the configuration, but at an higher level
- We will see later how to override this behaviour, to allow the configuration of kernels for a different architecture

Overview of kernel options (1)

- General setup
  - *Prompt for development/incomplete code* allows to be able to enable drivers or features that are not considered as completely stable yet
  - *Local version - append to kernel release* allows to concatenate an arbitrary string to the kernel version that an user can get using `uname -r`. Very useful for support!
  - *Support for swap*, can usually be disabled on most embedded devices
  - *Configure standard kernel features (for small systems)* allows to remove features from the kernel to reduce its size. Powerful, use with care!

Overview of kernel options (2)

- Loadable module support
  - Allows to enable or completely disable module support. If your system doesn't need kernel modules, best to disable since it saves a significant amount of space and memory
- Enable the block layer
  - If CONFIG_EMBEDDED is enabled, the block layer can be completely removed. Embedded systems using only Flash storage can safely disable the block layer
- Processor type and features (x86) or System type (ARM) or CPU selection (MIPS)
  - Allows to select the CPU or machine for which the kernel must be compiled
  - On x86, only optimization-related, on other architectures very important since there's no compatibility

Overview of kernel options (3)

- Kernel features
  - Tickless system, which allows to disable the regular timer tick and use on-demand ticks instead. Improves power savings
  - High resolution timer support. By default, the resolution of timer is the tick resolution. With high resolution timers, the resolution is as precise as the hardware can give
  - Preemptible kernel enables the preemption inside the kernel code (the userspace code is always preemptible). See our real-time presentation for details
- Power management
  - Global power management option needed for all power management related features
  - Suspend to RAM, CPU frequency scaling, CPU idle control, suspend to disk

Overview of kernel options (4)

- Networking support
  - The network stack
  - Networking options
    - Unix sockets, needed for a form of inter-process communication
    - TCP/IP protocol with options for multicast, routing, tunneling, Ipsec, Ipv6, congestion algorithms, etc.
    - Other protocols such as DCCP, SCTP, TIPC, ATM
    - Ethernet bridging, QoS, etc.
  - Support for other types of network
    - CAN bus, Infrared, Bluetooth, Wireless stack, WiMax stack, etc.

Overview of kernel options (5)

- Device drivers
  - MTD is the subsystem for Flash (NOR, NAND, OneNand, battery-backed memory, etc.)
  - Parallel port support
  - Block devices, a few misc block drivers such as loopback, NBD, etc.
  - ATA/ATAPI, support for IDE disk, CD-ROM and tapes. A new stack exists
  - SCSI
    - The SCSI core, needed not only for SCSI devices but also for USB mass storage devices, SATA and PATA hard drives, etc.
    - SCSI controller drivers

Overview of kernel options (6)

- Device drivers (cont)
  - SATA and PATA, the new stack for hard disks, relies on SCSI
  - RAID and LVM, to aggregate hard drivers and do replication
  - Network device support, with the network controller drivers. Ethernet, Wireless but also PPP
  - Input device support, for all types of input devices: keyboards, mices, joysticks, touchscreens, tablets, etc.
  - Character devices, contains various device drivers, amongst them
    - serial port controller drivers
    - PTY driver, needed for things like SSH or telnet
  - I2C, SPI, 1-wire, support for the popular embedded buses
  - Hardware monitoring support, infrastructure and drivers for thermal sensors

Overview of kernel options (7)

- Device drivers (cont)
  - Watchdog support
  - Multifunction drivers are drivers that do not fit in any other category because the device offers multiple functionality at the same time
  - Multimedia support, contains the V4L and DVB subsystems, for video capture, webcams, AM/FM cards, DVB adapters
  - Graphics support, infrastructure and drivers for framebuffers
  - Sound card support, the OSS and ALSA sound infrastructures and the corresponding drivers
  - HID devices, support for the devices that conform to the HID specification (Human Input Devices)

Overview of kernel options (8)

- Device drivers (cont)
  - USB support
    - Infrastructure
    - Host controller drivers
    - Device drivers, for devices connected to the embedded system
    - Gadget controller drivers
    - Gadget drivers, to let the embedded system act as a mass-storage device, a serial port or an Ethernet adapter
  - MMC/SD/SDIO support
  - LED support
  - Real Time Clock drivers
  - Voltage and current regulators
  - Staging drivers, crappy drivers being cleaned up

Overview of kernel options (9)

- For some categories of devices the driver is not implemented inside the kernel
  - Printers
  - Scanners
  - Graphics drivers used by X.org
  - Some USB devices
- For these devices, the kernel only provides a mechanism to access the hardware, the driver is implemented in userspace

Overview of kernel options (10)

- File systems
  - The common Linux filesystems for block devices: ext2, ext3, ext4
  - Less common filesystems: XFS, JFS, ReiserFS, GFS2, OCFS2, Btrfs
  - CD-ROM filesystems: ISO9660, UDF
  - DOS/Windows filesystems: FAT and NTFS
  - Pseudo filesystems: proc and sysfs
  - Miscellanous filesystems, with amongst other Flash filesystems such as JFFS2, UBIFS, SquashFS, cramfs
  - Network filesystems, with mainly NFS and SMB/CIFS
- Kernel hacking
  - Debugging features useful for kernel developers

Compiling and installing the kernel for the host system

Kernel compilation

- `make`
  - in the main kernel source directory
  - Remember to run `make -j 4` if you have multiple CPU cores to speed up the compilation process
  - No need to run as root !
- Generates
  - `vmlinux`, the raw uncompressed kernel image, at the ELF format, useful for debugging purposes, but cannot be booted
  - `arch/<arch>/boot/*Image`, the final, usually compressed, kernel image that can be booted
    - `bzImage` for x86, `zImage` for ARM, `vmImage.gz` for Blackfin, etc.
  - All kernel modules, spread over the kernel source tree, as `.ko` files.

Kernel installation

- `make install`
  - Does the installation for the host system by default, so needs to be run as root
- Installs
  - `/boot/vmlinuz-<version>`
    Compressed kernel image. Same as the one in `arch/<arch>/boot`
  - `/boot/System.map-<version>`
    Stores kernel symbol addresses
  - `/boot/config-<version>`
    Kernel configuration for this version
- Typically re-runs the bootloader configuration utility to take into account the new kernel.

Module installation

- `make modules_install`
  - Does the installation for the host system by default, so needs to be run as root
- Installs all modules in /lib/modules/<version>/
  - `kernel/`
    Module `.ko` (Kernel Object) files, in the same directory structure as in the sources.
  - `modules.alias`
    Module aliases for module loading utilities. Example line:
    `alias sound-service-?-0 snd_mixer_oss`
  - `modules.dep`
    Module dependencies
  - `modules.symbols`
    Tells which module a given symbol belongs to.

Kernel cleanup targets

- Clean-up generated files
  (to force re-compiling drivers):
  `make clean`
- Remove all generated files. Needed when switching from one architecture to another
  Caution: also removes your `.config` file!
  `make mrproper`
- Also remove editor backup and patch reject files:
  (mainly to generate patches):
  `make distclean`

Compiling and booting Linux

Linux device files

Character device files

- Accessed through a sequential flow of individual characters
- Character devices can be identified by their `c` type (`ls -l`):

```
crw-rw---- 1 root uucp   4,  64 Feb 23 2004 /dev/ttyS0
crw--w---- 1 jdoe tty  136,   1 Feb 23 2004 /dev/pts/1
crw------- 1 root root  13,  32 Feb 23 2004 /dev/input/mouse0
crw-rw-rw- 1 root root   1,   3 Feb 23 2004 /dev/null
```

- Example devices: keyboards, mice, parallel port, IrDA, Bluetooth port, consoles, terminals, sound, video...

Block device files

- Accessed through data blocks of a given size. Blocks can be accessed in any order.
- Block devices can be identified by their `b` type (`ls -l`):

```
brw-rw----   1 root disk     3,   1 Feb 23  2004 hda1
brw-rw----   1 jdoe floppy   2,   0 Feb 23  2004 fd0
brw-rw----   1 root disk     7,   0 Feb 23  2004 loop0
brw-rw----   1 root disk     1,   1 Feb 23  2004 ram1
brw-------   1 root root     8,   1 Feb 23  2004 sda1
```

- Example devices: hard or floppy disks, ram disks, loop devices...

Device major and minor numbers

As you could see in the previous examples, device files have 2 numbers associated to them:

- First number: *major* number
- Second number: *minor* number
- Major and minor numbers are used by the kernel to bind a driver to the device file. Device file names don't matter to the kernel!
- To find out which driver a device file corresponds to, or when the device name is too cryptic, see `Documentation/devices.txt`.

Device file creation

- Device files are not created when a driver is loaded.
- They have to be created in advance:
  `sudo mknod /dev/<device> [c|b] <major> <minor>`
- Examples:

```
sudo mknod /dev/ttyS0 c 4 64
sudo mknod /dev/hda1 b 3 1
```

- Configure your kernel
- Compile it
- Boot it on a virtual PC
- Modify a root filesystem image by adding entries to the `/dev/` directory

Compiling and booting Linux

Overall system startup

Traditional booting sequence

Bootloader
- Executed by the hardware at a fixed location in ROM / Flash
- Initializes support for the device where the kernel image is found (local storage, network, removable media)
- Loads the kernel image in RAM
- Executes the kernel image (with a specified command line)

Kernel
- Uncompresses itself
- Initializes the kernel core and statically compiled drivers (needed to access the root filesystem)
- Mounts the root filesystem (specified by the root kernel parameter)
- Executes the first userspace program (specified by the init kernel parameter)

First userspace program
- Configures userspace and starts up system services

Kernel command line parameters

The Linux kernel can be given parameters at boot time

- Kernel command line arguments are part of the bootloader configuration settings.
- They are copied to RAM by the bootloader, to a location where the kernel expects them.
- Useful to modify the behavior of the kernel at boot time, without having to recompile it.
- Useful to perform advanced kernel and driver initialization, without having to use complex user-space scripts.

Kernel command line example

HP iPAQ h2200 PDA booting example:

`root=/dev/ram0 \`	Root filesystem (first ramdisk)
`rw \`	Root filesystem mounting mode
`init=/linuxrc \`	First userspace program
`console=ttyS0,115200n8 \`	Console (serial)
`console=tty0 \`	Other console (framebuffer)
`ramdisk_size=8192 \`	Misc parameters...
`cachepolicy=writethrough`	

Hundreds of command line parameters described on `Documentation/kernel-parameters.txt`

Drawbacks

- Assumption that all device drivers needed to mount the root filesystem (storage and filesystem drivers) are statically compiled inside the kernel.
- Assumption can be correct for most embedded systems, where the hardware is known and the kernel can be fine-tuned for the system.
- Assumption is mostly wrong for desktop and servers, since a single kernel image should support a wide range of devices and filesystems
  - More flexibility was needed
  - Modules have this flexibility, but they are not available before mounting the root filesystem
  - Need to handle complex setups (RAID, NFS, etc.)

Solution

- A solution is to include a small temporary root filesystem with modules, in the kernel itself. This small filesystem is called the *initramfs.*
- This initramfs is a gzipped cpio archive of this basic root filesystem
  - A gzipped cpio archive is a kind of zip file, with a much simpler format
- The initramfs scripts will detect the hardware, load the corresponding kernel modules, and mount the real root filesystem.
- Finally the initramfs scripts will run the init application in the real root filesystem and the system can boot as usual.
- The initramfs technique completely replaces init ramdisks (initrds). Initrds were used in Linux 2.4, but are no longer needed.

Booting sequence with initramfs

Bootloader
- Executed by the hardware at a fixed location in ROM / Flash
- Initializes support for the device where the images are found (local storage, network, removable media)
- Loads the kernel image in RAM
- Executes the kernel image (with a specified command line)

Kernel
- Uncompresses itself
- Initializes the kernel core and statically compiled drivers
- Uncompresses an initramfs cpio archive (if existing, in the kernel image or copied to memory by the bootloader) and extracts it to the kernel file cache (no mounting, no filesystem).
- If found in the initramfs, executes the first userspace program: `/init`

unchanged

Userspace: `/init` script (what follows is just a typical scenario)
- Runs userspace commands to configure the device (such as network setup, mounting `/proc` and `/sys`...)
- Mounts a new root filesystem. Switch to it (`switch_root`)
- Runs `/sbin/init`

Userspace: `/sbin/init`
- Runs commands to configure the device (if not done yet in the initramfs)
- Starts up system services (daemons, servers) and user programs

Initramfs features and advantages

- Root filesystem directly embedded in the kernel image, or copied to RAM by the bootloader, simple solution.
- Just a plain compressed cpio archive extracted in the file cache. Neither needs a block nor a filesystem driver.
- Simpler to mount complex filesystems from flexible userspace scripts rather than from rigid kernel code. More complexity moved out to user-space!
- Possible to add non GPL files (firmware, proprietary drivers) in the filesystem. This is not linking, just file aggregation (not considered as a derived work by the GPL).

How to populate an initramfs

Using `CONFIG_INITRAMFS_SOURCE`
in kernel configuration (`General Setup` section)

- Either give an existing `cpio` archive (file name ending with `.cpio`)
- Or give a directory to be archived.
- Any other regular file will be taken as a text specification file (see next page).

see `Documentation/filesystems/ramfs-rootfs-initramfs.txt` and `Documentation/early-userspace/README` in kernel sources.

See also http://www.linuxdevices.com/articles/AT4017834659.html for a nice overview of initramfs (by Rob Landley).

Initramfs specification file example

major minor

```
dir /dev 755 0 0
nod /dev/console 644 0 0 c 5 1
nod /dev/loop0 644 0 0 b 7 0
dir /bin 755 1000 1000
file /bin/busybox /stuff/initramfs/busybox 755 0 0
slink /bin/sh busybox 777 0 0
dir /proc 755 0 0
dir /sys 755 0 0
dir /mnt 755 0 0
file /init /stuff/initramfs/init.sh 755 0 0
```

permissions

user id group id

No need for `root` user access!

Summary

- For embedded systems, two interesting solutions
  - No initramfs: all needed drivers are included inside the kernel, and the final root filesystem is mounted directly
  - Everything inside the initramfs

Compiling and booting Linux

Root filesystem over NFS

Usefulness of rootfs on NFS

Once networking works, your root filesystem could be a directory on your GNU/Linux development host, exported by NFS (Network File System). This is very convenient for system development:

- Makes it very easy to update files (driver modules in particular) on the root filesystem, without rebooting. Much faster than through the serial port.
- Can have a big root filesystem even if you don't have support for internal or external storage yet.
- The root filesystem can be huge. You can even build native compiler tools and build all the tools you need on the target itself (better to cross-compile though).

NFS boot setup (1)

On the host (NFS server)

- Install an NFS server (example: Debian, Ubuntu)
  `sudo apt-get install nfs-kernel-server`
- Add the exported directory to your `/etc/exports` file:
  `/home/rootfs 192.168.1.111(rw,no_root_squash,no_subtree_check)`
  client address NFS server options
- Start or restart your NFS server (example: Debian, Ubuntu)
  `sudo /etc/init.d/nfs-kernel-server restart`

NFS boot setup (2)

On the target (NFS client)

- Compile your kernel with `CONFIG_NFS_FS=y`, `CONFIG_IP_PNP=y` (configure IP at boot time) and `CONFIG_ROOT_NFS=y`
- Boot the kernel with the below command line options:
  `root=/dev/nfs`
  virtual device
  `ip=192.168.1.111`
  local IP address
  `nfsroot=192.168.1.110:/home/nfsroot`
  NFS server IP address Directory on the NFS server

Compiling and booting Linux

Cross-compiling the kernel

Cross-compiling the kernel

When you compile a Linux kernel for another CPU architecture

- Much faster than compiling natively, when the target system is much slower than your GNU/Linux workstation.
- Much easier as development tools for your GNU/Linux workstation are much easier to find.
- To make the difference with a native compiler, cross-compiler executables are prefixed by the name of the target system, architecture and sometimes library. Examples:

```
mips-linux-gcc
m68k-linux-uclibc-gcc
arm-linux-gnueabi-gcc
```

Specifying cross-compilation

The CPU architecture and cross-compiler prefix are defined through the ARCH and CROSS_COMPILE variables in the toplevel Makefile.

- The Makefile defines CC = $(CROSS_COMPILE)gcc
  See comments in Makefile for details
- The easiest solution is to modify the Makefile.
  Example, ARM platform, cross-compiler: arm-linux-gcc

```
ARCH    ?= arm
CROSS_COMPILE  ?= arm-linux-
```

- Other solutions
  - Pass ARCH and CROSS_COMPILE on the make command line
  - Define ARCH and CROSS_COMPILE as environment variables
  - Don't forget to have the values properly set at all steps, otherwise the kernel configuration and build system gets confused

Configuring the kernel

`make xconfig`

- Same as in native compiling
- The set of available options will be different
- Don't forget to set the right board / machine type!

Ready-made config files

```
assabet_defconfig       integrator_defconfig  mainstone_defconfig
badge4_defconfig        iq31244_defconfig     mx1ads_defconfig
bast_defconfig          iq80321_defconfig     neponset_defconfig
cerfcube_defconfig      iq80331_defconfig     netwinder_defconfig
clps7500_defconfig      iq80332_defconfig     omap_h2_1610_defconfig
ebsa110_defconfig       ixdp2400_defconfig    omnimeter_defconfig
edb7211_defconfig       ixdp2401_defconfig    pleb_defconfig
enp2611_defconfig       ixdp2800_defconfig    pxa255-idp_defconfig
ep80219_defconfig       ixdp2801_defconfig    rpc_defconfig
epxa10db_defconfig      ixp4xx_defconfig      s3c2410_defconfig
footbridge_defconfig    jornada720_defconfig  shannon_defconfig
fortunet_defconfig      lart_defconfig        shark_defconfig
h3600_defconfig         lpd7a400_defconfig    simpad_defconfig
h7201_defconfig         lpd7a404_defconfig    smdk2410_defconfig
h7202_defconfig         lubbock_defconfig     versatile_defconfig
hackkit_defconfig       lusl7200_defconfig
```

`arch/arm/configs` example

Using ready-made config files

- Default configuration files available for many boards / machines! Check if one exists in `arch/<arch>/configs/` for your target.
- Example: if you found an `acme_defconfig` file, you can run: `make acme_defconfig`
- Using `arch/<arch>/configs/` is a very good good way of releasing a default configuration file for a group of users or developers.

Like all `make` commands, you must run `make <machine>_defconfig` in the toplevel source directory.

Building the kernel

- Run
  `make`
- Copy
  `arch/<arch>/boot/zImage`
  to the target storage
- You can customize `arch/<arch>/boot/install.sh` so that `make install` does this automatically for you.
- `make INSTALL_MOD_PATH=<dir>/ modules_install`
  and copy `<dir>/lib/modules/` to `/lib/modules/` on the target storage.

Practical lab – Cross-compiling

- Set up a cross-compiling environment
- Configure the kernel `Makefile` accordingly
- Cross-compile the kernel for an `arm` target platform
- On this platform, interact with the bootloader and boot your kernel.

Using kernel modules

Loadable kernel modules

- Modules: add a given functionality to the kernel (drivers, filesystem support, and many others).
- Can be loaded and unloaded at any time, only when their functionality is need.
- Modules make it easy to develop drivers without rebooting: load, test, unload, rebuild, load...
- Useful to keep the kernel image size to the minimum (essential in GNU/Linux distributions for PCs).
- Also useful to reduce boot time: you don't spend time initializing devices and kernel features that you only need later.
- Caution: once loaded, have full access to the whole kernel address space. No particular protection.

Module dependencies

- Some kernel modules can depend on other modules, which need to be loaded first.
- Example: the `usb-storage` module depends on the `scsi_mod`, `libusual` and `usbcore` modules.
- Dependencies are described in `/lib/modules/<kernel-version>/modules.dep`
  This file is generated when you run `make modules_install`.

Kernel log

When a new module is loaded,
related information is available in the kernel log.

- The kernel keeps its messages in a circular buffer
(so that it doesn't consume more memory with many messages)
- Kernel log messages are available through the `dmesg` command.
(“**d**iagnostic **mes**sa**g**e”)
- Kernel log messages are also displayed in the system console
(console messages can be filtered by level using the `loglevel`
kernel, or completely disabled with the `quiet` parameter).
- Note that you can write to the kernel log from userspace too:
`echo “Debug info” > /dev/kmsg`

Module utilities (1)

- `modinfo <module_name>`
  `modinfo <module_path>.ko`
  Gets information about a module: parameters, license, description and dependencies.
  Very useful before deciding to load a module or not.
- `sudo insmod <module_path>.ko`
  Tries to load the given module. The full path to the module object file must be given.

Understanding module loading issues

- When loading a module fails,
  `insmod` often doesn't give you enough details!
- Details are often available in the kernel log.
- Example:

```
> sudo insmod ./intr_monitor.ko
insmod: error inserting './intr_monitor.ko': -1
Device or resource busy
> dmesg
[17549774.552000] Failed to register handler for
irq channel 2
```

Module utilities (2)

- `sudo modprobe <module_name>`
  Most common usage of `modprobe`: tries to load all the modules the given module depends on, and then this module. Lots of other options are available. Modprobe automatically looks in `/lib/modules/<version>/` for the object file corresponding to the given module name.
- `lsmod`
  Displays the list of loaded modules
  Compare its output with the contents of `/proc/modules`!

Module utilities (3)

- `sudo rmmod <module_name>`
  Tries to remove the given module.
  Will only be allowed if the module is no longer in use (for example, no more processes opening a device file)
- `sudo modprobe -r <module_name>`
  Tries to remove the given module and all dependent modules (which are no longer needed after the module removal)

Passing parameters to modules

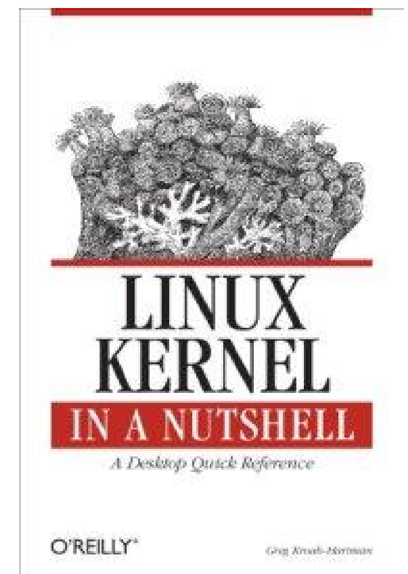
- Find available parameters:
  `modinfo snd-intel8x0m`
- Through `insmod`:
  `sudo insmod ./snd-intel8x0m.ko index=-2`
- Through `modprobe`:
  Set parameters in `/etc/modprobe.conf` or in any file in `/etc/modprobe.d/`:
  `options snd-intel8x0m index=-2`
- Through the kernel command line,
  when the driver is built statically into the kernel:
  `snd-intel8x0m.index=-2`

driver name
driver parameter name
driver parameter value

Useful reading

Linux Kernel in a Nutshell, Dec 2006

- By Greg Kroah-Hartman, O'Reilly
  http://www.kroah.com/lkn/
- A good reference book and guide on configuring, compiling and managing the Linux kernel sources.
- Freely available on-line!
  Great companion to the printed book for easy electronic searches!
  Available as single PDF file on
  http://free-electrons.com/community/kernel/lkn/



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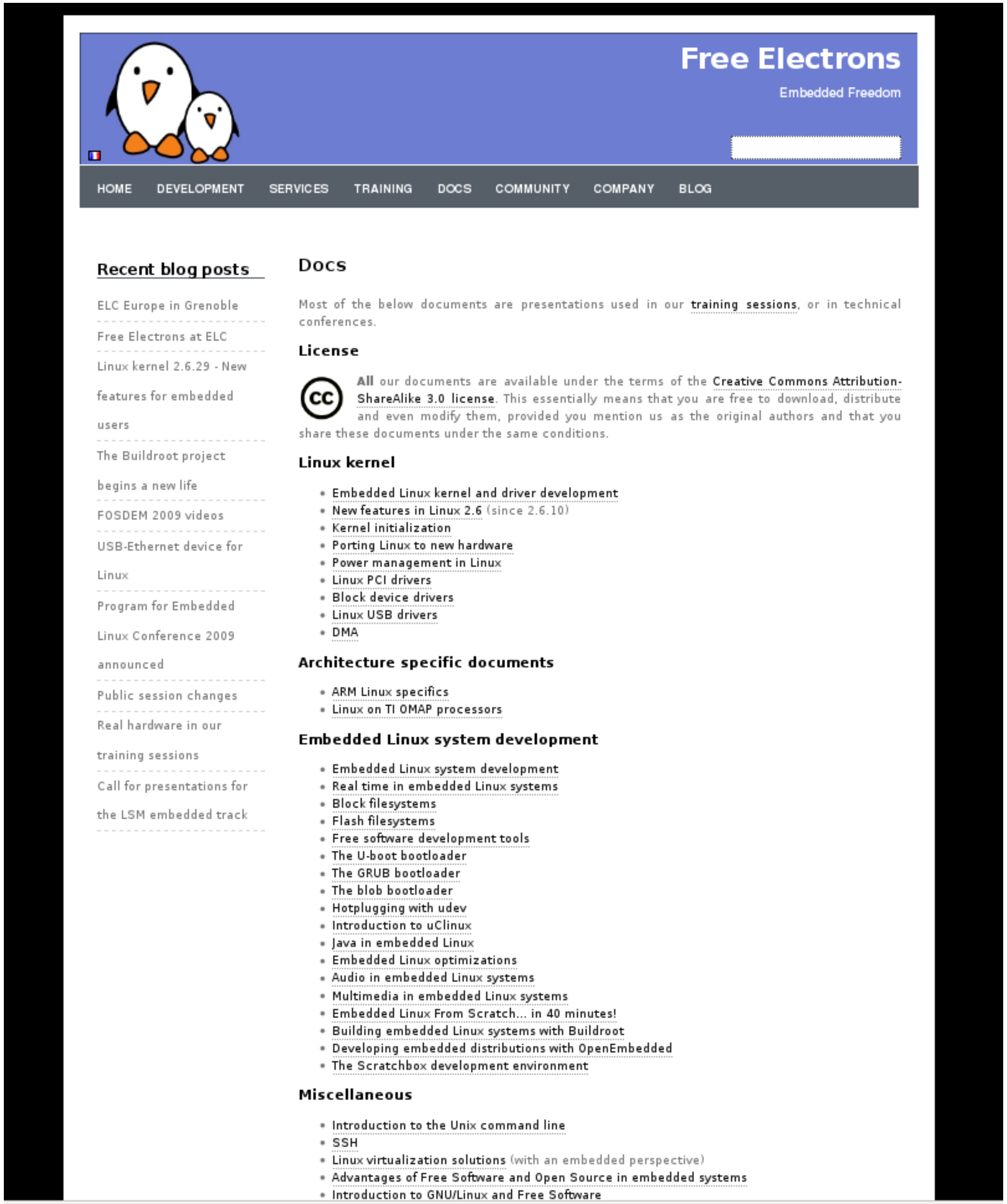

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