

# **Cross-Compiled Linux From Scratch - Embedded**

**Version GIT-20131024-mips**

# **Cross-Compiled Linux From Scratch - Embedded: Version GIT-20131024-mips**

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# Table of Contents

Preface .....	v
i. Foreword .....	v
ii. Audience .....	v
iii. Prerequisites .....	vi
iv. Typography .....	vii
v. Structure .....	viii
vi. Open Publication License .....	viii
vii. Master Changelog .....	x
viii. Cross-LFS Acknowledgements .....	xv
ix. Errata .....	xv
I. Introduction .....	1
1. Introduction .....	2
1.1. How to Build a CLFS System .....	2
1.2. Host System Requirements .....	2
1.3. Resources .....	4
1.4. Help .....	4
II. Preparing for the Build .....	7
2. Build Directory, Packages, and Patches .....	8
2.1. Introduction .....	8
2.2. Creating Build and Sources Directories .....	8
2.3. All Packages .....	8
2.4. Needed Patches .....	9
3. Final Preparations .....	11
3.1. About \$CLFS .....	11
3.2. Adding the CLFS User .....	11
3.3. Setting Up the Environment .....	12
III. Make the Cross-Compile Tools .....	14
4. Constructing Cross-Compile Tools .....	15
4.1. Introduction .....	15
4.2. Build CFLAGS .....	15
4.3. ABI Variables .....	15
4.4. Build Variables .....	16
4.5. Create the Sysroot Directory .....	17
4.6. Linux-Headers-3.0.80 .....	18
4.7. Binutils-2.23.2 .....	19
4.8. GCC-4.7.3 - Static .....	22
4.9. musl-libc-0.9.14 .....	25
4.10. GCC-4.7.3 - Final .....	26
IV. Building the CLFS System .....	28
5. Installing Basic System Software .....	29
5.1. Introduction .....	29
5.2. Creating Directories .....	29
5.3. Creating the passwd, group, and log Files .....	29
5.4. ToolChain Variables .....	31
5.5. BusyBox-1.21.1 .....	33
5.6. iana-etc-2.30 .....	34

6. Making the CLFS System Bootable .....	35
6.1. Introduction .....	35
6.2. Creating the /etc/fstab File .....	35
6.3. Linux-3.0.80 .....	36
6.4. Bootloaders .....	38
7. Setting Up System Bootscripts .....	39
7.1. Introduction .....	39
7.2. CLFS-Bootscripts-git master HEAD .....	40
7.3. Configure mdev .....	41
7.4. Creating /etc/profile .....	44
7.5. Creating /etc/inittab .....	44
7.6. Setting Hostname .....	45
7.7. Customizing the /etc/hosts File .....	45
7.8. Configuring the network Script .....	46
V. Beyond CLFS Embedded .....	48
8. Beyond Introduction .....	49
8.1. Introduction .....	49
9. Additional Libraries .....	50
9.1. Introduction .....	50
9.2. Beyond CLFS Additional Library Packages .....	50
9.3. Zlib-1.2.8 .....	51
10. Networking Software .....	52
10.1. Introduction .....	52
10.2. Beyond CLFS Networking Packages .....	52
10.3. Beyond CLFS Networking Patches .....	52
10.4. Dropbear-2013.60 .....	53
10.5. IPTables-1.4.19.1 .....	54
10.6. Wireless Tools-29 .....	55
11. File System Tools .....	56
11.1. Introduction .....	56
11.2. Beyond CLFS File System Packages .....	56
11.3. E2fsprogs-1.42.7 .....	57
VI. Cleanup and Boot .....	60
12. Backup and Cleanup .....	61
12.1. Copy Libraries .....	61
12.2. Changing the Ownership of the CLFS System .....	61
12.3. Copy to Target .....	61
13. The End .....	62
13.1. The End .....	62
13.2. Booting the System .....	62
13.3. What Now? .....	62
Index .....	64

# Preface

## Foreword

The Linux From Scratch Project has seen many changes in the few years of its existence. I personally became involved with the project in 2000, around the time of the 3.x releases. At that time, the build process was to create static binaries with the host system, then chroot and build the final binaries on top of the static ones.

Later came the use of the /static directory to hold the initial static builds, keeping them separated from the final system, then the PureLFS process developed by Ryan Oliver and Greg Schafer, introducing a new toolchain build process that divorces even our initial builds from the host. Finally, LFS 6 bought Linux Kernel 2.6, the udev dynamic device structure, sanitized kernel headers, and other improvements to the Linux From Scratch system.

The one "flaw" in LFS is that it has always been based on an x86 class processor. With the advent of the Athlon 64 and Intel EM64T processors, the x86-only LFS is no longer ideal. Throughout this time, Ryan Oliver developed and documented a process by which you could build Linux for any system and from any system, by use of cross-compilation techniques. Thus, the Cross-Compiled LFS (CLFS) was born.

CLFS Embedded follows the same guiding principles the LFS project has always followed, e.g., knowing your system inside and out by virtue of having built the system yourself. Additionally, during a CLFS Embedded build, you will learn advanced techniques such as cross-build toolchains, and how to create a smaller footprint system supporting architectures such as ARM and MIPS, in addition to x86.

We hope you enjoy building your own CLFS Embedded system, and the benefits that come from a system tailored to your needs.

--

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 Nathan Coulson, and Andrew Bradford - CLFS Developers

## Audience

There are many reasons why somebody would want to read this book. The principal reason is to install a Linux system from the source code. A question many people raise is, "why go through all the hassle of manually building a Linux system from scratch when you can just download and install an existing one?" That is a good question and is the impetus for this section of the book.

One important reason for the existence of CLFS is to help people understand how a Linux system works. Building an CLFS system helps demonstrate what makes Linux tick, and how things work together and depend on each other. One of the best things this learning experience provides is the ability to customize Linux to your own tastes and needs.

A key benefit of CLFS is that it allows users to have more control over their system without any reliance on a Linux implementation designed by someone else. With CLFS, *you* are in the driver's seat and dictate every aspect of the system, such as the directory layout and bootscript setup. You also dictate where, why, and how programs are installed.

Another benefit of CLFS is the ability to create a very compact Linux system. When installing a regular

distribution, one is often forced to include several programs which are probably never used. These programs waste disk space or CPU cycles. It is not difficult to build an CLFS Embedded system of less than 10 megabytes (MB), which is substantially smaller than the majority of existing installations. Try that with a regular distribution!

We could compare Linux distributions to a hamburger purchased at a fast-food restaurant—you have no idea what might be in what you are eating. CLFS, on the other hand, does not give you a hamburger. Rather, CLFS provides the recipe to make the exact hamburger desired. This allows users to review the recipe, omit unwanted ingredients, and add your own ingredients to enhance the flavor of the burger. When you are satisfied with the recipe, move on to preparing it. It can be made to exact specifications—broil it, bake it, deep-fry it, or barbecue it.

Another analogy that we can use is that of comparing CLFS with a finished house. CLFS provides the skeletal plan of a house, but it is up to you to build it. CLFS maintains the freedom to adjust plans throughout the process, customizing it to the needs and preferences of the user.

Security is an additional advantage of a custom built Linux system. By compiling the entire system from source code, you are empowered to audit everything and apply all the security patches desired. It is no longer necessary to wait for somebody else to compile binary packages that fix a security hole. Unless you examine the patch and implement it yourself, you have no guarantee that the new binary package was built correctly and adequately fixes the problem.

The goal of Cross Linux From Scratch is to build a complete and usable foundation-level system. Readers who do not wish to build their own Linux system from scratch may not benefit from the information in this book. If you only want to know what happens while the computer boots, we recommend the “From Power Up To Bash Prompt” HOWTO located at <http://axiom.anu.edu.au/~okeefe/p2b/> or on The Linux Documentation Project’s (TLDP) website at <http://www.tldp.org/HOWTO/From-PowerUp-To-Bash-Prompt-HOWTO.html>. The HOWTO builds a system which is similar to that of this book, but it focuses strictly on creating a system capable of booting to a shell prompt. Consider your objective. If you wish to build a Linux system and learn along the way, this book is your best choice.

There are too many good reasons to build your own CLFS system to list them all here. This section is only the tip of the iceberg. As you continue in your CLFS experience, you will find the power that information and knowledge truly bring.

## Prerequisites

Building a CLFS system is not a simple task. It requires a certain level of existing knowledge of Unix system administration in order to resolve problems, and correctly execute the commands listed. In particular, as an absolute minimum, the reader should already have the ability to use the command line (shell) to copy or move files and directories, list directory and file contents, and change the current directory. It is also expected that the reader has a reasonable knowledge of using and installing Linux software. A basic knowledge of the architectures being used in the Cross LFS process and the host operating systems in use is also required.

Because the CLFS book assumes *at least* this basic level of skill, the various CLFS support forums are unlikely to be able to provide you with much assistance. Your questions regarding such basic knowledge will likely go unanswered, or you will be referred to the CLFS essential pre-reading list.

Before building a CLFS system, we recommend reading the following HOWTOs:

- Software-Building-HOWTO  
<http://www.tldp.org/HOWTO/Software-Building-HOWTO.html>

This is a comprehensive guide to building and installing “generic” Unix software distributions under Linux.

-

## The Essential Pre-Reading Hint

[http://www.linuxfromscratch.org/hints/downloads/files/essential\\_prereading.txt](http://www.linuxfromscratch.org/hints/downloads/files/essential_prereading.txt)

This is a hint written specifically for users new to Linux. It includes a list of links to excellent sources of information on a wide range of topics. Anyone attempting to install CLFS should have an understanding of many of the topics in this hint.

## Typography

To make things easier to follow, there are a few typographical conventions used throughout this book. This section contains some examples of the typographical format found throughout Linux From Scratch.

```
./configure --prefix=/usr
```

This form of text is designed to be typed exactly as seen unless otherwise noted in the surrounding text. It is also used in the explanation sections to identify which of the commands is being referenced.

```
install-info: unknown option '--dir-file=/mnt/clfs/usr/info/dir'
```

This form of text (fixed-width text) shows screen output, probably as the result of commands issued. This format is also used to show filenames, such as `/etc/ld.so.conf`.

### *Emphasis*

This form of text is used for several purposes in the book. Its main purpose is to emphasize important points or items.

<http://cross-lfs.org/>

This format is used for hyperlinks, both within the CLFS community and to external pages. It includes HOWTOs, download locations, and websites.

```
cat > ${CLFS}/etc/group << "EOF"
root:x:0:
bin:x:1:
.....
EOF
```

This format is used when creating configuration files. The first command tells the system to create the file `${CLFS}/etc/group` from whatever is typed on the following lines until the sequence end of file (EOF) is encountered. Therefore, this entire section is generally typed as seen.

*[REPLACED TEXT]*

This format is used to encapsulate text that is not to be typed as seen or copied-and-pasted.

`passwd(5)`

This format is used to refer to a specific manual page (hereinafter referred to simply as a “man” page). The number inside parentheses indicates a specific section inside of **man**. For example, **passwd** has two man pages. **man passwd** will print the first man page it finds that matches “passwd”, which will be `/usr/share/man/man1/passwd.1`. For this example, you will need to run **man 5 passwd** in order to read the specific page being referred to. It should be noted that most man pages do not have duplicate page names in different sections. Therefore, **man [program name]** is generally sufficient.

## Structure

This book is divided into the following parts.

### Part I - Introduction

Part I explains a few important notes on how to proceed with the Cross-LFS installation. This section also provides meta-information about the book.

### Part II - Preparing for the Build

Part II describes how to prepare for the building process including downloading the packages.

### Part III - Make the Cross-Compile Tools

Part III shows you how to make a set of Cross-Compiler tools. These tools can run on your host system but allow you to build packages that will run on your target system.

### Part IV - Building the CLFS System

Part IV shows you how to build the core CLFS system. Compiling and installing Buxybox and other required packages, making the system bootable, setting up the bootscripts, and installing a bootloader.

### Part V - Beyond CLFS Embedded

Part V provides instructions on optional packages that can be installed to enhance your CLFS system.

### Part VI - Cleanup and Boot

Part VI finishes up the system by making sure the target file system is ready to be booted, copying it to the target, and finally booting the system.

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v1.0, 8 June 1999

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## Master Changelog

This is version GIT-20131024 of the Cross-Compiled Linux From Scratch book, dated October 24, 2013. If this book is more than six months old, a newer and better version is probably already available. To find out, please check one of the mirrors via <http://trac.cross-lfs.org/>.

Below is a list of detailed changes made since the previous release of the book.

### Changelog Entries:

- October 24, 2013
  - [abradford] - Shorten triplets.
  - [abradford] - Reorder variable tables for easier reading.
  - [abradford] - ARM and x86 are assumed little endian.
  - [abradford] - Fix musl installation symlinking.
  - [abradford] - Fix iana-etc 'make get'.
- October 21, 2013
  - [abradford] - Cleanup the kernel build.
  - [abradford] - Move bootloaders into bootable section, just give recommendations no exact steps.
  - [abradford] - Create top level README and LICENSE.

- October 18, 2013
  - [abradford] - Fix the networking configuration to use eth0 and DHCP to obtain a valid IP address.
- October 17, 2013
  - [abradford] - Update dropbear to 2013.60 and fix instructions.
  - [abradford] - Assorted docbook updates for common pages.
  - [abradford] - Reorganize things people don't need to read into the preface and things that really should be read into the chapters.
  - [abradford] - Delete hostapd and lib-nl.
  - [abradford] - Delete dependencies information, most of it was wrong or outdated and so long as you follow the book in order there's no issues.
- October 16, 2013
  - [abradford] - Remove uClibc, use musl-libc.
  - [abradford] - Build cross compiler completely separate from target file system.
  - [abradford] - Build GMP, MPFR, and MPC within GCC tree.
  - [abradford] - Linewrap many configure switches for easier reading and editing.
- August 12, 2013
  - [abradford] - Don't copy libiberty.h from binutils.
  - [abradford] - Install linux headers directly without cp.
  - [abradford] - Revert install of headers to cross-tools.
- July 24, 2013
  - [abradford] - Fix binutils build issue with some Texinfo.
  - [abradford] - Install headers to cross-tools.
- June 17, 2013
  - [abradford] - Change partitioning to creating build dir.
- June 13, 2013
  - [abradford] - Remove WRT arch.
- June 11, 2013
  - [abradford] - Many package updates.

- [abradford] - Removal of some LFS specific information.
- [abradford] - Update host requirements to at least Debian Squeeze.
- [kterrell] - Removal of sources from final tarball.
- September 22, 2012
  - [abradford] - Small fixes to prologue and ch 1 and 2.
- September 13, 2012
  - [ljump] - Fix System.map depmod command.
  - [ljump] - Fix console and null /dev node creation for final system.
- September 02, 2012
  - [William Harrington] - Fix uClibc patch MD5 sum.
- August 24, 2012
  - [William Harrington] - Change Beyond Net hostapd page to include bootscript and configuration sections.
- August 22, 2012
  - [William Harrington] - Change Beyond Net Dropbear page and edit the installation of bootscripts section.
  - [William Harrington] - Remove bash reference in hostreqs version script to use \$SHELL variable.
- August 08, 2012
  - [William Harrington] - Update version check script to find the libc version with hosts that use paths other than /lib and /lib64, such as multiarch distro.
- May 14, 2011
  - [abradford] - Updated /etc/mdev.conf to Alpine Linux's example to provide a better baseline example.
  - [abradford] - Reverted changes that removed the mknod'ing of /dev/console and /dev/null. These nodes may be needed on some systems for proper booting.
  - [abradford] - Added Wireless Tools package to Beyond Networking section. Thanks to Ivan Castell Rovira for providing a set of instructions for the installation of this package.
  - [abradford] - Fixed some Dropbear issues with symlinks and directory naming.
- April 20, 2011
  - [abradford] - Created a Beyond section just for extra libraries and moved zlib into it.
- April 19, 2011

- [abradford] - Created a Beyond section just for networking tools.
- [abradford] - Created a Beyond section just for file system tools and moved e2fsprogs into it.
- April 8, 2011
  - [jiciccone] - Cleaned up the acknowledgements page.
- March 31, 2011
  - [abradford] - Updated BusyBox to version 1.18.4.
  - [abradford] - Updated GCC to version 4.6.0.
  - [abradford] - Updated MPC to version 0.9.
  - [abradford] - Updated zlib to version 1.2.5.
  - [abradford] - Updated Linux kernel to version 2.6.38.2.
  - [abradford] - Require Gawk 3.1 or greater because of Iana-Etc requirements.
  - [abradford] - Updated "What Now?" section to include CBLFS link. Thanks go to Adrian Grigo.
  - [abradford] - Link `/${CLFS}/etc/init.d/rcS` to `/${CLFS}/etc/rc.d/startup` so that BusyBox's init can find the startup scripts.
  - [abradford] - Updated mdev configuration such that video output is disabled by default to ensure no errors if video is not available.
- March 23, 2011
  - [abradford] - Remove mknod commands as mdev takes care of creating all required entries in `/dev` automatically.
  - [abradford] - Moved change ownership section to be as late in the book as possible and only operate on a copy of the file system.
- March 18, 2011
  - [abradford] - Copy libgcc library to target as it's needed by at least e2fsprogs.
- March 7, 2011
  - [abradford] - Added optional information for building C++ compiler.
  - [abradford] - Updated bootscripts install target and package contents to match current bootscripts.
- February 24, 2011
  - [abradford] - Added `--disable-multilib` to GCC builds.
-

February 10, 2011

- [abradford] - Changed GCC Static and Final to build GCC for `#{CLFS_ABI}` for ARM and MIPS, `#{CLFS_CPU}` for x86. This removes the need for using the `#{BUILD}` variable when building packages.
- [abradford] - Updated Resources section.

January 30, 2011

- [abradford] - Updated MPFR download link.
- [abradford] - Updated GCC to version 4.5.2.
- [abradford] - Updated Binutils to version 2.21.
- [abradford] - Added information to GCC's configure options.
- [abradford] - Updated Iana-Etc to use more up-to-date data.

January 10, 2011

- [jiccone] - Changes Submitted By Andrew Bradford via the CLFS-Dev Mailing List. Updated E2fsprogs to 1.41.14 and changed some configure switches for uClibc compatibility.

November 28, 2010

- [jiccone] - Updated BusyBox to 1.17.3.
- [jiccone] - Updated uClibc to 0.9.31.

November 21, 2010

- [jiccone] - Added MPC 0.8.2.
- [jiccone] - Updated GCC to 4.5.1.
- [jiccone] - Updated Binutils to 2.20.1.
- [jiccone] - Updated MPFR to 3.0.0.
- [jiccone] - Updated GMP to 5.0.1.
- [jiccone] - Updated the Linux Kernel to 2.6.36.
- [jiccone] - Make sure we change `CLFS_HOST` before we set it. Also make sure that `CLFS_HOST` gets saved to the `bashrc`.

November 8, 2008

- [jiccone] - Updated Busybox to 1.12.1.
- [jiccone] - Updated uClibc to 0.9.30-rc3.

- November 8, 2008
  - [jiccone] - Dropped the uClibc Headers Page.
  - [jiccone] - Updated GCC to 4.3.2.
  - [jiccone] - Updated Binutils to 2.19.
- January 9, 2008
  - [jiccone] - Updated Busybox to 1.8.2.
- November 5, 2006
  - [jim] - Start of CLFS Embedded Development.

## Cross-LFS Acknowledgements

The CLFS team would like to acknowledge people who have assisted in making the book what it is today.

Our Leaders:

- Ryan Oliver - Build Process Developer.
- Joe Ciccone - Lead Developer.
- Jim Gifford - Lead Developer.

Our CLFS Team:

- Andrew Bradford - Embedded Developer.
- Manuel Canales Esparcia - Book XML.
- Justin Knierim - Website Architect.
- Maarten Lankhorst - MIPS/WRT Embedded Developer.
- Chris Staub - Testing and Quality Control.
- Zack Winkles - Testing and Quality Control.

Thank you all for your support.

## Errata

The software used to create a CLFS system is constantly being updated and enhanced. Security warnings and bug fixes may become available after the CLFS book has been released. Once a release of the CLFS Embedded book is made, this page will provide a link to the CLFS Embedded errata page.

# Part I. Introduction

# Chapter 1. Introduction

## 1.1. How to Build a CLFS System

The CLFS system will be built by using a previously installed Linux distribution (such as Debian, Fedora, Mandriva, SUSE, or Ubuntu). This existing Linux system (the host) will be used as a starting point to provide necessary programs, including a compiler, linker, and shell, to build the new system. Select the “development” option during the distribution installation to be able to access these tools.

As an alternative to installing an entire separate distribution onto your machine, you may wish to use the Linux From Scratch LiveCD. This CD works well as a host system, providing all the tools you need to successfully follow the instructions in this book. It does also contain source packages and patches for the LFS book, and a copy of the LFS book, but not the needed packages or book for CLFS. You can still use the CD for building CLFS, but you will need to download the packages, patches and book separately. You can also look at <http://www.linuxfromscratch.org/hints/downloads/files/lfsd-remastering-howto.txt> for information on building your own CD, replacing the LFS packages and book with those for CLFS. Once you have the CD, no network connection or additional downloads are necessary. For more information about the LFS LiveCD or to download a copy, visit <http://www.linuxfromscratch.org/livecd/>.

Build Directory, Packages, and Patches of this book describes how to create a temporary build directory and which packages and patches need to be downloaded to build a CLFS system. Final Preparations discusses the setup for an appropriate working environment. Please read Final Preparations carefully as it explains several important issues the developer should be aware of before beginning to work through Constructing Cross-Compile Tools and beyond.

Constructing Cross-Compile Tools explains the installation of cross-compile tools which will be built on the host but be able to compile programs that run on the target machine. These cross-compile tools will be used to create the final-system.

The process of building cross-compile tools first involves installing binutils into `${CLFS}/cross-tools`, so that we have an assembler and a linker for our target architecture. GCC is then compiled statically and installed into `${CLFS}/cross-tools`, this cross-compiler is used to build the `libc` for the final-system. The GCC cross-compiler is then rebuilt dynamically - this final cross-compiler is what will be used to build the final-system.

In Installing Basic System Software, the full CLFS system is cross-compiled. The system is built using a `sysroot` compiler. `Sysroot` is a parameter passed to `binutils` and `gcc` that modifies its default search paths.

To finish the installation, the CLFS-Bootscripts are set up in Setting Up System Bootscripts, and the kernel and boot loader are set up in Making the CLFS System Bootable. The End contains information on furthering the CLFS experience beyond this book. After the steps in this book have been implemented, the computer will be ready to reboot into the new CLFS system.

This is the process in a nutshell. Detailed information on each step is discussed in the following chapters and package descriptions. Items that may seem complicated will be clarified, and everything will fall into place as the reader embarks on the CLFS adventure.

## 1.2. Host System Requirements

You should be able to build a CLFS system from just about any recent Linux distribution. Your host system should have the following software with the minimum versions indicated. Also note that many distributions will place software headers into separate packages, often in the form of “[package-name]-devel” or “[package-name]-dev”. Be sure to install those if your distribution provides them.

- **Bash-4.0**
- **Binutils-2.20**
- **Bzip2-1.0.5**
- **Coreutils-8.1**
- **Diffutils-3.0**
- **Findutils-4.4.0**
- **Gawk-3.1**
- **GCC-4.4**
- **Glibc-2.11**
- **Grep-2.6**
- **Gzip-1.3**
- **Make-3.81**
- **Patch-2.6**
- **Sed-4.2.1**
- **Sudo-1.7.4p4**
- **Tar-1.23**
- **Texinfo-4.13**

To see whether your host system has all the appropriate versions, run the following:

```
cat > version-check.sh << "EOF"
#!/bin/bash

# Simple script to list version numbers of critical development tools

bash --version | head -n1 | cut -d" " -f2-4
echo -n "Binutils: "; ld --version | head -n1 | cut -d" " -f3-
bzip2 --version 2>&1 < /dev/null | head -n1 | cut -d" " -f1,6-
echo -n "Coreutils: "; chown --version | head -n1 | cut -d")" -f2
diff --version | head -n1
find --version | head -n1
gawk --version | head -n1
gcc --version | head -n1
ldd $(which ${SHELL}) | grep libc.so | cut -d ' ' -f 3 | ${SHELL} | head -n 1 \
| cut -d ' ' -f 1-10
grep --version | head -n1
gzip --version | head -n1
make --version | head -n1
patch --version | head -n1
sed --version | head -n1
sudo -V | head -n1
tar --version | head -n1
makeinfo --version | head -n1

EOF
```

```
bash version-check.sh
```

## 1.3. Resources

### 1.3.1. FAQ

If during the building of the CLFS system you encounter any errors, have any questions, or think there is a typo in the book, please start by consulting the Frequently Asked Questions (FAQ) that is located at <http://trac.cross-lfs.org/wiki/faq>.

### 1.3.2. Mailing Lists

The `cross-lfs.org` server hosts a number of mailing lists used for the development of the CLFS project. These lists include the main development and support lists, among others. If the FAQ does not solve the problem you are having, the next step would be to search the mailing lists at <http://trac.cross-lfs.org/wiki/lists>.

For information on the different lists, how to subscribe, archive locations, and additional information, visit <http://trac.cross-lfs.org/wiki/lists>.

### 1.3.3. IRC

Several members of the CLFS community offer assistance on our community Internet Relay Chat (IRC) network. Before using this support, please make sure that your question is not already answered in the CLFS FAQ or the mailing list archives. You can find the IRC network at `chat.freenode.net`. The support channel for cross-lfs is named `#cross-lfs`. If you need to show people the output of your problems, please use <http://pastebin.cross-lfs.org> and reference the pastebin URL when asking your questions.

### 1.3.4. Mirror Sites

The CLFS project has a number of world-wide mirrors to make accessing the website and downloading the required packages more convenient. Please visit <http://trac.cross-lfs.org/wiki/mirrors> for CLFS mirror information.

### 1.3.5. Contact Information

Please direct all your questions and comments to one of the CLFS mailing lists (see above).

## 1.4. Help

If an issue or a question is encountered while working through this book, check the FAQ page at <http://trac.cross-lfs.org/wiki/faq#generalfaq>. Questions are often already answered there. If your question is not answered on this page, try to find the source of the problem. The following hint will give you some guidance for troubleshooting: <http://www.linuxfromscratch.org/hints/downloads/files/errors.txt>.

We also have a wonderful CLFS community that is willing to offer assistance through the mailing lists and IRC (see the Section 1.3, “Resources” section of this book). However, we get several support questions everyday and many of them can be easily answered by going to the FAQ and by searching the mailing lists first. So for us to offer the best assistance possible, you need to do some research on your own first. This allows us to focus on the more unusual support needs. If your searches do not produce a solution, please include all relevant information (mentioned below) in your request for help.

### 1.4.1. Things to Mention

Apart from a brief explanation of the problem being experienced, the essential things to include in any request for help are:

- The version of the book being used (in this case CLFS Embedded GIT-20131024)
- The host distribution and version being used to create CLFS.
- The architecture of the host and target.
- The value of the `CLFS_TARGET`, and `BUILD` environment variables.
- The package or section in which the problem was encountered.
- The exact error message or symptom received. See Section 1.4.3, “Compilation Problems” below for an example.
- Note whether you have deviated from the book at all. A package version change or even a minor change to any command is considered deviation.

#### Note

Deviating from this book does *not* mean that we will not help you. After all, the CLFS project is about personal preference. Be upfront about any changes to the established procedure—this helps us evaluate and determine possible causes of your problem.

### 1.4.2. Configure Script Problems

If something goes wrong while running the **configure** script, review the `config.log` file. This file may contain the errors you encountered during **configure**. It often logs errors that may have not been printed to the screen. Include only the *relevant* lines if you need to ask for help.

### 1.4.3. Compilation Problems

Both the screen output and the contents of various files are useful in determining the cause of compilation problems. The screen output from the **configure** script and the **make** run can be helpful. It is not necessary to include the entire output, but do include enough of the relevant information. Below is an example of the type of information to include from the screen output from **make**:

```
gcc -DALIASPATH=\"/mnt/clfs/usr/share/locale:.\"
-DLOCALEDIR=\"/mnt/clfs/usr/share/locale\"
-DLIBDIR=\"/mnt/clfs/usr/lib\"
-DINCLUDEDIR=\"/mnt/clfs/usr/include\" -DHAVE_CONFIG_H -I. -I.
-g -O2 -c getopt1.c
gcc -g -O2 -static -o make ar.o arscan.o commands.o dir.o
expand.o file.o function.o getopt.o implicit.o job.o main.o
misc.o read.o remake.o rule.o signame.o variable.o vpath.o
default.o remote-stub.o version.o opt1.o
-lutil job.o: In function `load_too_high':
/clfs/tmp/make-3.79.1/job.c:1565: undefined reference
```

```
to `getloadavg'  
collect2: ld returned 1 exit status  
make[2]: *** [make] Error 1  
make[2]: Leaving directory `/clfs/tmp/make-3.79.1'  
make[1]: *** [all-recursive] Error 1  
make[1]: Leaving directory `/clfs/tmp/make-3.79.1'  
make: *** [all-recursive-am] Error 2
```

In this case, many people would just include the bottom section:

```
make [2]: *** [make] Error 1
```

This is not enough information to properly diagnose the problem because it only notes that something went wrong, not *what* went wrong. The entire section, as in the example above, is what should be saved because it includes the command that was executed and the associated error message(s).

An excellent article about asking for help on the Internet is available online at <http://catb.org/~esr/faqs/smart-questions.html>. Read and follow the hints in this document to increase the likelihood of getting the help you need.

## **Part II. Preparing for the Build**

## Chapter 2. Build Directory, Packages, and Patches

### 2.1. Introduction

This chapter creates a directory where the cross compiler toolchain will be built and a directory where sources are kept. It includes a list of packages that need to be downloaded for building a basic Linux system.

The listed version numbers correspond to versions of the software that are known to work, and this book is based on their use. We highly recommend not using newer or older versions because the build commands for one version may not work with another version.

Download locations may not always be accessible. If a download location has changed since this book was published, Google (<http://www.google.com/>) provides a useful search engine for most packages.

### 2.2. Creating Build and Sources Directories

Create a directory for the CLFS build (the exact location is up to you):

```
mkdir -p /mnt/clfs
```

Assign it to the CLFS environment variable:

```
export CLFS=/mnt/clfs
```

Ensure that this new directory has permissions that are not too restrictive such that you can write to it as a non-root user.

```
chmod 777 ${CLFS}
```

Downloaded packages and patches will need to be stored somewhere that is conveniently available throughout the entire build. A working directory is also required to unpack the sources and build them. `${CLFS}/sources` can be used both as the place to store the tarballs and patches and as a working directory.

Create a directory to store the sources:

```
mkdir -v ${CLFS}/sources
```

### 2.3. All Packages

Download or otherwise obtain the following packages:

- **Binutils (2.23.2) - 20937 KB:**

Home page: <http://www.gnu.org/software/binutils/>

Download: <http://ftp.gnu.org/gnu/binutils/binutils-2.23.2.tar.bz2>

MD5 sum: 4f8fa651e35ef262edc01d60fb45702e

- **BusyBox (1.21.1) - 2150 KB:**

Home page: <http://www.busybox.net>

Download: <http://busybox.net/downloads/busybox-1.21.1.tar.bz2>

MD5 sum: 795394f83903b5eec6567d51eebb417e

- **CLFS-Bootscripts (git master HEAD) - 5 KB:**

Home page: <http://git.cross-lfs.org/?p=bootscripts-embedded.git>

Download: <http://git.cross-lfs.org/?p=bootscripts-embedded.git;a=snapshot;h=HEAD;sf=tgz>

MD5 sum: N/A

• **GCC (4.7.3) - 80961 KB:**

Home page: <http://gcc.gnu.org>

Download: <ftp://gcc.gnu.org/pub/gcc/releases/gcc-4.7.3/gcc-4.7.3.tar.bz2>

MD5 sum: 86f428a30379bdee0224e353ee2f999e

• **GMP (5.1.2) - 2143 KB:**

Home page: <http://gmplib.org/>

Download: <http://ftp.gnu.org/gnu/gmp/gmp-5.1.2.tar.bz2>

MD5 sum: 7e3516128487956cd825fef01aafe4bc

• **iana-etc (2.30) - 200 KB:**

Home page: <http://sethwicklein.net/iana-etc>

Download: <http://sethwicklein.net/iana-etc-2.30.tar.bz2>

MD5 sum: 3ba3afb1d1b261383d247f46cb135ee8

• **Linux (3.0.80) - 75134 KB:**

Home page: <http://www.kernel.org>

Download: <http://www.kernel.org/pub/linux/kernel/v3.x/linux-3.0.80.tar.bz2>

MD5 sum: bf912b05870cd04ca620594e2b264a3c

• **MPC (1.0.1) - 609 KB:**

Home page: <http://www.multiprecision.org/>

Download: <http://www.multiprecision.org/mpc/download/mpc-1.0.1.tar.gz>

MD5 sum: b32a2e1a3daa392372fbd586d1ed3679

• **MPFR (3.1.2) - 1196 KB:**

Home page: <http://www.mpfr.org/>

Download: <http://gforge.inria.fr/frs/download.php/32210/mpfr-3.1.2.tar.bz2>

MD5 sum: ee2c3ac63bf0c2359bf08fc3ee094c19

• **musl-libc (0.9.14) - 806 KB:**

Home page: <http://musl-libc.org/>

Download: <http://www.musl-libc.org/releases/musl-0.9.14.tar.gz>

MD5 sum: bfb685695aa942e64c63170589e575b2

Total size of these packages: about 180 MB

## 2.4. Needed Patches

In addition to the packages, several patches are also required. These patches correct any mistakes in the packages that should be fixed by the maintainer. The patches also make small modifications to make the packages easier to work with. The following patches will be needed to build a CLFS system:

• **Binutils musl-libc Patch - 1 KB:**

Download: <http://patches.cross-lfs.org/embedded-dev/binutils-2.23.2-musl-1.patch>

MD5 sum: dde64feb7f4cf821cbd887b53026fd67

• **BusyBox musl-libc Patch - 1 KB:**

Download: <http://patches.cross-lfs.org/embedded-dev/busybox-1.21.1-musl-1.patch>

MD5 sum: 335622b0f2bf4e18e9d93fd48afe53da

- **GCC musl-libc Patch - 26 KB:**

Download: <http://patches.cross-lfs.org/embedded-dev/gcc-4.7.3-musl-1.patch>

MD5 sum: 5b43765740ca9865b8afe3cc945a3f5d

- **Iana-Etc Update Patch - 4 KB:**

Download: <http://patches.cross-lfs.org/embedded-dev/iana-etc-2.30-update-2.patch>

MD5 sum: b8e60c1322599c731734585d7af34945

Total size of these patches: about 32 KB

## Chapter 3. Final Preparations

### 3.1. About \$CLFS

Throughout this book, the environment variable `CLFS` will be used several times. It is paramount that this variable is always defined. It should be set to the mount point chosen for the CLFS partition. Check that the `CLFS` variable is set up properly with:

```
echo ${CLFS}
```

Make sure the output shows the path to the CLFS partition's mount point, which is `/mnt/clfs` if the provided example was followed. If the output is incorrect, the variable can be set with:

```
export CLFS=/mnt/clfs
```

Having this variable set is beneficial in that commands such as `install -d ${CLFS}/tools` can be typed literally. The shell will automatically replace “`${CLFS}`” with “`/mnt/clfs`” (or whatever the variable was set to) when it processes the command line.

Do not forget to check that `${CLFS}` is set whenever you leave and reenter the current working environment (as when doing a “`su`” to `root` or another user).

### 3.2. Adding the CLFS User

When logged in as user `root`, making a single mistake can damage or destroy a system. Therefore, we recommend building the packages as an unprivileged user. You could use your own user name, but to make it easier to set up a clean work environment, create a new user called `clfs` as a member of a new group (also named `clfs`) and use this user during the installation process.

```
sudo groupadd clfs
sudo useradd -s /bin/bash -g clfs -m -k /dev/null clfs
```

The meaning of the command line options:

`-s /bin/bash`

This makes **bash** the default shell for user `clfs`.

`-g clfs`

This option adds user `clfs` to group `clfs`.

`-m`

This creates a home directory for `clfs`.

`-k /dev/null`

This parameter prevents possible copying of files from a skeleton directory (default is `/etc/skel`) by changing the input location to the special null device.

`clfs`

This is the actual name for the created group and user.

To log in as `clfs` (as opposed to switching to user `clfs` when logged in as `root`, which does not require the `clfs` user to have a password), give `clfs` a password:

```
sudo passwd clfs
```

Grant `clfs` full access to `${CLFS}` by making `clfs` the directory's owner:

```
sudo chown -Rv clfs ${CLFS}
```

Next, login as user `clfs`. This can be done via a virtual console, through a display manager, or with the following substitute user command:

```
su - clfs
```

The “-” instructs `su` to start a login shell as opposed to a non-login shell. The difference between these two types of shells can be found in detail in `bash(1)` and **info bash**.

### 3.3. Setting Up the Environment

Set up a good working environment by creating two new startup files for the `bash` shell. While logged in as user `clfs`, issue the following command to create a new `.bash_profile`:

```
cat > ~/.bash_profile << "EOF"
exec env -i HOME=${HOME} TERM=${TERM} PS1='\u:\w\$ ' /bin/bash
EOF
```

When logged on as user `clfs`, the initial shell is usually a *login* shell which reads the `/etc/profile` of the host (probably containing some settings and environment variables) and then `.bash_profile`. The `exec env -i.../bin/bash` command in the `.bash_profile` file replaces the running shell with a new one with a completely empty environment, except for the `HOME`, `TERM`, and `PS1` variables. This ensures that no unwanted and potentially hazardous environment variables from the host system leak into the build environment. The technique used here achieves the goal of ensuring a clean environment.

The new instance of the shell is a *non-login* shell, which does not read the `/etc/profile` or `.bash_profile` files, but rather reads the `.bashrc` file instead. Create the `.bashrc` file now:

```
cat > ~/.bashrc << "EOF"
set +h
umask 022
CLFS=/mnt/clfs
LC_ALL=POSIX
PATH=${CLFS}/cross-tools/bin:/bin:/usr/bin
export CLFS LC_ALL PATH
EOF
```

The `set +h` command turns off `bash`'s hash function. Hashing is ordinarily a useful feature—`bash` uses a hash table to remember the full path of executable files to avoid searching the `PATH` time and again to find the same executable. However, the new tools should be used as soon as they are installed. By switching off the hash function, the shell will always search the `PATH` when a program is to be run. As such, the shell will find the newly compiled tools in `${CLFS}/cross-tools` as soon as they are available without remembering a previous version of the same program in a different location.

Setting the user file-creation mask (`umask`) to `022` ensures that newly created files and directories are only writable by their owner, but are readable and executable by anyone (assuming default modes are used by the `open(2)` system call, new files will end up with permission mode `644` and directories with mode `755`).

The `CLFS` variable should be set to the chosen mount point.

The `LC_ALL` variable controls the localization of certain programs, making their messages follow the conventions of a specified country. If the host system uses a version of Glibc older than 2.2.4, having `LC_ALL` set to something other than “POSIX” or “C” (during this chapter) may cause issues.

By putting `${CLFS}/cross-tools/bin` at the beginning of the `PATH`, the cross-compiler built in *Constructing Cross-Compile Tools* will be picked up by the build process for the temp-system packages before anything that may be installed on the host. This, combined with turning off hashing, helps to ensure that you will be using the cross-compile tools to build the temp-system in `/tools`.

Finally, to have the environment fully prepared for building the temporary tools, source the just-created user profile:

```
source ~/.bash_profile
```

# **Part III. Make the Cross-Compile Tools**

# Chapter 4. Constructing Cross-Compile Tools

## 4.1. Introduction

This chapter shows you how to create cross platform tools.

If for some reason you have to stop and come back later, remember to use the `su - clfs` command, and it will setup the build environment that you left.

### 4.1.1. Common Notes

#### Important

Before issuing the build instructions for a package, the package should be unpacked as user `clfs`, and a `cd` into the created directory should be performed. The build instructions assume that the `bash` shell is in use.

Several of the packages are patched before compilation, but only when the patch is needed to circumvent a problem or supply a default configuration. Warning messages about *offset* or *fuzz* may also be encountered when applying a patch. Do not worry about these warnings, as the patch was still successfully applied.

During the compilation of most packages, there will be several warnings that scroll by on the screen. These are normal and can safely be ignored. These warnings are as they appear—warnings about deprecated, but not invalid, use of the C or C++ syntax. C standards change fairly often, and some packages still use the older standard. This is not a problem, but does prompt the warning.

#### Important

After installing each package, both in this and the next chapters, delete its source and build directories, unless specifically instructed otherwise.

## 4.2. Build CFLAGS

CFLAGS and CXXFLAGS must not be set during the building of cross-tools.

To disable CFLAGS and CXXFLAGS use the following commands:

```
unset CFLAGS
unset CXXFLAGS
```

Now add these to `~/ .bashrc`, just in case you have to exit and restart building later:

```
echo unset CFLAGS >> ~/.bashrc
echo unset CXXFLAGS >> ~/.bashrc
```

## 4.3. ABI Variables

Setup for a Particular ABI:

```
export CLFS_ABI="[From Chart]"
```

```
echo export CLFS_ABI=\"\"${CLFS_ABI}\"\" >> ~/.bashrc
```

The following table gives the entires for the different ABI's that CLFS Embedded supports. Make sure you select one for your build, this will ensure capatibilty of your build with your target architecture.

**Table 4.1. List of Build Variables**

ABI	CLFS_ABI=Value	Notes
O32	32	For 32 bit CPUs only
N32	n32	For 64 bit CPUs operating in 32 bit mode
N64	64	For 64 bit CPUs operating in 64 bit mode

## 4.4. Build Variables

### Setting Host and Target

During the building of the cross-compile tools you will need to set a few variables that will be dependent on your particular needs. You will need to set the target triplet for the target architecture, the MIPS level, and CPU endianness. If you do not know what triplet or level you want, you can use the table as a reference. Set the command using the method listed below:

```
export CLFS_HOST=$(echo ${MACHTYPE} | sed "s/-[^-]*/-cross/")
export CLFS_TARGET="[target triplet]"
```

**Table 4.2. Processor Type and Target Triplets**

Processor	Target Triplet	MIPS Level
MIPS 32 bits Little Endian	mipsel-linux-musl	1
MIPS 32 bits Big Endian	mips-linux-musl	1
MIPS 64 bits Little Endian	mips64el-linux-musl	3
MIPS 64 bits Big Endian	mips64-linux-musl	3

Now we will set the architecture and endianness of the CPU based on the target triplet provided above:

```
export CLFS_ARCH=mips
export CLFS_ENDIAN=$(echo ${CLFS_ARCH} | sed -e 's/mipsel/little/' -e 's/mips/big')
```

Now you will need to set the MIPS LEVEL. This determines how your GCC and C library are built. There are currently 5 MIPS ISA Levels. To keep things simple we are only using two. For more information, see [http://www.linux-mips.org/wiki/Instruction\\_Set\\_Architecture](http://www.linux-mips.org/wiki/Instruction_Set_Architecture)

```
export CLFS_MIPS_LEVEL="[mips level]"
```

We also need to select the floating point capability of the CPU. If the CPU has built-in hardware for performing floating point calculations, choose "hard", otherwise choose "soft":

```
export CLFS_FLOAT="[hard or soft]"
```

Now we will add this to `~/ .bashrc`, just in case you have to exit and restart building later:

```
echo export CLFS_HOST=\ "${CLFS_HOST}\ " >> ~/.bashrc
echo export CLFS_TARGET=\ "${CLFS_TARGET}\ " >> ~/.bashrc
echo export CLFS_ARCH=\ "${CLFS_ARCH}\ " >> ~/.bashrc
echo export CLFS_ENDIAN=\ "${CLFS_ENDIAN}\ " >> ~/.bashrc
echo export CLFS_MIPS_LEVEL=\ "${CLFS_MIPS_LEVEL}\ " >> ~/.bashrc
echo export CLFS_FLOAT=\ "${CLFS_FLOAT}\ " >> ~/.bashrc
```

## 4.5. Create the Sysroot Directory

Create a `sysroot` directory which will be used when building the cross compiler and link its `usr` directory to itself such that everything installs to the `sysroot`:

```
mkdir -p ${CLFS}/cross-tools/${CLFS_TARGET}
ln -sfv . ${CLFS}/cross-tools/${CLFS_TARGET}/usr
```

## 4.6. Linux-Headers-3.0.80

The Linux Kernel contains a make target that installs “sanitized” kernel headers.

### 4.6.1. Installation of Linux Headers

For this step you will need the kernel tarball.

Install the header files that are common to all architectures:

```
make mrproper
make ARCH=${CLFS_ARCH} headers_check
make ARCH=${CLFS_ARCH} INSTALL_HDR_PATH=${CLFS}/cross-tools/${CLFS_TARGET} headers_install
```

### 4.6.2. Contents of Linux-Headers

**Installed headers:**           \${CLFS}/cross-tools/\${CLFS\_TARGET}/include/{asm,asm-generic,drm,linux,mtd,rdma,scsi}

#### Short Descriptions

`${CLFS}/cross-tools/${CLFS_TARGET}/include/{asm,asm-generic,drm,linux,mtd,rdma,scsi}` The Linux API headers

## 4.7. Binutils-2.23.2

The Binutils package contains a linker, an assembler, and other tools for handling object files.

### 4.7.1. Installation of Cross Binutils

It is important that Binutils be the first package compiled because both the C library and GCC perform various tests on the available linker and assembler to determine which of their own features to enable.

In order to work with musl-libc, binutils needs to be patched:

```
patch -Np1 -i ../binutils-2.23.2-musl-1.patch
```

The Binutils documentation recommends building Binutils outside of the source directory in a dedicated build directory:

```
mkdir -v ../binutils-build
cd ../binutils-build
```

Prepare Binutils for compilation:

```
../binutils-2.23.2/configure \
  --prefix=${CLFS}/cross-tools \
  --target=${CLFS_TARGET} \
  --with-sysroot=${CLFS}/cross-tools/${CLFS_TARGET} \
  --disable-nls \
  --disable-multilib
```

The meaning of the configure options:

*--prefix=\${CLFS}/cross-tools*

This tells the configure script to prepare to install the package in the `${CLFS}/cross-tools` directory.

*--target=\${CLFS\_TARGET}*

When used with `--host`, this creates a cross-architecture executable that creates files for `${CLFS_TARGET}` but runs on the host system.

*--with-sysroot=\${CLFS}/cross-tools/\${CLFS\_TARGET}*

This tells configure that `${CLFS}` is going to be the root of our system. It will now use the specified `sysroot`, `${CLFS}`, as a prefix of the default search paths.

*--disable-nls*

This disables internationalization as `i18n` is not needed for the cross-compile tools.

*--disable-multilib*

This option disables the building of a multilib capable binutils.

Compile the package:

```
make configure-host
make
```

The meaning of the make options:

*configure-host*

This checks the host environment and makes sure all the necessary tools are available to compile Binutils.

Install the package:

```
make install
```

## 4.7.2. Contents of Binutils

**Installed programs:** addr2line, ar, as, c++filt, elfedit, gprof, ld, nm, objcopy, objdump, ranlib, readelf, size, strings, and strip

**Installed libraries:** libiberty.a, libbfd.[a,so], and libopcodes.[a,so]

## Short Descriptions

**addr2line** Translates program addresses to file names and line numbers; given an address and the name of an executable, it uses the debugging information in the executable to determine which source file and line number are associated with the address

**ar** Creates, modifies, and extracts from archives

**as** An assembler that assembles the output of **gcc** into object files

**c++filt** Used by the linker to de-mangle C++ and Java symbols and to keep overloaded functions from clashing

**elfedit** Examine and modify ELF metadata within an ELF object

**gprof** Displays call graph profile data

**ld** A linker that combines a number of object and archive files into a single file, relocating their data and tying up symbol references

**nm** Lists the symbols occurring in a given object file

**objcopy** Copy the contents of one object file to another

**objdump** Displays information about the given object file, with options controlling the particular information to display; the information shown is useful to programmers who are working on the compilation tools

**ranlib** Generates an index of the contents of an archive and stores it in the archive; the index lists all of the symbols defined by archive members that are relocatable object files

**readelf** Displays information about ELF type binaries

**size** Lists the section sizes and the total size for the given object files

**strings** Outputs, for each given file, the sequences of printable characters that are of at least the specified length (defaulting to four); for object files, it prints, by default, only the strings from the initializing and loading sections while for other types of files, it scans the entire file

**strip** Discards symbols from object files

**libiberty** Contains routines used by various GNU programs, including **getopt**, **obstack**, **strerror**, **strtol**, and **strtoul**

**libbfd** The Binary File Descriptor library

`libopcodes` A library for dealing with opcodes—the “readable text” versions of instructions for the processor; it is used for building utilities like **objdump**.

## 4.8. GCC-4.7.3 - Static

The GCC package contains the GNU compiler collection, which includes the C compiler.

### 4.8.1. Installation of Cross GCC Compiler with Static libgcc and no Threads

In order to work with musl-libc, GCC needs to be patched:

```
patch -Np1 -i ../gcc-4.7.3-musl-1.patch
```

GCC requires the GMP, MPFR, and MPC packages to either be present on the host or to be present in source form within the gcc source tree. Unpack these into the GCC directory after unpacking GCC:

```
tar xf ../mpfr-3.1.2.tar.bz2
mv -v mpfr-3.1.2 mpfr
tar xf ../gmp-5.1.2.tar.bz2
mv -v gmp-5.1.2 gmp
tar xf ../mpc-1.0.1.tar.gz
mv -v mpc-1.0.1 mpc
```

The GCC documentation recommends building GCC outside of the source directory in a dedicated build directory:

```
mkdir -v ../gcc-build
cd ../gcc-build
```

Prepare GCC for compilation:

```
../gcc-4.7.3/configure \
--prefix=${CLFS}/cross-tools \
--build=${CLFS_HOST} \
--host=${CLFS_HOST} \
--target=${CLFS_TARGET} \
--with-sysroot=${CLFS}/cross-tools/${CLFS_TARGET} \
--disable-nls \
--disable-shared \
--without-headers \
--with-newlib \
--disable-decimal-float \
--disable-libgomp \
--disable-libmudflap \
--disable-libssp \
--disable-libatomic \
--disable-libquadmath \
--disable-threads \
--enable-languages=c \
--disable-multilib \
--with-mpfr-include=$(pwd)/../gcc-4.7.3/mpfr/src \
--with-mpfr-lib=$(pwd)/mpfr/src/.libs \
--with-abi=${CLFS_ABI} \
--with-arch=mips${CLFS_MIPS_LEVEL} \
--with-float=${CLFS_FLOAT} \
--with-endian=${CLFS_ENDIAN}
```

The meaning of the configure options:

`--prefix=${CLFS}/cross-tools`

This tells the configure script to prepare to install the package in the `${CLFS}/cross-tools` directory.

`--build=${CLFS_HOST}`

This tells the configure script the triplet to use to build GCC. It will use `${CLFS_HOST}` as that's where it's being built.

`--host=${CLFS_HOST}`

This tells the configure script the triplet of the machine GCC will be executed on when actually cross compiling. It will use `${CLFS_HOST}` as that's where GCC will execute when cross compiling software later.

`--target=${CLFS_TARGET}`

This tells the configure script the triplet of the machine GCC will build executables for. It will use `${CLFS_TARGET}` so that software compiled with this version of GCC can be executed on the embedded machine target.

`--with-sysroot=${CLFS}/cross-tools/${CLFS_TARGET}`

This tells configure that `${CLFS}/cross-tools/${CLFS_TARGET}` is going to be the temporary root of our system. It will now use the specified sysroot as a prefix of the default search paths.

`--disable-nls`

This disables internationalization as i18n is not needed for the cross-compile tools.

`--disable-shared`

Disables the creation of the shared libraries.

`--without-headers`

Tells configure to not use any headers from any C libraries. This is needed as we haven't yet built the C library and to prevent influence from the host environment.

`--with-newlib`

Tells configure to build libgcc without needing any C libraries.

`--disable-decimal-float`

Tells configure to disable IEEE 754-2008 decimal floating point support. Decimal floating point support isn't needed yet.

`--disable-libgomp`

Tells configure to not build the GOMP run-time libraries. GOMP is the GNU implementation of OpenMP, a API for shared-memory parallel programming.

`--disable-libmudflap`

Tells configure to not build libmudflap. Mudflap is a library that can be used to help check for proper pointer usage.

`--disable-libssp`

Tells configure not to build run-time libraries for stack smashing detection.

`--disable-libatomic`

Tells configure not to build atomic operations.

`--disable-libquadmath`

Tells configure not to build quad math operations.

`--disable-threads`

This will prevent GCC from looking for the multi-thread include files, since they haven't been created for this architecture yet. GCC will be able to find the multi-thread information after the glib headers are created.

`--enable-languages=c`

This option ensures that only the C compiler is built.

`--disable-multilib`

This option specifies that multiple target libraries should not be built.

`--with-mpfr-include=$(pwd)/../gcc-4.7.3/mpfr/src`

Tells configure how to find the mpfr headers.

`--with-mpfr-lib=$(pwd)/mpfr/src/.libs`

Tells configure to use the mpfr libraries built within the GCC build directory. This happens automatically but is needed to prevent GCC from searching the host's normal library paths.

`--with-abi=${CLFS_ABI}`

This option sets the ABI selected earlier.

`--with-arch=mips${CLFS_MIPS_LEVEL}`

This option sets the MIPS architecture ISA. Generic options that apply to this book are of the form "mips\${CLFS\_MIPS\_LEVEL}". For example, "mips1" or "mips3". For a more expanded list of choices, please see the GCC documentation at <http://gcc.gnu.org/onlinedocs/gcc/MIPS-Options.html>

`--with-float=${CLFS_FLOAT}`

This option sets the floating point mode selected earlier.

`--with-endian=${CLFS_ENDIAN}`

This option sets the endianness of the CPU selected earlier. GCC's configure scripts may not be able to determine the endianness based only on the target triplet (as other architectures do).

Continue with compiling the package:

```
make all-gcc all-target-libgcc
```

Install the package:

```
make install-gcc install-target-libgcc
```

Details on this package are located in Section 4.10.2, "Contents of GCC."

## 4.9. musl-libc-0.9.14

The musl-libc package contains the main C library. This library provides the basic routines for allocating memory, searching directories, opening and closing files, reading and writing files, string handling, pattern matching, arithmetic, and so on.

### 4.9.1. Installation of musl-libc

Configure the package:

```
CC=${CLFS_TARGET}-gcc ./configure \
  --prefix=/ \
  --target=${CLFS_TARGET}
```

Compile the package:

```
CC=${CLFS_TARGET}-gcc make
```

Install the package:

```
DESTDIR=${CLFS}/cross-tools/${CLFS_TARGET} make install
```

### 4.9.2. Contents of musl-libc

<b>Installed Programs:</b>	ld-musl-libc.so.0
<b>Installed Libraries:</b>	libc.so.0, libcrypt.so.0, libdl.so.0, libm.so.0, libpthread.so.0, librt.so.0
<b>Installed Headers:</b>	To be written...

### Short Descriptions

<b>ld-musl-libc</b>	The musl-libc dynamic linker / loader
libc	The C library
libcrypt	The cryptographic library
libdl	The musl-libc dynamic linker / loader library
libm	The math library
libpthread	The POSIX thread library
librt	The clock and timer library

## 4.10. GCC-4.7.3 - Final

The GCC package contains the GNU compiler collection, which includes the C compiler.

### 4.10.1. Installation of GCC Cross Compiler

In order to work with musl-libc, GCC needs to be patched:

```
patch -Np1 -i ../gcc-4.7.3-musl-1.patch
```

GCC requires the GMP, MPFR, and MPC packages to either be present on the host or to be present in source form within the gcc source tree. Unpack these into the GCC directory after unpacking GCC:

```
tar xf ../mpfr-3.1.2.tar.bz2
mv -v mpfr-3.1.2 mpfr
tar xf ../gmp-5.1.2.tar.bz2
mv -v gmp-5.1.2 gmp
tar xf ../mpc-1.0.1.tar.gz
mv -v mpc-1.0.1 mpc
```

The GCC documentation recommends building GCC outside of the source directory in a dedicated build directory:

```
mkdir -v ../gcc-build
cd ../gcc-build
```

Prepare GCC for compilation:

#### Note

If you would like to build a C++ compiler in addition to the C compiler, change the following `--enable-languages=c` option to be `--enable-languages=c,c++` instead. A C++ compiler is not required for any of the software included in this book.

```
../gcc-4.7.3/configure \
--prefix=${CLFS}/cross-tools \
--build=${CLFS_HOST} \
--target=${CLFS_TARGET} \
--host=${CLFS_HOST} \
--with-sysroot=${CLFS}/cross-tools/${CLFS_TARGET} \
--disable-nls \
--enable-languages=c \
--enable-c99 \
--enable-long-long \
--disable-libmudflap \
--disable-multilib \
--with-mpfr-include=$(pwd)/../gcc-4.7.3/mpfr/src \
--with-mpfr-lib=$(pwd)/mpfr/src/.libs \
--with-abi=${CLFS_ABI} \
--with-arch=mips${CLFS_MIPS_LEVEL} \
--with-float=${CLFS_FLOAT} \
--with-endian=${CLFS_ENDIAN}
```

The meaning of the configure options not used previously:

`--enable-c99`

Enable C99 support for C programs.

`--enable-long-long`

Enables long long support in the compiler.

Continue with compiling the package:

```
make
```

Install the package:

```
make install
```

## 4.10.2. Contents of GCC

**Installed programs:** gcc, and gcov  
**Installed libraries:** libgcc.a, libgcc\_eh.a, and libgcc\_s.so

### Short Descriptions

**gcc** The C compiler

**gcov** A coverage testing tool; it is used to analyze programs to determine where optimizations will have the most effect

**libgcc** Contains run-time support for **gcc**

# Part IV. Building the CLFS System

## Chapter 5. Installing Basic System Software

### 5.1. Introduction

In this chapter, we enter the building site and start constructing the CLFS system in earnest. The installation of this software is straightforward. Although in many cases the installation instructions could be made shorter and more generic, we have opted to provide the full instructions for every package to minimize the possibilities for mistakes. The key to learning what makes a Linux system work is to know what each package is used for and why the user (or the system) needs it. For every installed package, a summary of its contents is given, followed by concise descriptions of each program and library the package installed.

The order that packages are installed in this chapter needs to be strictly followed to ensure that no program accidentally acquires a path referring to `${CLFS}/cross-tools` hard-wired into it. For the same reason, do not compile packages in parallel. Compiling in parallel may save time (especially on dual-CPU machines), but it could result in a program containing a hard-wired path to `${CLFS}/cross-tools`, which will cause the program to stop working when that directory is removed.

### 5.2. Creating Directories

It is time to create some structure in the target CLFS file system. Create a standard directory tree by issuing the following commands:

```
mkdir -pv ${CLFS}/targetfs/{bin,boot,dev,etc,home,lib/{firmware,modules}}
mkdir -pv ${CLFS}/targetfs/{mnt,opt,proc,sbin,svr,sys}
mkdir -pv ${CLFS}/targetfs/var/{cache,lib,local,lock,log,opt,run,spool}
install -dv -m 0750 ${CLFS}/targetfs/root
install -dv -m 1777 ${CLFS}/targetfs/tmp
mkdir -pv ${CLFS}/targetfs/usr/{,local/}{bin,include,lib,sbin,share,src}
```

Directories are, by default, created with permission mode 755, but this is not desirable for all directories. In the commands above, two changes are made—one to the home directory of user `root`, and another to the directories for temporary files.

The first mode change ensures that not just anybody can enter the `/root` directory—the same as a normal user would do with his or her home directory. The second mode change makes sure that any user can write to the `/tmp` and `/var/tmp` directories, but cannot remove another user's files from them. The latter is prohibited by the so-called “sticky bit,” the highest bit (1) in the 1777 bit mask.

#### 5.2.1. FHS Compliance Note

The directory tree is based on the Filesystem Hierarchy Standard (FHS) (available at <http://www.pathname.com/fhs/>).

### 5.3. Creating the `passwd`, `group`, and `log` Files

A proper Linux system maintains a list of the mounted file systems in the file `/etc/mtab`. With the way our embedded system is designed, we will be using a symlink to `/proc/mounts`:

```
ln -svf ../proc/mounts ${CLFS}/targetfs/etc/mtab
```

In order for user `root` to be able to login and for the name “root” to be recognized, there must be relevant entries

in the `/etc/passwd` and `/etc/group` files.

Create the `/etc/passwd` file by running the following command:

```
cat > ${CLFS}/targetfs/etc/passwd << "EOF"
root::0:0:root:/root:/bin/ash
EOF
```

The actual password for `root` (the `::` used here is just a placeholder and allow you to login with no password) will be set later.

**Additional optional users you may want to add:**

```
bin:x:1:1:bin:/bin:/bin/false
```

Can be useful for compatibility with legacy applications.

```
daemon:x:2:6:daemon:/sbin:/bin/false
```

It is often recommended to use an unprivileged User ID/Group ID for daemons in order to limit their access to the system.

```
adm:x:3:16:adm:/var/adm:/bin/false
```

Was used for programs that performed administrative tasks.

```
lp:x:10:9:lp:/var/spool/lp:/bin/false
```

Used by programs for printing.

```
mail:x:30:30:mail:/var/mail:/bin/false
```

Often used by email programs.

```
news:x:31:31:news:/var/spool/news:/bin/false
```

Often used for network news servers.

```
uucp:x:32:32:uucp:/var/spool/uucp:/bin/false
```

Often used for Unix-to-Unix Copy of files from one server to the next

```
operator:x:50:0:operator:/root:/bin/ash
```

Often used to allow system operators to access the system.

```
postmaster:x:51:30:postmaster:/var/spool/mail:/bin/false
```

Generally used as an account that receives all the information of troubles with the mail server.

```
nobody:x:65534:65534:nobody:/:/bin/false
```

Used by NFS.

Create the `/etc/group` file by running the following command:

```
cat > ${CLFS}/targetfs/etc/group << "EOF"
root:x:0:
bin:x:1:
sys:x:2:
kmem:x:3:
tty:x:4:
tape:x:5:
daemon:x:6:
floppy:x:7:
disk:x:8:
lp:x:9:
dialout:x:10:
audio:x:11:
```

```
video:x:12:
utmp:x:13:
usb:x:14:
cdrom:x:15:
EOF
```

### Additional optional groups you may want to add

```
adm:x:16:root,adm,daemon
```

All users in this group are allowed to do administrative tasks

```
console:x:17:
```

This group has direct access to the console

```
cdrw:x:18:
```

This group is allowed to use the CDRW drive

```
mail:x:30:mail
```

Used by MTAs (Mail Transport Agents)

```
news:x:31:news
```

Used by Network News Servers

```
uucp:x:32:uucp
```

Used by the Unix-to-Unix copy users

```
users:x:100:
```

The default GID used by shadow for new users

```
nogroup:x:65533:
```

This is a default group used by some programs that do not require a group

```
nobody:x:65534:
```

This is used by NFS

The created groups are not part of any standard—they are groups decided on in part by the requirements of the Udev configuration in this chapter, and in part by common convention employed by a number of existing Linux distributions. The Linux Standard Base (LSB, available at <http://www.linuxbase.org>) recommends only that, besides the group `root` with a Group ID (GID) of 0, a group `bin` with a GID of 1 be present. All other group names and GIDs can be chosen freely by the system administrator since well-written programs do not depend on GID numbers, but rather use the group's name.

The `login`, `agetty`, and `init` programs (and others) use a number of log files to record information such as who was logged into the system and when. However, these programs will not write to the log files if they do not already exist. Initialize the log files and give them proper permissions:

```
touch ${CLFS}/targetfs/var/run/utmp ${CLFS}/targetfs/var/log/{btmp,lastlog,wtmp}
chmod -v 664 ${CLFS}/targetfs/var/run/utmp ${CLFS}/targetfs/var/log/lastlog
```

The `/var/run/utmp` file records the users that are currently logged in. The `/var/log/wtmp` file records all logins and logouts. The `/var/log/lastlog` file records when each user last logged in. The `/var/log/btmp` file records the bad login attempts.

## 5.4. ToolChain Variables

Setup target-specific variables for the compiler and linkers. This time we keep them:

```
echo export CC="\${CLFS_TARGET}-gcc\" >> ~/.bashrc
echo export CXX="\${CLFS_TARGET}-g++\" >> ~/.bashrc
echo export AR="\${CLFS_TARGET}-ar\" >> ~/.bashrc
echo export AS="\${CLFS_TARGET}-as\" >> ~/.bashrc
echo export LD="\${CLFS_TARGET}-ld\" >> ~/.bashrc
echo export RANLIB="\${CLFS_TARGET}-ranlib\" >> ~/.bashrc
echo export READELF="\${CLFS_TARGET}-readelf\" >> ~/.bashrc
echo export STRIP="\${CLFS_TARGET}-strip\" >> ~/.bashrc
source ~/.bashrc
```

## 5.5. BusyBox-1.21.1

BusyBox combines tiny versions of many common UNIX utilities into a single small executable. It provides replacements for most of the utilities you usually find in GNU fileutils, shellutils, etc. The utilities in BusyBox generally have fewer options than their full-featured GNU cousins; however, the options that are included provide the expected functionality and behave very much like their GNU counterparts. BusyBox provides a fairly complete environment for any small or embedded system.

### 5.5.1. Installation of BusyBox

First ensure the BusyBox source is completely clean:

```
make distclean
```

The following patch is needed for musl-libc:

```
patch -Np1 -i ../busybox-1.21.1-musl-1.patch
```

#### Note

We tell BusyBox to use the generic defconfig. For those for more adventurous, you can use **make menuconfig**, and create a custom or modified configuration for your build.

The following tells BusyBox to use the default configuration:

```
ARCH="${CLFS_ARCH}" make defconfig
```

Disable building both ifplugd and inetd as they both have issues building against musl-libc:

```
sed -i 's/\(CONFIG_\)\(.*\)\(INETD\)\(.*\)=y/# \1\2\3\4 is not set/g' .config
sed -i 's/\(CONFIG_IFPLUGD\)=y/# \1 is not set/' .config
```

Compile the package:

```
ARCH="${CLFS_ARCH}" CROSS_COMPILE="${CLFS_TARGET}"- make
```

Install the package:

```
ARCH="${CLFS_ARCH}" CROSS_COMPILE="${CLFS_TARGET}"- make \
CONFIG_PREFIX="${CLFS}/targetfs" install
```

If you're going to build your kernel with modules, you will need to make sure **depmod.pl** is available:

```
cp examples/depmod.pl ${CLFS}/cross-tools/bin
chmod 755 ${CLFS}/cross-tools/bin/depmod.pl
```

### 5.5.2. Contents of BusyBox

Installed programs:           To be Written

## 5.6. iana-etc-2.30

The `iana-etc` package provides data for network services and protocols.

### 5.6.1. Installation of iana-Etc

`iana-etc` comes with outdated data and IANA has changed the download location used to obtain up-to-date data. Apply the following patch to correct the download location:

```
patch -Np1 -i ../iana-etc-2.30-update-2.patch
```

Update the data used to the current IANA lists:

```
make get
```

The following command converts the raw data provided by IANA into the correct formats for the `/etc/protocols` and `/etc/services` data files:

```
make STRIP=yes
```

Install the package:

```
make DESTDIR=${CLFS}/targetfs install
```

### 5.6.2. Contents of iana-etc

**Installed files:** `/etc/protocols` and `/etc/services`

#### Short Descriptions

<code>/etc/protocols</code>	Describes the various DARPA Internet protocols that are available from the TCP/IP subsystem
<code>/etc/services</code>	Provides a mapping between friendly textual names for internet services, and their underlying assigned port numbers and protocol types

## Chapter 6. Making the CLFS System Bootable

### 6.1. Introduction

It is time to make the CLFS system bootable. This chapter discusses creating an `fstab` file, building a kernel for the new CLFS system, and installing the boot loader so that the CLFS system can be selected for booting at startup.

### 6.2. Creating the `/etc/fstab` File

The `/etc/fstab` file is used by some programs to determine where file systems are to be mounted by default, in which order, and which must be checked (for integrity errors) prior to mounting. Create a new file systems table like this:

```
cat > ${CLFS}/targetfs/etc/fstab << "EOF"
# Begin /etc/fstab

# file system  mount-point  type  options  dump  fsck
#                                     order

/dev/[xxx]    /             [fff] defaults  1      1
/dev/[yyy]    swap          swap    pri=1     0      0
proc          /proc         proc    defaults  0      0
sysfs         /sys          sysfs   defaults  0      0
devpts        /dev/pts      devpts  gid=4,mode=620  0      0
shm           /dev/shm     tmpfs   defaults  0      0
# End /etc/fstab
EOF
```

Replace `[xxx]`, `[yyy]`, and `[fff]` with the values appropriate for the system, for example, `hda2`, `hda5`, and `ext2`. For details on the six fields in this file, see **man 5 `fstab`**.

The `/dev/shm` mount point for `tmpfs` is included to allow enabling POSIX-shared memory. The kernel must have the required support built into it for this to work (more about this is in the next section). Please note that very little software currently uses POSIX-shared memory. Therefore, consider the `/dev/shm` mount point optional. For more information, see `Documentation/filesystems/tmpfs.txt` in the kernel source tree.

## 6.3. Linux-3.0.80

The Linux package contains the Linux kernel.

### 6.3.1. Installation of the kernel

Building the kernel involves a few steps—configuration, compilation, and installation. Read the README file in the kernel source tree for alternative methods to the way this book configures the kernel.

Prepare for compilation by running the following command:

```
make mrproper
```

This ensures that the kernel tree is absolutely clean. The kernel team recommends that this command be issued prior to each kernel compilation. Do not rely on the source tree being clean after un-tarring.

Configure the kernel via a menu-driven interface. Be sure to enable DEVTMPFS so that /dev will be populated automatically.

#### Note

Since you are building for an embedded system make sure all key components are built into the kernel and not as modules. The key components are console/video, disk, and network. With out these built in, the system will not function properly. It is recommended to configure the kernel without modules in order to conserve disk space and to simplify.

```
make ARCH=${CLFS_ARCH} CROSS_COMPILE=${CLFS_TARGET}- menuconfig
```

Alternatively, the `make oldconfig` or `make ${CLFS_TARGET}_defconfig` may be more appropriate in some situations. See the README file for more information.

If desired, skip kernel configuration by copying the kernel config file, `.config`, from an example system (assuming it is available) to the root directory of the unpacked kernel sources.

#### Note

If you are using the u-boot bootloader, creating a uImage type kernel is recommended. Install the u-boot tools (not documented here) and append "uImage" when compiling the kernel.

Compile the configured kernel image and modules:

```
make ARCH=${CLFS_ARCH} CROSS_COMPILE=${CLFS_TARGET}-
```

If using kernel modules, an `/etc/modprobe.conf` file may be needed. Information pertaining to modules and kernel configuration is located in the kernel documentation in the Documentation directory of the kernel sources tree. Also, `modprobe.conf(5)` may be of interest.

If building modules, install the modules:

```
make ARCH=${CLFS_ARCH} CROSS_COMPILE=${CLFS_TARGET}- \
INSTALL_MOD_PATH=${CLFS}/targetfs modules_install
```

The kernel configuration file `.config` produced by the **make menuconfig** step above contains all the configuration selections for the kernel that was just compiled. It is a good idea to keep this file for future reference.

The resulting kernel will be located within the `arch/${CLFS_ARCH}/boot`. There may be more than one version of the same kernel, simply with different compression or bootloader helpers added. Follow your bootloader's instructions on how to copy the kernel to the final system.

## 6.3.2. Contents of Linux

**Installed files:** `.config`, Image files, and `System.map`

### Short Descriptions

<code>.config</code>	Contains all the configuration selections for the kernel
<code>zImage</code> , <code>uImage</code> , <code>bzImage</code> , <code>vmlinux</code>	The compiled Linux kernel.
<code>System.map</code>	A list of addresses and symbols; it maps the entry points and addresses of all the functions and data structures in the kernel. Useful for debugging, sometimes.

## 6.4. Bootloaders

There are many different bootloaders. Creating detailed instructions on how to use even the more popular ones is difficult as each architecture and board often has different levels of support or configuration options within each bootloader. Often, development kits will ship with a bootloader already configured, if your board comes with a bootloader pre-configured, it's best to start using that and then venture on to building the bootloader yourself later.

A few of the popular bootloaders include:

Barebox

*<http://barebox.org/>*

CoLo

*<http://www.colonel-panic.org/cobalt-mips/>*

GNU GRUB

*<https://www.gnu.org/software/grub/>*

Syslinux

*[http://www.syslinux.org/wiki/index.php/The\\_Syslinux\\_Project](http://www.syslinux.org/wiki/index.php/The_Syslinux_Project)*

u-boot

*<http://www.denx.de/wiki/U-Boot>*

# Chapter 7. Setting Up System Bootscripts

## 7.1. Introduction

This chapter details how to install and configure the CLFS-Bootscripts package. Most of these scripts will work without modification, but a few require additional configuration files because they deal with hardware-dependent information.

System-V style init scripts are employed in this book because they are widely used. For additional options, a hint detailing the BSD style init setup is available at <http://www.linuxfromscratch.org/hints/downloads/files/bsd-init.txt>. Searching the LFS mailing lists for “depinit” will also offer additional choices.

If using an alternative style of init scripts, skip this chapter and move on to Making the CLFS System Bootable.

## 7.2. CLFS-Bootscripts-git master HEAD

The CLFS-Bootscripts package contains a set of scripts to start/stop the CLFS system at bootup/shutdown.

### 7.2.1. Installation of CLFS-Bootscripts

#### Important

Unlike other chapters, after installing the bootscripts, do not delete the bootscripts source directory. The bootscripts source directory may be needed later.

Install the package:

```
make DESTDIR=${CLFS}/targetfs install-bootscripts
```

The CLFS startup bootscript is `/etc/rc.d/startup`, but BusyBox will look for `/etc/init.d/rcS` to use as its startup script. To ensure BusyBox finds the startup script, create the `${CLFS}/targetfs/etc/init.d` directory and a symlink:

```
install -dv ${CLFS}/targetfs/etc/init.d
ln -sv ../rc.d/startup ${CLFS}/targetfs/etc/init.d/rcS
```

### 7.2.2. Contents of CLFS-Bootscripts

Installed scripts:                functions, startup, shutdown, and syslog.

#### Short Descriptions

<b>functions</b>	Contains common functions, such as error and status checking, that are used by several bootscripts
<b>startup</b>	Performs all startup script operations
<b>shutdown</b>	Performs all shutdown operations
<b>syslog</b>	Starts and stops the system log daemons

## 7.3. Configure mdev

Is a BusyBox replacement of udev. With a different rule base.

### 7.3.1. Creating /etc/mdev.conf

Now we will create the mdev.conf file for use with our system:

```

cat > ${CLFS}/targetfs/etc/mdev.conf<< "EOF"
# /etc/mdev/conf

# Devices:
# Syntax: %s %d:%d %s
# devices user:group mode

# null does already exist; therefore ownership has to be changed with command
null root:root 0666 @chmod 666 $MDEV
zero root:root 0666
grsec root:root 0660
full root:root 0666

random root:root 0666
urandom root:root 0444
hwrandom root:root 0660

# console does already exist; therefore ownership has to be changed with command
#console root:tty 0600 @chmod 600 $MDEV && mkdir -p vc && ln -sf ../$MDEV vc/0
console root:tty 0600 @mkdir -pm 755 fd && cd fd && for x in 0 1 2 3 ; do ln -sf

fd0 root:floppy 0660
kmem root:root 0640
mem root:root 0640
port root:root 0640
ptmx root:tty 0666

# ram.*
ram([0-9]*) root:disk 0660 >rd/%1
loop([0-9]+) root:disk 0660 >loop/%1
sd[a-z].* root:disk 0660 */lib/mdev/usbdisk_link
hd[a-z][0-9]* root:disk 0660 */lib/mdev/ide_links
md[0-9]          root:disk 0660

tty          root:tty 0666
tty[0-9]    root:root 0600
tty[0-9][0-9] root:tty 0660
ttyS[0-9]*  root:tty 0660
pty.*       root:tty 0660
vcs[0-9]*  root:tty 0660
vcsa[0-9]* root:tty 0660

ttyLTM[0-9] root:dialout 0660 @ln -sf $MDEV modem
ttySHSF[0-9] root:dialout 0660 @ln -sf $MDEV modem
slamr          root:dialout 0660 @ln -sf $MDEV slamr0
slusb          root:dialout 0660 @ln -sf $MDEV slusb0
fuse           root:root 0666

```

```

# dri device
card[0-9] root:video 0660 =dri/

# alsa sound devices and audio stuff
pcm.*      root:audio 0660 =snd/
control.*  root:audio 0660 =snd/
midi.*     root:audio 0660 =snd/
seq        root:audio 0660 =snd/
timer      root:audio 0660 =snd/

adsp       root:audio 0660 >sound/
audio      root:audio 0660 >sound/
dsp        root:audio 0660 >sound/
mixer      root:audio 0660 >sound/
sequencer.* root:audio 0660 >sound/

# misc stuff
agpgart    root:root 0660 >misc/
psaux     root:root 0660 >misc/
rtc        root:root 0664 >misc/

# input stuff
event[0-9]+ root:root 0640 =input/
mice       root:root 0640 =input/
mouse[0-9] root:root 0640 =input/
ts[0-9]    root:root 0600 =input/

# v4l stuff
vbi[0-9]   root:video 0660 >v4l/
video[0-9] root:video 0660 >v4l/

# dvb stuff
dvb.*      root:video 0660 */lib/mdev/dvbdev

# load drivers for usb devices
usbdev[0-9].[0-9] root:root 0660 */lib/mdev/usbdev
usbdev[0-9].[0-9]_* root:root 0660

# net devices
tun[0-9]*  root:root 0600 =net/
tap[0-9]*  root:root 0600 =net/

# zaptel devices
zap(.*)    root:dialout 0660 =zap/%1
dahdi!(.*) root:dialout 0660 =dahdi/%1

# raid controllers
cciss!(.*) root:disk 0660 =cciss/%1
ida!(.*)  root:disk 0660 =ida/%1
rd!(.*)   root:disk 0660 =rd/%1

sr[0-9]    root:cdrom 0660 @ln -sf $MDEV cdrom

# hpilo
hpilo!(.*) root:root 0660 =hpilo/%1

```

```
# xen stuff
xvd[a-z] root:root 0660 */lib/mdev/xvd_links
EOF
```

## 7.4. Creating /etc/profile

Is the file that specifies how to your environment will function.

Now we will create the profile file for use with our system:

```
cat > ${CLFS}/targetfs/etc/profile<< "EOF"
# /etc/profile

# Set the initial path
export PATH=/bin:/usr/bin

if [ `id -u` -eq 0 ] ; then
    PATH=/bin:/sbin:/usr/bin:/usr/sbin
    unset HISTFILE
fi

# Setup some environment variables.
export USER=`id -un`
export LOGNAME=$USER
export HOSTNAME=`/bin/hostname`
export HISTSIZE=1000
export HISTFILESIZE=1000
export PAGER='/bin/more '
export EDITOR='/bin/vi'

# End /etc/profile
EOF
```

## 7.5. Creating /etc/inittab

Is the file that specifies how to boot and shutdown a system.

Now we will create the inittab file for use with our system:

```
cat > ${CLFS}/targetfs/etc/inittab<< "EOF"
# /etc/inittab

::sysinit:/etc/rc.d/startup

tty1::respawn:/sbin/getty 38400 tty1
tty2::respawn:/sbin/getty 38400 tty2
tty3::respawn:/sbin/getty 38400 tty3
tty4::respawn:/sbin/getty 38400 tty4
tty5::respawn:/sbin/getty 38400 tty5
tty6::respawn:/sbin/getty 38400 tty6

# Put a getty on the serial line (for a terminal)
# uncomment this line if your using a serial console
#::respawn:/sbin/getty -L ttyS0 115200 vt100

::shutdown:/etc/rc.d/shutdown
::ctrlaltdel:/sbin/reboot
EOF
```

## 7.6. Setting Hostname

Part of the job of the bootscripts is setting the system's hostname. This needs to be configured in the `/etc/HOSTNAME` file.

Create the `HOSTNAME` file and enter a hostname by running:

```
echo "[clfs]" > ${CLFS}/targetfs/etc/HOSTNAME
```

`[clfs]` needs to be replaced with the name given to the computer. Do not enter the Fully Qualified Domain Name (FQDN) here. That information will be put in the `/etc/hosts` file in the next section.

## 7.7. Customizing the `/etc/hosts` File

If a network card is to be configured, decide on the IP address, FQDN, and possible aliases for use in the `/etc/hosts` file. The syntax is:

```
<IP address> myhost.example.org aliases
```

Unless the computer is to be visible to the Internet (i.e., there is a registered domain and a valid block of assigned IP addresses—most users do not have this), make sure that the IP address is in the private network IP address range. Valid ranges are:

Class	Networks
A	10.0.0.0
B	172.16.0.0 through 172.31.0.255
C	192.168.0.0 through 192.168.255.255

A valid IP address could be `192.168.1.1`. A valid FQDN for this IP could be `www.linuxfromscratch.org` (not recommended because this is a valid registered domain address and could cause domain name server issues).

Even if not using a network card, an FQDN is still required. This is necessary for certain programs to operate correctly.

Create the `/etc/hosts` file by running:

```
cat > ${CLFS}/targetfs/etc/hosts << "EOF"
# Begin /etc/hosts (network card version)

127.0.0.1 localhost
[192.168.1.1] [<HOSTNAME>.example.org] [HOSTNAME]

# End /etc/hosts (network card version)
EOF
```

The `[192.168.1.1]` and `[<HOSTNAME>.example.org]` values need to be changed for specific users or requirements (if assigned an IP address by a network/system administrator and the machine will be connected to an existing network).

If a network card is not going to be configured, create the `/etc/hosts` file by running:

```
cat > ${CLFS}/targetfs/etc/hosts << "EOF"
# Begin /etc/hosts (no network card version)
```

```
127.0.0.1 [<HOSTNAME>.example.org] [HOSTNAME] localhost
# End /etc/hosts (no network card version)
EOF
```

## 7.8. Configuring the network Script

### 7.8.1. Creating Network Interface Configuration Files

Which interfaces are brought up and down by the network utilities depends on the files and directories in the `/etc/network` directory. The `interfaces` file should contain a description of the interfaces, as done by Debian, and each of the directories contain scripts for actions to perform on each type of network event.

The following command creates the required directories and the `interfaces` file, assuming DHCP will be used for `eth0`:

```
mkdir -pv ${CLFS}/targetfs/etc/network/if-{post-{up,down},pre-{up,down},up,down}
mkdir -pv ${CLFS}/targetfs/usr/share/udhcp

cat > ${CLFS}/targetfs/etc/network/interfaces << "EOF"
auto eth0
iface eth0 inet dhcp
EOF
```

For DHCP to work properly with `udhcp`, the BusyBox `dhcp` client, a configuration script is needed. Create a simple script to assign the provided DHCP address and update `/etc/resolv.conf`:

```
cat > ${CLFS}/targetfs/usr/share/udhcp/default.script << "EOF"
#!/bin/sh
# udhcp Interface Configuration
# Based on http://lists.debian.org/debian-boot/2002/11/msg00500.html
# udhcp script edited by Tim Riker <Tim@Rikers.org>

[ -z "$1" ] && echo "Error: should be called from udhcp" && exit 1

RESOLV_CONF="/etc/resolv.conf"
[ -n "$broadcast" ] && BROADCAST="broadcast $broadcast"
[ -n "$subnet" ] && NETMASK="netmask $subnet"

case "$1" in
    deconfig)
        /sbin/ifconfig $interface 0.0.0.0
        ;;

    renew|bound)
        /sbin/ifconfig $interface $ip $BROADCAST $NETMASK

        if [ -n "$router" ] ; then
            while route del default gw 0.0.0.0 dev $interface ; do
                true
            done

            for i in $router ; do
                route add default gw $i dev $interface
            done
        fi
    esac
EOF
```

```
                done
            fi

            echo -n > $RESOLV_CONF
            [ -n "$domain" ] && echo search $domain >> $RESOLV_CONF
            for i in $dns ; do
                echo nameserver $i >> $RESOLV_CONF
            done
        ;;
    esac

    exit 0
EOF

chmod +x ${CLFS}/targetfs/usr/share/udhcpc/default.script
```

# **Part V. Beyond CLFS Embedded**

## Chapter 8. Beyond Introduction

### 8.1. Introduction

Now that we have our base system built, we may add some optional additional functionality.

In this section, we explain how to compile additional packages for use with the system. We will also cover how to configure some of the BusyBox Utilities.

## Chapter 9. Additional Libraries

### 9.1. Introduction

This chapter provides instructions on installing additional optional libraries. Please note that some of these libraries will be required in order to install other Beyond packages.

### 9.2. Beyond CLFS Additional Library Packages

Download or otherwise obtain the following packages:

Zlib (1.2.8) - 557 KB:

Home page: <http://www.zlib.net>

Download: <http://downloads.sourceforge.net/libpng/zlib-1.2.8.tar.gz>

MD5 sum: 44d667c142d7cda120332623eab69f40

Total size of these packages: about 557 KB

## 9.3. Zlib-1.2.8

The Zlib package contains compression and decompression routines used by some programs.

### 9.3.1. Installation of Zlib

Change the default optimization to Os

```
cp configure{,.orig}
sed -e 's/-O3/-Os/g' configure.orig > configure
```

Prepare Zlib for compilation:

```
./configure --shared
```

The meaning of the configure options:

*--shared*  
Tells Zlib to build its shared library.

Compile the package:

```
make
```

Install the package:

```
make prefix=${CLFS}/cross-tools/${CLFS_TARGET} install
```

### 9.3.2. Contents of Zlib

Installed libraries:       libz.[a,so]

#### Short Descriptions

`libz`   Contains compression and decompression functions used by some programs

## Chapter 10. Networking Software

### 10.1. Introduction

This chapter provides instructions on installing networking related packages.

### 10.2. Beyond CLFS Networking Packages

Download or otherwise obtain the following packages:

Dropbear (2013.60) - 1547 KB:

Home page: <http://matt.ucc.asn.au/dropbear/dropbear.html>

Download: <http://matt.ucc.asn.au/dropbear/releases/dropbear-2013.60.tar.bz2>

MD5 sum: fffa2fec0c887201bed3a3cc6df7fa35

Iptables (1.4.19.1) - 531 KB:

Home page: <http://www.netfilter.org/projects/iptables/>

Download: <http://www.netfilter.org/projects/iptables/files/iptables-1.4.19.1.tar.bz2>

MD5 sum: be97ce9007fa42c867901b496c935a0a

Wireless Tools (29) - 288 KB:

Home page: [http://www.hpl.hp.com/personal/Jean\\_Tourrilhes/Linux/Tools.html](http://www.hpl.hp.com/personal/Jean_Tourrilhes/Linux/Tools.html)

Download: [http://www.hpl.hp.com/personal/Jean\\_Tourrilhes/Linux/wireless\\_tools.29.tar.gz](http://www.hpl.hp.com/personal/Jean_Tourrilhes/Linux/wireless_tools.29.tar.gz)

MD5 sum: e06c222e186f7cc013fd272d023710cb

Total size of these packages: about 2,366 KB

### 10.3. Beyond CLFS Networking Patches

In addition to the packages, several patches are also required. These patches correct any mistakes in the packages that should be fixed by the maintainer. The patches also make small modifications to make the packages easier to work with. The following patches will be needed in order to build the associated packages:

Total size of these patches: about 0 KB

## 10.4. Dropbear-2013.60

Dropbear is a relatively small SSH server and client. Dropbear has a small memory footprint suitable for memory-constrained environments, while still having the same features as OpenSSH. It does not depend on OpenSSL and it has a MIT style license.

### 10.4.1. Installation of Dropbear

Fix dropbear so it doesn't install man pages:

```
sed -i 's/.*mandir.*//g' Makefile.in
```

Configure dropbear:

```
CC="${CC} -Os" ./configure --prefix=/usr --host=${CLFS_TARGET}
```

#### Note

We are just telling dropbear to use the default configuration plus scp. For those for more adventurous, edit options.h to further configure dropbear.

Compile the package:

```
make MULTI=1 \
  PROGRAMS="dropbear dbclient dropbearkey dropbearconvert scp"
```

Install the package:

```
make MULTI=1 \
  PROGRAMS="dropbear dbclient dropbearkey dropbearconvert scp" \
  install DESTDIR=${CLFS}/targetfs
```

Create the directory for the dropbear key files:

```
install -dv ${CLFS}/targetfs/etc/dropbear
```

### 10.4.2. Installation of Dropbear Bootscripts

From the clfs-bootscripts package, install the Dropbear bootscripts:

```
make install-dropbear DESTDIR=${CLFS}/targetfs
```

### 10.4.3. Contents of Dropbear

**Installed programs:**        /usr/bin/dropbearmulti

## 10.5. IPTables-1.4.19.1

iptables is the userspace command line program used to configure the Linux firewall.

### 10.5.1. Installation of iptables

Configure IPTables:

```
CC="${CC} -Os" ./configure --prefix=/usr --host=${CLFS_TARGET} \  
--libexecdir=/lib/iptables --without-kernel --enable-libipq --enable-shared
```

Compile the package:

```
make
```

Install the package:

```
make DESTDIR=${CLFS}/targetfs install
```

### 10.5.2. Contents of iptables

Installed programs:           To be Written

## 10.6. Wireless Tools-29

Wireless Tools is the reference implementation of tools supporting the ability to manipulate the Wireless Extensions API supported by most wireless LAN networking drivers.

### 10.6.1. Installation of Wireless Tools

Wireless Tools' Makefile contains explicitly which **gcc**, **ar**, and **ranlib** to use. Make sure the `${CLFS}/cross-tools` versions of these programs are used instead of the host's:

```
sed -i s/gcc/\${CLFS\_TARGET}\-gcc/g Makefile
sed -i s/\ ar/\ \${CLFS\_TARGET}\-ar/g Makefile
sed -i s/ranlib/\${CLFS\_TARGET}\-ranlib/g Makefile
```

Compile the package:

#### Note

There are options that can be passed to **make** and **make install** that will reduce the size and functionality of the Wireless Tools. See the Wireless Tools `INSTALL` file for more information.

```
make PREFIX=${CLFS}/targetfs/usr
```

Install the package:

```
make install PREFIX=${CLFS}/targetfs/usr
```

### 10.6.2. Contents of Wireless Tools

**Installed programs:** iwconfig, iwevent, iwgetid, iwlist, iwpriv, and iwspy  
**Installed libraries:** libiw.so

# Chapter 11. File System Tools

## 11.1. Introduction

This chapter provides instructions on installing file system related packages.

## 11.2. Beyond CLFS File System Packages

Download or otherwise obtain the following packages:

E2fsprogs (1.42.7) - 5840 KB:

Home page: <http://e2fsprogs.sourceforge.net>

Download: <http://downloads.sourceforge.net/e2fsprogs/e2fsprogs-1.42.7.tar.gz>

MD5 sum: a1ec22ef003688dae9f76c74881b22b9

Total size of these packages: about 6 MB

## 11.3. E2fsprogs-1.42.7

The E2fsprogs package contains the utilities for handling the `ext2` file system. It also supports the `ext3` and `ext4` journaling file systems.

### 11.3.1. Installation of E2fsprogs

The E2fsprogs documentation recommends that the package be built in a subdirectory of the source tree:

```
mkdir -v build
cd build
```

Prepare E2fsprogs for compilation:

```
CC="${CC} -Os" ../configure --prefix=/usr \
  --with-root-prefix="" --host=${CLFS_TARGET} --disable-tls \
  --disable-debugfs --disable-e2initrd-helper --disable-nls
```

The meaning of the configure options:

*--with-root-prefix=""*

Certain programs (such as the `e2fsck` program) are considered essential programs. When, for example, `/usr` is not mounted, these programs still need to be available. They belong in directories like `/lib` and `/sbin`. If this option is not passed to E2fsprogs' `configure`, the programs are installed into the `/usr` directory.

*--disable-tls*

Disable thread local support

*--disable-debugfs*

Disable building of the `debugfs` program. The `debugfs` program relies upon `utime.h` which is not available in the embedded system.

*--disable-e2initrd-helper*

Disable building of the `e2initrd-helper`. The `e2initrd-helper` program relies upon `utime.h` which is not available in the embedded system.

*--disable-nls*

Disable native language support.

Compile the package:

```
make
```

Install the binaries, documentation, and shared libraries:

```
make DESTDIR=${CLFS}/targetfs install
```

Install the static libraries and headers:

```
make DESTDIR=${CLFS}/targetfs install-libs
```

### 11.3.2. Contents of E2fsprogs

**Installed programs:** badblocks, blkid, chattr, compile\_et, dumpe2fs, e2fsck, e2image, e2label, filefrag, findfs, fsck, fsck.ext2, fsck.ext3, fsck.ext4, logsave, lsattr, mk\_cmds, mke2fs, mkfs.ext2, mkfs.ext3, mkfs.ext4, mklost+found, resize2fs, tune2fs, and uuidgen.

**Installed libraries:** libblkid.[a,so], libcom\_err.[a,so], libe2p.[a,so], libext2fs.[a,so], libss.[a,so], and libuuid.[a,so]

## Short Descriptions

**badblocks** Searches a device (usually a disk partition) for bad blocks

**blkid** A command line utility to locate and print block device attributes

**chattr** Changes the attributes of files on an `ext2` file system; it also changes `ext3` file systems, the journaling version of `ext2` file systems

**compile\_et** An error table compiler; it converts a table of error-code names and messages into a C source file suitable for use with the `com_err` library

**dumpe2fs** Prints the super block and blocks group information for the file system present on a given device

**e2fsck** Is used to check, and optionally repair `ext2` file systems and `ext3` file systems

**e2image** Is used to save critical `ext2` file system data to a file

**e2label** Displays or changes the file system label on the `ext2` file system present on a given device

**filefrag** Reports on how badly fragmented a particular file might be

**findfs** Finds a file system by label or Universally Unique Identifier (UUID)

**fsck** Is used to check, and optionally repair, file systems

**fsck.ext2** By default checks `ext2` file systems

**fsck.ext3** By default checks `ext3` file systems

**fsck.ext4** By default checks `ext4` file systems

**logsave** Saves the output of a command in a log file

**lsattr** Lists the attributes of files on a second extended file system

**mk\_cmds** Converts a table of command names and help messages into a C source file suitable for use with the `libss` subsystem library

**mke2fs** Creates an `ext2` or `ext3` file system on the given device

**mkfs.ext2** By default creates `ext2` file systems

**mkfs.ext3** By default creates `ext3` file systems

**mkfs.ext4** By default creates `ext4` file systems

**mklost+found** Used to create a `lost+found` directory on an `ext2` file system; it pre-allocates disk blocks to this directory to lighten the task of **e2fsck**

**resize2fs** Can be used to enlarge or shrink an `ext2` file system

**tune2fs** Adjusts tunable file system parameters on an `ext2` file system

**uuidgen** Creates new UUIDs. Each new UUID can reasonably be considered unique among all UUIDs created, on the local system and on other systems, in the past and in the future

**libblkid**

	Contains routines for device identification and token extraction
<code>libcom_err</code>	The common error display routine
<code>libe2p</code>	Used by <b>dumpe2fs</b> , <b>chattr</b> , and <b>lsattr</b>
<code>libext2fs</code>	Contains routines to enable user-level programs to manipulate an <code>ext2</code> file system
<code>libss</code>	Contains routines for command line interface parsing
<code>libuuid</code>	Contains routines for generating unique identifiers for objects that may be accessible beyond the local system

# **Part VI. Cleanup and Boot**

## Chapter 12. Backup and Cleanup

### 12.1. Copy Libraries

Since the cross compiler was built within `${CLFS}/cross-tools`, the generated libraries need to be copied to the target:

```
cp -vP ${CLFS}/cross-tools/${CLFS_TARGET}/lib/*.so* ${CLFS}/targetfs/lib/
```

Optionally, strip the libraries to reduce their size:

```
${CLFS_TARGET}-strip ${CLFS}/targetfs/lib/*
```

### 12.2. Changing the Ownership of the CLFS System

Throughout the book, every package has been compiled and installed as the `clfs` user. The final system should be owned by `root`.

#### Important

The commands on this page of the book must be performed while logged in as `root`. Check that `${CLFS}` is still set:

```
echo ${CLFS}
```

Make `root` the owner of the entire CLFS system:

```
chown -Rv root:root ${CLFS}/targetfs
```

The following files should not to belong to the `root` group, they should belong to the `utmp` group (group 13):

```
chgrp -v 13 ${CLFS}/targetfs/var/run/utmp ${CLFS}/targetfs/var/log/lastlog
```

### 12.3. Copy to Target

We just created a cleaned-up version of our build, now compress it so it can be archived and transferred to the target.

Create a tarball of the build:

```
install -dv ${CLFS}/build
cd ${CLFS}/targetfs
tar jcfv ${CLFS}/build/clfs-embedded.tar.bz2 *
```

Now you can move your compressed tarball to your target system. This will be different on every embedded device.

When uncompressing the tarball, make sure to pass tar the `"-p"` switch to ensure permissions are preserved.

## Chapter 13. The End

### 13.1. The End

Well done! The new CLFS system is installed! We wish you much success with your shiny new custom-built Linux system.

It may be a good idea to create an `/etc/clfs-release` file. By having this file, it is very easy for you (and for us if you need to ask for help at some point) to find out which CLFS version is installed on the system. Create this file by running:

```
echo CLFS-Embedded-GIT-20131024 > ${CLFS}/etc/clfs-release
```

### 13.2. Booting the System

Assuming the boot loader was set up properly, *CLFS GIT-20131024* will boot automatically when you power on the target.

When the boot is complete, the embedded CLFS system is ready for use!

### 13.3. What Now?

Thank you for reading this CLFS book. We hope that you have found this book helpful and have learned more about the system creation process.

Now that the CLFS system is installed, you may be wondering “What next?” To answer that question, we have compiled a list of resources for you.

- Maintenance
 

Bugs and security notices are reported regularly for all software. Since an CLFS system is compiled from source, it is up to you to keep abreast of such reports. There are several online resources that track such reports, some of which are shown below:

  - Freshmeat.net (<http://freshmeat.net/>)
 

Freshmeat can notify you (via email) of new versions of packages installed on your system.
  - CERT (Computer Emergency Response Team)
 

CERT has a mailing list that publishes security alerts concerning various operating systems and applications. Subscription information is available at <http://www.us-cert.gov/cas/signup.html>.
  - Bugtraq
 

Bugtraq is a full-disclosure computer security mailing list. It publishes newly discovered security issues, and occasionally potential fixes for them. Subscription information is available at <http://www.securityfocus.com/archive>.
- Community Driven Beyond Linux From Scratch
 

The Community Driven Beyond Linux From Scratch wiki provides information, installation procedures, and other tips for a large variety of software that can be installed on a CLFS system. The CBLFS wiki is located at

<http://cblfs.cross-lfs.org/>.

- Beyond Linux From Scratch

The Beyond Linux From Scratch book covers installation procedures for a wide range of software beyond the scope of the LFS Book. The BLFS project is located at <http://www.linuxfromscratch.org/blfs/>.

- LFS Hints

The LFS Hints are a collection of educational documents submitted by volunteers in the LFS community. The hints are available at <http://www.linuxfromscratch.org/hints/list.html>.

- Mailing lists

There are several LFS mailing lists you may subscribe to if you are in need of help, want to stay current with the latest developments, want to contribute to the project, and more. See Chapter 1 - Mailing Lists for more information.

- The Linux Documentation Project

The goal of The Linux Documentation Project (TLDP) is to collaborate on all of the issues of Linux documentation. The TLDP features a large collection of HOWTOs, guides, and man pages. It is located at <http://www.tldp.org/>.

# Index

## Packages

Binutils  
 cross tools: 19  
 Bootscripts: 40  
 BusyBox: 33  
 Dropbear: 53  
 E2fsprogs: 57  
 GCC  
 cross tools, final: 26  
 cross tools, static: 22  
 iana-etc: 34  
 iptables: 54  
 musl-libc  
 cross tools: 25  
 Linux: 36  
 Linux-Headers: 18  
 mdev: 41  
 wireless\_tools: 55  
 Zlib: 51

## Programs

addr2line: 19, 20  
 ar: 19, 20  
 as: 19, 20  
 badblocks: 57, 58  
 blkid: 57, 58  
 c++filt: 19, 20  
 chattr: 57, 58  
 compile\_et: 57, 58  
 dumpe2fs: 57, 58  
 e2fsck: 57, 58  
 e2image: 57, 58  
 e2label: 57, 58  
 elfedit: 19, 20  
 filefrag: 57, 58  
 findfs: 57, 58  
 fsck: 57, 58  
 fsck.ext2: 57, 58  
 fsck.ext3: 57, 58  
 fsck.ext4: 57, 58  
 gcc: 26, 27  
 gcov: 26, 27  
 gprof: 19, 20  
 ld: 19, 20  
 ld-musl-libc: 25, 25  
 logsave: 57, 58

lsattr: 57, 58  
 mke2fs: 57, 58  
 mkfs.ext2: 57, 58  
 mkfs.ext3: 57, 58  
 mkfs.ext4: 57, 58  
 mklost+found: 57, 58  
 mk\_cmds: 57, 58  
 nm: 19, 20  
 objcopy: 19, 20  
 objdump: 19, 20  
 ranlib: 19, 20  
 readelf: 19, 20  
 resize2fs: 57, 58  
 size: 19, 20  
 strings: 19, 20  
 strip: 19, 20  
 tune2fs: 57, 58  
 uuidgen: 57, 58

## Libraries

libbfd: 19, 20  
 libblkid: 57, 58  
 libc: 25, 25  
 libcom\_err: 57, 59  
 libcrypt: 25, 25  
 libdl: 25, 25  
 libe2p: 57, 59  
 libext2fs: 57, 59  
 libgcc\*: 26, 27  
 libiberty: 19, 20  
 libm: 25, 25  
 libopcodes: 19, 21  
 libpthread: 25, 25  
 librt: 25, 25  
 libss: 57, 59  
 libuuid: 57, 59  
 libz: 51, 51

## Scripts

functions: 40, 40  
 localnet  
 /etc/hosts: 45  
 configuring: 45  
 network  
 /etc/hosts: 45  
 configuring: 46  
 shutdown: 40, 40  
 startup: 40, 40  
 syslog: 40, 40

## Others

/usr/include/{asm,linux}/\*.h: 18, 18  
/etc/clfs-release: 62  
/etc/fstab: 35  
/etc/group: 29  
/etc/hosts: 45  
/etc/inittab: 44  
/etc/mdev.conf: 41  
/etc/passwd: 29  
/etc/profile: 44  
/etc/protocols: 34  
/etc/services: 34  
/var/log/btmp: 29  
/var/log/lastlog: 29  
/var/log/wtmp: 29  
/var/run/utmp: 29