Sourcery G++ Lite

MIPS ELF

Sourcery G++ Lite 4.3-81

Getting Started

CODESOURCERY

Sourcery G++ Lite: MIPS ELF: Sourcery G++ Lite 4.3-81: Getting Started

CodeSourcery, Inc.

Abstract

This guide explains how to install and build applications with Sourcery G++ Lite, CodeSourcery's customized, validated, and supported version of the GNU Toolchain. Sourcery G++ Lite includes everything you need for application development, including C and C++ compilers, assemblers, linkers, and libraries.

When you have finished reading this guide, you will know how to use Sourcery G++ from the command line.

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Preface

This preface introduces *Getting Started With Sourcery G++ Lite*. It explains the structure of this guide and lists other sources of information that relate to Sourcery G++ Lite.

1. Intended Audience

This guide is written for people who will install and/or use Sourcery G++ Lite. This guide provides a step-by-step guide to installing Sourcery G++ Lite and to building simple applications. Parts of this document assume that you have some familiarity with using the command-line interface.

2. Organization

This document is organized into the following chapters and appendices:

Chapter 1, *Sourcery G++ Lite Licenses*	This chapter provides information about the software licenses that apply to Sourcery G++ Lite. Read this chapter to understand your legal rights and obligations as a user of Sourcery G++ Lite.
Chapter 2, *Sourcery G++ Subscriptions*	This chapter provides information about Sourcery G++ subscriptions. CodeSourcery customers with Sourcery G++ subscriptions receive comprehensive support for Sourcery G++. Read this chapter to find out how to obtain and use a Sourcery G++ subscription.
Chapter 3, *Sourcery G++ Lite for MIPS ELF*	This chapter provides information about this release of Sourcery G++ Lite including any special installation instructions, recent improvements, or other similar information. You should read this chapter before building applications with Sourcery G++ Lite.
Chapter 4, *Installation and Configuration*	This chapter describes how to download, install and configure Sourcery G++ Lite. This section describes the available installation options and explains how to set up your environment so that you can build applications.
Chapter 5, *Using Sourcery G++ from the Command Line*	This chapter explains how to build applications with Sourcery G++ Lite using the command line. In the process of reading this chapter, you will build a simple application that you can use as a model for your own programs.
Chapter 6, *CS3™: The CodeSourcery Common Startup Code Sequence*	CS3 is CodeSourcery's low-level board support library. This chapter describes the organization of the system startup code and tells you how you can customize it, such as by defining your own interrupt handlers. This chapter also documents the boards supported by Sourcery G++ Lite and the compiler and linker options you need to use with them.
Chapter 7, *Next Steps with Sourcery G++*	This chapter describes where you can find additional documentation and information about using Sourcery G++ Lite and its components.

3. Typographical Conventions

The following typographical conventions are used in this guide:

`> command arg ...`	A command, typed by the user, and its output. The “`>`” character is the command prompt.
command	The name of a program, when used in a sentence, rather than in literal input or output.
`literal`	Text provided to or received from a computer program.
`placeholder`	Text that should be replaced with an appropriate value when typing a command.
`\`	At the end of a line in command or program examples, indicates that a long line of literal input or output continues onto the next line in the document.

Chapter 1
Sourcery G++ Lite Licenses

Sourcery G++ Lite contains software provided under a variety of licenses. Some components are “free” or “open source” software, while other components are proprietary. This chapter explains what licenses apply to your use of Sourcery G++ Lite. You should read this chapter to understand your legal rights and obligations as a user of Sourcery G++ Lite.

1.1. Licenses for Sourcery G++ Lite Components

The table below lists the major components of Sourcery G++ Lite for MIPS ELF and the license terms which apply to each of these components.

Some free or open-source components provide documentation or other files under terms different from those shown below. For definitive information about the license that applies to each component, consult the source package corresponding to this release of Sourcery G++ Lite. Sourcery G++ Lite may contain free or open-source components not included in the list below; for a definitive list, consult the source package corresponding to this release of Sourcery G++ Lite.

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GNU Binary Utilities	GNU General Public License 3.0 [1]
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GNU Debugger	GNU General Public License 3.0 [3]
Newlib C Library	Newlib License [4]
GNU Make	GNU General Public License 2.0 [5]
GNU Core Utilities	GNU General Public License 2.0 [6]

The CodeSourcery License is available in Section 1.2, “Sourcery G++™ Software License Agreement”.

> **Important**
>
> Although some of the licenses that apply to Sourcery G++ Lite are “free software” or “open source software” licenses, none of these licenses impose any obligation on you to reveal the source code of applications you build with Sourcery G++ Lite. You can develop proprietary applications and libraries with Sourcery G++ Lite.

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Chapter 2
Sourcery G++ Subscriptions

CodeSourcery provides support contracts for Sourcery G++. This chapter describes these contracts and explains how CodeSourcery customers can access their support accounts.

2.1. About Sourcery G++ Subscriptions

CodeSourcery offers Sourcery G++ subscriptions. Professional Edition subscriptions provide unlimited support, with no per-incident fees. CodeSourcery's support covers questions about installing and using Sourcery G++, the C and C++ programming languages, and all other topics relating to Sourcery G++. CodeSourcery provides updated versions of Sourcery G++ to resolve critical problems. Personal Edition subscriptions do not include support, but do include free upgrades as long as the subscription remains active.

CodeSourcery's support is provided by the same engineers who build Sourcery G++. A Sourcery G++ subscription is like having a team of compiler engineers and programming language experts available as consultants!

Subscription editions of Sourcery G++ also include many additional features not included in the free Lite editions:

- **Sourcery G++ IDE.** The Sourcery G++ IDE, based on Eclipse, provides a fully visual environment for developing applications, including an automated project builder, syntax-highlighting editor, and a graphical debugging interface. The debugger provides features especially useful to embedded systems programmers, including the ability to step through code at both the source and assembly level, view registers, and examine stack traces. CodeSourcery's enhancements to Eclipse include improved support for hardware debugging via JTAG or ICE units and complete integration with the rest of Sourcery G++.
- **Debug Sprites.** Sourcery G++ Debug Sprites provide hardware debugging support using JTAG and ICE devices. On some systems, Sourcery G++ Sprites can automatically program flash memory and display control registers. And the board initialization performed by each Sprite can be customized with simple XML-based configuration files to insert delays and write to particular memory addresses. Debug Sprites included in Lite editions of Sourcery G++ include only a subset of the functionality of the Sprites in the subscription editions.
- **QEMU Instruction Set Simulator.** The QEMU instruction set simulator can be used to run — and debug — programs even without target hardware. Most bare-metal configurations of Sourcery G++ include QEMU and linker scripts targeting the simulator. Configurations of Sourcery G++ for GNU/Linux targets include a user-space QEMU emulator that runs on Linux hosts.
- **Sysroot Utilities.** Subscription editions of Sourcery G++ include a set of sysroot utilities for GNU/Linux targets. These utilities simplify use of the Sourcery G++ dynamic linker and shared libraries on the target and also support remote debugging with **gdbserver**.
- **CS3.** CS3 provides a uniform, cross-platform approach to board initialization and interrupt handling on ARM EABI, ColdFire ELF, fido ELF, and Stellaris EABI platforms.
- **GNU/Linux Prelinker.** For select GNU/Linux target systems, Sourcery G++ includes the GNU/Linux prelinker. The prelinker is a postprocessor for GNU/Linux applications which can dramatically reduce application launch time. CodeSourcery has modified the prelinker to operate on non-GNU/Linux host systems, including Microsoft Windows.
- **Library Reduction Utility.** Sourcery G++ also includes a Library Reduction Utility for GNU/Linux targets. This utility allows the GNU C Library to be relinked to include only those functions used by a given collection of binaries.

- **Additional Libraries.** For some platforms, additional run-time libraries optimized for particular CPUs are available. Pre-built binary versions of the libraries with debug information are also available to subscribers.

If you would like more information about Sourcery G++ subscriptions, including a price quote or information about evaluating Sourcery G++, please send email to `<sales@codesourcery.com>`.

2.2. Accessing your Sourcery G++ Subscription Account

If you have a Sourcery G++ subscription, you may access your account by visiting the Sourcery G++ Portal[1]. If you have a support account, but are unable to log in, send email to `<support@codesourcery.com>`.

[1] https://support.codesourcery.com/GNUToolchain/

Chapter 3
Sourcery G++ Lite for MIPS ELF

This chapter contains information about using Sourcery G++ Lite on your target system. This chapter also contains information about changes in this release of Sourcery G++ Lite. You should read this chapter to learn how to best use Sourcery G++ Lite on your target system.

3.1. Library Configurations

Sourcery G++ includes copies of run-time libraries that have been built with optimizations for different target architecture variants or other sets of build options. Each such set of libraries is referred to as a *multilib*. When you build a target application, Sourcery G++ automatically selects the multilib matching the build options you have selected.

Note that a given multilib may be compatible with additional processors and configurations beyond those explicitly named here.

The following library configurations are available in Sourcery G++ Lite for MIPS ELF.

MIPS32 revision 2 - Big-Endian, O32	
Command-line option(s):	default

MIPS32 revision 2 - Little-Endian, O32	
Command-line option(s):	`-EL`

MIPS32 revision 2 - Big-Endian, O32, mips16	
Command-line option(s):	`-mips16`

MIPS32 revision 2 - Big-Endian, O32, fp64	
Command-line option(s):	`-mfp64`

MIPS32 - Soft-Float, O32	
Command-line option(s):	`-msoft-float`

MIPS32 - No-Float, O32	
Command-line option(s):	`-mno-float`

MIPS32 revision 2 - Big-Endian, O32, mips16, fp64	
Command-line option(s):	`-mips16 -mfp64`

MIPS32 revision 2 - Big-Endian, O32, mips16, Soft-Float	
Command-line option(s):	`-mips16 -msoft-float`

MIPS32 revision 2 - Big-Endian, O32, mips16, No-Float	
Command-line option(s):	`-mips16 -mno-float`

MIPS32 revision 2 - Big-Endian, O32, mips16, code-readable=no	
Command-line option(s):	`-mips16 -mcode-readable=no`

MIPS32 revision 2 - Big-Endian, O32, mips16, fp64, code-readable=no	
Command-line option(s):	`-mips16 -mfp64 -mcode-readable=no`

MIPS32 revision 2 - Big-Endian, O32, mips16, Soft-Float, code-readable=no	
Command-line option(s):	`-mips16 -msoft-float -mcode-readable=no`

MIPS32 revision 2 - Big-Endian, O32, mips16, No-Float, code-readable=no	
Command-line option(s):	`-mips16 -mno-float -mcode-readable=no`

MIPS32 revision 2 - Little-Endian, O32, mips16	
Command-line option(s):	`-EL -mips16`

MIPS32 revision 2 - Little-Endian, O32, fp64	
Command-line option(s):	`-EL -mfp64`

MIPS32 revision 2 - Little-Endian, O32, Soft-Float	
Command-line option(s):	`-EL -msoft-float`

MIPS32 revision 2 - Little-Endian, O32, No-Float	
Command-line option(s):	`-EL -mno-float`

MIPS32 revision 2 - Little-Endian, O32, mips16, fp64	
Command-line option(s):	`-EL -mips16 -mfp64`

MIPS32 revision 2 - Little-Endian, O32, mips16, Soft-Float	
Command-line option(s):	`-EL -mips16 -msoft-float`

MIPS32 revision 2 - Little-Endian, O32, mips16, No-Float	
Command-line option(s):	`-EL -mips16 -mno-float`

MIPS32 revision 2 - Little-Endian, O32, mips16, code-readable=no	
Command-line option(s):	`-EL -mips16 -mcode-readable=no`

MIPS32 revision 2 - Little-Endian, O32, mips16, fp64, code-readable=no	
Command-line option(s):	`-EL -mips16 -mfp64 -mcode-readable=no`

MIPS32 revision 2 - Little-Endian, O32, mips16, Soft-Float, code-readable=no	
Command-line option(s):	`-EL -mips16 -msoft-float -mcode-readable=no`

MIPS32 revision 2 - Little-Endian, O32, mips16, No-Float, code-readable=no	
Command-line option(s):	`-EL -mips16 -mno-float -mcode-readable=no`

3.2. Using Flash Memory

Sourcery G++ Lite supports development and debugging of applications loaded into flash memory on MIPS ELF targets. There are three steps involved:

1. You must use an appropriate linker script that identifies the ROM memory region on your target board, and locates the program text within that region. Refer to Chapter 6, *CS3™: The Code-*

Sourcery Common Startup Code Sequence for information about the boards supported by Sourcery G++.

2. Next, load your program into the flash memory on your target board. You must use third-party tools to program the flash memory.

3. Finally, when debugging a program in flash memory, GDB must be told about the ROM region so that it knows where it must use hardware breakpoints to control program execution.

   When using GDB from the command line, you can mark the flash memory as read-only by using the command:

   ```
   (gdb) mem start end ro
   ```

   where `start` and `end` define the address range of the read-only memory region.

3.3. Sourcery G++ Lite Release Notes

This section documents Sourcery G++ Lite changes for each released revision.

3.3.1. Changes in Sourcery G++ Lite 4.3-81

C++ named operators bug fix. A bug has been fixed that caused the compiler to crash in some cases when the C++ operators `and_eq`, `bitand`, `bitor`, `compl`, `not_eq`, `or_eq` and `xor_eq` were used in contexts where the preprocessor converts their names to strings.

GDB target extended-remote error. A bug in GDB has been fixed that caused **target extended-remote** to report `Remote failure reply: E01` if no remote program was running.

GDB segment warning. Some compilers produce binaries including uninitialized data regions, such as the stack and heap. GDB incorrectly displayed the warning `Loadable segment "name" outside of ELF segments` for such binaries; the warning has now been fixed.

3.3.2. Changes in Sourcery G++ Lite 4.3-59

Setting breakpoints on Windows. A bug in GDB on Microsoft Windows hosts has been fixed. The bug caused setting breakpoints on a source line by using the file's full path to fail with `No source file named filename.`

Handling of out-of-range values by `strtof`. The `strtof` function now sets `errno` to `ERANGE` when the input is not representable as a `float`, as required by the ISO C standard.

Printing casted values in GDB. A GDB bug that caused incorrect output for expressions containing casts, such as in the `print *(Type *)ptr` command, has been fixed.

Bug fix for objcopy/strip. An objcopy bug that corrupted COMDAT groups when creating new binaries has been fixed. This bug also affected **strip -g**.

Bug fix for assembly listing. A bug that caused the assembler to produce corrupted listings (via the `-a` option) on Windows hosts has been fixed.

DSP support. The compiler now automatically enables support for the DSP ASE when the `-march` option is used to specify a core in the 24KE, 34K, or 74K families. It is no longer necessary to provide the `-mdsp` option explicitly.

GDB update. The included version of GDB has been updated to 6.8.50.20080821. This update adds numerous bug fixes and new features, including support for decimal floating point, the new **find** command to search memory, the new `/m` (mixed source and assembly) option to the **disassemble** command, and the new **macro define** command to define C preprocessor macros interactively.

PIE linking fix. A bug in the GCC `-fpie` and `-fPIE` options has been fixed. The bug caused linker errors referring to `R_MIPS_HI16`.

Binutils support for DWARF Version 3. The **addr2line** command now supports binaries containing DWARF 3 debugging information. The **ld** command can display error messages with source locations for input files containing DWARF 3 debugging information.

GDB support for YAMON. GDB now supports debugging via the YAMON boot loader GDB stub. Consult YAMON documentation for details on enabling the GDB stub.

GDB Support for MIPSsim on Windows. A bug in the GDB support for MIPSsim on Microsoft Windows hosts has been fixed. The bug caused the `target mdi` command to fail with the error `Cannot find MIPSsim config file template: mipssim.cfg`.

CodeSourcery Common Startup Code Sequence. Support for CS3, CodeSourcery's unified startup scheme, has been added to this release. CS3 replaces the MIPS-provided MDI startup code and linker scripts included in previous releases. Refer to Chapter 6, *CS3™: The CodeSourcery Common Startup Code Sequence* for more information about CS3, including details about the boards and linker scripts supported by this release. Note that the Malta board configuration is usable by MIPSsim and the included GDB simulator as well as actual Malta hardware targets.

GDB display of source. A bug has been fixed that prevented GDB from locating debug information in some cases. The debugger failed to display source code for or step into the affected functions.

FPU defaults. The `-ffast-math` option now causes subnormal numbers to be immediately flushed to zero. It also sets the rounding mode to round-to-nearest.

Connecting to the target using a pipe. A bug in GDB's **target remote |** ***`program`*** command has been fixed. When launching the specified *`program`* failed, the bug caused GDB to crash, hang, or give a message `Error: No Error`.

Output files removed on error. When GCC encounters an error, it now consistently removes any incomplete output files that it may have created.

Placing bss-like regions in load regions. The linker no longer issues an incorrect error message when a bss-like section is placed at specific load region. The linker formerly incorrectly considered the section as taking up space in the load region.

`-mwarn-framesize=`*`size`* option. GCC has a new command-line option, `-mwarn-framesize=`*`size`*, which causes warnings if any function's stack frame exceeds the given *`size`*. This option is useful when generating code for environments with limited or absent stack, e.g., BIOS.

Newlib manuals. The documentation packaged with Sourcery G++ Lite now includes the Newlib C Library and Math Library manuals.

GCC version 4.3.2. Sourcery G++ Lite for MIPS ELF is now based on GCC version 4.3.2. For more information about changes from GCC version 4.2 that was included in previous releases, see `http://gcc.gnu.org/gcc-4.3/changes.html`.

Spurious GDB error message fixed. A spurious `Current thread went away!?` message is no longer generated when using GDB to debug programs running on cores that do not support hardware multi-threading. This problem was specific to the MDI target support in GDB.

Unnecessary section removed. A linker bug that caused an unnecessary `.rel.dyn` section to be placed in the executable has been fixed.

Linker bug fix for `--gc-sections`. A linker bug that caused certain linker-generated sections to be incorrectly omitted from the executable when the `--gc-sections` option is used has been fixed.

Errors after loading the debugged program. An intermittent GDB bug has been fixed. The bug could cause a GDB internal error after the **load** command.

Bug fix for objdump on Windows. An objdump bug that caused the `-S` option not to work on Windows in some cases has been fixed.

Persistent remote server connections. A GDB bug has been fixed that caused the **target extended-remote** command to fail to tell the remote server to make the connection persistent across program invocations.

3.3.3. Changes in Sourcery G++ Lite 4.2-166

No significant changes. There are no significant changes for MIPS ELF in this release.

3.3.4. Changes in Sourcery G++ Lite 4.2-162

No significant changes. There are no significant changes for MIPS ELF in this release.

3.3.5. Changes in Sourcery G++ Lite 4.2-160

MIPS SDE Kit. The SDE kit directory now includes all subdirectories. The SDE kit is in the `mips-sde-elf/kit` subdirectory of your installation.

Architecture level inference fix. The `-march=4kp` and `-march=4ksc` options now imply `-mips32` and the `-march=4ksd` option implies `-mips32r2`. The erroneous option `-march=4kf` has been removed.

Flags fix. The `-mips3d` and `-mpaired-single` options can now be used with `-mips32r2` as well as `-mips64`.

Program exit cleanup actions. A bug causing programs to fail to flush their buffers on exit has been fixed.

"Can't find matching LO16" linker error fixed. An assembler bug that caused errors when linking files containing mixed MIPS16 and non-MIPS16 code has been fixed.

Multilib matching fix. The `-mips16e` option now causes the same multilibs to be used as the `-mips16` option.

Misaligned accesses to packed structures fix. A bug that caused GCC to generate misaligned accesses to packed structures has been fixed.

3.3.6. Changes in Sourcery G++ Lite 4.2-157

MIPS SDE Examples. Sourcery G++ Lite now includes examples showing how to use the MIPS SDE Library. You can find these examples in the `mips-sde-elf/examples/` subdirectory of your installation.

`jalx` instruction. The assembler no longer reports an error if the `jalx` instruction is used outside of MIPS16 mode.

3.3.7. Changes in Sourcery G++ Lite 4.2-127

Initial release. This is the initial release for MIPS ELF.

Chapter 4
Installation and Configuration

This chapter explains how to install Sourcery G++ Lite. You will learn how to:

1. Verify that you can install Sourcery G++ Lite on your system.
2. Download the appropriate Sourcery G++ Lite installer.
3. Install Sourcery G++ Lite.
4. Configure your environment so that you can use Sourcery G++ Lite.

4.1. Terminology

Throughout this document, the term *host system* refers to the system on which you run Sourcery G++ while the term *target system* refers to the system on which the code produced by Sourcery G++ runs. The target system for this version of Sourcery G++ is `mips-sde-elf`.

If you are developing a workstation or server application to run on the same system that you are using to run Sourcery G++, then the host and target systems are the same. On the other hand, if you are developing an application for an embedded system, then the host and target systems are probably different.

4.2. System Requirements

4.2.1. Host Operating System Requirements

This version of Sourcery G++ supports the following host operating systems and architectures:

- Microsoft Windows NT 4, Windows 2000, Windows XP, and Windows Vista systems using IA32, AMD64, and EM64T processors.
- GNU/Linux systems using IA32, AMD64, or EM64T processors, including Debian 3.0 (and later), Red Hat Enterprise Linux 3 (and later), and SuSE Enterprise Linux 8 (and later).

Sourcery G++ is built as a 32-bit application. Therefore, even when running on a 64-bit host system, Sourcery G++ requires 32-bit host libraries. If these libraries are not already installed on your system, you must install them before installing and using Sourcery G++ Lite. Consult your operating system documentation for more information about obtaining these libraries.

4.2.2. Host Hardware Requirements

In order to install and use Sourcery G++ Lite, you must have at least 128MB of available memory.

The amount of disk space required for a complete Sourcery G++ Lite installation directory depends on the host operating system and the number of target libraries included. Typically, you should plan on at least 400MB. In addition, the graphical installer requires a similar amount of temporary space during the installation process.

4.2.3. Target System Requirements

See Chapter 3, *Sourcery G++ Lite for MIPS ELF* for requirements that apply to the target system.

4.3. Downloading an Installer

If you have received Sourcery G++ Lite on a CD, or other physical media, then you do not need to download an installer. You may skip ahead to Section 4.4, “Installing Sourcery G++ Lite”.

If you have a Sourcery G++ subscription (or evaluation), then you can log into the Sourcery G++ Portal[1] to download your Sourcery G++ toolchain(s). CodeSourcery also makes some toolchains available to the general public from the Sourcery G++ web site[2]. These publicly available toolchains do not include all the functionality of CodeSourcery's product releases.

[1] https://support.codesourcery.com/GNUToolchain/
[2] http://www.codesourcery.com/gnu_toolchains/

Once you have navigated to the appropriate web site, download the installer that corresponds to your host operating system. For Microsoft Windows systems, the Sourcery G++ installer is provided as an executable, with the `.exe` extension. For GNU/Linux systems Sourcery G++ Lite is provided as an executable installer package with the `.bin` extension, or as a compressed archive `.tar.bz2`.

On Microsoft Windows systems, save the installer to the desktop. On GNU/Linux systems, save the download package in your home directory.

4.4. Installing Sourcery G++ Lite

The method used to install Sourcery G++ Lite depends on your host system.

4.4.1. Installing Sourcery G++ Lite on Microsoft Windows

If you have received Sourcery G++ Lite on CD, insert the CD in your computer. On most computers, the installer then starts automatically. If your computer has been configured not to automatically run CDs, open `My Computer`, and double click on the CD. If you downloaded Sourcery G++ Lite, double-click on the installer.

After the installer starts, follow the on-screen dialogs to install Sourcery G++ Lite.

If you prefer, you can run the installer in console mode rather than using the graphical interface. To do this, invoke the installer with the `-i console` command-line option. For example:

```
> /path/to/package.exe -i console
```

4.4.2. Using the Sourcery G++ Lite Installer on GNU/Linux Hosts

Start the graphical installer by invoking the executable shell script:

```
> /bin/sh ./path/to/package.bin
```

After the installer starts, follow the on-screen dialogs to install Sourcery G++ Lite.

If you prefer, or if your host system does not run the X Window System, you can run the installer in console mode rather than using the graphical interface. To do this, invoke the installer with the `-i console` command-line option. For example:

```
> /bin/sh ./path/to/package.bin -i console
```

4.4.3. Installing Sourcery G++ Lite on Solaris or GNU/Linux Hosts from a Compressed Archive

You do not need to be a system administrator to install Sourcery G++ Lite on a GNU/Linux or Solaris system. You may install Sourcery G++ Lite using any user account and in any directory to which you have write access. This guide assumes that you have decided to install Sourcery G++ Lite in the `$HOME/CodeSourcery` subdirectory of your home directory and that the filename of the package you have downloaded is `/path/to/package.tar.bz2`. After installation the toolchain will be in `$HOME/CodeSourcery/sourceryg++-4.3`.

First, uncompress the package file:

```
> bunzip2 /path/to/package.tar.bz2
```

Next, create the directory in which you wish to install the package:

```
> mkdir -p $HOME/CodeSourcery
```

Change to the installation directory:

```
> cd $HOME/CodeSourcery
```

Unpack the package:

```
> tar xf /path/to/package.tar
```

4.5. Installing Sourcery G++ Lite Updates

If you have already installed an earlier version of Sourcery G++ Lite for MIPS ELF on your system, it is not necessary to uninstall it before using the installer to unpack a new version in the same location. The installer detects that it is performing an update in that case.

If you are installing an update from a compressed archive, it is recommended that you remove any previous installation in the same location, or install in a different directory.

Note that the names of the Sourcery G++ commands for the MIPS ELF target all begin with **mips-sde-elf**. This means that you can install Sourcery G++ for multiple target systems in the same directory without conflicts.

4.6. Uninstalling Sourcery G++ Lite

The method used to uninstall Sourcery G++ Lite depends on your host system. If you have modified any files in the installation it is recommended that you back up these changes. The uninstall procedure may remove the files you have altered.

4.6.1. Uninstalling Sourcery G++ Lite on Microsoft Windows

Select `Start`, then `Control Panel`. Select `Add or Remove Programs`. Scroll down and click on `Sourcery G++ for MIPS ELF`. Select `Change/Remove` and follow the on-screen dialogs to uninstall Sourcery G++ Lite.

You can run the uninstaller in console mode, rather than using the graphical interface, by invoking the Uninstall executable found in your Sourcery G++ Lite installation directory with the `-i console` command-line option.

To uninstall third-party drivers bundled with Sourcery G++ Lite, first disconnect the associated hardware device. Then use `Add or Remove Programs` to remove the drivers separately. Depending on the device, you may need to reboot your computer to complete the driver uninstall.

4.6.2. Uninstalling Sourcery G++ Lite on Microsoft Windows Vista

Select `Start`, then `Settings` and finally `Control Panel`. Select the `Uninstall a program` task. Scroll down and double click on `Sourcery G++ for MIPS ELF`. Follow the on-screen dialogs to uninstall Sourcery G++ Lite.

You can run the uninstaller in console mode, rather than using the graphical interface, by invoking the Uninstall executable found in your Sourcery G++ Lite installation directory with the `-i console` command-line option.

To uninstall third-party drivers bundled with Sourcery G++ Lite, first disconnect the associated hardware device. Then use `Uninstall a program` to remove the drivers separately. Depending on the device, you may need to reboot your computer to complete the driver uninstall.

4.6.3. Using the Sourcery G++ Lite Uninstaller on GNU/Linux

If you installed Sourcery G++ Lite on GNU/Linux using the installer script, then you must use the corresponding uninstaller to remove Sourcery G++ Lite. The `mips-sde-elf` directory located in the install directory will be removed entirely by the uninstaller. Please back up any changes you have made to this directory, such as modified linker scripts.

Start the graphical uninstaller by invoking the executable Uninstall shell script located in your installation directory. After the uninstaller starts, follow the on-screen dialogs to uninstall Sourcery G++ Lite.

You can run the uninstaller in console mode, rather than using the graphical interface, by invoking the Uninstall script with the `-i console` command-line option.

4.6.4. Uninstalling Sourcery G++ Lite on GNU/Linux or Solaris

If you installed Sourcery G++ Lite from a `.tar.bz2` file, you can uninstall it by manually deleting the installation directory created in the install procedure.

4.7. Setting up the Environment

As with the installation process itself, the steps required to set up your environment depend on your host operating system.

4.7.1. Setting up the Environment on Microsoft Windows

On a non-Vista Microsoft Windows system, the installer automatically adds Sourcery G++ to your `PATH`. You can test that your `PATH` is set up correctly by using the following command:

```
> mips-sde-elf-g++ -v
```

and verifying that the last line of the output contains: `Sourcery G++ Lite 4.3-81`.

On a Microsoft Windows Vista system, the installer does not automatically add Sourcery G++ to your `PATH`. To set up your `PATH` on Microsoft Windows Vista, use the following command in a `cmd.exe` shell:

```
> setx PATH "%PATH%;C:\Program Files\Sourcery G++\bin"
```

where `C:\Program Files\Sourcery G++` should be changed to the path of your Sourcery G++ Lite installation. You can verify that the command worked by starting a second `cmd.exe` shell and running:

```
> mips-sde-elf-g++ -v
```

Verify that the last line of the output contains: `Sourcery G++ Lite 4.3-81`.

4.7.1.1. Working with Cygwin

Sourcery G++ Lite does not require Cygwin or any other UNIX emulation environment. You can use Sourcery G++ directly from the Windows command shell. You can also use Sourcery G++ from within the Cygwin environment, if you prefer.

The Cygwin emulation environment translates Windows path names into UNIX path names. For example, the Cygwin path `/home/user/hello.c` corresponds to the Windows path `c:\cygwin\home\user\hello.c`. Because Sourcery G++ is not a Cygwin application, it does not, by default, recognize Cygwin paths.

If you are using Sourcery G++ from Cygwin, you should set the `CYGPATH` environment variable. If this environment variable is set, Sourcery G++ Lite automatically translates Cygwin path names into Windows path names. To set this environment variable, type the following command in a Cygwin shell:

```
> export CYGPATH=cygpath
```

To resolve Cygwin path names, Sourcery G++ relies on the **cygpath** utility provided with Cygwin. You must provide Sourcery G++ with the full path to `cygpath` if **cygpath** is not in your `PATH`. For example:

```
> export CYGPATH=c:/cygwin/bin/cygpath
```

directs Sourcery G++ Lite to use `c:/cygwin/bin/cygpath` as the path conversion utility. The value of `CYGPATH` must be an ordinary Windows path, not a Cygwin path.

4.7.2. Setting up the Environment on GNU/Linux or Solaris

If you installed Sourcery G++ Lite using the `.bin` graphical installer then you may skip this step. The graphical installer does this setup for you.

Before using Sourcery G++ Lite you should add it to your `PATH`. The command you must use varies with the particular command shell that you are using. If you are using the C Shell (**csh** or **tcsh**), use the command:

```
> setenv PATH $HOME/CodeSourcery/sourceryg++-4.3/bin:$PATH
```

If you are using Bourne Shell (**sh**), the Korn Shell (**ksh**), or another shell, use:

```
> PATH=$HOME/CodeSourcery/sourceryg++-4.3/bin:$PATH
> export PATH
```

If you are not sure which shell you are using, try both commands. In both cases, if you have installed Sourcery G++ Lite in an alternate location, you must replace the directory above with `bin` subdirectory of the directory in which you installed Sourcery G++ Lite.

You may also wish to set the `MANPATH` environment variable so that you can access the Sourcery G++ manual pages, which provide additional information about using Sourcery G++. To set the `MANPATH` environment variable, follow the same steps shown above, replacing `PATH` with `MANPATH`, and `bin` with `share/doc/sourceryg++-mips-sde-elf/man`.

You can test that your `PATH` is set up correctly by using the following command:

```
> mips-sde-elf-g++
```

and verifying that you receive the message:

```
mips-sde-elf-g++: no input files
```

Chapter 5
Using Sourcery G++ from the Command Line

This chapter demonstrates the use of Sourcery G++ Lite from the command line. This chapter assumes you have installed Sourcery G++ Lite as described in Chapter 4, *Installation and Configuration*.

5.1. Building an Application

This chapter explains how to build an application with Sourcery G++ Lite using the command line. As elsewhere in this manual, this section assumes that your target system is mips-sde-elf, as indicated by the **mips-sde-elf** command prefix.

Using an editor (such as **notepad** on Microsoft Windows or **vi** on UNIX-like systems), create a file named `hello.c` containing the following simple program:

```
#include <stdio.h>

int
main (void)
{
  printf("Hello World!\n");
  return 0;
}
```

Compile and link this program using the command:

```
> mips-sde-elf-gcc -o hello hello.c -T script
```

Sourcery G++ requires that you specify a linker script with the `-T` option to build applications for bare-board targets. Linker errors like `undefined reference to `read'` are a symptom of failing to use an appropriate linker script. Default linker scripts are provided in `mips-sde-elf/lib`. Refer to Chapter 6, *CS3™: The CodeSourcery Common Startup Code Sequence* for information about the boards and linker scripts supported by Sourcery G++ Lite.

There should be no output from the compiler. (If you are building a C++ application, instead of a C application, replace **mips-sde-elf-gcc** with **mips-sde-elf-g++**.)

5.2. Running Applications on the Target System

Consult your target board documentation for instructions on loading programs onto the target, and running them.

5.3. Running Applications in the Simulator

Sourcery G++ Lite includes a simulator that you can use on the host system to run programs compiled for the target system. Since you do not need target hardware, this is the easiest way to try out Sourcery G++.

To use the simulator run:

```
> mips-sde-elf-run hello
```

You should see the expected output:

```
Hello, world!
```

You can also use the simulator to execute target programs when debugging with GDB. See Section 5.4, “Running Applications from GDB” for more information.

5.4. Running Applications from GDB

You can run GDB, the GNU Debugger, on your host system to debug programs running remotely on a target board or system. You can also run and debug programs using the GDB simulator.

While this section explains the alternatives for using GDB to run and debug application programs, explaining the use of the GDB command-line interface is beyond the scope of this document. Please refer to the GDB manual for further instructions.

5.4.1. Connecting to the GDB Simulator

GDB includes a simulator that allows you to debug MIPS ELF applications without target hardware. To start and connect to the simulator from within GDB, use this command:

```
(gdb) target sim
```

5.4.2. Connecting to an External GDB Server

From within GDB, you can connect to a running **gdbserver** or other debugging stub that uses the GDB remote protocol using:

```
(gdb) target remote host:port
```

where *host* is the host name or IP address of the machine the stub is running on, and *port* is the port number it is listening on for TCP connections.

5.4.3. Connecting with MDI

Sourcery G++ Lite for MIPS ELF supports debugging with third-party simulators and hardware debug devices that implement the MDI (Microprocessor Debug Interface) API.

Before you can connect to a target using the MDI API, you must tell GDB which shared library or DLL to load for your simulator or device, and set up parameters to select your MDI target. This can be done either by means of environment variables or GDB commands. For example, you may want to put the GDB configuration commands in your `.gdbinit` file, which is loaded automatically when you start GDB.

This section describes the basic MDI usage; refer to the documentation for your MDI simulator or debug device for details specific to that target. Note, in particular, that some MDI targets may require you to set up a configuration file and/or license in addition to the steps given here.

In order to tell GDB which MDI library to load, on Linux hosts you should add the directory containing the shared library files to your `LD_LIBRARY_PATH` environment variable. On Windows hosts, add the directory containing the DLLs to your `PATH` environment variable. Then, either set the environment variable `GDBMDILIB` to the base name of the MDI library before starting GDB, or select the library within GDB using the command:

```
(gdb) set mdi library name
```

To verify that your shared library configuration is correct, you can query it from GDB for the devices it supports:

```
(gdb) show mdi devices
```

Each device is identified by a target number and device number. You can select the values you want to use with the following GDB commands:

```
(gdb) set mdi target targetnum
(gdb) set mdi device devicenum
```

Alternatively, you can set the environment variables `GDBMDITARGET` and `GDBMDIDEVICE`.

At this point, you can establish a connection to the selected MDI device using:

```
(gdb) target mdi
```

Then you can load and run your program on the target.

Chapter 6
CS3™: The CodeSourcery Common Startup Code Sequence

CS3 is CodeSourcery's low-level board support library. This chapter describes the organization of the system startup code and tells you how you can customize it, such as by defining your own interrupt handlers. This chapter also documents the boards supported by Sourcery G++ Lite and the compiler and linker options you need to use with them.

Many developers turn to the GNU toolchain for its cross-platform consistency: having a single system support so many different processors and boards helps to limit risk and keep learning curves gentle. Historically, however, the GNU toolchain has lacked a consistent set of conventions for processor- and board-level initialization, language run-time setup, and interrupt and trap handler definition.

The CodeSourcery Common Startup Code Sequence (CS3) addresses this problem. For each supported system, CS3 provides a set of linker scripts describing the system's memory map, and a board support library providing generic reset, startup, and interrupt handlers. These scripts and libraries all follow a standard set of conventions across a range of processors and boards.

6.1. Startup Sequence

CS3 divides the startup sequence into three phases:

- In the *hard reset phase*, we initialize the memory controller and set up the memory map.
- In the *assembly initialization phase*, we prepare the stack to run C code, and jump to the C initialization function.
- In the *C initialization phase*, we initialize the data areas, run constructors for statically-allocated objects, and call `main`.

The hard reset and assembly initialization phases are necessarily written in assembly language; at reset, there may not yet be stack to hold compiler temporaries, or perhaps even any RAM accessible to hold the stack. These phases do the minimum necessary to prepare the environment for running simple C code. Then, the code for the final phase may be written in C; CS3 leaves as much as possible to be done at this point.

The CodeSourcery board support library provides default code for all three phases. The hard reset phase is implemented by board-specific code. The assembly initialization phase is implemented by code specific to the processor family. The C initialization phase is implemented by generic code.

6.1.1. The Hard Reset Phase

This phase is responsible for initializing board-specific registers, such as memory base registers and DRAM controllers, or scanning memory to check the available size. It is written in assembler and ends with a jump to `_start`, which is where the assembly initialization phase begins.

The hard reset code is in a section named `.cs3.reset`. The section must define a symbol named `__cs3_reset_`*`sys`*, where *`sys`* is a name for the board being initialized; for example, the reset code for a Malta 24Kc board would be named `__cs3_reset_malta_24kc`. The linker script defines the symbol `__cs3_reset` to refer to this reset address. If you need to refer to the reset address from generic code, you can use this non-specific `__cs3_reset` name.

When using the Sourcery G++ Debug Sprite, the Sprite is responsible for carrying out the initialization done in this phase. In this case execution begins at the start of the assembly initialization phase, except for simulators as described below.

Some simulators provide a supervisory operation to determine the amount of available memory. This operation is performed in the hard reset phase. Thus for simulators, execution always begins at `__cs3_reset_`*`sys`*.

The CodeSourcery board support library provides reasonable default reset code, but you may provide your own reset code by defining `__cs3_reset_`*`sys`* in an object file or library, in a `.cs3.reset` section.

6.1.2. The Assembly Initialization Phase

This phase is responsible for initializing the stack pointer and creating an initial stack frame. It ends with a call or jump to `__cs3_start_c`. The symbol `_start` marks the entry point of the assembly initialization code.

The value of the symbol `__cs3_stack` provides the initial value of the stack pointer. The CodeSourcery linker scripts provide a default value for this symbol, which you may override by defining `__cs3_stack` yourself.

Some processors initialize the stack pointer automatically on reset. However, because the assembly initialization phase is executed during debugging, it is required to set the stack pointer explicitly here in all cases.

The initial stack frame is created for the use of ordinary C and C++ calling conventions. The stack should be initialized so that backtraces stop cleanly at this point; this might entail zeroing a dynamic link pointer, or providing hand-written DWARF call frame information.

Finally, we call the C function `__cs3_start_c`. This function never returns, and `_start` need not be prepared to handle a return from it.

As with the hard reset code, the CodeSourcery board support library provides reasonable default assembly initialization code. However, you may provide your own code by providing a definition for `_start`, either in an object file or a library.

The symbol `_start` lacks the `__cs3` prefix, because many debuggers and integrated development environments assume that name is used for this purpose.

6.1.3. The C Initialization Phase

Finally, C code can be executed. The C startup function is declared as follows:

```
void __cs3_start_c (void) __attribute__ ((noreturn));
```

In this function we take the following steps:

- Initialize all `.data`-like sections by copying their contents.
- Clear all `.bss`-like sections.
- Run constructors for statically-allocated objects, recorded using whatever conventions are usual for C++ on the target architecture.

  CS3 reserves priorities from 0 to 100 for use by initialization code. You can handle tasks like enabling interrupts, initializing coprocessors, pointing control registers at interrupt vectors, and so on by defining constructors with appropriate priorities.
- Call `main` as appropriate.
- Call `exit`, if it is available.

As with the hard reset and assembly initialization code, the CodeSourcery board support library provides a reasonable definition for the `__cs3_start_c` function. You may override this by providing a definition for `__cs3_start_c`, either in an object file or in a library.

The CodeSourcery-provided definition of __cs3_start_c can pass command-line arguments to main using the normal C argc and argv mechanism if the board support package provides corresponding definitions for __cs3_argc and __cs3_argv. For example:

```
int __cs3_argc;
char **__cs3_argv;
```

These variables should be initialized using a constructor function, which is run by __cs3_start_c after it initializes the data segment. Use the constructor attribute on the function definition:

```
__attribute__((constructor))
static void __cs3_init_args (void) {
   __cs3_argc = ...;
   __cs3_argv = ...;
}
```

The constructor function may have an arbitrary name; __cs3_init_args is used only for illustrative purposes here.

If definitions of __cs3_argc and __cs3_argv are not provided, then the default __cs3_start_c function invokes main with zero as the argc argument and a null pointer as argv.

6.2. Exit and Embedded Systems

A program running on an embedded system is usually designed never to exit — if it needs to halt it may simply power down the system. The C and C++ standards leave it unspecified as to whether exit is called at program termination. If the program never exits, then there is no reason to include exit, facilities to run functions registered with atexit, or global destructors. This code would never be run and would therefore just waste space in the application.

The CS3 startup code, by itself, does not cause exit to be present in the application. It dynamically checks whether exit is present, and only calls it if it is. If you require exit to be present, either refer to it within your application, or add -Wl,-u,exit to the linking command line.

Similarly, code to register global destructors is only invoked when atexit is already in the executable; CS3, by itself, does not cause atexit to be present. If you require atexit, either refer to it within your application, or add -Wl,-u,atexit to the linking command line.

6.3. Memory Layout

The header file cs3.h declares variables and types that describe the layout of memory on the system to C code. The variables are defined by the CS3 linker script or in the board support library.

The following variables describe the regions of memory to be initialized at startup:

```
/* The number of elements in __cs3_regions.  */
const size_t __cs3_region_num;

/* An untyped object, aligned on an eight-byte boundary.  */
typedef unsigned char __cs3_byte_align8
                      __attribute__ ((aligned (8)));

struct __cs3_region
{
```

```
  /* Flags for this region.  None defined yet.  */
  unsigned flags;

  __cs3_byte_align8 *init;  /* Region's initial contents.  */
  __cs3_byte_align8 *data;  /* Region's start address.  */

  /* These sizes are always a multiple of eight.  */
  size_t init_size;     /* Size of initial data.  */
  size_t zero_size;     /* Additional size to be zeroed.  */
};

/* An array of memory regions.  __cs3_regions[0] describes
   the region holding .data and .bss.  */
extern const struct __cs3_region __cs3_regions[];
```

The following variables describe the area of memory to be used for the dynamically-allocated heap:

```
/* The addresses of these objects are the start and end of
   free space for the heap, typically following .data and .bss.
   However, &__cs3_heap_end may be zero, meaning that we must
   determine the heap limit in some other way --- perhaps via a
   supervisory operation on a simulator, or simply by treating
   the stack pointer as the limit.  */
extern __cs3_byte_align8 __cs3_heap_start[];
extern __cs3_byte_align8 __cs3_heap_end[];

/* The end of free space for the heap, or zero if we haven't been
   able to determine it.  It usually points to __cs3_heap_end,
   but in some configurations, may be overridden by a supervisory
   call in the reset code.  */
extern void *__cs3_heap_limit;
```

For each region named *R*, `cs3.h` declares the following variables:

```
/* The start of the region.  */
extern unsigned char __cs3_region_start_R[]
                     __attribute__ ((aligned (8)));

/* The region's size, in bytes.  */
extern const size_t __cs3_region_size_R;
```

At the assembly level, the linker script also defines symbols with the same names and values.

If the region is initialized, then `cs3.h` also declares the following variables, corresponding to the region's element in `__cs3_regions`:

```
/* The data we initialize the region with.  */
extern const unsigned char __cs3_region_init_R[]
                           __attribute__ ((aligned (8)));

/* The size of the initialized portion of the region.  */
extern const size_t __cs3_region_init_size_R;

/* The size of the additional portion to be zeroed.  */
extern const size_t __cs3_region_zero_size_R;
```

Any of these identifiers may actually be defined as preprocessor macros that expand to expressions of the appropriate type and value.

Like the `struct __cs3_region` members, these regions are all aligned on eight-byte boundaries, and their sizes are multiples of eight bytes.

CS3 linker scripts place the contents of sections named `.cs3.region-head.`*`R`* at the start of each memory region. Note that CS3 itself may want to place items (like interrupt vector tables) at these locations; if there is a conflict, CS3 raises an error at link time.

6.4. Interrupt Vectors and Handlers

CS3 provides standard handlers for interrupts, exceptions and traps, but also allows you to easily define your own handlers as needed. In this section, we use the term *interrupt* as a generic term for this entire class of events.

Different processors handle interrupts in various ways, but there are two general approaches:

- Some processors fetch an address from an array indexed by the interrupt number, and jump to that address. We call these *address vector* processors; 24Kc systems are a typical example.
- Others multiply the interrupt number by some constant factor, add a base address, and jump directly to that address. Here, the interrupt vector consists of blocks of code, so we call these *code vector* processors; PowerPC systems are a typical example.

On address vector processors, the CS3 library provides an array of pointers to interrupt handlers named `__cs3_interrupt_vector_`*`form`*, occupying a section named `.cs3.interrupt_vector`, where *`form`* identifies the particular processor variant the vector is appropriate for. If the processor supports more than one variety of interrupt vector (for example, a full-length form and a shortened form), then *`form`* identifies the variety as well. Each entry in the vector holds a reference to a symbol named `__cs3_isr_`*`int`*, where *`int`* is the customary name of that interrupt on the processor, or a number if there is no consistently used name. The library further provides a reasonable default definition for each `__cs3_isr_`*`int`* handler routine.

To override an individual handler, provide your own definition for the appropriate `__cs3_isr_`*`int`* symbol. The definition need not be placed in any particular object file section.

Interrupt handlers may be written in C using the `interrupt` attribute. For example, to override the `__cs3_isr_access_error` handler, use the following definition:

```
void __attribute__ ((interrupt)) __cs3_isr_access_error (void)
{
  ... custom handler code ...
}
```

To override the entire interrupt vector, you can define `__cs3_interrupt_vector_`*`form`*, placing the definition in a section named `.cs3.interrupt_vector`. The linker script reports an error if the `.cs3.interrupt_vector` section is empty, to ensure that the definition of `__cs3_interrupt_vector_`*`form`* occupies the proper section.

You may define the vector in C with an array of pointers using the `section` attribute to place it in the appropriate section. For example, to override the interrupt vector on a Malta 24Kc board, make the following definition:

```
typedef void handler(void);
handler *__attribute__((section (".cs3.interrupt_vector")))
  __cs3_interrupt_vector_coldfire[] =
{ ... };
```

On code vector processors, we follow the same conventions, with the following exceptions:

- In addition to being named `__cs3_isr_int`, each interrupt handler must also occupy a section named `.cs3.interrupt_int`. Naturally, each handler must fit within a single interrupt vector entry.
- Instead of providing a default definition for `__cs3_interrupt_vector_form` in the library, the linker script gathers the `.cs3.interrupt_int` sections together, in the proper order and on the necessary address boundaries, and defines the `__cs3_interrupt_vector_form` symbol to refer to its start.

To override an individual handler on a code vector processor, you provide your own definition for `__cs3_isr_int`, placed in an appropriate section. The linker script ensures that each `.cs3.interrupt_int` section is non-empty, so that placing a handler in the wrong section elicits an error at link time.

CS3 does not allow you to override the entire interrupt vector on code vector processors, because the code vector must be constructed by the linker script, and thus cannot come from a library or object file. However, the portion of the linker script that constructs the interrupt vector occupies its own file, which other linker scripts can incorporate using the **INCLUDE** linker script command, making it easier to replace the linker script entirely and still take advantage of CS3's other features.

Some processors, like the Innovasic fido, use more than one interrupt vector: the processor provides several interrupt vector pointer registers, each used in different circumstances. Each register may point to a different vector, or some or all may share vectors.

On these processors, CS3 provides only a single pre-constructed interrupt vector, but defines a separate symbol for each interrupt vector pointer register; all the symbols point to the pre-constructed vector by default. The CS3 startup code initializes each register from the corresponding symbol. You can provide your own vectors by defining the appropriate symbols.

For example, the fido processor has five contexts, each of which can use its own interrupt vector; on this architecture, CS3 defines the standard `__cs3_interrupt_vector_fido` symbol referring to the pre-constructed vector, and then goes on to define per-context symbols `__cs3_interrupt_vector_fido_ctx0`, `__cs3_interrupt_vector_fido_ctx1`, and so on, all referring to `__cs3_interrupt_vector_fido`. The CS3 startup code sets each context's vector register to the value of the corresponding symbol. By default, all the contexts share an interrupt vector, but if your code provides its own definition for `__cs3_interrupt_vector_fido_ctx1`, then the startup code initializes context one's register to point to that vector instead.

This arrangement requires you to use a different approach to specify a handler for a secondary context that differs from the corresponding handler in the primary context. For example, to handle division-by-zero exceptions in context 1 with the function `ctx1_divide_by_zero`, you should write the following:

```
typedef void (*handler_type) (void);
handler_type __cs3_interrupt_vector_fido_ctx1[256];
extern handler_type __cs3_interrupt_vector_fido[256];
```

```
__attribute__((interrupt))
void
ctx1_divide_by_zero (void)
{
  /* Your code here.  */
}

__attribute__((constructor))
void
initialize_vector_ctx1 (void)
{
  /* Initialize our custom vector from the
     pre-constructed CS3 vector.  */
  memcpy (__cs3_interrupt_vector_fido_ctx1,
          __cs3_interrupt_vector_fido,
          sizeof (__cs3_interrupt_vector_fido));

  /* Initialize custom interrupt handlers.  */
  __cs3_interrupt_vector_fido_ctx1[5] = ctx1_divide_by_zero;
}
```

With this code in place, when a division-by-zero exception occurs in context 1, the processor calls `ctx1_divide_by_zero` to handle it. Defining `initialize_vector_ctx1` with the `constructor` attribute arranges for CS3 to call it before calling your program's `main` function.

6.5. Linker Scripts

CS3 provides linker scripts for each board that is supported. Each board may be used in a number of different configurations, and these are reflected in the linker script name. The linker scripts are named *`board-profile-hosted`*`.ld`, where *`board`* is the name of the board, *`profile`* describes the memory arrangement used and *`-hosted`* indicates whether semihosting is provided.

> **Caution**
>
> If you do not explicitly specify a linker script, Sourcery G++ produces a link error, preventing you from creating an executable program.

6.5.1. Program and Data Placement

Many boards have both RAM and ROM (flash) memory devices. CS3 provides distinct linker scripts to place the application either entirely in RAM, or in ROM where data is initialized during the C initialization phase.

Some boards have very small amounts of RAM memory. If you use large library functions (such as `printf` and `malloc`), you may overflow the available memory. You may need to use the ROM-based linker scripts for such programs, so that the program itself is stored in ROM. You may be able to reduce the total amount of memory used by your program by replacing portions of the Sourcery G++ runtime library and/or startup code.

6.5.2. Semihosting

CS3 is designed to support boards where there may be no operating system. To allow functions like `open` and `write` to work, a *semihosting* feature is supported, in conjunction with the debugger.

With semihosting enabled, these system calls are translated into equivalent function calls on your host system. You can only use these function calls while connected to the debugger; if you try to use them when disconnected from the debugger, you will get a hardware exception.

A good use of semihosting is to display debugging messages. For example, this program prints a message on the standard error stream on the host:

```
#include <unistd.h>

int main () {
  write (STDERR_FILENO, "Hello, world!\n", 14);
  return 0;
}
```

The hosted CS3 linker scripts provide the semihosting support, and as such programs linked with them may only be run with the debugger. The unhosted CS3 linker scripts provide stub versions of the system calls, which return an appropriate error value in `errno`. If such a stub system call is required in the executable, the linker also produces a warning. Such a warning may indicate that you have left debugging code active, and that your executable is larger than it might need to be.

6.5.3. Choosing a Linker Script from the Command Line

From the command line, you must add `-T` *`script`* to your linking command, where *`script`* is the appropriate linker script. For example, if you are using a Malta 24Kc board, you could link with `-T malta-24kc-ram-hosted.ld`.

6.6. Supported Boards for MIPS ELF

The following linker scripts are provided for mips-sde-elf.

6.6.1. Malta 24Kc

- Processor name: 24Kc
- Processor options: `-march=24kc`
- Memory regions: `ram`

Profile & Hosting	Linker Script	Reset name
RAM Hosted	`malta-24kc-ram-hosted.ld`	`__cs3_reset_malta_24kc`
RAM Unhosted	`malta-24kc-ram.ld`	`__cs3_reset_malta_24kc`
YAMON	`malta-24kc-yamon.ld`	`__cs3_reset_malta_24kc_yamon`

6.7. Interrupt Vector Tables

6.8. Regions and Memory Sections

The following regions are defined for MIPS ELF.

Region	Contents
ram	.data and .bss sections. In ram-based profiles, also contains .text and other program-like sections.

Note that not all regions are provided in every linker script or profile; see the documentation of the individual linker scripts in Section 6.6, “Supported Boards for MIPS ELF”, above.

Regions documented as "Memory regions" correspond to similarly-named program sections. For example, the linker script assigns the .ram section to the ram region. You can explicitly locate data or code in these sections using section attributes in your source C or C++ code. Section attributes are especially useful on code compiled for boards that include special memory banks, such as a fast on-chip cache memory, in addition to the default ram and/or rom regions. CS3 arranges for additional data-like sections to be initialized in the same way as the default .data section.

As an example to illustrate the attribute syntax, you can put a variable v in the .ram section using:

```
int v __attribute__ ((section (".ram")));
```

To declare a function f in this section, use:

```
int f (void) __attribute__ ((section (".ram"))) {...}
```

For more information about attribute syntax, see the GCC manual.

Regions documented as "Other regions" do not have a corresponding program section. Typically, these regions correspond to memory-mapped control and I/O registers that cannot be used for general data or program storage. If you need to manipulate data in these regions, you can use the CS3 memory layout facilities declared in cs3.h, as described in Section 6.3, “Memory Layout”.

Chapter 7
Next Steps with Sourcery G++

This chapter describes where you can find additional documentation and information about using Sourcery G++ Lite and its components.

7.1. Sourcery G++ Knowledge Base

The Sourcery G++ Knowledge Base is available to registered users at the Sourcery G++ Portal[1]. Here you can find solutions to common problems including installing Sourcery G++, making it work with specific targets, and interoperability with third-party libraries. There are also additional example programs and tips for making the most effective use of the toolchain and for solving problems commonly encountered during debugging. The Knowledge Base is updated frequently with additional entries based on inquiries and feedback from customers.

For more information on CodeSourcery support, see Chapter 2, *Sourcery G++ Subscriptions*.

7.2. Manuals for GNU Toolchain Components

Sourcery G++ Lite includes the full user manuals for each of the GNU toolchain components, such as the compiler, linker, assembler, and debugger. Most of the manuals include tutorial material for new users as well as serving as a complete reference for command-line options, supported extensions, and the like.

When you install Sourcery G++ Lite, links to both the PDF and HTML versions of the manuals are created in the shortcuts folder you select. If you elected not to create shortcuts when installing Sourcery G++ Lite, the documentation can be found in the `share/doc/sourceryg++-mips-sde-elf/` subdirectory of your installation directory.

In addition to the detailed reference manuals, Sourcery G++ Lite includes a Unix-style manual page for each toolchain component. You can view these by invoking the **man** command with the pathname of the file you want to view. For example, you can first go to the directory containing the man pages:

```
> cd $INSTALL/share/doc/sourceryg++-mips-sde-elf/man/man1
```

Then you can invoke **man** as:

```
> man ./mips-sde-elf-gcc.1
```

Alternatively, if you use **man** regularly, you'll probably find it more convenient to add the directory containing the Sourcery G++ man pages to your `MANPATH` environment variable. This should go in your `.profile` or equivalent shell startup file; see Section 4.7, “Setting up the Environment” for instructions. Then you can invoke **man** with just the command name rather than a pathname.

Finally, note that every command-line utility program included with Sourcery G++ Lite can be invoked with a `--help` option. This prints a brief description of the arguments and options to the program and exits without doing further processing.

[1] https://support.codesourcery.com/GNUToolchain/