Sourcery G++ Lite

MIPS ELF

Sourcery G++ Lite 4.4-305

Getting Started

Sourcery G++ Lite: MIPS ELF: Sourcery G++ Lite 4.4-305: Getting Started

CodeSourcery, Inc.

Abstract

This guide explains how to install and build applications with Sourcery G++ Lite, CodeSourcery's customized and validated 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 the Sourcery G++ Lite Getting Started guide. It explains the structure of this guide and describes the documentation conventions used.

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, “Quick Start”	This chapter includes a brief checklist to follow when installing and using Sourcery G++ Lite for the first time. You may use this chapter as an abbreviated guide to the rest of this manual.
Chapter 2, “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 3, “Sourcery G++ Lite for MIPS ELF”	This chapter contains information about using Sourcery G++ Lite that is specific to MIPS ELF targets. You should read this chapter to learn how to best use Sourcery G++ Lite on your target system.
Chapter 4, “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 5, “CS3™: The CodeSourcery Common Startup Code Sequence”	CS3 is CodeSourcery's low-level board support library. This chapter documents the boards supported by Sourcery G++ Lite and the compiler and linker options you need to use with them. It also explains how you can use and modify CS3-provided definitions for memory maps, system startup code and interrupt vectors in your own code.
Chapter 6, “Sourcery G++ Debug Sprite”	This chapter describes the use of the Sourcery G++ Debug Sprite for remote debugging. The Sprite allows you to debug programs running on a bare board without an operating system. This chapter includes information about the debugging devices and boards supported by the Sprite for MIPS ELF.
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. It also provides information about Sourcery G++ subscriptions. CodeSourcery customers with Sourcery G++ subscriptions receive comprehensive support for Sourcery G++.
Appendix A, “Sourcery G++ Lite Release Notes”	This appendix contains information about changes in this release of Sourcery G++ Lite for MIPS ELF. You should read through these notes to learn about new features and bug fixes.

Appendix B, “Sourcery G++ Lite Licenses”	This appendix provides information about the software licenses that apply to Sourcery G++ Lite. Read this appendix to understand your legal rights and obligations as a user of Sourcery G++ Lite.

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
Quick Start

This chapter includes a brief checklist to follow when installing and using Sourcery G++ Lite for the first time. You may use this chapter as an abbreviated guide to the rest of this manual.

Sourcery G++ Lite for MIPS ELF is intended for developers working on embedded applications or firmware for boards without an operating system, or that run an RTOS or boot loader. This Sourcery G++ configuration is not intended for Linux or uClinux kernel or application development.

Follow the steps given in this chapter to install Sourcery G++ Lite and build and run your first application program. The checklist given here is not a tutorial and does not include detailed instructions for each step; however, it will help guide you to find the instructions and reference information you need to accomplish each step.

You can find additional details about the components, libraries, and other features included in this version of Sourcery G++ Lite in Chapter 3, “Sourcery G++ Lite for MIPS ELF”.

1.1. Installation and Set-Up

Install Sourcery G++ Lite on your host computer. You may download an installer package from the Sourcery G++ web site[1], or you may have received an installer on CD. The installer is an executable program that pops up a window on your computer and leads you through a series of dialogs to configure your installation. If the installation is successful, it will offer to launch the Getting Started guide. For more information about installing Sourcery G++ Lite, including host system requirements and tips to set up your environment after installation, refer to Chapter 2, “Installation and Configuration”.

Install drivers for your debug device. If you plan to use the Sourcery G++ Debug Sprite, you may need to install drivers, libraries, or other software on your host system. Refer to Chapter 6, “Sourcery G++ Debug Sprite” for a list of supported devices and information about installing drivers and other device set-up. Sourcery G++ Lite also supports third-party debug devices that communicate via the GDB remote serial protocol. If you plan to use one of these devices, follow the manufacturer's directions to connect the device and install any required drivers or software.

1.2. Configuring Sourcery G++ Lite for the Target System

Identify your target board. On bare-metal targets, you must explicitly specify a linker script for your target board on your link command line. Supported boards are listed in Chapter 5, “CS3™: The CodeSourcery Common Startup Code Sequence”. You can also choose a simulator as your target board.

1.3. Building Your Program

Build your program with Sourcery G++ command-line tools. Create a simple test program, and follow the directions in Chapter 4, “Using Sourcery G++ from the Command Line” to compile and link it using Sourcery G++ Lite. On bare-metal targets, you must specify a linker script using the `-T` option on your link command line. Supported boards and linker scripts are listed in Chapter 5, “CS3™: The CodeSourcery Common Startup Code Sequence”.

1.4. Running and Debugging Your Program

The steps to run or debug your program depend on your target system and how it is configured. Choose the appropriate method for your target.

[1] http://www.codesourcery.com/gnu_toolchains/

Run or debug your program in the simulator. Sourcery G++ Lite includes an instruction-set simulator, which provides an easy way to run or debug your program without requiring target hardware. The simulator can be run directly from the command line (see Section 4.3, “Running Applications in the Simulator”) or via the debugger (see Section 4.4, “Running Applications from GDB”).

Debug your program on the target using the Debug Sprite. You can use the Sourcery G++ Debug Sprite to load and execute your program on the target from the debugger. Refer to Section 4.4, “Running Applications from GDB” for instructions on using the Sprite from the GDB command line. Detailed reference material for the Sourcery G++ Debug Sprite, including information about supported debug devices, can be found in Chapter 6, “Sourcery G++ Debug Sprite”.

Run your program on the target using YAMON. You can run programs built with Sourcery G++ Lite on MIPS ELF targets via the YAMON boot monitor. For instructions, refer to Section 3.5, “Using Sourcery G++ with YAMON”. Note that you must select a YAMON linker script profile when building your program.

Debug your program on the target using a third-party debug device. Sourcery G++ supports debugging programs on the remote target using third-party debug devices that can communicate via the GDB remote serial protocol. For command-line GDB instructions, see Section 4.4, “Running Applications from GDB”.

Chapter 2
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.

2.1. 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.

2.2. System Requirements

2.2.1. Host Operating System Requirements

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

- Microsoft Windows 2000, Windows XP, Windows Vista, and Windows 7 systems using IA32, AMD64, and Intel 64 processors.
- GNU/Linux systems using IA32, AMD64, or Intel 64 processors, including Debian 3.1 (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.

Installing on Ubuntu and Debian GNU/Linux Hosts

The Sourcery G++ graphical installer is incompatible with the `dash` shell, which is the default `/bin/sh` for recent releases of the Ubuntu and Debian GNU/Linux distributions. To install Sourcery G++ Lite on these systems, you must make `/bin/sh` a symbolic link to one of the supported shells: `bash`, `csh`, `tcsh`, `zsh`, or `ksh`.

For example, on Ubuntu systems, the recommended way to do this is:

```
> sudo dpkg-reconfigure -plow dash
Install as /bin/sh? No
```

This is a limitation of the installer and uninstaller only, not of the installed Sourcery G++ Lite toolchain.

2.2.2. 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. On Microsoft Windows hosts, the installer uses the location specified by the `TEMP` environment variable for these temporary files. If there is not enough free space on that volume, the installer

prompts for an alternate location. On Linux hosts, the installer puts temporary files in the directory specified by the `IATEMPDIR` environment variable, or `/tmp` if that is not set.

2.2.3. Target System Requirements

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

2.3. 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 2.4, “Installing Sourcery G++ Lite”.

You can download Sourcery G++ Lite from the Sourcery G++ web site[1]. This free version of Sourcery G++, which is made available to the general public, does not include all the functionality of CodeSourcery's product releases. If you prefer, you may instead purchase or register for an evaluation of CodeSourcery's product toolchains at the Sourcery G++ Portal[2].

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. You may also install from a compressed archive with the `.tar.bz2` extension.

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

2.4. Installing Sourcery G++ Lite

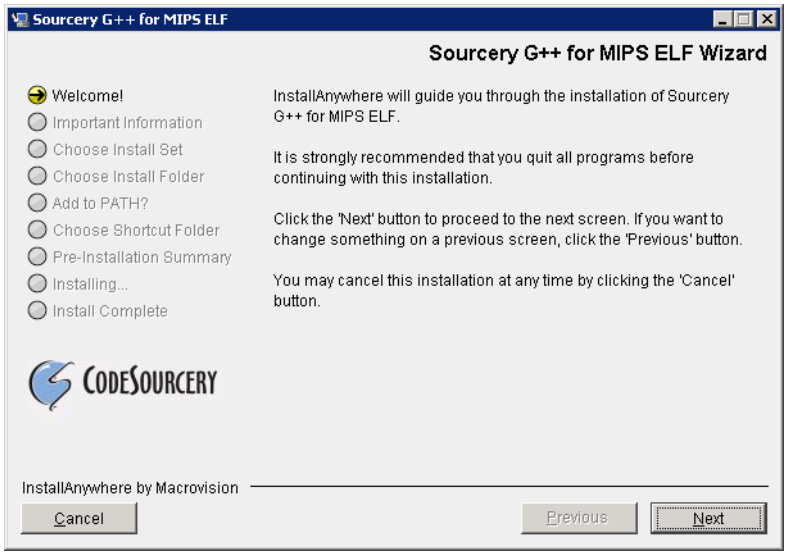
The method used to install Sourcery G++ Lite depends on your host system and the kind of installation package you have downloaded.

2.4.1. Using the Sourcery G++ Lite Installer 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.

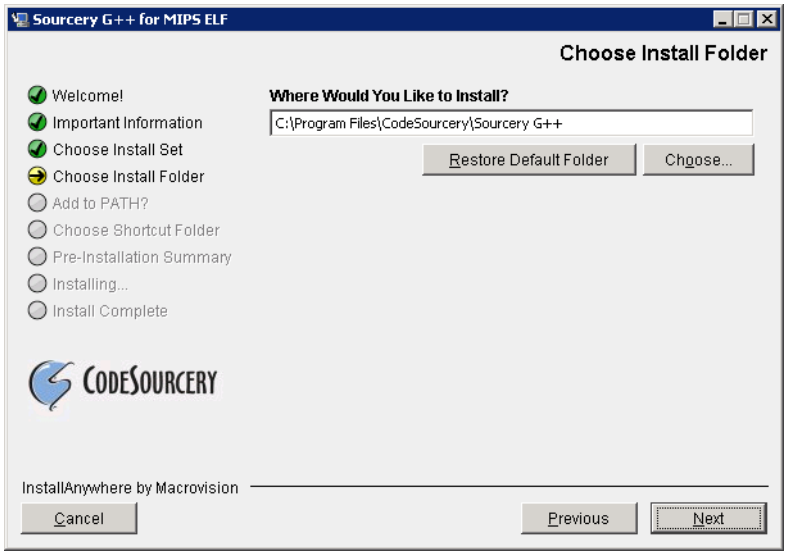
After the installer starts, follow the on-screen dialogs to install Sourcery G++ Lite. The installer is intended to be self-explanatory and on most pages the defaults are appropriate.

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

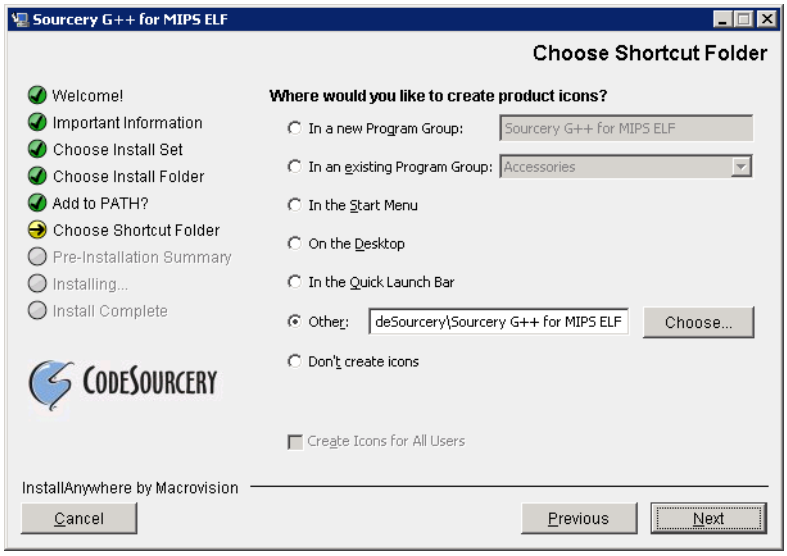


Running the Installer. The graphical installer guides you through the steps to install Sourcery G++ Lite.

You may want to change the install directory pathname and customize the shortcut installation.

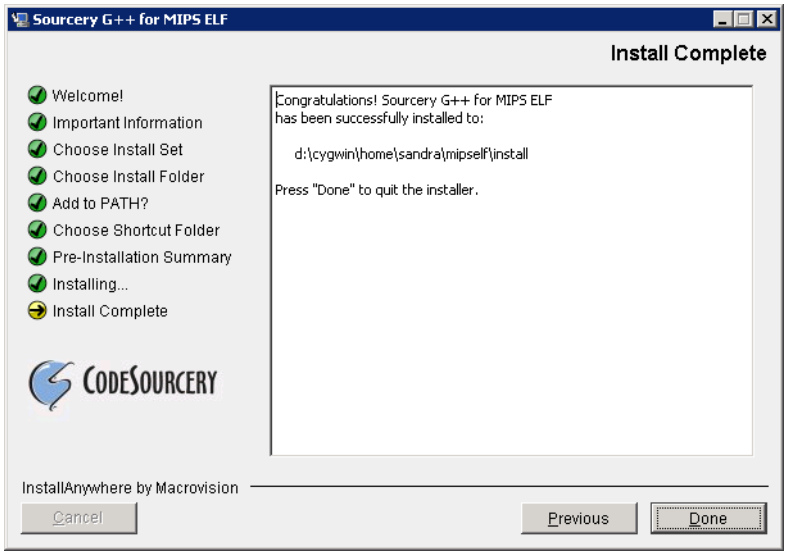


Choose Install Folder. Select the pathname to your install directory.



Choose Shortcut Folder. You can customize where the installer creates shortcuts for quick access to Sourcery G++ Lite.

When the installer has finished, it asks if you want to launch a viewer for the Getting Started guide. Finally, the installer displays a summary screen to confirm a successful install before it exits.



Install Complete. You should see a screen similar to this after a successful install.

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
```

2.4.2. 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. For additional details on running the installer, see the discussion and screen shots in the Microsoft Windows section above.

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
```

2.4.3. Installing Sourcery G++ Lite from a Compressed Archive

You do not need to be a system administrator to install Sourcery G++ Lite from a compressed archive. 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++-4.4`.

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
```

2.5. 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.

2.6. Setting up the Environment

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

2.6.1. Setting up the Environment on Microsoft Windows Hosts

2.6.1.1. Setting the PATH

In order to use the Sourcery G++ tools from the command line, you should add them to your PATH. You may skip this step if you used the graphical installer, since the installer automatically adds Sourcery G++ to your PATH.

To set the PATH on a Microsoft Windows Vista system, 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.

To set the PATH on a system running a Microsoft Windows version other than Vista, from the desktop bring up the Start menu and right click on My Computer. Select Properties, go to the Advanced tab, then click on the Environment Variables button. Select the PATH variable and click the Edit. Add the string ;C:\Program Files\Sourcery G++\bin to the end, and click OK. Again, you must adjust the pathname to reflect your installation directory.

You can verify that your PATH is set up correctly by starting a new cmd.exe shell and running:

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

Verify that the last line of the output contains: Sourcery G++ Lite 4.4-305.

2.6.1.2. 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.

2.6.2. Setting up the Environment on GNU/Linux Hosts

If you installed Sourcery G++ Lite using the graphical installer then you may skip this step. The 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 $HOME/CodeSourcery/Sourcery_G++/bin:$PATH
```

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

```
> PATH=$HOME/CodeSourcery/Sourcery_G++/bin:$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 running the following command:

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

Verify that the last line of the output contains: `Sourcery G++ Lite 4.4-305`.

2.7. Uninstalling Sourcery G++ Lite

The method used to uninstall Sourcery G++ Lite depends on the method you originally used to install it. 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. In particular, the `mips-sde-elf` directory located in the install directory will be removed entirely by the uninstaller.

2.7.1. Using the Sourcery G++ Lite Uninstaller on Microsoft Windows

You should use the provided uninstaller to remove a Sourcery G++ Lite installation originally created by the graphical installer. Start the graphical uninstaller by invoking the executable Uninstall executable located in your installation directory, or use the uninstall shortcut created during installation. 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 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` (non-Vista) or `Uninstall a program` (Vista) to remove the drivers separately. Depending on the device, you may need to reboot your computer to complete the driver uninstall.

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

You should use the provided uninstaller to remove a Sourcery G++ Lite installation originally created by the executable installer script. 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.

2.7.3. Uninstalling a Compressed Archive Installation

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.

Chapter 3
Sourcery G++ Lite for MIPS ELF

This chapter contains information about features of Sourcery G++ Lite that are specific to MIPS ELF targets. You should read this chapter to learn how to best use Sourcery G++ Lite on your target system.

3.1. Included Components and Features

This section briefly lists the important components and features included in Sourcery G++ Lite for MIPS ELF, and tells you where you may find further information about these features.

Component	Version	Notes
GNU programming tools		
GNU Compiler Collection	4.4.1	Separate manual included.
GNU Binary Utilities	2.19.51	Includes assembler, linker, and other utilities. Separate manuals included.
Debugging support and simulators		
GNU Debugger	7.0.50	Separate manual included.
Sourcery G++ Debug Sprite for MIPS	4.4-305	See Chapter 6, “Sourcery G++ Debug Sprite”.
GDB Simulator	N/A	See Section 4.3, “Running Applications in the Simulator”.
Target libraries		
CodeSourcery Common Startup Code Sequence	4.4-305	See Chapter 5, “CS3™: The CodeSourcery Common Startup Code Sequence”.
Newlib C Library	1.17.0	Separate manuals included.
Other utilities		
GNU Make	N/A	Build support on Windows hosts.
GNU Core Utilities	N/A	Build support on Windows hosts.

3.2. Library Configurations

Sourcery G++ Lite for MIPS ELF includes the following library configuration.

MIPS32 revision 2 - Big-Endian, O32	
Command-line option(s):	default
Library subdirectory:	`./`

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

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

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

MIPS32 revision 2 - Soft-Float, O32	
Command-line option(s):	`-msoft-float`
Library subdirectory:	`sof/`

MIPS32 revision 2 - No-Float, O32	
Command-line option(s):	`-mno-float`
Library subdirectory:	`nof/`

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

MIPS32 revision 2 - Big-Endian, O32, micromips	
Command-line option(s):	`-mmicromips`
Library subdirectory:	`micromips/`

MIPS32 revision 2 - Big-Endian, O32, micromips, Soft-Float	
Command-line option(s):	`-mmicromips -msoft-float`
Library subdirectory:	`micromips/sof/`

MIPS32 revision 2 - Little-Endian, O32, micromips	
Command-line option(s):	`-EL -mmicromips`
Library subdirectory:	`el/micromips/`

MIPS32 revision 2 - Little-Endian, O32, micromips, Soft-Float	
Command-line option(s):	`-EL -mmicromips -msoft-float`
Library subdirectory:	`el/micromips/sof/`

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 link a target application, Sourcery G++ selects the multilib matching the build options you have selected.

Sourcery G++ Lite's library support includes linker scripts that pull in appropriate CS3 startup code, as well as the libraries themselves. You can find these linker scripts in multilib-specific subdirectories of the `mips-sde-elf/lib` directory of your Sourcery G++ install.

3.3. CS3 Support

Sourcery G++ Lite includes CS3 linker scripts and initialization code to support three different classes of target configurations:

- Simulator targets, such as MIPSsim, running under control of the debugger.
- Malta or SEAD-3 hardware targets running in a bare-metal configuration under control of the debugger.
- Malta or SEAD-3 hardware targets running under control of the YAMON boot monitor.

You must use the appropriate linker script to match your target, since the memory layouts and startup code sequences are different in each case. Refer to Chapter 5, “CS3™: The CodeSourcery Common Startup Code Sequence” for details on the supported boards for this version of Sourcery G++ Lite.

For simulator and bare-metal targets, CS3 provides semihosted I/O via the debugger console on the host. For instructions on loading and running code on the target from command-line GDB, see Section 4.4, “Running Applications from GDB”.

3.4. Using Sourcery G++ with MIPS Boards

The provided CS3 linker scripts for MIPS Malta and SEAD-3 boards (both bare-metal and YAMON profiles) assume a minimum amount of RAM is available on the target. Refer to the following table for the specific requirements. If your target board has less memory, you must adjust the memory layout used by the linker by specifying a custom linker script.

Board	**Memory Requirement**
Malta	128MB
SEAD-3 LX50	4MB
SEAD-3 LX110	128MB

Find the linker script for your selected profile, such as `mips-sde-elf/lib/malta-ram-hosted.ld`, in your Sourcery G++ Lite installation and copy it to your project

working directory. In your local copy, find the `MEMORY` directive and edit the `LENGTH` expression to match the amount of memory available on your board. Then, use the full absolute pathname of your modified linker script with the `-T` command-line option when linking your program.

3.5. Using Sourcery G++ with YAMON

For YAMON targets, CS3 provides basic I/O services via the YAMON console. This section briefly covers how to load and run programs using YAMON.

To prepare an application to run from YAMON, you must first convert the executable file to SREC format. You can do this from the command line on your host system using the objcopy utility provided with Sourcery G++ Lite.

```
> mips-sde-elf-objcopy -O srec prog prog.srec
```

Next, use YAMON to load the SREC image file into RAM. For example, to load via TFTP, use a command similar to:

```
YAMON> load tftp://host/path/prog.srec
```

Then, start the program from the YAMON prompt:

```
YAMON> go .
```

For more detailed information about YAMON usage and features, refer to the *YAMON User's Manual*.

3.6. Profiling Support

Sourcery G++ Lite includes CS3 support for code profiling on MIPS ELF targets using `gprof`. To enable profiling, compile your program with the `-pg` option. You must also build your program with a hosted linker script.

You can run a program built with profiling from the debugger the same as you would any other hosted application. While your program is running, profiling data is saved in buffers in the heap memory area on the target. This may affect the amount of memory available to your application, and it is also possible that the profiler itself may run out of memory. Profiling data is written to a file on the host (`gmon.out`) only when your application exits. Since many embedded applications are structured to run indefinitely rather than exit, you may need to add an explicit `exit` call in order to collect profiling data.

For instructions on using the `mips-sde-elf-gprof` utility to process the collected `gmon.out` data, refer to the GNU Profiler (gprof) manual included with Sourcery G++ Lite.

3.7. 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 5, “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. If you are using the Sourcery G++ Debug Sprite to debug your program, the Sprite does this automatically, using the memory map provided in the board configuration file. Otherwise, you must provide this information explicitly.

   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.

Although GDB automatically attempts to use hardware breakpoints on code locations in the read-only memory region, on many targets the number of available hardware breakpoints is very small. Furthermore, GDB also uses hardware breakpoints internally to implement commands such as `step`, `next`, and `finish`. Thus the number of breakpoints you can explicitly set in ROM may be fewer than the number supported by the target system.

3.8. Additional Documentation

A document that provides additional details on using Sourcery G++ Lite for MIPS ELF is provided. The document can be found at `share/doc/sourceryg++-mips-sde-elf/pdf/MIPS_TOOLCHAIN.pdf` within your installation directory.

Chapter 4
Using Sourcery G++ from the Command Line

This chapter demonstrates the use of Sourcery G++ Lite from the command line.

4.1. 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 `main.c` containing the following simple factorial program:

```
#include <stdio.h>

int factorial(int n) {
  if (n == 0)
    return 1;
  return n * factorial (n - 1);
}

int main () {
  int i;
  int n;
  for (i = 0; i < 10; ++i) {
    n = factorial (i);
    printf ("factorial(%d) = %d\n", i, n);
  }
  return 0;
}
```

Compile and link this program using the command:

```
> mips-sde-elf-gcc -o factorial main.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 5, “CS3™: The CodeSourcery Common Startup Code Sequence” for information about the boards and linker scripts supported by Sourcery G++ Lite. You must also add the processor options for your board, as documented in that chapter, to your compile and link command lines.

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++`.)

4.2. Running Applications on the Target System

Consult your target board documentation for instructions on loading programs onto the target, and running them. Alternatively, you can use the Sourcery G++ Debug Sprite from within GDB to download and run programs on the target via a supported hardware debugging device.

4.3. 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 factorial
```

You should see the expected output:

```
factorial(0) = 1
factorial(1) = 1
factorial(2) = 2
factorial(3) = 6
factorial(4) = 24
factorial(5) = 120
factorial(6) = 720
factorial(7) = 5040
factorial(8) = 40320
factorial(9) = 362880
```

You can also use the simulator to execute target programs when debugging with GDB. See Section 4.4, “Running Applications from GDB” for more information.

The simulator supports the MIPS32r2 instruction set, including the MIPS16e, MIPS DSP and DSP Revision 2, SmartMIPS, and MIPS-3D ASEs. It can also emulate earlier variants of the MIPS architecture.

4.4. 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.

When starting GDB, give it the pathname to the program you want to debug as a command-line argument. For example, if you have built the factorial program as described in Section 4.1, “Building an Application”, enter:

```
> mips-sde-elf-gdb factorial
```

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.

4.4.1. 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
```

4.4.2. Connecting to the Sourcery G++ Debug Sprite

The Sourcery G++ Debug Sprite is a program that runs on the host system to support hardware debugging devices. You can use the Debug Sprite to run and debug programs on a target board without an operating system, or to debug an operating system kernel. See Chapter 6, “Sourcery G++ Debug Sprite” for detailed information about the supported devices.

You can start the Sprite directly from within GDB:

```
(gdb) target remote | mips-sde-elf-sprite arguments
```

Refer to Section 6.3, “Invoking Sourcery G++ Debug Sprite” for a full description of the Sprite arguments.

4.4.3. 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.

4.4.4. Loading and Running Applications

Connecting to a bare-metal target or simulator from GDB does not cause your program to be loaded into target memory. You must do this explicitly from GDB after you connect:

```
(gdb) load
```

Alternatively, you can use third-party tools to load your application into flash memory before starting GDB.

To begin execution of your application, you should generally use the `continue` command:

```
(gdb) continue
```

However, you should use `run` instead of `continue` to start your program if you used `target sim` to connect:

```
(gdb) run
```

Chapter 5
CS3™: The CodeSourcery Common Startup Code Sequence

CS3 is CodeSourcery's low-level board support library. This chapter documents the boards supported by Sourcery G++ Lite and the compiler and linker options you need to use with them. It also explains how you can use and modify CS3-provided definitions for memory maps, system startup code and interrupt vectors in your own code.

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.

In addition to providing linker support, CS3's functionality is fully integrated with the Sourcery G++ Debug Sprite. For each supported board, CS3 provides the board file containing the memory map and initialization sequence required for debugging applications on the board via the Sprite, as documented in Section 6.7, “Supported Board Files”.

This chapter is organized in two parts. The first part explains CS3 concepts:

- Section 5.1, “Linker Scripts” provides basic information you need to know in order to select an appropriate CS3-provided linker script for your MIPS ELF board.
- CS3's program startup and termination model is discussed in Section 5.2, “Program Startup and Termination”.
- Section 5.3, “Memory Layout” discusses the mapping from program sections to memory regions. It also explains how you can refer to memory regions using CS3-provided symbolic names from C, assembly language, or the linker script, and customize placement of code or data in your program.

The second part provides details about the CS3 implementation for MIPS ELF:

- Section 5.5, “Supported Boards for MIPS ELF” lists the boards supported by CS3 for MIPS ELF, and the available linker scripts for them.

5.1. Linker Scripts

When you build programs for MIPS ELF targets, you must use a linker script. The linker script serves several purposes:

- It determines the memory addresses for placement of code and data sections.
- It defines symbolic names for memory regions present on the board, which you can use programmatically within your code.
- It provides appropriate program startup and termination code, and causes the linker to pull in any low-level board support libraries that are required to run code on the target.
- It optionally provides a *hosting* library for basic I/O functionality.
- It provides a default interrupt vector appropriate for the target processor.

When invoking the Sourcery G++ linker from the command line, you must explicitly supply a linker script using the `-T` option; otherwise a link error results.

CS3 may provide multiple linker scripts for different configurations using the same board. For example, on some boards CS3 may support running the program from either RAM or ROM (flash). Some CS3 link configurations are also designed to co-exist with, or be run from, a boot monitor on

the target board. Simulator targets typically require different startup code configurations than hardware targets. In CS3 terminology, each of these different configurations is referred to as a *profile*.

The remainder of this section discusses profile and hosting selection considerations in more detail. You can find the full list of supported boards and linker scripts included in this release of Sourcery G++ Lite in Section 5.5, “Supported Boards for MIPS ELF”.

5.1.1. 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 to place code and read-only data in ROM.

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 profile 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.

5.1.2. Hosting and Semihosting

CS3 is designed to support boards without an operating system. To allow functions like `open` and `write` to work without operating system support, 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.

Semihosting requires support from the remote GDB debugging stub or agent, as well as the debugger itself. The Sourcery G++ Debug Sprite implements semihosting for all supported devices. Semihosting is also supported by the GDB Simulator included with Sourcery G++ Lite. However, semihosting may not be supported by debugging stubs provided by third parties. If you are using a debug device that communicates with GDB using the GDB remote protocol, check the documentation for your device to see whether semihosting is supported.

A good use of semihosting is to display debugging messages. For example, this program prints a message on the debugger console 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. For production code, or programs where memory usage is tightly constrained, use the unhosted CS3 linker scripts instead. These 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, or that your program contains unused code.

As an alternative to semihosting via the debugger, some targets supported by CS3 can run a boot monitor that provides console I/O services and other basic system calls. CS3 can also provide hosting

via these facilities; where a boot monitor is supported, this is noted in the board tables below. Unlike semihosting, hosting via the boot monitor can be used when running programs outside of the debugger.

5.1.3. Specifying a Linker Script

When using Sourcery G++ from the command line, you must add `-T` *`script`* to your linking command, where *`script`* is the appropriate linker script. For example, to target MIPS Malta boards, you could link with `-T malta-ram-hosted.ld`.

5.2. Program Startup and Termination

This section documents CS3's model for target initialization prior to invoking the `main` function of your program, and aspects of program termination that are left unspecified in the C and C++ standards. It explains how you can customize or override the default behavior for your application.

CS3 divides the startup sequence into three phases:

- The *hard reset phase* (`__cs3_reset`) includes actions such as initializing the memory controller and setting up the memory map.
- The *assembly initialization phase* (`__cs3_start_asm`) prepares the stack to run C code, and jumps to the C initialization function.
- The *C initialization phase* (`__cs3_start_c`) is responsible for initializing the data areas, running constructors for statically-allocated objects, and calling `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- and profile-specific code. The assembly initialization phase is implemented by profile-specific code. The C initialization phase is implemented by generic code.

5.2.1. The Hard Reset Phase

This phase, which begins at `__cs3_reset`, 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 `__cs3_start_asm`, which is where the assembly initialization phase begins.

The hard reset code is in a section named `.cs3.reset`. CS3 linker scripts define `__cs3_reset` as an alias for a board- and profile-specific entry point. You may override the CS3-provided reset code by defining your own `__cs3_reset` entry point in the `.cs3.reset` section.

Program execution always begins at `__cs3_reset`, whether the program is started from the reset vector, the debugger, or a boot monitor. However, the `__cs3_reset` code linked into the application is typically non-empty only for ROM-based profiles. For example, in a RAM-based profile, resetting the memory controllers would overwrite the code being executed.

When using the Sourcery G++ Debug Sprite, the Sprite is responsible for carrying out the hard reset actions before the program is loaded onto the target. This is performed prior to execution of both RAM- and ROM-profile applications from the debugger. Thus, when debugging a ROM-profile ap-

plication, hard reset is actually performed twice — once by the Sprite, and once by the application itself.

5.2.2. The Assembly Initialization Phase

This phase is responsible for initializing the stack pointer and creating an initial stack frame. The symbol `__cs3_start_asm` marks the entry point of the assembly initialization code. The assembly initialization phase ends with a call or jump to `__cs3_start_c`.

The assembly initialization phase is profile-specific. For example, while bare-board applications typically must initialize the stack themselves, CS3 also supports boot-monitor profiles where the stack is initialized by the boot monitor before it launches the application. Likewise, some simulators automatically initialize the stack pointer and initial stack frame on startup, while others require a supervisory operation on startup to determine the amount of available memory. Each of these scenarios requires different assembly initialization behavior.

Note that on bare-board targets setting the stack pointer explicitly in the assembly initialization phase is required even if the processor itself initializes the stack pointer automatically on reset. This is to support running programs from the debugger as well as from processor reset.

For backwards compatibility with previous versions of CS3, on RAM and ROM profiles the symbol `__cs3_start_asm` is actually an alias for a symbol named `_start`. However, referencing or defining `_start` directly is now deprecated.

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

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.

The last action of the assembly initialization phase is to call the C function `__cs3_start_c`. This function never returns, and `__cs3_start_asm` 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 `__cs3_start_asm`, either in an object file or a library.

5.2.3. 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));
```

This function performs the following steps:

- Initialize all `.data`-like sections by copying their contents. For example, ROM-profile linker scripts use this mechanism to initialize writable data in RAM from the read-only data program image.
- 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.

5.2.4. Arguments to `main`

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`.

5.2.5. Program Termination

A program running on an embedded system is usually designed never to exit — it runs until the system is powered down. 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.

5.3. Memory Layout

Boards supported by CS3 can have multiple banks or regions of memory with different characteristics. This section describes how program sections are mapped onto memory regions, and how you can use these CS3 features to customize placement of your program's code or data in memory. CS3 also provides a uniform set of symbolic names for each region, allowing you to programmatically refer to each region's address range from C or assembly language as well as from the linker script.

5.3.1. Memory Regions and Program Sections

The regions that are available on a particular board are listed in the table for that board in Section 5.5, “Supported Boards for MIPS ELF”, below. There are two kinds of regions: those documented as "Memory regions", which are general-purpose memory banks that can be used for program or data storage; and those documented as "Other regions", which typically correspond to memory-mapped control registers or other special-purpose storage.

CS3 supports boards that include both `ram` and `rom` memory regions. The `ram` region holds the `.data` and `.bss` sections, and the `.text` section in RAM profiles. In ROM profiles, the `rom` region holds the `.text` section and initialization values for the writable data sections.

In addition, all regions documented as "Memory regions" correspond to similarly-named program sections. For example, the linker script assigns the `.ram` section to the `ram` region.

More generally, for a memory region named *R*, CS3 linker scripts define a section named `.`*R*, which may contain initialized data or code. There is also a section named `.bss.`*R* for zero-initialized data (BSS), which is placed after the initialized data section for this region.

You can explicitly locate data or code in a section corresponding to a particular memory region 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's start-up code 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.

In addition to the `.`*R* and `.bss.`*R* sections, CS3 places a `.cs3.region-head.`*R* section at the beginning of each region *R*. Explicitly placing data in `.cs3.region-head.`*R* sections is discouraged, because 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.

Regions documented as "Other regions" in the tables in Section 5.5, “Supported Boards for MIPS ELF” do not have corresponding program sections. Typically, these regions contain memory-mapped control and I/O registers and cannot be used for general data or program storage. If your program needs to manipulate data in these regions, you can use the CS3 memory map access interface declared in `cs3.h`, as described in Section 5.3.2, “Programmatic Access to the CS3 Memory Map”.

Memory maps for boards supported by Sourcery G++ Lite for MIPS ELF are documented in the linker scripts in the `mips-sde-elf/lib/` subdirectory of your Sourcery G++ installation directory.

5.3.2. Programmatic Access to the CS3 Memory Map

CS3 makes C declarations describing the memory regions on the target board available to your program via the header file `cs3.h`, which you can find in the `mips-sde-elf/include` directory within your install.

For each region named *R*, `cs3.h` declares a byte array variable `__cs3_region_start_`*R* at the region's start address, and a `size_t` variable `__cs3_region_size_`*R* to represent the total size of the region. These symbols are defined by the linker script and so may also be referenced from assembly language. Note that all regions are aligned on eight-byte boundaries and sizes are also multiples of eight bytes.

For memory regions that can correspond to program sections (as described in Section 5.3.1, "Memory Regions and Program Sections"), there are additional symbols `__cs3_region_init_`*R* and `__cs3_region_init_size_`*R* that describe constant data used to initialize the region. During the C initialization phase (Section 5.2, "Program Startup and Termination"), this data is copied into the lower part of the memory region. The symbol `__cs3_region_zero_size_`*R* represents the size of the zero-initialized `.bss.`*R* section following the initialized data. Any of these identifiers may actually be defined as a preprocessor macro that expands to an expression of the appropriate type and value.

To perform the memory region initializations during startup, CS3 internally uses the array variable `__cs3_regions`, which contains descriptors for all of the writable (RAM) memory regions. These descriptors are also exposed in `cs3.h`; refer to the header file for details.

5.3.3. Heap and Stack Placement

CS3 linker scripts provide default placement of the heap and stack in the RAM region. However, you can override the defaults by providing your own definitions of the associated CS3 variables. For example, you may put the heap and/or stack in some other memory region.

Heap placement is controlled by defining the symbol `__cs3_heap_start` at the beginning of the heap, and either the symbol `__cs3_heap_end` or the pointer variable `__cs3_heap_limit` to mark the end of the heap. For example, this fragment of C code places the heap in a region named `extsram`:

```
#define HEAPSIZE ...  /* However big you want to make it. */
unsigned char __cs3_heap_start[HEAPSIZE]
    __attribute__ ((section (".bss.extsram"), aligned(8)));
unsigned char *__cs3_heap_limit = __cs3_heap_start + HEAPSIZE;
```

The default initial stack pointer for bare-metal profiles is given by the symbol `__cs3_stack`. Stack initialization is discussed in more detail in Section 5.2.2, "The Assembly Initialization Phase".

You can find C declarations for the CS3 heap and stack symbols in the header file `cs3.h`.

5.4. Interrupt Vectors and Handlers

CS3 provides standard handlers for interrupts, exceptions and traps, but also allows you to 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.
- 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.

MIPS processors use the code vector model. The remainder of this section assumes that you have some understanding of the specific requirements for your target; refer to the architecture manuals if necessary.

5.4.1. MIPS ELF Interrupt Vector Implementation

On MIPS ELF targets, CS3 provides interrupt and exception handling support using the MIPS SDE library interface, which is integrated with the exception support provided by the YAMON boot monitor. The interfaces are modelled on the POSIX signal handling mechanism and are declared in the C header file `mips/xcpt.h`.

5.4.2. Writing Interrupt Handlers

Interrupt handlers typically require special call/return and register usage conventions that are target-specific and beyond the scope of this document. In many cases, normal C functions cannot be used as interrupt handlers.

As an alternative to writing interrupt handlers in assembly language, on MIPS targets they may be written in C using the `interrupt` attribute. This tells the compiler to generate appropriate function entry and exit sequences for an interrupt handler. There are additional MIPS-specific attributes you can specify to modify the behavior of the interrupt handler. Refer to the GCC manual for more details about attribute syntax and usage.

5.5. Supported Boards for MIPS ELF

CS3 provides support for the following boards on MIPS ELF targets.

MIPS Malta		
Processor name:	unspecified	
Processor options:	none	
Memory regions:	`ram`	
Linker scripts:	RAM Hosted	`malta-ram-hosted.ld`
	RAM Unhosted	`malta-ram.ld`
	YAMON	`malta-yamon.ld`

MIPS SEAD-3 LX110		
Processor name:	unspecified	
Processor options:	none	
Memory regions:	`ram`	
Linker scripts:	RAM Hosted	`sead3-lx110-ram-hosted.ld`
	RAM Unhosted	`sead3-lx110-ram.ld`
	YAMON	`sead3-lx110-yamon.ld`

MIPS SEAD-3 LX50		
Processor name:	unspecified	
Processor options:	none	
Memory regions:	`ram`, `isram` (64K Instruction SRAM), `dsram` (64K Data SRAM)	
Linker scripts:	RAM Hosted	`sead3-lx50-ram-hosted.ld`
	RAM Unhosted	`sead3-lx50-ram.ld`
	Dual SRAM Hosted	`sead3-lx50-dual-sram-hosted.ld`
	Dual SRAM Unhosted	`sead3-lx50-dual-sram.ld`
	YAMON	`sead3-lx50-yamon.ld`
	YAMON Dual SRAM	`sead3-lx50-yamon-dual-sram.ld`

MIPSsim		
Processor name:	unspecified	
Processor options:	none	
Memory regions:	`ram`	
Linker scripts:	Simulator Hosted	`mipssim-hosted.ld`
	Simulator Unhosted	`mipssim.ld`

Chapter 6
Sourcery G++ Debug Sprite

This chapter describes the use of the Sourcery G++ Debug Sprite for remote debugging. The Sprite allows you to debug programs running on a bare board without an operating system. This chapter includes information about the debugging devices and boards supported by the Sprite for MIPS ELF.

Sourcery G++ Lite contains the Sourcery G++ Debug Sprite for MIPS ELF. This Sprite is provided to allow debugging of programs running on a bare board. You can use the Sprite to debug a program when there is no operating system on the board, or for debugging the operating system itself. If the board is running an operating system, and you wish to debug a program running on that OS, you should use the facilities provided by the OS itself (for instance, using `gdbserver`).

The Sprite acts as an interface between GDB and external debug devices and libraries. Refer to Section 6.3, "Invoking Sourcery G++ Debug Sprite" for information about the specific devices supported by this version of Sourcery G++ Lite.

Important

The Sourcery G++ Debug Sprite is not part of the GNU Debugger and is not free or open-source software. You may use the Sourcery G++ Debug Sprite only with the GNU Debugger. You may not distribute the Sourcery G++ Debug Sprite to any third party.

6.1. Probing for Debug Devices

Before running the Sourcery G++ Debug Sprite for the first time, or when attaching new debug devices to your host system, it is helpful to verify that the Sourcery G++ Debug Sprite recognizes your debug hardware. From the command line, invoke the Sprite with the `-i` option:

```
> mips-sde-elf-sprite -i
```

This prints out a list of supported device types. For devices that can be autodetected, it additionally probes for and prints out a list of attached devices. For instance:

```
CodeSourcery MIPS Debug Sprite (Sourcery G++ Lite 4.4-305)
mdi: [lib=<file>&cfg=<file>&rst=<n>] MDI device
  mdi:/23/1 - 24KE     (Instruction)/24KE LE
  mdi:/23/2 - 24KE     (Instruction)/24KE BE
  mdi:/24/1 - 24KE     (Cycle)/24KE LE
  mdi:/24/2 - 24KE     (Cycle)/24KE BE
  mdi:/$Target/$Device - Generic MDI target/device
```

This shows that MDI (Microprocessor Debug Interface) devices are supported. Four MIPSsim devices have been autodetected. Note that additional configuration steps for the MDI library are required to allow the Sprite to autodetect devices; see Section 6.5, "MDI Devices".

6.2. Debug Sprite Example

Start by compiling and linking a simple test program for your target board, following the instructions in Chapter 4, "Using Sourcery G++ from the Command Line". Use the `-g` option to tell the compiler to generate debugging information.

For example, to build the `factorial` program to run on MIPSsim, use:

```
> mips-sde-elf-gcc -g -Tmipssim-hosted.ld  main.c -o factorial
```

Next start the debugger on your host system:

```
> mips-sde-elf-gdb factorial
```

To connect GDB to the MDI target, use a command similar to:

```
(gdb) target remote | mips-sde-elf-sprite mdi:/23/2 mipssim
```

Refer to Section 6.5, “MDI Devices” for additional set-up required to use the Sprite with MDI devices.

The Sprite prints some status messages as it connects to your debug device and target board. If the connection is successful, you should see output similar to:

```
mips-sde-elf-sprite:Target reset
0x00008936 in ?? ()
(gdb)
```

Next, use GDB to load your program onto the target board.

```
(gdb) load
```

At this point you can use GDB to control the execution of your program as required. For example:

```
(gdb) break main
(gdb) continue
```

6.3. Invoking Sourcery G++ Debug Sprite

The Debug Sprite is invoked as follows:

```
> mips-sde-elf-sprite [options] device-url board-file
```

The *device-url* specifies the debug device to use to communicate with the board. It follows the standard format:

```
scheme:scheme-specific-part[?device-options]
```

Most device URL schemes also follow the regular format:

```
scheme:[//hostname:[port]]/path[?device-options]
```

The meanings of *hostname*, *port*, *path* and *device-options* parts depend on the *scheme* and are described below. The following schemes are supported in Sourcery G++ Lite for MIPS ELF:

`mdi` Use a Microprocessor Debug Interface (MDI) debugging device. Refer to Section 6.5, “MDI Devices”.

The optional `?`*device-options* portion is allowed in all schemes. These allow additional device-specific options of the form *name=value*. Multiple options are concatenated using `&`.

The *board-file* specifies an XML file that describes how to initialize the target board, as well as other properties of the board used by the debugger. If *board-file* refers to a file (via a relative or absolute pathname), it is read. Otherwise, *board-file* can be a board name, and the toolchain's board directory is searched for a matching file. See Section 6.7, “Supported Board Files” for the list of supported boards, or invoke the Sprite with the `-b` option to list the available board files. You can also write a custom board file; see Section 6.8, “Board File Syntax” for more information about the file format.

Both the *device-url* and *board-file* command-line arguments are required to correctly connect the Sprite to a target board.

6.4. Sourcery G++ Debug Sprite Options

The following command-line options are supported by the Sourcery G++ Debug Sprite:

`-b` Print a list of *`board-file`* files in the board config directory.

`-h` Print a list of options and their meanings. A list of *`device-url`* syntaxes is also shown.

`-i` Print a list of the accessible devices. If a *`device-url`* is also specified, only devices for that device type are scanned. Each supported device type is listed along with the options that can be appended to the *`device-url`*. For each discovered device, the *`device-url`* is printed along with a description of that device.

`-l` *`[host]:port`* Specify the host address and port number to listen for a GDB connection. If this option is not given, the Debug Sprite communicates with GDB using stdin and stdout. If you start the Sprite from within GDB using the `target remote | mips-sde-elf-sprite ...` command, you do not need this option.

`-m` Listen for multiple sequential connections. Normally the Debug Sprite terminates after the first connection from GDB terminates. This option instead makes it listen for a subsequent connection. To terminate the Sprite, open a connection and send the string `END\n`.

`-q` Do not print any messages.

`-v` Print additional messages.

If any of `-b`, `-i` or `-h` are given, the Debug Sprite terminates after providing the information rather than waiting for a debugger connection.

6.5. MDI Devices

The Sourcery G++ Debug Sprite for MIPS supports MDI (Microprocessor Debug Interface) devices. Each MDI device is identified by a target number and device number; these form the *`path`* part of the device URL, and the *`hostname`* and *`port`* must be empty or omitted. Thus, the *`device-url`* has the form:

```
mdi:///targetnum/devicenum[?device-options]
```

You can also use the environment variables `GDBMDITARGET` and `GDBMDIDEVICE` to provide defaults for the *`targetnum`* and *`devicenum`*.

The following *`device-options`* are permitted:

`lib=`*`filename`* This option specifies the MDI library to load. It is equivalent to setting the `GDBMDILIB` environment variable.

`cfg=`*`filename`* Some MDI target libraries, such as MIPSsim, require a configuration file. (This is distinct from the Sprite's own *`board-file`*.) You can use this option to specify the file. It is equivalent to setting the `GDBMIPSSIMCONFIG` environment variable.

`rst=`*`seconds`*

This option can be used to specify a delay after the target is reset by the Sprite. If the value of *`seconds`* is greater than zero, then execution is resumed for the specified number of seconds; this can be used to allow power-on firmware to initialize the memory controller and peripherals. Then the target is halted again and queried for configuration.

If the value of *`seconds`* is `-1`, then the target is queried immediately without reset. This is the same effect as passing the `-a` command-line option to the Sprite, which allows the Sprite to attach to a running program.

This option is equivalent to setting the `GDBMDICONNRST` environment variable. If neither the option nor the environment variable are provided, the default is to reset the target and query it immediately unless the `-a` option is specified.

`group=`*`/targetn/devicen`*

This option may be specified multiple times and is cumulative. Each of the specified devices is opened and queried and they are all treated as threads of execution, subject to being enabled or active; if a device is disabled or has no active thread contexts associated with it, it is not visible to GDB but is still under control of the Sprite in case its state changes. This option cannot be used in combination with the `team=` option.

`team=`*`/targetn/devicen`*

This option may be specified multiple times and is cumulative. The specified devices are not opened, but are associated with the base device by means of the MDI team mechanism for the purpose of synchronization. The specified devices may still be opened and controlled by another debugger (such as another instance of the Debug Sprite) independently. This option cannot be used in combination with the `group=` option.

Before you can connect to a target using the MDI API, you must tell the Debug Sprite which shared library or DLL to load for your simulator or device. 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 the Debug Sprite, or use the `lib=` device option to specify the library to load.

Similarly, the `-i` command-line option can only probe for devices if you have set the `PATH` or `LD_LIBRARY_PATH` environment variable appropriately, and specify an MDI library using either the `GDBMDILIB` environment variable or the `lib=` device option. Otherwise, it reports only the generic *`device-url`* syntax.

For example, to use an FS2 probe on a Windows host to debug a MIPS Malta board, first add the directory containing the MDI DLLs to your `PATH`. Then you can invoke the Sprite from GDB using a command line similar to:

```
(gdb) target remote | mips-sde-elf-sprite \
'mdi:/2/2?lib=jnetfs2mdilib.dll&rst=7' malta
```

The quotes are required to prevent special characters in the *`device-url`* from being interpreted by the shell.

In the above command, the `rst=7` option provides for a sufficient delay for the board's reset code to execute on connection. Since this takes several seconds, GDB may time out waiting for the Sprite to respond. You can prevent this by issuing this command before you connect to the Sprite:

```
(gdb) set remotetimeout 10
```

To use the Sprite with MIPSsim, a configuration file is required. The configuration files provided with the MIPSsim distribution are intended for use with standalone execution from the command line, rather than running the program from the debugger. So, make a copy and comment out the `APP_FILE` setting. It is also recommended that you comment out `TRACE_FILE` as well, since the trace files can be very large.

To connect to MIPSsim using the Sprite on a Linux host, first set your `LD_LIBRARY_PATH` and `GDBMDILIB` as described above. You can run the Sprite from the shell to probe for devices to verify that your setup is correct:

```
> mips-sde-elf-sprite -i
```

Then, from GDB, use a command similar to:

```
(gdb) target remote | mips-sde-elf-sprite \
'mdi:/23/2?cfg=24KE.cfg&rst=-1' mipssim
```

Fill in your target and device numbers as reported by the probe output, and the full pathname to your configuration file. The `rst=-1` option is required, as MIPSsim does not support reset.

This section describes only 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 license in addition to the steps given here.

6.6. Debugging a Remote Board

You can run the Sourcery G++ Debug Sprite on a different machine from the one on which GDB is running. For example, if your board is connected to a machine in your lab, you can run the debugger on your laptop and connect to the remote board. The Sourcery G++ Debug Sprite must run on the machine that is connected to the target board. You must have Sourcery G++ installed on both machines.

To use this mode, you must start the Sprite with the `-l` option and specify the port on which you want it to listen. For example:

```
> mips-sde-elf-sprite -l :10000 device-url board-file
```

starts the Sprite listening on port 10000.

When running GDB from the command line, use the following command to connect GDB to the remote Sprite:

```
(gdb) target remote host:10000
```

where *`host`* is the name of the remote machine. After this, debugging is just as if you are debugging a target board connected to your host machine.

For more detailed instructions on using the Sourcery G++ Debug Sprite in this way, please refer to the Sourcery G++ Knowledge Base[1].

6.7. Supported Board Files

The Sourcery G++ Debug Sprite for MIPS ELF includes support for the following target boards. Specify the appropriate *`board-file`* as an argument when invoking the Sprite from the command line.

Board	**Config**
MIPS Malta	`malta`
MIPS SEAD-3 LX110	`sead3-lx110`
MIPS SEAD-3 LX50	`sead3-lx50`
MIPSsim	`mipssim`

6.8. Board File Syntax

The *`board-file`* can be a user-written XML file to describe a non-standard board. The Sourcery G++ Debug Sprite searches for board files in the `mips-sde-elf/lib/boards` directory in the installation. Refer to the files in that directory for examples.

The file's DTD is:

```
<!-- Board description files

     Copyright (c) 2007-2009 CodeSourcery, Inc.

     THIS FILE CONTAINS PROPRIETARY, CONFIDENTIAL, AND TRADE
     SECRET INFORMATION OF CODESOURCERY AND/OR ITS LICENSORS.

     You may not use or distribute this file without the express
     written permission of CodeSourcery or its authorized
     distributor.  This file is licensed only for use with
     Sourcery G++.  No other use is permitted.
     -->

<!ELEMENT board
 (properties?, feature?, initialize?, memory-map?)>

<!ELEMENT properties
 (description?, property*)>

<!ELEMENT initialize
 (write-register | write-memory | delay
  | wait-until-memory-equal | wait-until-memory-not-equal)* >
<!ELEMENT write-register EMPTY>
<!ATTLIST write-register
          address CDATA   #REQUIRED
                        value   CDATA   #REQUIRED
```

[1] https://support.codesourcery.com/GNUToolchain/kbentry132

```
                        bits    CDATA   #IMPLIED>
<!ELEMENT write-memory EMPTY>
<!ATTLIST write-memory
          address CDATA   #REQUIRED
                        value   CDATA   #REQUIRED
                        bits    CDATA   #IMPLIED>
<!ELEMENT delay EMPTY>
<!ATTLIST delay
          time CDATA   #REQUIRED>
<!ELEMENT wait-until-memory-equal EMPTY>
<!ATTLIST wait-until-memory-equal
          address CDATA   #REQUIRED
                        value   CDATA   #REQUIRED
                        timeout CDATA   #IMPLIED
                        bits    CDATA   #IMPLIED>
<!ELEMENT wait-until-memory-not-equal EMPTY>
<!ATTLIST wait-until-memory-not-equal
          address CDATA   #REQUIRED
                        value   CDATA   #REQUIRED
                        timeout CDATA   #IMPLIED
                        bits    CDATA   #IMPLIED>

<!ELEMENT memory-map (memory-device)*>
<!ELEMENT memory-device (property*, description?, sectors*)>
<!ATTLIST memory-device
                        address CDATA   #REQUIRED
          size    CDATA   #REQUIRED
          type    CDATA   #REQUIRED
                        device  CDATA   #IMPLIED>

<!ELEMENT description (#PCDATA)>
<!ELEMENT property (#PCDATA)>
<!ATTLIST property name CDATA #REQUIRED>
<!ELEMENT sectors EMPTY>
<!ATTLIST sectors
 size CDATA #REQUIRED
 count CDATA #REQUIRED>

<!ENTITY % gdbtarget SYSTEM "gdb-target.dtd">
%gdbtarget;
```

All values can be provided in decimal, hex (with a `0x` prefix) or octal (with a `0` prefix). Addresses and memory sizes can use a `K`, `KB`, `M`, `MB`, `G` or `GB` suffix to denote a unit of memory. Times must use a `ms` or `us` suffix.

The following elements are available:

`<board>` — This top-level element encapsulates the entire description of the board. It can contain `<properties>`, `<feature>`, `<initialize>` and `<memory-map>` elements.

`<properties>` — The `<properties>` element specifies specific properties of the target system. This element can occur at most once. It can contain a `<description>` element.

`<initialize>` The `<initialize>` element defines an initialization sequence for the board, which the Sprite performs before downloading a program. It can contain `<write-register>`, `<write-memory>` and `<delay>` elements.

`<feature>` This element is used to inform GDB about additional registers and peripherals available on the board. It is passed directly to GDB; see the GDB manual for further details.

`<memory-map>` This element describes the memory map of the target board. It is used by GDB to determine where software breakpoints may be used and when flash programming sequences must be used. This element can occur at most once. It can contain `<memory-device>` elements.

`<memory-device>` This element specifies a region of memory. It has four attributes: `address`, `size`, `type` and `device`. The `address` and `size` attributes specify the location of the memory device. The `type` attribute specifies that device as `ram`, `rom` or `flash`. The `device` attribute is required for `flash` regions; it specifies the flash device type. The `<memory-device>` element can contain a `<description>` element.

`<write-register>` This element writes a value to a control register. It has three attributes: `address`, `value` and `bits`. The `bits` attribute, specifying the bit width of the write operation, is optional; it defaults to 32.

`<write-memory>` This element writes a value to a memory location. It has three attributes: `address`, `value` and `bits`. The `bits` attribute is optional and defaults to 32. Bit widths of 8, 16 and 32 bits are supported. The address written to must be naturally aligned for the size of the write being done.

`<delay>` This element introduces a delay. It has one attribute, `time`, which specifies the number of milliseconds, or microseconds to delay by.

`<description>` This element encapsulates a human-readable description of its enclosing element.

`<property>` The `<property>` element allows additional name/value pairs to be specified. The property name is specified in a `name` attribute. The property value is the body of the `<property>` element.

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.

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 2.6, “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/

Appendix A
Sourcery G++ Lite Release Notes

This appendix contains information about changes in this release of Sourcery G++ Lite for MIPS ELF. You should read through these notes to learn about new features and bug fixes.

A.1. Changes in Sourcery G++ Lite for MIPS ELF

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

A.1.1. Changes in Sourcery G++ Lite 4.4-305

GCC fix for reference to undefined label. A bug in the optimizer that caused GCC to emit references to undefined labels has been fixed.

MIPS 34Kn support. Sourcery G++ now includes support for MIPS 34Kn processors. To compile for these processors, use `-march=34kn`.

microMIPS and MIPS16 diagnostic. The compiler now reports an error if the options `-mmicromips` and `-mips16` are both specified.

Array bounds warning bug fix. An optimizer bug has been fixed that caused GCC to incorrectly report the warning `array subscript is above array bounds`.

DSPR2 support. The compiler now automatically enables support for the DSPR2 ASE when the `-march` option is used to specify a core in the 74K family. It is no longer necessary to provide the `-mdspr2` option explicitly.

Static variables and inlining bug fix. A bug in GCC that caused miscompilation of functions containing static variables when they were inlined at `-O2` or above has been fixed. The bug also occurred at other optimization levels when the `-fremove-local-statics` command-line option was used.

Improved linker diagnostic. The linker now produces a less cryptic error message when a jump instruction that does not support interlinking is used to change modes.

C++ code bloat with `-g`. An assembler bug that caused C++ programs that do not use exceptions to include unnecessary library routines when built with debug information enabled has been fixed.

Strip bug fix. A bug has been fixed in the `strip` and `objcopy` utilities which caused them to sometimes produce stripped object files that the linker could not recognize.

Default heap size. The amount of memory reserved for the heap has been increased to 5MB in the CS3-provided linker scripts for all boards except the MIPS SEAD-3 LX50.

Multiple definition linker error. A bug that caused the linker errors `multiple definition of `_mips_atomic_update'` and `multiple definition of `_mips_atomic_cas'` has been fixed. This error was reported for applications built with the options `-pg -march=m4k -mips16`.

Argument initialization bug fix. The CS3 startup code now correctly initializes the argument counter, argument list and environment vector to null when the program is started from reset.

`malloc` fix. A bug that sometimes caused `free` to dereference an invalid address has been fixed. The bug was caused by incorrect handling within `malloc` of calls to `sbrk` from outside of `malloc`.

Debug Sprite abnormal termination bug fix. The Sourcery G++ Debug Sprite no longer terminates abnormally if GDB run on a Windows host is killed while the target is waiting for semihosted I/O to complete.

Debug Sprite remote reset support. The Sourcery G++ Debug Sprite now supports resetting the remote target with GDB's `monitor reset` command. Further subcommands are supported – use GDB's `monitor help reset` command for details.

Debug Sprite single stepping performance improvements. The Sourcery G++ Debug Sprite has been tuned for better single stepping performance with MT processors, such as the MIPS 34K CPU.

Debug Sprite MIPSsim profiling support. The Sourcery G++ Debug Sprite now supports gathering instruction- and cycle-accurate profile information with MIPSsim.

Debug Sprite initial frame bug fix. A bug in the Sourcery G++ Debug Sprite has been fixed that caused the debugger to report incorrect call frame information on the initial connection.

A.1.2. Changes in Sourcery G++ Lite 4.4-226

CS3 run-time code relocation support. The CS3 startup code now supports self-relocation. If a program is run from a target memory address other than the one selected at link time, it will copy itself to its designated link address and continue from there. This feature allows programs linked to execute from RAM to be loaded into ROM and started via the reset vector.

Profiling bug fix. A CS3 bug that caused applications compiled with `-pg` to hang has been fixed. Note that profiling is only supported for hosted simulator and RAM profiles, as it requires semihosting I/O to write the collected profile data file on the host.

Fix for invalid code generation bug. An optimizer bug has been fixed that caused GCC to emit incorrect code for some programs involving casts of a `struct` pointer to a pointer to the structure's first element.

A.1.3. Changes in Sourcery G++ Lite 4.4-191

Debug Sprite termination behavior. The Sourcery G++ Debug Sprite has been enhanced to better support GDB's different debugger shutdown modes. The GDB `kill` command now makes the target run from the reset vector, while the `disconnect` command now leaves the target halted at its current location. Formerly, both of these commands incorrectly caused the target to continue running freely from the point where it had been stopped. That behavior is now supported by the Sprite in response to the GDB `detach` command instead.

Debug Sprite termination bug fix. A bug in the Sourcery G++ Debug Sprite has been fixed that caused it to crash upon termination if the device being closed reported a fatal condition while shutdown was in progress.

Semihosting `open` bug fix. A bug in the Sourcery G++ Debug Sprite semihosting support has been fixed. The bug caused GDB to crash when handling calls to `open`.

Improved code generation for `if` statements. The compiler can now generate better code for `if` statements when the then and else clauses contain similar code.

SEAD-3 board support. The provided linker scripts for SEAD-3 LX50 and SEAD-3 LX110 boards have been renamed for consistency with the board names. For example, if you were formerly using the `sead3-m14kc-yamon.ld` linker script, you should now use `sead3-lx110-yamon.ld`. In addition, the SEAD-3 LX50 board now supports two additional profiles, Dual SRAM and YAMON Dual SRAM, which locate program text and data regions in the ISRAM and DSRAM memory (respectively) rather than in RAM. Refer to Chapter 5, “CS3™: The

CodeSourcery Common Startup Code Sequence" for a full listing of supported boards and provided linker scripts in this version of Sourcery G++ Lite.

microMIPS coprocessor 1 emulation. The coprocessor 1 (floating point coprocessor) emulation included in the CS3 library now supports the microMIPS instruction set.

Coprocessor 1 emulation cache fix. A bug in the coprocessor 1 (floating point coprocessor) emulation has been fixed. This bug caused crashes and data corruption when the CPU instruction cache was enabled.

Debug Sprite remote command support. The Sourcery G++ Debug Sprite now supports remote commands with GDB's `monitor mdi` command. Any arguments specified to this command are passed on to the MDI library for interpretation. For more information about commands supported see documentation supplied with the MDI library used.

Optimized software floating-point routines. The software floating-point emulation routines used by GCC when linking with `-msoft-float` have been updated. The new routines provide significant speed increases.

Linker script processing improvement. The linker can now automatically place sections that are not mentioned in your linker script. Previously, it issued the error `no memory region specified for loadable section`.

GCC internal compiler error. A bug has been fixed that caused GCC to crash when compiling some C++ code using templates at `-O2` or `-O3`.

Linker script compatibility. A bug that caused the linker error `undefined reference to` `` `__cs3_start_asm' `` has been fixed. The bug applied to projects using a linker script from an older version of Sourcery G++ with a newer CS3 library.

Debug Sprite performance improvements. The Sourcery G++ Debug Sprite has been tuned to give better performance when single stepping.

GCC internal compiler error with `optimize` attribute. A bug has been fixed that caused the compiler to crash when invoked with the `-O0` or `-O1` option on code using the `optimize` attribute to specify higher optimization levels for individual functions.

Stack initialization for YAMON profiles. The start up code for YAMON profiles now initializes the stack pointer.

A.1.4. Changes in Sourcery G++ Lite 4.4-147

Incorrect code generation bug fix. A bug in GCC has been fixed that resulted in incorrect code for some `unsigned short` array accesses when compiling with `-mdsp`.

Linker bug fix for `--section-start`. A linker bug that caused `--section-start` to fail to work as documented if the section is defined in multiple object files has been fixed.

Low level interrupt support. CS3 now provides the `intrupt` function, declared in `mips/xcpt.h`, for compatibility with SDE.

GDB shared library support. GDB now supports targets that report loaded shared libraries using the `qXfer:libraries:read` Remote Serial Protocol packet. For more information, see the GDB manual.

microMIPS coprocessor 0 access macros. A bug in the CS3 library for microMIPS targets has been fixed that caused the coprocessor 0 access macros declared in `mips/cpu.h` to raise an address error exception.

Debug Sprite device path interpretation bug fix. A bug in the Sourcery G++ Debug Sprite's interpretation of device paths has been fixed. Target and device numbers are now stable between debug sessions as long as the configuration of the target board or simulator remains the same. Previously the numbers could change in some cases.

Debugging preprocessed source code. A compiler bug has been fixed that caused debug output to erroneously contain the name of the intermediate preprocessed file.

GDB update. The included version of GDB has been updated to 7.0.50.20100218. This update adds numerous bug fixes and new features, including improved C++ language support, automatic caching of stack memory, and Position Independent Executable (PIE) support.

GDB MDI target support. Microprocessor Debug Interface (MDI) protocol support is now provided by the Sourcery G++ Debug Sprite for MIPS. The direct MDI support within GDB, which was deprecated with the introduction of the Sprite in a previous release of Sourcery G++ Lite, has now been removed. This includes GDB commands such as `target mdi`. For information about using the Sprite to debug MDI targets, refer to Chapter 6, “Sourcery G++ Debug Sprite”.

GDB asynchronous mode fix. GDB can now be used from the command line in asynchronous mode with remote targets. Previously, GDB did not accept user input while asynchronous commands (such as `continue &`) were running.

GDB interrupt handling bug fix. A bug in GDB has been fixed that caused it to sometimes fail to indicate that the target had stopped after being interrupted. The bug affected clients using GDB's MI front end.

Function breakpoint bug fix. A bug in GDB has been fixed that sometimes caused breakpoints on functions without an associated stack frame to be placed at the wrong address.

Debug Sprite multiple connections fix. When started with the `-m` option, the Sourcery G++ Debug Sprite no longer exits if the connection to GDB is lost when sending a response. Instead, it goes back to waiting for another connection.

GDB and programs linked with the `--gc-sections` linker option. GDB has been improved to better handle debug information found in programs and libraries linked with the `--gc-sections` option. GDB formerly selected the wrong debug information in some cases, resulting in incorrect behavior when stepping over a function or displaying local variables, for example.

GDB memory find bug fix. A bug in GDB's `find` command has been fixed. The bug caused searches on large memory areas to fail or report matches at incorrect addresses.

Interrupt handler code generation bug fix. A GCC bug has been fixed that caused an assembler warning for some functions marked with the `interrupt` attribute.

Debugger errors after loading program. A bug in GDB has been fixed that sometimes caused a GDB internal error after the `load` command.

Frame manipulation bug fix. A bug in GDB has been fixed that caused frame manipulation commands to report an internal error in some cases when used on arbitrary stack frames specified by an address.

Read watchpoints bug fix. A GDB bug has been fixed that caused watchpoints set to trigger on memory reads to be silently ignored in some cases.

Setting thread-specific breakpoints in GDB. A bug in GDB has been fixed that caused a syntax error for the `break *`*`expression`* `thread` *`threadnum`* command.

CS3 program startup behavior revised. CS3's model for program startup has been made more uniform across different target profiles. Changes include:

- Execution now consistently begins at hard reset (`__cs3_reset`) for all profiles. Formerly, the debugger began execution at assembly initialization (`_start`) instead.
- All profiles now perform the assembly initialization phase, using profile-specific code. Formerly, simulator and boot monitor profiles skipped this initialization phase.

Most existing programs using customized linker scripts or startup code based on the previous CS3 initialization model should continue to work as before with the new CS3 library. For more details on the CS3 startup model, refer to Section 5.2, “Program Startup and Termination”.

CS3 improvements. Several changes have been made to CS3 to make it easier to customize, including improved documentation and additions and corrections to the header file `cs3.h`. For details, see Chapter 5, “CS3™: The CodeSourcery Common Startup Code Sequence”.

MIPS32 revision 2.61 `SYNC` instruction types. Binary utilities have been extended to support additional `SYNC` instruction types introduced with revision 2.61 of the MIPS32 architecture specification.

Static constructor and destructor ordering fixes. The linker now correctly ensures that static destructors with priorities are executed after destructors without priorities. Another linker bug that caused incorrect static constructor and destructor ordering with partial linking involved has been fixed.

A.1.5. Changes in Sourcery G++ Lite 4.4-124

MIPS startup code fix. The CS3 startup code for RAM and simulator profile boards now automatically enables the cache.

A.1.6. Changes in Sourcery G++ Lite 4.4-111

Support for MIPS M14K and M14Kc processors. Sourcery G++ Lite now supports the MIPS M14K and M14Kc processors. To compile for these targets, use the `-march=m14k -mmicromips` command-line options. Additionally, CS3 board support is provided for the MIPS SEAD-3 LX50 and LX110 boards which include these processors. Refer to Chapter 5, “CS3™: The CodeSourcery Common Startup Code Sequence” for more information about boards supported by Sourcery G++ Lite.

Support for microMIPS instruction encoding. Sourcery G++ Lite now supports the microMIPS instruction set architecture. To enable microMIPS code generation, compile and link with `-mmicromips`.

Code size with `-g`. A bug that caused binary code size regressions in GCC 4.4 when compiling with `-g` has been fixed.

A.1.7. Changes in Sourcery G++ Lite 4.4-87

Incorrect symbol addresses bug fix. A bug in the linker that caused it to assign incorrect addresses to symbols has been fixed. The bug occurred when the input objects contained sections not explicitly mentioned in the linker script.

Sourcery G++ Debug Sprite for MIPS. This release of Sourcery G++ Lite includes the new Sourcery G++ Debug Sprite for MIPS. The Sprite provides similar functionality to the Microprocessor Debug Interface (MDI) protocol support in GDB, but is implemented as an external program which can be run from GDB, rather than in GDB itself. The GDB MDI support is deprecated and will be removed in a future release of Sourcery G++ Lite. For information about using the Sprite, refer to Chapter 6, "Sourcery G++ Debug Sprite".

Debugging programs built by Green Hills compilers. GDB has been further extended to accommodate non-standard debug information produced by some Green Hills toolchains.

Static variables and `asm` statements bug fix. A bug in GCC that caused functions containing static variables and `asm` statements to be miscompiled at `-O2` or above has been fixed. The bug also occurred at other optimization levels when the `-fremove-local-statics` command-line option was used.

Optimizer bug fixes. Two bugs in GCC related to loop optimization have been fixed. One bug caused internal compiler errors, while the other caused functions with complex loop nests to be miscompiled. Both bugs occurred at `-O2` or above, or at other optimization levels when the `-fpromote-loop-indices` command-line option was used.

Improved assembler error checking. The assembler has been improved to perform additional checks for invalid inputs.

A.1.8. Changes in Sourcery G++ Lite 4.4-58

GDB `finish` internal error. A bug has been fixed that caused a GDB internal error when using the `finish` command. The bug occurred when debugging optimized code.

GDB update. The included version of GDB has been updated to 6.8.50.20090630. This update adds numerous bug fixes and new features, including support for multi-byte and wide character sets and improved C++ template support.

Arguments to `main`. A bug in CS3 YAMON support has been fixed that formerly caused command-line arguments provided on program startup to be ignored. In YAMON profiles, the arguments are now correctly passed to `main` via *`argc`* and *`argv`*.

GDB and third-party compilers. Some bugs that caused GDB to crash when debugging programs compiled with third-party tools have been fixed. These bugs did not affect programs built with Sourcery G++.

GDB internal warning fix. A GDB bug has been fixed that caused warnings of the form `warning: (Internal error: pc` *`address`* `in read in psymtab, but not in symtab.)`.

`@`*`FILE`* **fix. A bug has been fixed in the processing of `@`*`FILE`* command-line options by GCC, GDB, and other tools. The bug caused any options in *`FILE`* following a blank line to be ignored.

Preprocessor error handling. The preprocessor now treats failing to find a file referenced via `#include` as a fatal error.

New header file. The header file `mips/m32cache.h` has been added to provide declarations for MIPS32 cache management functions. For more information, refer to the *MIPS® Toolchain Specifics* document.

Bug fix for `read`. A bug in CS3's console I/O support for YAMON has been fixed. The bug caused `read` to return immediately rather than waiting for input to become available.

ELF file corruption with `strip`. A bug that caused `strip` to corrupt unusual ELF files has been fixed.

GDB support for Cygwin pathnames. A bug in GDB's translation of Cygwin pathnames has been fixed.

Startup code debugging fixes. Two GDB bugs have been fixed that caused errors when debugging startup code. One bug caused an internal error message; the other caused the error `Cannot find bounds of current function`.

MIPS32 TLB support. Functions for initialization and maintenance of the CPU's memory management Translation Lookaside Buffer (TLB) have been added to CS3. For more information about TLB support on MIPS ELF targets, refer to the *MIPS® Toolchain Specifics* document.

Debugging programs built by Green Hills compilers. GDB has been extended to accommodate non-standard debug information produced by some Green Hills toolchains.

Linker script fixes. A bug in CS3 linker scripts for YAMON and simulator profiles has been fixed. The bug resulted in data memory being too small, which sometimes caused the stack to be overwritten during initialization, or reduced space for `malloc` to allocate.

GCC internal compiler error. A bug has been fixed that caused the compiler to crash when optimizing code that casts between structure types and the type of the first field.

ELF Program Headers. The linker now better diagnoses errors in the usage of `FILEHDR` and `PHDRS` keywords in `PHDRS` command of linker scripts. Refer to the linker manual for more information.

A.1.9. Changes in Sourcery G++ Lite 4.4-25

Remote debugging hardware watchpoint bug fix. A GDB bug has been fixed that caused hardware watchpoint hits to be incorrectly reported in some cases.

Optimizer improvements. When optimizing for speed, the compiler now uses improved heuristics to limit certain types of optimizations that may adversely affect both code size and speed. This change also makes it possible to produce better code when optimizing for space rather than speed.

Binutils update. The binutils package has been updated to version 2.19.51.20090709 from the FSF trunk. This update includes numerous bug fixes.

Destructor function bug fix. A bug in CS3 has been fixed that caused functions with the `destructor` attribute not to be run on program termination.

Support for MIPS 1004K cores. Sourcery G++ now includes basic compiler and assembler support for MIPS 1004K cores. Use the `-march=1004kc` (integer cores), `-march=1004kf2_1` (half-speed FPU), `-march=1004kf1_1` (full-speed FPU), or `-march=1004kf` (alias for `1004kf2_1`) command-line options.

Malta board support. The Malta 24Kc board definition has been removed from CS3. This board definition was made obsolete in a previous release by the addition of a new generic Malta board definition that is not restricted to 24Kc processors. You should use this generic Malta board definition in place of the deleted 24Kc-specific one. For example, if you were formerly using the `malta-24kc-yamon.ld` linker script, you should now use `malta-yamon.ld`. Refer to Chapter 5, "CS3™: The CodeSourcery Common Startup Code Sequence" for a full listing of supported boards and provided linker scripts in this version of Sourcery G++ Lite.

Register variable corruption. A compiler bug has been fixed that caused incorrect code to be generated when the frame pointer or other special-use registers are used as explicit local register variables, introduced via the `asm` keyword on their declarations.

Stack unwinding termination bug fix. A bug has been fixed that caused GDB not to detect the outermost frame correctly while doing stack unwinding. The bug sometimes caused the debugger to go into an infinite loop, or other unpredictable behavior.

`-fremove-local-statics` optimization. The `-fremove-local-statics` optimization is now enabled by default at `-O2` and higher optimization levels.

Elimination of spurious warnings about `NULL`. The C++ compiler no longer issues spurious warnings about comparisons between pointers to members and `NULL`.

Profiling support. Profiling is now supported for MIPS ELF targets. For more information on profiling with `gprof`, please see Section 3.6, "Profiling Support".

Vectorizer improvements. The compiler now generates improved code for accesses to static nested array variables (e.g. `static int foo[8][8];`).

Function attributes to support interrupt handling. Support for the `interrupt` attribute has been implemented. `use_debug_exception`, `keep_interrupts_masked`, and `use_shadow_register_set` have also been implemented. These are attributes which can be used to modify the behavior of the interrupt handler. For more information on how to use these attributes, please refer to the GCC manual.

GCC version 4.4.1. Sourcery G++ Lite for MIPS ELF is now based on GCC version 4.4.1. For more information about changes from GCC version 4.3 that was included in previous releases, see `http://gcc.gnu.org/gcc-4.4/changes.html`.

Linker map address sorting. The map generated by the linker `-Map` option now lists symbols sorted by address.

Floating-point register initialization for YAMON. A bug that caused the floating-point registers to be initialized in the incorrect mode has been fixed. The reset code for YAMON applications now initializes the floating-point register mode to conform to the compilation mode of the application.

A.1.10. Changes in Sourcery G++ Lite 4.3-221

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

A.1.11. Changes in Sourcery G++ Lite 4.3-219

Malta board support memory map. Other recent changes to Sourcery G++ have required changing CS3's memory map for MIPS Malta boards to reserve an area of low memory for interrupt vectors. If you are using a CS3-provided Malta linker script for your program, you will pick up the

changes automatically. If you are using a copied or custom linker script, you may need to adjust it for this change.

MIPSsim board support. CS3 now includes a board definition intended specifically for use with MIPSsim targets. If you were previously using a Malta linker script to build a program intended to run on MIPSsim, you must change to use the new MIPSsim linker script instead. When invoking the linker from the command line, use the `-T mipssim-hosted.ld` option to select the new linker script. Using the new MIPSsim-specific linker script for MIPSsim targets is now necessary because other recent changes to Sourcery G++ have required changes to the memory map used by CS3 that are incompatible between MIPSsim and Malta hardware targets.

A.1.12. Changes in Sourcery G++ Lite 4.3-199

MIPS Malta board support. Support for a generic Malta board has been added to CS3. This is similar to the existing Malta 24Kc board support, but is not specific to a particular processor, to reflect the fact that these boards can be configured with a number of different processors. If you were previously using the Malta 24Kc CS3 board support with a processor other than the 24Kc, you should switch to using the new generic Malta board instead. Refer to Chapter 5, "CS3™: The CodeSourcery Common Startup Code Sequence" for more information about CS3 support for these boards.

Incorrect linker diagnostic removed. The linker has been corrected to not emit an error message when the load address of an output section with no contents overlaps an output section with contents. This can occur in linker scripts that use `MEMORY` regions and `AT>` to place initialized contents into ROM.

GDB backwards compatibility fix. A bug has been fixed that caused GDB to crash when loading symbols from binaries built by very old versions of GCC.

Overloaded function resolution. The C++ compiler now correctly diagnoses an error when the second operand of a comma expression is an unresolved set of overloaded functions. Previously, it incorrectly used the context of the comma expression to resolve the function.

Pointer-to-member functions. A bug has been fixed that caused the C++ compiler to crash when compiling a pointer-to-member function reference without an explicit `&` operator. This syntax is allowed only when the `-fms-extensions` command-line option is used.

New assembler option: `-mfix-24k`. The assembler now accepts the `-mfix-24k` command-line option. The use of this option causes the assembler to work around hardware errata in the `eret` and `deret` instructions on 24K and 24KE cores.

A.1.13. Changes in Sourcery G++ Lite 4.3-152

Reduced compilation time. Compilation and build times when using Sourcery G++ Lite are now slightly faster. This performance improvement is the result of building the compilers and other host tools with a recent version of Sourcery G++, rather than an older GCC version.

Linker script load address processing. A bug in the linker has been fixed affecting linker scripts using `AT>region` to set the load address. This now follows the documented behavior of maintaining the virtual address to load address difference in output section statements. Refer to the "Output Section LMA" section of the linker manual for details of how to control the load address.

Hardware floating point emulation library. The hardware floating point emulation support which was formerly included with the SDE library is now available as part of CS3. This library provides trap handlers for unsupported floating-point instructions, which invoke the corresponding soft-float library routines. To use the library in your code, compile with `-mhard-float` and link

with `-lcs3-mips-cp1 -lcs3-mips-fpemu -Wl,--defsym,__cs3_mips_float_type=2` . For more information about floating-point support on MIPS ELF targets, refer to the *MIPS® Toolchain Specifics* document.

`mips-sde-elf-objcopy` bug fix. A bug has been fixed that caused `mips-sde-elf-objcopy` to issue an error when generating output in the Intel HEX format and using `--change-section-lma` to change section addresses.

Linker script search path. The bug in the linker has been fixed that caused it not to follow its documented behavior for searching for linker scripts named with the `-T` option. Now scripts are looked up first in the current directory, then in library directories specified with `-L` command-line options, and finally in the default system linker script directory.

Internal compiler error when optimizing. A bug has been fixed that caused `internal compiler error: in build2_stat` when compiling.

Corruption of block-scope variables. A compiler optimization bug that sometimes caused corruption of stack-allocated variables has been fixed. The bug affected variables declared in a local block scope in functions containing multiple non-overlapping lexical block scopes, a technique commonly used by programmers to reduce stack frame size. In some rare cases, other optimizations performed by the compiler were ignoring the local extent of such block-scope variables.

A.1.14. Changes in Sourcery G++ Lite 4.3-147

Optimized math routines. The Newlib implementations of `rint`, `drem`, `sqrtf` and `sqrt` have been replaced with the versions of these functions that were formerly included with the SDE math library, and are optimized specifically for MIPS targets.

`mips-sde-elf-objdump` bug fix. A bug has been fixed that caused `mips-sde-elf-objdump` to enter an infinite loop.

Incorrect code when using `-falign-labels`. A bug that caused the compiler to generate incorrect code for `switch` statements when the `-falign-labels` option is used has been fixed.

Debug section placement. A linker script bug in CS3 has been fixed that caused `.debug_ranges` debug sections to be misplaced.

MDI semihosting. A bug in MDI semihosting that could result in a crash when making a system call (such as `read` or `write`) has been fixed.

Interrupting the target from the debugger. GDB has been improved to be more responsive to attempts to interrupt the target (as by a **Ctrl**+**C** when using GDB from the command line) during execution of programs using semihosting.

Loop optimization improvements. A new option, `-fpromote-loop-indices`, has been added to the compiler. Specifying this option enables an optimization that improves the performance of loops with index variables of integer types narrower than the target machine word size, such as `char` or `short`. This optimization also applies to `int` on 64-bit targets.

Optimized string and memory functions. The Newlib implementations of `memcpy`, `memcmp`, `bzero`, `strcmp`, `strcpy`, `strlen` and `memset` have been replaced with the versions of these functions that were formerly included with the SDE C library, and are optimized specifically for MIPS targets.

Remote debugging connection auto-retry. The `target remote` command within GDB now uses a configurable auto-retry timeout when establishing TCP connections. This is useful in avoiding

race conditions when the remote GDB stub or GDB server is launched simultaneously with GDB. The auto-retry behavior is enabled by default; refer to the GDB manual for details.

Extraneous linker error messages. A linker bug that caused extraneous error messages of the form `Dwarf Error: Offset (507) greater than or equal to .debug_str size (421).` has been corrected. This bug did not affect the correctness of output binaries.

GDB `quit` error. A bug in GDB has been fixed that caused `quit` to report `Quitting: You can't do that without a process to debug.` when debugging a core dump file.

GDB update. The included version of GDB has been updated to 6.8.50.20081022. This update includes numerous bug fixes.

A.1.15. Changes in Sourcery G++ Lite 4.3-113

GCC version 4.3.3. Sourcery G++ Lite for MIPS ELF is now based on GCC version 4.3.3. This is a bug fix update to GCC. For more information about changes from GCC version 4.3.2 that was included in previous releases, see `http://gcc.gnu.org/gcc-4.3/changes.html`.

Arguments to `main`. A bug in CS3 hosting support has been fixed that formerly caused command-line arguments provided on program startup to be ignored. In hosted environments, the arguments are now correctly passed to `main` via *`argc`* and *`argv`*.

Internal compiler error with `-O3` or `-fpredictive-commoning`. A bug has been fixed that caused internal compiler errors when compiling some code with `-O3` or `-fpredictive-commoning`.

Debug information for anonymous structure types. A GCC bug in the generation of debug information for anonymous structure types in C++ code has been fixed. The bug caused printing the type information for such structures in the debugger (via the `ptype` command) to fail with an error message.

Out-of-range branches. A bug has been fixed that caused the compiler to emit incorrect branch code in some very large functions when generating position-independent code (`-fpic`) for O32 (`-mabi=32`) or O64 (`-mabi=o64`) ABIs.

Newlib update. The Newlib package has been updated to version 1.17.0, with additions from the community CVS trunk as of 2009-02-24. This update provides new C99 wide-character functions; POSIX regex functions; string-function performance improvements; an improved `sprintf` implementation that no longer requires I/O functions like `_open`, `_write`, and `_close`; and other bug fixes and improvements. For more information, refer to the Newlib C Library and Math Library manuals, and to the Newlib web site at `http://sourceware.org/newlib/`.

Installer fails during upgrade. The Sourcery G++ installer for Microsoft Windows hosts could fail during an upgrade while waiting for the previous version to be uninstalled. This bug has been fixed.

Uninstaller removed by upgrade. The uninstaller could be incorrectly deleted during an upgrade on Microsoft Windows hosts. This bug has been fixed.

Compile-time error for some `-march` options. A bug has been fixed that caused the error message: `mips-sde-elf-gcc: switch '|march=octeon' does not start with '-'` to be reported. The bug affected programs compiled with the options `-march=mips64`, `-march=5k`, `-march=20k`, `-march=sb1` and `-march=r71000`.

Internal compiler errors when optimizing. A defect that occasionally caused internal compiler errors when partial redundancy elimination (PRE) optimization was enabled has been corrected.

Install directory pathnames. Bugs in the install and uninstall scripts for Linux hosts that caused errors or incorrect behavior when the Sourcery G++ install directory pathname contains whitespace characters have been fixed.

Temporary files on Microsoft Windows. On Microsoft Windows hosts, Sourcery G++ Lite now uses the standard Windows algorithm to choose the directory in which to place temporary files. This change eliminates a crash that occurred if none of the `TEMP`, `TMP`, or `TMPDIR` variables were set to a suitable directory.

Binutils update. The binutils package has been updated to version 2.19.51.20090205 from the FSF trunk. This update includes numerous bug fixes.

CS3 board and processor support. CS3 board and processor support has been cleaned up to remove entries that are not appropriate for or supported by Sourcery G++ Lite on MIPS ELF targets. This includes processors for which Sourcery G++ Lite does not include appropriate run-time libraries. These changes are intended to simplify processor and board selection. For the full list of boards supported by CS3, refer to Chapter 5, "CS3™: The CodeSourcery Common Startup Code Sequence".

Internal compiler error with `-fremove-local-statics`. An internal compiler error that occurred when using the `-fremove-local-statics` option has been fixed. The error occurred when compiling code with function-local `static` array or structure variables.

A.1.16. 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.

A.1.17. 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 5, “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.

A.1.18. Changes in Older Releases

For information about changes in older releases of Sourcery G++ Lite for MIPS ELF, please refer to the Getting Started guide packaged with those releases.

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