Sourcery CodeBench Lite

MIPS ELF

Sourcery CodeBench Lite 2013.05-44

Getting Started

Sourcery CodeBench Lite: MIPS ELF: Sourcery CodeBench Lite 2013.05-44: Getting Started

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Abstract

This guide explains how to install and build applications with Sourcery CodeBench Lite, CodeSourcery's customized and validated version of the GNU Toolchain. Sourcery CodeBench 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 CodeBench from the command line.

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Preface

This preface introduces the Sourcery CodeBench 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 CodeBench Lite. This guide provides a step-by-step guide to installing Sourcery CodeBench 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 CodeBench 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 CodeBench 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 CodeBench Lite for MIPS ELF”	This chapter contains information about using Sourcery CodeBench Lite that is specific to MIPS ELF targets. You should read this chapter to learn how to best use Sourcery CodeBench Lite on your target system.
Chapter 4, “Using Sourcery CodeBench from the Command Line”	This chapter explains how to build applications with Sourcery CodeBench 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 CodeBench 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 CodeBench Debug Sprite”	This chapter describes the use of the Sourcery CodeBench 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 CodeBench”	This chapter describes where you can find additional documentation and information about using Sourcery CodeBench Lite and its components. It also provides information about Sourcery CodeBench subscriptions. CodeSourcery customers with Sourcery CodeBench subscriptions receive comprehensive support for Sourcery CodeBench.
Appendix A, “Sourcery CodeBench Lite Release Notes”	This appendix contains information about changes in this release of Sourcery CodeBench Lite for MIPS ELF. You should

	read through these notes to learn about new features and bug fixes.
Appendix B, "Sourcery CodeBench Lite Licenses"	This appendix provides information about the software licenses that apply to Sourcery CodeBench Lite. Read this appendix to understand your legal rights and obligations as a user of Sourcery CodeBench 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 CodeBench Lite for the first time. You may use this chapter as an abbreviated guide to the rest of this manual.

Sourcery CodeBench 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 CodeBench configuration is not intended for Linux or uClinux kernel or application development.

Follow the steps given in this chapter to install Sourcery CodeBench 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 CodeBench Lite in Chapter 3, “Sourcery CodeBench Lite for MIPS ELF”.

1.1. Installation and Set-Up

Install Sourcery CodeBench Lite on your host computer. You may download an installer package from the Sourcery CodeBench 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. When the installation is complete, it offers to launch the Getting Started guide. For more information about installing Sourcery CodeBench 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 CodeBench Debug Sprite, you may need to install drivers, libraries, or other software on your host system. Refer to Chapter 6, “Sourcery CodeBench Debug Sprite” for a list of supported devices and information about installing drivers and other device set-up. Sourcery CodeBench 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 CodeBench 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 CodeBench command-line tools. Create a simple test program, and follow the directions in Chapter 4, “Using Sourcery CodeBench from the Command Line” to compile and link it using Sourcery CodeBench 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://go.mentor.com/codebench/

Run or debug your program in the simulator. Sourcery CodeBench 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 CodeBench 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 CodeBench Debug Sprite, including information about supported debug devices, can be found in Chapter 6, "Sourcery CodeBench Debug Sprite".

Run your program on the target using YAMON. You can run programs built with Sourcery CodeBench Lite on MIPS ELF targets via the YAMON boot monitor. For instructions, refer to Section 3.5, "Using Sourcery CodeBench 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 CodeBench 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 CodeBench Lite. You will learn how to:

1. Verify that you can install Sourcery CodeBench Lite on your system.

2. Download the appropriate Sourcery CodeBench Lite installer.

3. Install Sourcery CodeBench Lite.

4. Configure your environment so that you can use Sourcery CodeBench Lite.

2.1. Terminology

Throughout this document, the term *host system* refers to the system on which you run Sourcery CodeBench while the term *target system* refers to the system on which the code produced by Sourcery CodeBench runs. The target system for this version of Sourcery CodeBench 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 CodeBench, 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 CodeBench supports the following host operating systems and architectures:

- Microsoft Windows XP (SP1), 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 5 (and later), Red Hat Enterprise Linux 5 (and later), SuSE Enterprise Linux 10 (and later), and Ubuntu 8.04 (and later).

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

Installing on Ubuntu and Debian GNU/Linux Hosts

The Sourcery CodeBench 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 CodeBench 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 CodeBench Lite toolchain.

2.2.2. Host Hardware Requirements

The amount of disk space required for a complete Sourcery CodeBench Lite installation directory depends on the host operating system and the number of target libraries included. When you start the graphical installer, it checks whether there is sufficient disk space before beginning to install. Note that the graphical installer also requires additional temporary disk 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 CodeBench Lite for MIPS ELF" for requirements that apply to the target system.

2.3. Downloading an Installer

If you have received Sourcery CodeBench 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 CodeBench Lite".

You can download Sourcery CodeBench Lite from the Sourcery CodeBench web site[1]. This free version of Sourcery CodeBench, 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 CodeBench 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 CodeBench installer is provided as an executable with the `.exe` extension. For GNU/Linux systems Sourcery CodeBench 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 CodeBench Lite

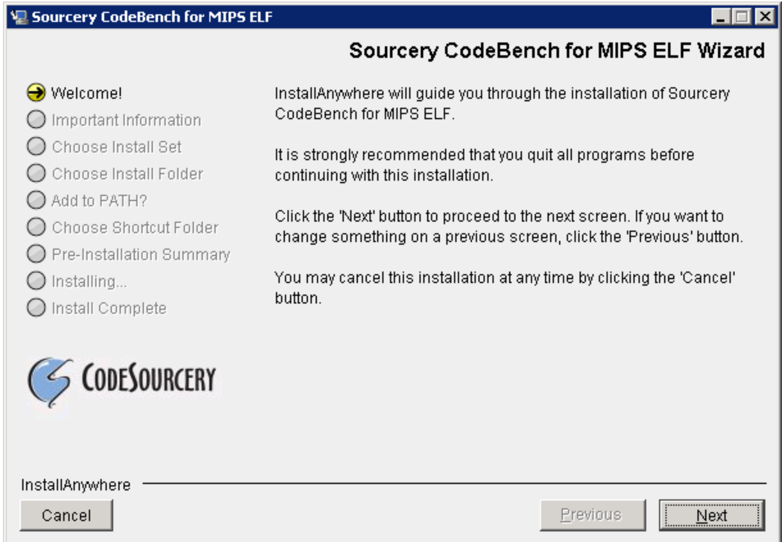
The method used to install Sourcery CodeBench Lite depends on your host system and the kind of installation package you have downloaded.

2.4.1. Using the Sourcery CodeBench Lite Installer on Microsoft Windows

If you have received Sourcery CodeBench 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 CodeBench Lite, double-click on the installer.

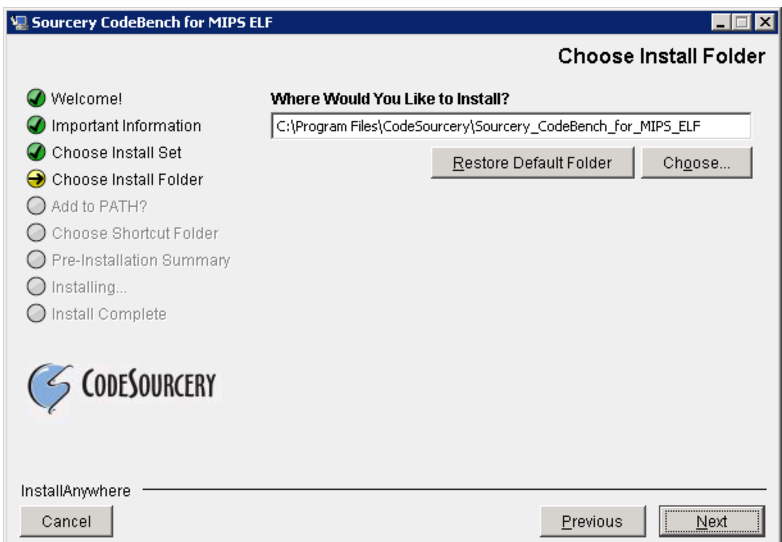
After the installer starts, follow the on-screen dialogs to install Sourcery CodeBench Lite. The installer is intended to be self-explanatory and on most pages the defaults are appropriate.

[1] http://go.mentor.com/codebench/
[2] https://sourcery.mentor.com/GNUToolchain/

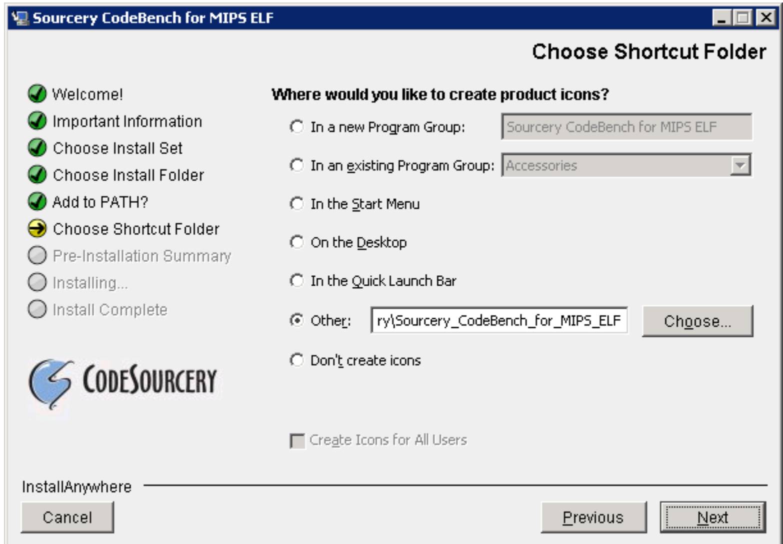


Running the Installer. The graphical installer guides you through the steps to install Sourcery CodeBench Lite.

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

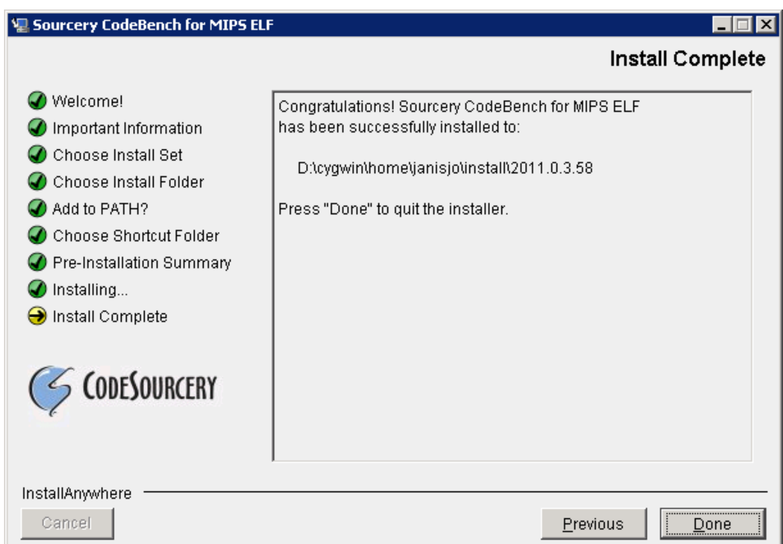


Choose Install Folder. Select the pathname to your install directory.



Choose Shortcut Folder. You can customize where the installer creates shortcuts for quick access to Sourcery CodeBench 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 CodeBench 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 CodeBench 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 CodeBench Lite from a Compressed Archive

You do not need to be a system administrator to install Sourcery CodeBench Lite from a compressed archive. You may install Sourcery CodeBench 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 CodeBench 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++-2013.05`.

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 CodeBench Lite Updates

If you have already installed an earlier version of Sourcery CodeBench 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 CodeBench commands for the MIPS ELF target all begin with `mips-sde-elf`. This means that you can install Sourcery CodeBench 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

The graphical installer for Sourcery CodeBench Lite does this setup for you, however it may not take effect until you next log in.

In order to use the Sourcery CodeBench tools from the command line, you should add them to your PATH. In the instructions that follow, replace *installdir* with the full pathname of your Sourcery CodeBench Lite installation directory, including the drive letter.

To set the PATH on a Microsoft Windows Vista system, use the following command in a cmd.exe shell:

```
> setx PATH "%PATH%;installdir\bin"
```

To set the PATH on a system running Microsoft Windows 7, from the desktop bring up the Start menu and right click on Computer. Select Properties and click on Advanced system settings. Go to the Advanced tab, then click on the Environment Variables button. Select the PATH variable and click Edit. Add the string ;*installdir*\bin to the end, and click OK.

To set the PATH on older versions of Microsoft Windows, 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 ;*installdir*\bin to the end, and click OK.

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

```
> mips-sde-elf-gcc -v
```

Verify that the last line of the output contains: Sourcery CodeBench Lite 2013.05-44.

2.6.1.2. Working with Cygwin

Sourcery CodeBench Lite does not require Cygwin or any other UNIX emulation environment. You can use Sourcery CodeBench directly from the Windows command shell. You can also use Sourcery CodeBench 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 CodeBench is not a Cygwin application, it does not, by default, recognize Cygwin paths.

If you are using Sourcery CodeBench from Cygwin, you should set the CYGPATH environment variable. If this environment variable is set, Sourcery CodeBench 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 CodeBench relies on the cygpath utility provided with Cygwin. You must provide Sourcery CodeBench with the full path to cygpath if cygpath is not in your PATH. For example:

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

directs Sourcery CodeBench 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

The graphical installer for Sourcery CodeBench Lite does this setup for you, however it may not take effect until you next log in.

Before using Sourcery CodeBench 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 installdir/bin:$PATH
```

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

```
> PATH=installdir/bin:$PATH
> export PATH
```

If you are not sure which shell you are using, try both commands. In both cases, replace *`installdir`* with the full pathname of your Sourcery CodeBench Lite installation directory.

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

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

```
> mips-sde-elf-gcc -v
```

Verify that the last line of the output contains: `Sourcery CodeBench Lite 2013.05-44`.

2.7. Uninstalling Sourcery CodeBench Lite

The method used to uninstall Sourcery CodeBench 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 CodeBench Lite Uninstaller on Microsoft Windows

You should use the provided uninstaller to remove a Sourcery CodeBench Lite installation originally created by the graphical installer. Start the graphical uninstaller by invoking the 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 CodeBench Lite.

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

To uninstall third-party drivers bundled with Sourcery CodeBench Lite, first disconnect the associated hardware device. Then use `Uninstall a program` (Vista and newer) or `Add or Remove`

`Programs` (older versions of Windows) 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 CodeBench Lite Uninstaller on GNU/Linux

You should use the provided uninstaller to remove a Sourcery CodeBench 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 CodeBench 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 CodeBench Lite from a `.tar.bz2` file, you can uninstall it by manually deleting the installation directory created in the install procedure.

Chapter 3
Sourcery CodeBench Lite for MIPS ELF

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

3.1. Included Components and Features

This section briefly lists the important components and features included in Sourcery CodeBench 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	4.7.3	Separate manual included.
GNU Binary Utilities	2.23.52	Includes assembler, linker, and other utilities. Separate manuals included.
Debugging support and simulators		
GNU Debugger	7.4.50	Separate manual included.
Sourcery CodeBench Debug Sprite	2013.05-44	See Chapter 6, “Sourcery CodeBench Debug Sprite”.
GDB Simulator	N/A	See Section 4.3, “Running Applications in the Simulator”.
Target libraries		
CodeSourcery Common Startup Code Sequence	2013.05-44	See Chapter 5, “CS3™: The CodeSourcery Common Startup Code Sequence”.
Newlib C Library	1.18.0	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 CodeBench 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, Soft-Float, O32	
Command-line option(s):	`-msoft-float`
Library subdirectory:	`sof/`

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

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

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, mips16, Soft-Float	
Command-line option(s):	`-EL -mips16 -msoft-float`
Library subdirectory:	`el/mips16/sof/`

MIPS32 revision 2 - Big-Endian, 2008 NaN, O32	
Command-line option(s):	`-mnan2008`
Library subdirectory:	`nan2008/`

MIPS32 revision 2 - Little-Endian, 2008 NaN, O32	
Command-line option(s):	`-EL -mnan2008`
Library subdirectory:	`el/nan2008/`

MIPS32 revision 2 - Big-Endian, O32, mips16, 2008 NaN	
Command-line option(s):	`-mips16 -mnan2008`
Library subdirectory:	`mips16/nan2008/`

MIPS32 revision 2 - Little-Endian, O32, mips16, 2008 NaN	
Command-line option(s):	`-EL -mips16 -mnan2008`
Library subdirectory:	`el/mips16/nan2008/`

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/`

MIPS64 revision 2 - Big Endian, N64	
Command-line option(s):	`-mabi=64`
Library subdirectory:	`64/`

MIPS64 revision 2 - Big Endian, N64, Soft-Float	
Command-line option(s):	`-msoft-float -mabi=64`
Library subdirectory:	`sof/64/`

MIPS64 revision 2 - Little Endian, N64	
Command-line option(s):	`-EL -mabi=64`
Library subdirectory:	`el/64/`

MIPS64 revision 2 - Little Endian, N64, Soft-Float	
Command-line option(s):	`-EL -msoft-float -mabi=64`
Library subdirectory:	`el/sof/64/`

Sourcery CodeBench 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 CodeBench selects the multilib matching the build options you have selected.

Sourcery CodeBench 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 CodeBench install.

3.3. CS3 Support

Sourcery CodeBench 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 CodeBench 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 CodeBench 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 CodeBench 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 CodeBench 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 CodeBench 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*.

Warning

Using YAMON with 64-bit multilibs is not fully supported and may have issues. YAMON is usually built using the O32 ABI, which is not forward-compatible with the N64 ABI used in 64-bit multilibs.

3.6. Profiling Support

Sourcery CodeBench 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 CodeBench Lite.

3.7. Using Flash Memory

Sourcery CodeBench 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 CodeSourcery Common Startup Code Sequence” for information about the boards supported by Sourcery CodeBench.

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 CodeBench 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.

In addition to GDB's automatic use of hardware breakpoints in the ROM region, you can also set hardware breakpoints explicitly from the debugger. However, 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 of hardware breakpoints supported by the target system.

Chapter 4
Using Sourcery CodeBench from the Command Line

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

4.1. Building an Application

This chapter explains how to build an application with Sourcery CodeBench 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 CodeBench 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 CodeBench 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 CodeBench 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 CodeBench 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 CodeBench.

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 CodeBench Debug Sprite

The Sourcery CodeBench 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 CodeBench 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 CodeBench 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 CodeBench 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 CodeBench 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 CodeBench 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 CodeBench 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 CodeBench 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 CodeBench Debug Sprite implements semihosting for all supported devices. Semihosting is also supported by the GDB Simulator included with Sourcery CodeBench 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 CodeBench from the command line or from a `Makefile`, 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-yamon.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 CodeBench 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 application, 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. See Section 5.3.3, “Heap and Stack Placement” for an example of a custom stack.

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 CodeBench Lite for MIPS ELF are documented in the linker scripts in the `mips-sde-elf/lib/` subdirectory of your Sourcery CodeBench 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`, and the stack grows downward from this address. 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`.

The `cs3.h` header file also defines a macro for creating a custom stack. The custom stack is created as a block of RAM in the zero-initialized data section (BSS). The specified size must be a compile-time constant. To account for alignment, the final size of the stack may be a few bytes less than the requested size. The symbol `__cs3_stack` is initialized to point to the last extent of the stack block, and is 16-byte aligned. For example, the following fragment of C code creates a stack of 8192 bytes:

```
#include <cs3.h>

CS3_STACK(2 * 4096);
```

As indicated in Section 5.2.2, “The Assembly Initialization Phase”, there are cases where a boot monitor or simulator overrides a custom stack.

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 three 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.
- Still other processors use a more complicated descriptor mechanism for the interrupt table.

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 Malta 64-bit		
Processor name:	unspecified	
Processor options:	none	
Memory regions:	`ram`	
Linker scripts:	RAM Hosted	`malta64-ram-hosted.ld`
	RAM Unhosted	`malta64-ram.ld`
	YAMON	`malta64-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 CodeBench Debug Sprite

This chapter describes the use of the Sourcery CodeBench 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 CodeBench Lite contains the Sourcery CodeBench 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 CodeBench Debug Sprite" for information about the specific devices supported by this version of Sourcery CodeBench Lite.

Important

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

6.1. Probing for Debug Devices

Before running the Sourcery CodeBench Debug Sprite for the first time, or when attaching new debug devices to your host system, it is helpful to verify that the Sourcery CodeBench 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:

```
Sourcery CodeBench Debug Sprite for MIPS (Sourcery CodeBench Lite \
2013.05-44)
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 CodeBench 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 CodeBench 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 CodeBench 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 CodeBench Debug Sprite Options

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

`-a`
: Attach to a process already running on the target. Without this option, the default behavior is to reset the target on the initial connection, in preparation for loading a new program from the debugger.

`-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 CodeBench 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 CodeBench 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 CodeBench Debug Sprite must run on the machine that is connected to the target board. You must have Sourcery CodeBench 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 CodeBench Debug Sprite in this way, please refer to the Sourcery CodeBench Knowledge Base[1].

6.7. Supported Board Files

The Sourcery CodeBench 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 Malta 64-bit	`malta64`
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 CodeBench 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) 2007-2012 Mentor Graphics Corporation.

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

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

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

<!-- Board category to group boards list into the tree -->
```

[1] https://sourcery.mentor.com/GNUToolchain/kbentry132

```
<!ELEMENT category (#PCDATA)>

<!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
                        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>

<!-- Definition of default option values for each debug interface -->
<!ELEMENT debuggerDefaults (debugInterface*)>
<!ELEMENT debugInterface (option*)>
<!ATTLIST debugInterface
```

```
 name CDATA #REQUIRED
>
<!ELEMENT option EMPTY>
<!ATTLIST option
 name CDATA #REQUIRED
 defaultValue 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 `<category>`, `<properties>`, `<feature>`, `<initialize>` and `<memory-map>` elements.

`<category>`
: The `<category>` element specifies a '.' separated categorization of this board (e.g., Vendor.Family) to allow grouping similar boards in a tree structure.

`<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.

`<debuggerDefaults>` The `<debuggerDefaults>` element defines the default option values for each debug interface.

Chapter 7
Next Steps with Sourcery CodeBench

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

7.1. Sourcery CodeBench Knowledge Base

The Sourcery CodeBench Knowledge Base is available to registered users at the Sourcery CodeBench Portal[1]. Here you can find solutions to common problems including installing Sourcery CodeBench, 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 CodeBench 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 CodeBench 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 CodeBench Lite, the documentation can be found in the `share/doc/mips-mips-sde-elf/` subdirectory of your installation directory.

In addition to the detailed reference manuals, Sourcery CodeBench 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/mips-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 CodeBench 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 CodeBench 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://sourcery.mentor.com/GNUToolchain/

Appendix A
Sourcery CodeBench Lite Release Notes

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

A.1. Changes in Sourcery CodeBench Lite for MIPS ELF

This section documents Sourcery CodeBench Lite changes for each released revision.

A.1.1. Changes in Sourcery CodeBench Lite 2013.05-44

Installer `PATH` bug fix. An installer bug that caused it to set the `PATH` variable incorrectly has been fixed.

CS3 missing 2008 NaN multilib linker scripts bug fix. Missing linker scripts targeting Malta and SEAD-3 boards have been added for the 2008 NaN multilibs.

GDB support for removing symbols. GDB now supports the `remove-symbol-file` command. Refer to the GDB manual for full documentation.

`cs-rm -f` bug fix. A bug that caused `cs-rm -f` on Windows hosts to incorrectly issue an error when passed a glob pattern that matched nothing has been fixed.

A.1.2. Changes in Sourcery CodeBench Lite 2013.05-35

C++ exception handling format. The C++ exception handling format has been changed to fix a defect in the specification. The new format is not backwards-compatible with code produced by Sourcery CodeBench beginning with 2012.09 releases; you should recompile all C++ code using exceptions. The compatibility issue does not affect code produced by older Sourcery CodeBench Lite releases or third-party libraries built with other compilers.

IEEE 754 soft float NaN interpretation bug fixes. The IEEE 754 soft-float emulation libraries have been corrected to consistently use the legacy NaN representations.

Exception handling bug fix. A bug that sometimes caused an incorrect call to terminate during exception handling has been fixed.

N64 ABI fast software floating-point libraries. A bug in GCC has been fixed that caused the fast software floating-point libraries to be disabled for the N64 ABI.

Temporary register assembler bug fix. A bug has been fixed that caused `$zero` to be used as a temporary register for address calculation on some loads targeting that register.

Assembler bug fix for `.stab` directives. An assembler bug has been fixed that caused incorrect code to be generated when `.stab` directives were used in microMIPS or MIPS16 mode.

Assembler bug fix for microMIPS symbol loads. An assembler bug has been fixed that caused some microMIPS symbols to be loaded from an incorrect address.

N64 linker assertion failure fix. A linker bug has been fixed that caused an assertion failure when linking N64 code using the special `__ehdr_start` symbol.

N64 FPU emulation bug fix. A bug in the CS3 FPU emulation library has been fixed that made N64 hard-float code execute incorrectly on non-FPU processors.

GDB CP0 register access bug fix. A bug in GDB has been fixed that made CP0 registers inaccessible.

Debug Sprite spurious error message bug fix. A bug in the Sourcery CodeBench Debug Sprite has been fixed that caused a spurious `Error initializing the target` message upon startup in the attachment (`-a`) mode.

A.1.3. Changes in Sourcery CodeBench Lite 2013.05-8

Conditional expression bug fix. A bug that caused an internal compiler error in some programs with conditional expressions has been fixed.

Missed optimization. A bug that caused GCC to miss an opportunity to use short instructions when compiling with `-mmicromips` has been fixed.

Exception handling bug fix. A bug that sometimes caused incorrect results when using C++ exception specifications has been fixed.

Incorrect optimization bug fix. A compiler bug has been fixed that caused incorrect code to be generated for some comparisons unless optimization was suppressed with `-fno-forward-propagate`.

GCC version 4.7.3. Sourcery CodeBench Lite for MIPS ELF is now based on GCC version 4.7.3. This update incorporates numerous bug fixes. For more information, see `http://gcc.gnu.org/gcc-4.7/changes.html`.

GCC option `-meva`. GCC now passes the `-meva` command-line option to GAS.

IEEE 754-2008 features and multilibs added. Support for some IEEE 754-2008 floating-point arithmetic standard features has been added to the toolchain for processors that implement them. This includes changes to the compiler, binutils, the dynamic linker and floating-point environment library functions. The changes enable support for the recommended encoding of NaN data introduced by the said revision of the standard as well as the use of the floating-point `ABS.fmt` and `NEG.fmt` instructions in a non-arithmetic manner. Multilibs built with the updated encoding of NaN data have been added. For information as to how to control these features, please refer to the compiler and assembler manuals.

Linker `--gc-sections` crash fix. A bug that caused the linker to sometimes crash when using `--gc-sections` has been fixed.

Improved error message for incompatible object files. The linker error message emitted when attempting to link objects with incompatible error handling formats now includes the object names.

Binutils update. The binutils package has been updated to version 2.23.52.20130219 from the FSF trunk. This update includes numerous bug fixes.

Installer warnings fixed. A bug that caused Gtk warnings relating to `libappmenu.so` when running the installer on 64-bit Ubuntu GNU/Linux hosts has been fixed.

microMIPS FPU emulation bug fix. Support for the missing microMIPS `RECIP.fmt` and `RSQRT.fmt` instructions has been added to the CS3 FPU emulation library.

IEEE 754 integer conversion bug fix. A bug in the CS3 FPU emulator has been fixed that caused integer conversion instructions to produce incorrect results. The bug triggered for the minimum valid, out-of-range, infinite and NaN inputs to the `CEIL.L.fmt`, `CEIL.W.fmt`, `CVT.L.fmt`, `CVT.W.fmt`, `FLOOR.L.fmt`, `FLOOR.W.fmt`, `ROUND.L.fmt`, `ROUND.W.fmt`, `TRUNC.L.fmt`, and `TRUNC.W.fmt` instructions run on processors without an FPU as well as processors whose FPU traps to the emulator for any of such inputs.

IEEE 754 signaling NaN interpretation bug fix. A bug in the CS3 FPU emulator has been fixed that caused legacy signaling NaN data encoded with a zero payload to be interpreted as quiet NaN data. As a result IEEE 754 exception state was not set correctly for floating-point operations receiving such data as input. The bug affected hard-float code run on processors without an FPU as well as processors whose FPU traps to the emulator for signaling NaN input.

MIPS32r2 FPU emulation bug fix. The CS3 FPU emulation library now correctly supports multiply-accumulate and reciprocal approximation instructions in MIPS32r2 code.

CS3 FPU emulator IEEE 754 features. The CS3 FPU emulation library now supports some of the IEEE 754-2008 standard features recently added to the MIPS architecture. These are a new encoding of NaN data and a different treatment of `ABS.fmt` and `NEG.fmt` instructions as well as the associated new Floating Point Control and Status register state to switch between the IEEE 754-2008 and legacy mode.

Improved source line stepping. GDB and `gdbserver` now implement range stepping, which improves the performance of single stepping over a source line by reducing the number of control messages from GDB.

GDB hang fix. A bug that caused GDB to sometimes hang when setting a breakpoint has been fixed.

Sprite remote communication bug fix. A bug in the Sourcery CodeBench Debug Sprite that caused it to exit with the error `Remote communication error. Target disconnected.: Invalid argument.` on some Microsoft Windows hosts has been fixed.

Debug Sprite with multiple connections. The Sourcery CodeBench Debug Sprite now works correctly when using multiple connections (`-m`) with the Mentor Embedded Sourcery Probe. Previously, the Sprite exited with an error after the first connection.

Debug Sprite source line stepping improvement. The Sourcery CodeBench Debug Sprite now supports range stepping when used with debug devices that implement this MDI feature.

A.1.4. Changes in Sourcery CodeBench Lite 2012.09-98

Fast software floating-point libraries. A bug that caused the fast software floating-point libraries to be disabled has been fixed.

microMIPS branch generation fixed. A bug in GCC has been fixed that caused it to generate out-of-range microMIPS branches, which resulted in a linker error `relocation truncated to fit: R_MICROMIPS_PC16_S1`.

Compact C++ language-specific data. GCC now defaults to emitting a compact encoding of the C++ language-specific data for exception handling. For more information, refer to the documentation of the `-mcompact-eh` and `-mno-compact-eh` options in the GCC manual.

Pointer comparison bug fixed. A bug in GCC that caused it to incorrectly optimize away a pointer comparison has been fixed.

Loop optimization bug fix. A compiler bug that caused some forms of loop to be mis-optimized when using the `-fpromote-loop-indices` option has been fixed.

Wrong-code bug fix. A bug in GCC's scheduler has been fixed that sometimes caused incorrect code to be generated.

Performance regression fixed. A bug that introduced unnecessary instructions to zero-extend unsigned `char` or `short` values has been fixed.

Linker raw binary input crash fix. A bug that caused the linker to crash when linking binary inputs (`--format=binary`) while using `--gc-sections` has been fixed.

Assembler bug fixes. Assembler bugs have been fixed that caused assembly errors or incorrect code to be produced for the `LUI` instruction, microMIPS `B16`, `BEQZ16`, and `BNEZ16` suffixed instruction mnemonics, as well as 32-bit microMIPS instructions placed in a 16-bit delay slot of a branch or a jump.

Install to empty directory failure fixed. A bug that prevented installation of Sourcery CodeBench Lite into an existing empty directory has been fixed.

CS3 linking fix. A bug has been fixed that caused `relocation truncated to fit` errors when linking the CS3 libraries against object files compiled with a `-G` option value less than 4.

`ssize_t` type definition bug fix. The definition of the POSIX `ssize_t` data type has been corrected for 64-bit targets to match the width of the ISO C `size_t` type.

A.1.5. Changes in Sourcery CodeBench Lite 2012.09-42

GCC version 4.7.2. Sourcery CodeBench Lite for MIPS ELF is now based on GCC version 4.7.2. For more information about changes from GCC version 4.6 that was included in previous releases, see `http://gcc.gnu.org/gcc-4.7/changes.html`.

Optimization bug fix. A GCC bug has been fixed that caused incorrect code to be generated for `builtin_unreachable` when optimizing.

Linker crash bug fix. A bug has been fixed that caused the linker to crash when using customized linker scripts without a `.eh_frame_hdr` output section description.

Assembler `%hi` and `%lo` operator bug fixes . Several bugs have been fixed in the handling of `%hi` and `%lo` assembly operators applied to expressions involving forward symbol references. The bugs caused the assembler to fail with a `relocation overflow` error message or to produce incorrect code.

Linker script symbols. The linker now supports a new `HIDDEN` keyword to define symbols with object scope. Refer to the linker manual for details.

microMIPS `SWXC1` instruction encoding bug fix . A bug in the encoding of the microMIPS `SWXC1` instruction has been fixed. The bug caused `LWXC1` to be produced by the assembler and listed by the disassembler instead.

Binutils version 2.23. Sourcery CodeBench Lite for MIPS ELF is now based on binutils version 2.23.

EVA instruction assembler bug fix. An assembler bug in branch delay slot optimization involving EVA instructions has been fixed.

Assembler internal error bug fix. A bug has been fixed that caused the assembler to sometimes fail with a `fixup not contained within frag` error message. The bug was triggered by the branch delay slot optimization, not normally used for compiler-generated code.

N64 MDI semihosting bug fix. A bug in MDI semihosting has been fixed that caused incorrect return values for the N64 ABI.

GDB update. The included version of GDB has been updated to 7.4.50.20120716. This update adds numerous bug fixes and features. Refer to `http://www.gnu.org/software/gdb/news` for more information.

Non-stop support. The Sourcery CodeBench Debug Sprite now supports non-stop debugging.

Updated system requirements. The host operating system requirements for Sourcery CodeBench Lite have been updated. The minimum versions of GNU/Linux now supported are Red Hat Enterprise Linux 5, SuSE Enterprise Linux 10, Fedora Core 6, Ubuntu 8.04, and Debian 5, or later versions of these distributions running on 32-bit or 64-bit Intel or AMD CPUs.

A.1.6. Changes in Sourcery CodeBench Lite 2012.03-64

`__attribute__((nomips16))` code generation bug fix. A bug in GCC that caused incorrect code to be generated for functions with the `__attribute__((nomips16))` attribute while compiling with `-mips16` has been fixed.

C++ bug fix. A bug that caused unpredictable program behavior in C++ programs has been fixed.

Invalid microMIPS relocation fixed. A bug in branch code generation for microMIPS, reported by the linker as `relocation truncated to fit: R_MICROMIPS_PC16_S1`, has been fixed.

Improved size optimization for microMIPS. The compiler now aligns microMIPS functions more efficiently when the `-Os` option is used.

Compiler crash fixed. A GCC bug that occasionally caused an internal compiler error during register allocation has been fixed.

Register allocation bug fix. A bug in the register allocator that caused incorrect code generation has been fixed.

Linker `--gc-sections` bug fix. A linker bug that incorrectly caused undefined references to be diagnosed when the `--gc-sections` option is used has been fixed.

EVA support. GAS now supports MIPS EVA instructions. You can specify the `-meva` option to GCC and GAS to indicate that EVA instructions are being used.

A.1.7. Changes in Sourcery CodeBench Lite 2012.03-41

Nondeterministic code generation bug fix. A GCC bug has been fixed that caused nondeterministic code generation for some input files when optimizing.

GCC version 4.6. Sourcery CodeBench Lite for MIPS ELF is now based on GCC version 4.6. For more information about changes from GCC version 4.5 that was included in previous releases, see `http://gcc.gnu.org/gcc-4.6/changes.html`.

Fix for internal compiler error. A GCC bug has been fixed that caused an internal compiler error when using pointer casts in C++0x `constexpr` initialization expressions.

Compact C++ exception handling tables. GCC now defaults to emitting a compact encoding of C++ exception handling tables, rather than using a DWARF-based scheme. For more information, refer to the documentation of the `-mcompact-eh` and `-mno-compact-eh` options in the GCC manual.

Fix for bit-field optimization bug. A compiler bug that caused incorrect code to be generated for programs using bit-fields has been fixed.

Incorrect accesses to volatile memory. The compiler no longer generates SWP, LWP, SWM or LWM instructions to access objects declared with the `volatile` type qualifier, as these instructions can cause multiple memory accesses of unspecified ordering.

GCC version 4.6.3. Sourcery CodeBench Lite for MIPS ELF is now based on GCC version 4.6.3. For more information about issues that have been fixed since version 4.6.1, see `http://gcc.gnu.org/gcc-4.6/changes.html`.

GCC stack usage improvement. GCC now generates better code for stack allocation in some cases when compiling with `-fno-strict-aliasing`.

Linker `--gc-sections` option bug fix. A bug has been fixed that caused the linker to incorrectly remove the `.debug_types` section when using the `--gc-sections` option.

Installer failure during upgrade. Some recent releases were affected by an installer bug on Windows hosts that caused installing a newer version of Sourcery CodeBench Lite into the same directory to fail with the error `Sourcery CodeBench Lite for MIPS ELF upgrade failed`. This bug has now been fixed, but the affected releases cannot be upgraded. As a workaround, uninstall the older release before installing the new version.

C++ debugging bug fix. A GDB bug has been fixed that caused GDB to fail to find `enum` constants in base classes when debugging C++ code.

Fix for crash in GDB. A memory corruption bug in GDB has been fixed that under very rare circumstances made it crash or exhibit other unpredictable behavior. On GNU/Linux hosts, this bug caused crashes with an error message similar to: `*** glibc detected *** mips-sde-elf-gdb: free(): invalid next size (normal): 0x09466198 ***` followed by a backtrace.

Fix debugger remote target interruption. A bug in GDB's handling of requests to interrupt execution on a remote target has been fixed that caused it to stop the target but not emit a stopped MI record.

GDB internal error fix. A bug has been fixed that caused GDB to produce messages of the form: `warning: (Internal error: pc 0x1000a0 in read in psymtab, but not in symtab.)` when taking the addresses of symbols from objects added with the `add-symbol-file` command.

A.1.8. Changes in Older Releases

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

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Rev. 120305, Part No. 252061

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