Sourcery CodeBench Lite

ARM EABI

Sourcery CodeBench Lite 2013.05-23

Getting Started

Sourcery CodeBench Lite: ARM EABI: Sourcery CodeBench Lite 2013.05-23: Getting Started

Mentor Graphics, Inc.

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 ARM EABI”	This chapter contains information about using Sourcery CodeBench Lite that is specific to ARM EABI 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, “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 ARM EABI. 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 ARM EABI 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 ARM EABI”.

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. Sourcery CodeBench Lite 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”.

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.

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 commu-

[1] http://go.mentor.com/codebench/

nicate via the GDB remote serial protocol. For command-line GDB instructions, see Section 4.3, “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 `arm-none-eabi`.

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 ARM EABI” 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

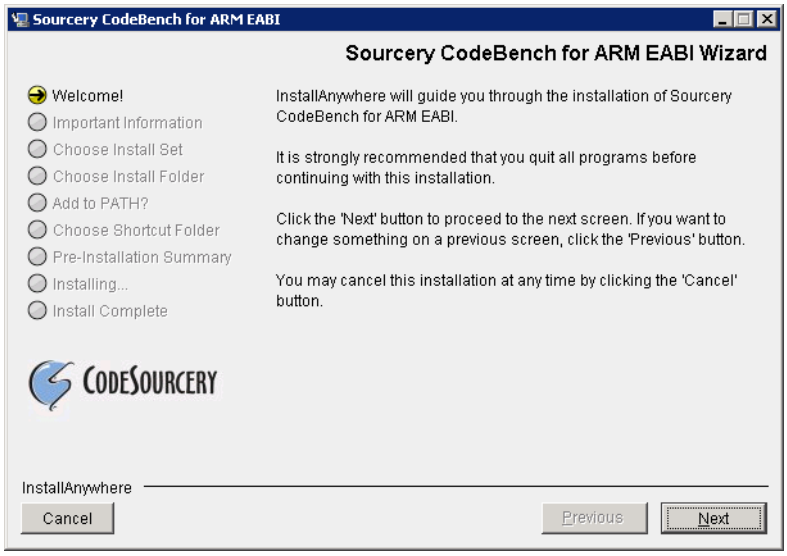
The method used to install Sourcery CodeBench Lite depends on your host system and the kind of installation package you have downloaded.

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.

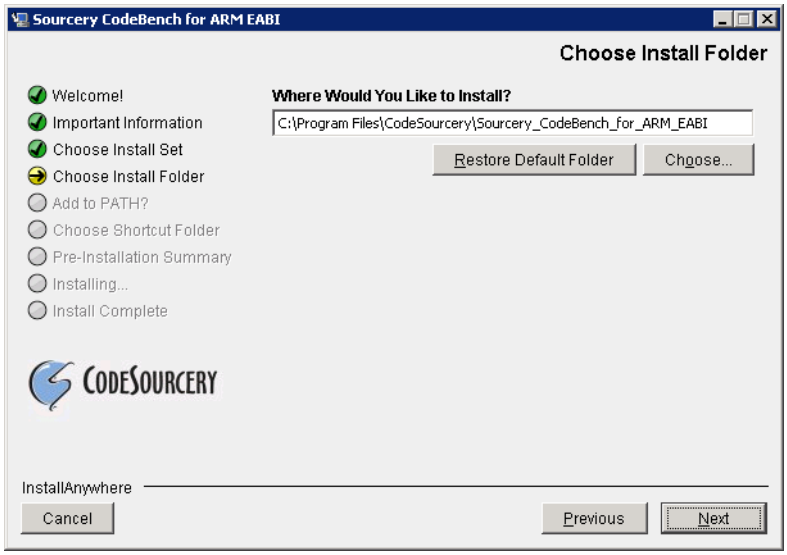
After the installer starts, follow the on-screen dialogs to install Sourcery CodeBench Lite. The installer is intended to be self-explanatory and on most pages the defaults are appropriate.

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

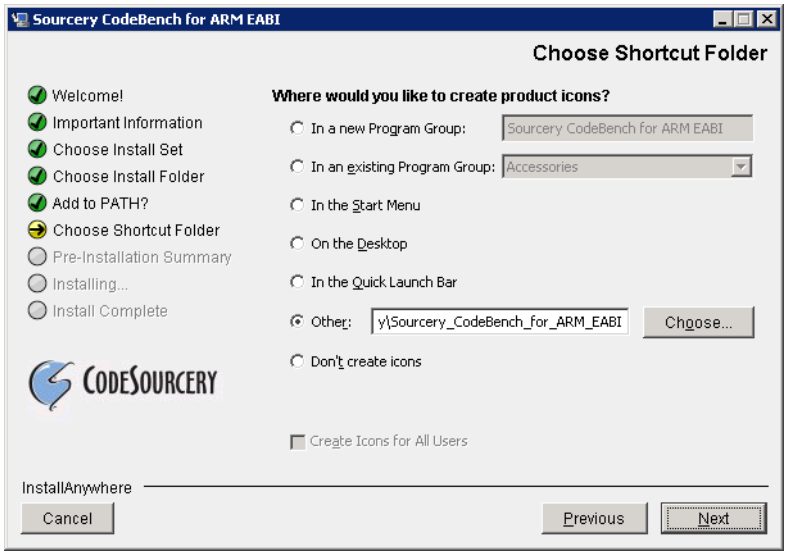


Running the Installer. The graphical installer guides you through the steps to install Sourcery CodeBench Lite.

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

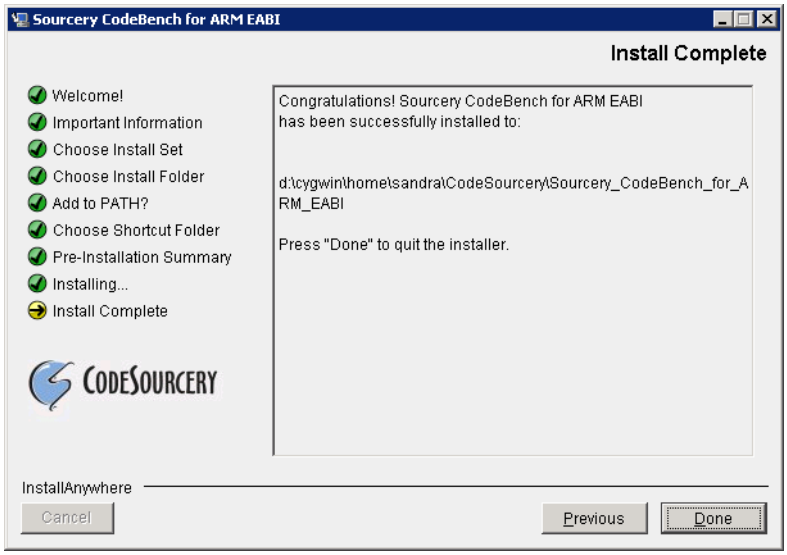


Choose Install Folder. Select the pathname to your install directory.



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 ARM EABI 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 ARM EABI target all begin with `arm-none-eabi`. 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:

```
> arm-none-eabi-gcc -v
```

Verify that the last line of the output contains: Sourcery CodeBench Lite 2013.05-23.

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/arm-arm-none-eabi/man`.

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

```
> arm-none-eabi-gcc -v
```

Verify that the last line of the output contains: `Sourcery CodeBench Lite 2013.05-23`.

2.7. Customer Experience Improvement Program

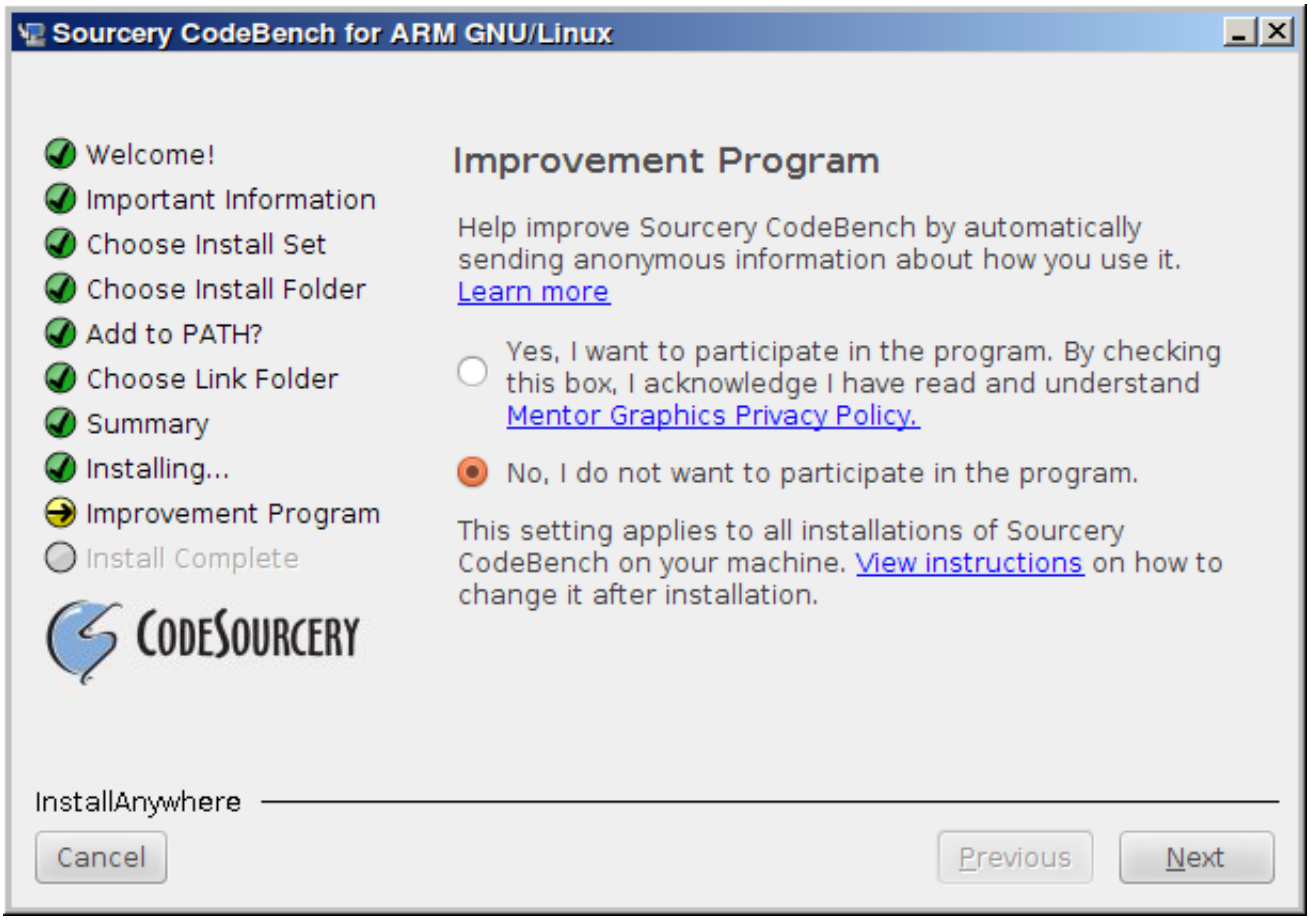
Opting into the Customer Experience Improvement Program (CEIP) permits Mentor Graphics to collect anonymous information about how you use Sourcery CodeBench Lite. For more information, please see the following web pages:

- CEIP Details[3].
- Privacy Policy[4].

You can opt in or out of the CEIP in any of the following ways.

- Check the box in the graphical installer.

[3] http://go.mentor.com/scbceip
[4] http://go.mentor.com/mentpp



Installer CEIP page.

This affects your personal opt-in settings only, and does not affect those of other users. If you have multiple instances of Sourcery CodeBench Lite installed, this setting applies to all of them.

- Set the configuration via the command line.

  To opt in:

  ```
  > arm-none-eabi-cs -O cloud_mode=online
  ```

  Or, to opt out:

  ```
  > arm-none-eabi-cs -O cloud_mode=offline
  ```

  This affects your personal opt-in settings for all installed instances of Sourcery CodeBench Lite.

  These commands are equivalent to editing `$HOME/.cs.conf`. It's also possible to edit this setting system-wide in `/opt/codesourcery/etc/cs.conf`, or per cache in *`cache_dir`*`/cs.conf`. For more information, see `man cs`.

2.8. 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 `arm-none-eabi` directory located in the install directory will be removed entirely by the uninstaller.

2.8.1. 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.

2.8.2. 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.

2.8.3. 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 ARM EABI

This chapter contains information about features of Sourcery CodeBench Lite that are specific to ARM EABI 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 ARM EABI, 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.
Target libraries		
CodeSourcery Common Startup Code Sequence	2013.05-23	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 ARM EABI includes the following library configuration.

ARMv4 - Little-Endian, Soft-Float	
Command-line option(s):	default
Library subdirectory:	`./`

ARMv4 Thumb - Little-Endian, Soft-Float	
Command-line option(s):	`-mthumb`
Library subdirectory:	`thumb/`

ARMv7 Thumb-2 - Little-Endian, Soft-Float	
Command-line option(s):	`-mthumb -march=armv7 -mfix-cortex-m3-ldrd`
Library subdirectory:	`thumb2/`

ARMv6-M Thumb - Little-Endian, Soft-Float	
Command-line option(s):	`-mthumb -march=armv6-m`
Library subdirectory:	`armv6-m/`

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 sub-directories of the `arm-none-eabi/lib` directory of your Sourcery CodeBench install.

3.3. Using Flash Memory

Sourcery CodeBench Lite supports development and debugging of applications loaded into flash memory on ARM EABI 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.

   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.

For example, ARM7TDMI cores support only one hardware breakpoint, which must also be used internally by the debugger if you set any software breakpoints in RAM. On ARM9 cores, there are two hardware breakpoints supported and one is consumed by the debugger if you set any software breakpoints.

3.4. Using VFP Floating Point

3.4.1. Enabling Hardware Floating Point

GCC provides three basic options for compiling floating-point code:

- Software floating point emulation, which is the default. In this case, the compiler implements floating-point arithmetic by means of library calls.

- VFP hardware floating-point support using the soft-float ABI. This is selected by the `-mfloat-abi=softfp` option. When you select this variant, the compiler generates VFP

floating-point instructions, but the resulting code uses the same call and return conventions as code compiled with software floating point.

- VFP hardware floating-point support using the VFP ABI, which is the VFP variant of the Procedure Call Standard for the ARM® Architecture (AAPCS). This ABI uses VFP registers to pass function arguments and return values, resulting in faster floating-point code. To use this variant, compile with `-mfloat-abi=hard`.

You can freely mix code compiled with either of the first two variants in the same program, as they both use the same soft-float ABI. However, code compiled with the VFP ABI is not link-compatible with either of the other two options. If you use the VFP ABI, you must use this option to compile your entire program, and link with libraries that have also been compiled with the VFP ABI. For example, you may need to use the VFP ABI in order to link your program with other code compiled by the ARM RealView® compiler, which uses this ABI.

Sourcery CodeBench Lite for ARM EABI includes libraries built with software floating point, which are compatible with VFP code compiled using the soft-float ABI. While the compiler is capable of generating code using the VFP ABI, no compatible runtime libraries are provided in Sourcery CodeBench Lite. However, VFP hard-float libraries built with both ABIs are available to Sourcery CodeBench Standard and Professional Edition subscribers.

Note that, in addition to selecting hard/soft float and the ABI via the `-mfloat-abi` option, you can also compile for a particular FPU using the `-mfpu` option. For example, `-mfpu=neon` selects VFPv3 with NEON coprocessor extensions.

3.4.2. NEON SIMD Code

Sourcery CodeBench includes support for automatic generation of NEON SIMD vector code. Autovectorization is a compiler optimization in which loops involving normal integer or floating-point code are transformed to use NEON SIMD instructions to process several data elements at once.

To enable generation of NEON vector code, use the command-line options `-ftree-vectorize -mfpu=neon -mfloat-abi=softfp`. The `-mfpu=neon` option also enables generation of VFPv3 scalar floating-point code.

Sourcery CodeBench also includes support for manual generation of NEON SIMD code using C intrinsic functions. These intrinsics, the same as those supported by the ARM RealView® compiler, are defined in the `arm_neon.h` header and are documented in the 'ARM NEON Intrinsics' section of the GCC manual. The command-line options `-mfpu=neon -mfloat-abi=softfp` must be specified to use these intrinsics; `-ftree-vectorize` is not required.

3.4.3. Half-Precision Floating Point

Sourcery CodeBench for ARM EABI includes support for half-precision (16-bit) floating point, including the new `__fp16` data type in C and C++, support for generating conversion instructions when compiling for processors that support them, and library functions for use in other cases.

To use half-precision floating point, you must explicitly enable it via the `-mfp16-format` command-line option to the compiler. For more information about `__fp16` representations and usage from C and C++, refer to the GCC manual.

3.5. Fixed-Point Arithmetic

Sourcery CodeBench for ARM EABI includes experimental support for fixed-point arithmetic using a set of new data types, as described in the draft ISO/IEC technical report TR 18037. This support is provided for all ARM targets, and uses specialized instructions where available, e.g. saturating add and subtract operations on ARMv6T2 and above. Library functions are used for operations which are not natively supported on the target architecture.

This feature is a GNU extension, so is only available when the selected language standard includes GNU extensions (e.g. `-std=gnu90`, which is the default). Furthermore, only C is supported, not C++.

TR 18037 leaves up to the implementation the sizes of various quantities within the new data types it defines. For Sourcery CodeBench for ARM EABI, these are, briefly:

- `short _Fract`: One sign bit, 7 fractional bits
- `_Fract`: One sign bit, 15 fractional bits
- `long _Fract`: One sign bit, 31 fractional bits
- `unsigned short _Fract`: 8 fractional bits
- `unsigned _Fract`: 16 fractional bits
- `unsigned long _Fract`: 32 fractional bits
- `short _Accum`: One sign bit, 7 fractional bits, 8 integral bits
- `_Accum`: One sign bit, 15 fractional bits, 16 integral bits
- `long _Accum`: One sign bit, 31 fractional bits, 32 integral bits
- `unsigned short _Accum`: 8 fractional bits, 8 integral bits
- `unsigned _Accum`: 16 fractional bits, 16 integral bits
- `unsigned long _Accum`: 32 fractional bits, 32 integral bits

These values (and various other useful constants) are also defined in the header file `stdfix.h` for use in your programs. Note that there is currently no support for the new standard-library functions described in TR 18037, nor for the pragmas controlling precision of operations.

Fixed-point extensions are not currently supported by GDB, nor are they compliant with the ARM EABI (which does not specify anything about fixed-point types at present). Code using fixed-point types cannot be expected to interact properly (across ABI boundaries) with code generated by other compilers for the ARM architecture.

3.6. ABI Compatibility

The Application Binary Interface (ABI) for the ARM Architecture is a collection of standards, published by ARM Ltd. and other organizations. The ABI makes it possible to combine tools from different vendors, including Sourcery CodeBench and ARM RealView®.

Sourcery CodeBench implements the ABI as described in these documents, which are available from the ARM Information Center[1]:

- BSABI - ARM IHI 0036B (28 October 2009)
- BPABI - ARM IHI 0037B (28 October 2009)
- EHABI - ARM IHI 0038A (28 October 2009)
- CLIBABI - ARM IHI 0039B (4 November 2009)
- AADWARF - ARM IHI 0040A (28 October 2009)
- CPPABI - ARM IHI 0041C (5 October 2009)
- AAPCS - ARM IHI 0042D (16 October 2009)
- RTABI - ARM IHI 0043C (19 October 2009)
- AAELF - ARM IHI 0044D (28 October 2009)
- ABI Addenda - ARM IHI 0045C (4 November 2009)

Sourcery CodeBench currently produces DWARF version 2, rather than DWARF version 3 as specified in AADWARF.

3.7. ARM Profiling Implementation

Profiling is enabled by means of the `-pg` compiler option. In this mode, the compiler inserts a call to `__gnu_mcount_nc` into every function prologue. However, no implementation of `__gnu_mcount_nc` is provided (to do so would be impossible without knowledge of the execution environment).

You must provide your own implementation of `__gnu_mcount_nc` . Here are the requirements:

- On exit, pop the top value from the stack, and place it in the `lr` register. The `sp` register should be adjusted accordingly. For example, this is how to write it as a stub function:

```
        .globl __gnu_mcount_nc
        .type __gnu_mcount_nc, %function
__gnu_mcount_nc:
        mov    ip, lr
        pop    { lr }
        bx     ip
```

- Preserve all other register state except for `r12` and the CPSR condition code bits. In particular all coprocessor state and registers `r0-r3` must be preserved.
- Record and count all occurrences of the function calls in the program. The caller can be determined from the `lr` value stored on the top of the stack (on entry to `__gnu_mcount_nc`), and the callee can be determined from the current value of the `lr` register (i.e. the caller of this function).

[1] http://infocenter.arm.com

- Arrange for the data to be saved to a file named `gmon.out` when the program exits (via `atexit`). Refer to the `gprof` profiler manual for more information.

3.8. Object File Portability

It is possible to create object files using Sourcery CodeBench for ARM EABI that are link-compatible with the GNU C library provided with Sourcery CodeBench for ARM GNU/Linux as well as with the CodeSourcery C Library or Newlib C Library provided with ARM bare-metal toolchains. These object files are additionally link-compatible with other ARM C Library ABI-compliant static linking environments and toolchains.

To use this feature, when compiling your files with the bare-metal ARM EABI toolchain define the preprocessor constant `_AEABI_PORTABILITY_LEVEL` to 1 before including any system header files. For example, pass the option `-D_AEABI_PORTABILITY_LEVEL=1` on your compilation command line. No special options are required when linking the resulting object files. When building applications for ARM EABI, files compiled with this definition may be linked freely with those compiled without it.

Files compiled in this manner may not use the functions `fgetpos` or `fsetpos`, or reference the type `fpos_t`. This is because Newlib assumes a representation for `fpos_t` that is not AEABI-compliant.

Note that object files are only portable from bare-metal toolchains to GNU/Linux, and not vice versa; object files compiled for ARM GNU/Linux targets cannot be linked into ARM EABI executables.

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 arm-none-eabi, as indicated by the `arm-none-eabi` 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:

```
> arm-none-eabi-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 `arm-none-eabi/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 `arm-none-eabi-gcc` with `arm-none-eabi-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.

4.3. 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.

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:

```
> arm-none-eabi-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.

4.3.1. 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.

4.3.2. 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
```

4.4. Using the Compiler Cache

Note on Availability

This feature is currently available on Linux hosts only.

Compiling source code can be quite slow, and frequently recompiling that code can be extremely inefficient. Sourcery CodeBench Lite includes a tool named `arm-none-eabi-cs` that solves this problem via *caching*.

The caching tool intercepts compiler invocations, generates a unique signature from the source files, command-line parameters, and other environmental information, and serves the object file and warning messages directly from the cache. If the object is not currently cached then the real compiler is called, and the cache updated.

The first time you build with caching enabled you can expect the build to take 10-30% *longer*. The second time you build it might be 80% *faster*. The memory and CPU usage savings may also mean it is possible to use higher levels of build parallelism (e.g. `make -j`) and gain even more performance.

`arm-none-eabi-cs` is based on the well-known open-source tool *ccache*. Refer to `man cs` for more information.

4.4.1. Invoking `arm-none-eabi-cs`

There are two ways you can run the caching tool with command-line builds.

- Explicitly invoke `arm-none-eabi-cs`. For example, like this:

  ```
  > arm-none-eabi-cs arm-none-eabi-gcc -c hello.c
  ```

  or like this:

  ```
  > make CC="arm-none-eabi-cs arm-none-eabi-gcc"
  ```

- Add *`installdir`*`/bin/cache` to the head of your `PATH`, and run your normal compile command:

  ```
  > export PATH=installdir/bin/cache:installdir/bin:$PATH
  > arm-none-eabi-gcc -c hello.c
  ```

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.

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 ARM EABI 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.
- Section 5.4, “Interrupt Vectors and Handlers” covers CS3's interrupt handling model, and discusses how you can customize the CS3-provided interrupt vector tables.

The second part provides details about the CS3 implementation for ARM EABI:

- Section 5.5, “Supported Boards for ARM EABI” lists the boards supported by CS3 for ARM EABI, and the available linker scripts for them.
- Section 5.6, “Interrupt Vector Tables” documents the details of the provided interrupt vectors for CS3-supported devices.

5.1. Linker Scripts

When you build programs for ARM EABI 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 ARM EABI”.

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. 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 Altera Cyclone III Cortex-M1 boards, you could link with `-T cycloneiii-cm1-ram-hosted.ld`.

5.2. Program Startup and Termination

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

CS3 divides the startup sequence into three phases:

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

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

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

5.2.1. The Hard Reset Phase

This phase, which begins at `__cs3_reset`, is responsible for initializing board-specific registers, such as memory base registers and DRAM controllers, or scanning memory to check the available size. It is written in assembler and ends with a jump to `__cs3_start_asm`, which is where the assembly initialization phase begins.

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

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

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 ARM EABI”, 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 ARM EABI” 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 ARM EABI are documented in XML files in the `arm-none-eabi/lib/boards/` 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 `arm-none-eabi/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.

M-profile processors like the Cortex-M3 use the address vector model. Classic ARM processors (including ARM7/ARM9 as well as Cortex-A/R series processors) are technically code vector processors. However, each vector slot only holds a single instruction. CS3 emulates the address vector model on these processors by placing an indirect branch instruction in each slot of the real exception vector. 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. ARM EABI Interrupt Vector Implementation

On address vector processors, the CS3 library provides an array of pointers to interrupt handlers named `__cs3_interrupt_vector_`*`form`*, where *`form`* identifies the particular processor variant the vector is appropriate for. Each entry in the vector holds a reference to a symbol named `__cs3_isr_`*`name`*, where *`name`* is the customary name of that interrupt on the processor, or a number if there is no consistently used name. You can find the interrupt vector details in Section 5.6, “Interrupt Vector Tables”. The particular vector used by a given CS3-supported board is documented in the tables in Section 5.5, “Supported Boards for ARM EABI”.

CS3 provides a reasonable default definition for each `__cs3_isr_`*`name`* handler. Many of these symbols are aliased to a common handler routine. If your program stops at a default interrupt handler, its name as shown in backtraces may therefore not correctly reflect which interrupt occurred.

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

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

You may define the vector in C with an array of pointers using the `section` attribute to place it in the appropriate section. For example, to override the interrupt vector on Altera Cyclone III Cortex-M1 boards, make the following definition:

```
typedef void handler(void);
handler *__attribute__((section (".cs3.interrupt_vector")))
  __cs3_interrupt_vector_micro[] =
{ ... };
```

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. For example, the EABI requires that the stack be 8-byte aligned, but on some ARMv7-M processors, only 4-byte stack alignment is guaranteed when calling an interrupt vector. This can cause subtle runtime failures, usually when 8-byte types are used.

As an alternative to writing interrupt handlers in assembly language, on ARM 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. For example, to override the `__cs3_isr_nmi` handler, use the following definition:

```
void __attribute__ ((interrupt)) __cs3_isr_nmi (void)
{
  ... custom handler code ...
}
```

On ARM targets, the `interrupt` attribute also takes an optional parameter to specify the type of interrupt. Refer to the GCC manual for more details about attribute syntax and usage.

5.5. Supported Boards for ARM EABI

CS3 provides support for the following boards on ARM EABI targets.

Altera Cyclone III Cortex-M1		
Processor name:	Cortex-M1	
Processor options:	`-mcpu=cortex-m1 -mthumb`	
Memory regions:	`itcm`, `ram` (SRAM), `rom` (Flash)	
Interrupt vector:	`__cs3_interrupt_vector_micro`	
Linker scripts:	RAM Hosted	`cycloneiii-cm1-ram-hosted.ld`
	RAM Unhosted	`cycloneiii-cm1-ram.ld`
	ROM Hosted	`cycloneiii-cm1-rom-hosted.ld`
	ROM Unhosted	`cycloneiii-cm1-rom.ld`

ARM M-profile Simulator		
Processor name:	Cortex-M3	
Processor options:	`-mcpu=cortex-m3 -mthumb`	
Memory regions:	`ram`	
Interrupt vector:	`__cs3_interrupt_vector_micro`	
Linker scripts:	Simulator Hosted	`generic-m-hosted.ld`
	Simulator Unhosted	`generic-m.ld`

ARM Simulator		
Processor name:	unspecified	
Processor options:	none	
Memory regions:	`ram`	
Interrupt vector:	`__cs3_interrupt_vector_arm`	
Linker scripts:	Simulator Hosted	`generic-hosted.ld`
	Simulator Unhosted	`generic.ld`

ARM Simulator (VFP)		
Processor name:	unspecified	
Processor options:	none	
Memory regions:	`ram`	
Interrupt vector:	`__cs3_interrupt_vector_arm`	
Linker scripts:	Simulator Hosted	`generic-vfp-hosted.ld`
	Simulator Unhosted	`generic-vfp.ld`

ARMulator (RDI)		
Processor name:	unspecified	
Processor options:	none	
Memory regions:	`ram`	
Interrupt vector:	`__cs3_interrupt_vector_arm`	
Linker scripts:	RAM Hosted	`armulator-ram-hosted.ld`
	RAM Unhosted	`armulator-ram.ld`

Xilinx Zynq-7000		
Processor name:	Cortex-A9	
Processor options:	`-mcpu=cortex-a9`	
Memory regions:	`ram` (1024MB DDR SDRAM), `rom` (64MB NOR Flash Memory)	
Interrupt vector:	`__cs3_interrupt_vector_arm`	
Linker scripts:	RAM Hosted	`zynq7000-ram-hosted.ld`
	RAM Unhosted	`zynq7000-ram.ld`
	ROM Hosted	`zynq7000-rom-hosted.ld`
	ROM Unhosted	`zynq7000-rom.ld`

5.6. Interrupt Vector Tables

5.6.1. `__cs3_interrupt_vector_arm`

The ARM interrupt vector table (`__cs3_interrupt_vector_arm`) contents are:

Number	Name	Meaning
0	`__cs3_reset`	Reset entry point
1	`__cs3_isr_undef`	Undefined Instruction
2	`__cs3_isr_swi`	Software Interrupt/Supervisor Call
3	`__cs3_isr_pabort`	Prefetch Abort
4	`__cs3_isr_dabort`	Data Abort
5	`__cs3_isr_reserved`	
6	`__cs3_isr_irq`	External Interrupt (IRQ)
7	`__cs3_isr_fiq`	Fast Interrupt (FIQ)

5.6.2. `__cs3_interrupt_vector_micro`

The Microcontroller Profile interrupt vector table (`__cs3_interrupt_vector_micro`) contents are:

Number	Name	Meaning
0	`__cs3_stack`	Initial stack pointer
1	`__cs3_reset`	Reset entry point
2	`__cs3_isr_nmi`	Non Maskable Interrupt
3	`__cs3_isr_hard_fault`	Hardware fault
4	`__cs3_isr_mpu_fault`	MPU fault
5	`__cs3_isr_bus_fault`	Bus fault
6	`__cs3_isr_usage_fault`	Usage fault
7..10	`__cs3_isr_reserved_7..10`	Reserved for future use
11	`__cs3_isr_svcall`	System Vector Call
12	`__cs3_isr_debug`	Debug interrupt
13	`__cs3_isr_reserved_13`	Reserved for future use
14	`__cs3_isr_pendsv`	
15	`__cs3_isr_systick`	System Ticker
16..47	`__cs3_isr_external_0..31`	External interrupt

Chapter 6
Next Steps with Sourcery CodeBench

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

6.1. 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.

6.2. 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/arm-arm-none-eabi/` 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/arm-arm-none-eabi/man/man1
```

Then you can invoke `man` as:

```
> man ./arm-none-eabi-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 ARM EABI. You should read through these notes to learn about new features and bug fixes.

A.1. Changes in Sourcery CodeBench Lite for ARM EABI

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

A.1.1. Changes in Sourcery CodeBench Lite 2013.05-23

GCC version 4.7.3. Sourcery CodeBench Lite for ARM EABI 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`.

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.

A.1.2. Changes in Sourcery CodeBench Lite 2013.05-4

C++ fix for ARMv6-M. A bug that prevented C++ multiple inheritance from working in position-independent code compiled for ARMv6-M has been fixed.

Multilib selection bug fix. A compiler bug that caused the wrong multilib to be chosen when compiling with `-mthumb -mcpu=cortex-m4 -mfloat-abi=softfp` has been fixed.

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

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.

Linker assertion failure fix. A linker bug has been fixed that caused an assertion failure when linking unoptimized code using thread-local storage.

`ldralt` assembly bug fix. A bug that caused the assembly of `ldralt` instructions to sometimes produce the error message `selected processor does not support ARM mode` has been fixed.

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

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

A.1.3. Changes in Sourcery CodeBench Lite 2012.09-63

Code size optimization improvement. When compiling with `-Os` or `-O2` and higher GCC no longer enables the `-funroll-loops` option by default. This change reduces the size of optimized code produced by Sourcery CodeBench and brings its behavior back into conformance with other

GCC distributions. For more information about the tradeoffs between optimizing for size versus speed please see the Sourcery CodeBench Knowledge Base [1].

Loop optimization bug fix. A compiler bug that caused some forms of loop to be mis-optimized when using the `-fpromote-loop-indices` option (enabled by default when optimizing for speed) has been fixed.

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

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

GDB simulator removed. The built-in ARM processor simulator has been removed from the debugger. The stand-alone `arm-none-eabi-run` executable has also been removed.

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.1.4. Changes in Sourcery CodeBench Lite 2012.09-17

GCC version 4.7.2. Sourcery CodeBench Lite for ARM EABI 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`.

Select correct multilib for `-mcpu=cortex-a15`. A GCC bug has been fixed that caused an incorrect multilib to be selected when compiling with `-mcpu=cortex-a15`.

Incorrect warnings for naked functions fixed. A bug in the C++ compiler has been fixed that caused it to incorrectly warn about missing return statements in functions with the `naked` attribute, which can only include inline assembly statements.

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

Binutils version 2.23. Sourcery CodeBench Lite for ARM EABI is now based on binutils version 2.23.

Fix for interrupts on Cortex-M3. A bug in CS3 has been fixed that caused errors while linking RAM-profile applications using interrupts for Cortex-M3 targets.

Support for Xilinx ZC702 Evaluation Kit. Sourcery CodeBench Lite now includes support for creating and debugging of applications for the Xilinx Zynq-7000 EPP ZC702 Evaluation Kit.

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.

Removal of the Sourcery CodeBench Debug Sprite. The Sourcery CodeBench Debug Sprite has been removed.

[1] https://support.codesourcery.com/GNUToolchain/kbentry77

A.1.5. Changes in Sourcery CodeBench Lite 2012.03-56

New Sourcery CodeBench Lite branding. Sourcery G++ has been renamed to Sourcery CodeBench. This change affects the names of the default installation directory and installer-created shortcuts, but no internal pathnames or tool names within the installation directory have been changed.

Fix for internal compiler error. A bug that caused GCC to report an internal compiler error in `push_minipool_fix` has been fixed.

Internal compiler error with NEON intrinsics. A compiler bug has been fixed that caused internal compiler errors when using certain NEON intrinsics.

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

Fix for compiler hang. A bug that caused GCC to become stuck in an infinite loop in the optimizer has been fixed.

Internal compiler error. A GCC bug has been fixed that caused an internal compiler error when sign extending the result of an array subscript expression with an index greater than 255.

GCC version 4.6. Sourcery CodeBench Lite for ARM EABI 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.

ARM VFP9-S errata workaround. A compiler workaround for ARM Errata Notice GENC-010704 (760019: Canceled FDIV or FSQRT can be executed twice) has been implemented.

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

GCC version 4.6.3. Sourcery CodeBench Lite for ARM EABI 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`.

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

Map file name demangling bug fix. GCC now properly passes the `--demangle` and `--no-demangle` options to the linker to control map file output. The default behavior on all hosts is now to demangle C++ names.

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

ARM miscompilation fix. A bug has been fixed that caused miscompilation of some expressions involving the minimum or maximum idiom, such as `(a > 0) ? a : 0`.

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

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.

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.

Binutils version 2.21. Sourcery CodeBench Lite for ARM EABI is now based on binutils version 2.21.

Assembler crash. The assembler now warns when there is line information for the `*ABS*` section, rather than crash. This can occur when the `.offset` directive is used incorrectly.

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 ARM EABI 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.

CS3 bug fix for Xilinx Zynq-7000. A bug that caused undefined symbol errors in the CS3 library when linking programs for the Xilinx Zynq-7000 has been fixed.

Freescale i.MX53 QSB support. Sourcery CodeBench Lite now supports the Freescale i.MX53 QSB board.

Fix for crash in GDB `maint print arch`. A bug in the GDB command `maint print arch` that sometimes caused GDB to crash has been fixed.

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 *** arm-none-eabi-gdb: free(): invalid next size (normal): 0x09466198 ***` followed by a backtrace.

GDB interrupt handling bug fix. A bug in GDB has been fixed that caused it to sometimes fail to interrupt lengthy single-step operations (as by a **Ctrl**+**C** when using GDB from the command line).

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.

Fix GDB crash during connection to debug agent. A bug has been fixed that caused GDB to crash while connecting to any debug agent through standard IO where the debug agent had detected an early error and terminated the communication.

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.

Improved disassembler performance in the debugger. GDB's disassembler has been improved to use more efficient memory access on remote targets.

Fix GDB crash in debugging Thumb assembly routines. A bug in GDB has been fixed that caused a crash when debugging Thumb assembly routines that switch stacks by writing the stack pointer in the function prologue.

Debug Sprite option defaults. The Sourcery CodeBench Debug Sprite now uses default option values specified in board configuration files. Options included in the device URL override the default values.

Changes to host operating system requirements. The minimum required Microsoft Windows OS needed to run Sourcery CodeBench Lite is now Windows XP (SP1).

A.1.6. Changes in Older Releases

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

Appendix B
Sourcery CodeBench Lite Licenses

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

The Mentor Graphics License is available in Section B.1, “Sourcery CodeBench Lite License Agreement”.

B.1. Sourcery CodeBench Lite License Agreement

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The latest version of the License Agreement is available on-line at http://www.mentor.com/terms_conditions/embedded_software_license.

B.1.1. Embedded Software and Hardware License Agreement

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1. **Definitions.**

    1.1. "Customer's Product" means Customer's end-user product identified by a unique SKU (including any Related SKUs) in an applicable Addenda that is developed, manufactured, branded and shipped solely by Customer or an authorized manufacturer or subcontractor on behalf of Customer to end-users or consumers;

1.2. "Developer" means a unique user, as identified by a unique user identification number, with access to Embedded Software at an authorized Development Location. A unique user is an individual who works directly with the embedded software in source code form, or creates, modifies or compiles software that ultimately links to the Embedded Software in Object Code form and is embedded into Customer's Product at the point of manufacture;

1.3. "Development Location" means the location where Products may be used as authorized in the applicable Addenda;

1.4. "Development Tools" means the software that may be used by Customer for building, editing, compiling, debugging or prototyping Customer's Product;

1.5. "Embedded Software" means Software that is embeddable;

1.6. "End-User" means Customer's customer;

1.7. "Executable Code" means a compiled program translated into a machine-readable format that can be loaded into memory and run by a certain processor;

1.8. "Hardware" means a physically tangible electro-mechanical system or sub-system and associated documentation;

1.9. "Linkable Object Code" or "Object Code" means linkable code resulting from the translation, processing, or compiling of Source Code by a computer into machine-readable format;

1.10. "Mentor Embedded Linux" or "MEL" means Mentor Graphics' tools, source code, and recipes for building Linux systems;

1.11. "Open Source Software" or "OSS" means software subject to an open source license which requires as a condition for redistribution of such software, including modifications thereto, that the: (i) redistribution be in source code form or be made available in source code form; (ii) redistributed software be licensed to allow the making of derivative works; or (iii) redistribution be at no charge;

1.12. "Processor" means the specific microprocessor to be used with Software and implemented in Customer's Product;

1.13. "Products" means Software, Term-Licensed Products and/or Hardware;

1.14. "Proprietary Components" means the components of the Products that are owned and/or licensed by Mentor Graphics and are not subject to an Open Source Software license, as more fully set forth herein;

1.15. "Redistributable Components" means those components that are intended to be incorporated or linked into Customer's Linkable Object Code developed with the Software, as more fully set forth herein;

1.16. "Related SKU" means two or more Customer Products identified by logically-related SKUs, where there is no difference or change in the electrical hardware or software content between such Customer Products;

1.17. "Software" means software programs, Embedded Software and/or Development Tools, including any updates, modifications, revisions, copies, documentation and design data that are licensed under this Agreement;

1.18. "Source Code" means software in a form in which the program logic is readily understandable by a human being;

1.19. "Sourcery CodeBench Software" means Mentor Graphics' Development Tool for C/C++ embedded application development;

1.20. "Sourcery VSIPL++" is Software providing C++ classes and functions for writing embedded signal processing applications designed to run on one or more processors;

1.21. "Stock Keeping Unit" or "SKU" is a unique number or code used to identify each distinct product, item or service available for purchase;

1.22. "Subsidiary" means any corporation more than 50% owned by Customer, excluding Mentor Graphics competitors. Customer agrees to fulfill the obligations of such Subsidiary in the event of default. To the extent Mentor Graphics authorizes any Subsidiary's use of Products under this Agreement, Customer agrees to ensure such Subsidiary's compliance with the terms of this Agreement and will be liable for any breach by a Subsidiary; and

1.23. "Term-Licensed Products" means Products licensed to Customer for a limited time period ("Term").

2. **Orders, Fees and Payment.**

2.1. To the extent Customer (or if agreed by Mentor Graphics, Customer's appointed third party buying agent) places and Mentor Graphics accepts purchase orders pursuant to this Agreement ("Order(s)"), each Order will constitute a contract between Customer and Mentor Graphics, which shall be governed solely and exclusively by the terms and conditions of this Agreement and any applicable Addenda, whether or not these documents are referenced on the Order. Any additional or conflicting terms and conditions appearing on an Order will not be effective unless agreed in writing by an authorized representative of Customer and Mentor Graphics.

2.2. Amounts invoiced will be paid, in the currency specified on the applicable invoice, within 30 days from the date of such invoice. All invoices will be sent electronically to Customer on the date stated on the invoice unless otherwise specified in an Addendum. Any past due invoices will be subject to the imposition of interest charges in the amount of one and one-half percent per month or the applicable legal rate currently in effect, whichever is lower. Prices do not include freight, insurance, customs duties, taxes or other similar charges, which Mentor Graphics will state separately in the applicable invoice(s). Unless timely provided with a valid certificate of exemption or other evidence that items are not taxable, Mentor Graphics will invoice Customer for all applicable taxes including, but not limited to, VAT, GST, sales tax, consumption tax and service tax. Customer will make all payments free and clear of, and without reduction for, any withholding or other taxes; any such taxes imposed on payments by Customer hereunder will be Customer's sole responsibility. If Customer appoints a third party to place purchase orders and/or make payments on Customer's behalf, Customer shall be liable for payment under Orders placed by such third party in the event of default.

2.3. All Products are delivered FCA factory (Incoterms 2010), freight prepaid and invoiced to Customer, except Software delivered electronically, which shall be deemed delivered when made available to Customer for download. Mentor Graphics' delivery of Software by electronic means is subject to Customer's provision of both a primary and an alternate e-mail address.

3. **Grant of License.**

3.1. The Products installed, downloaded, or otherwise acquired by Customer under this Agreement constitute or contain copyrighted, trade secret, proprietary and confidential information of Mentor Graphics or its licensors, who maintain exclusive title to all Software and retain all rights not expressly granted by this Agreement. Mentor Graphics grants to Customer, subject to payment of applicable license fees, a nontransferable, nonexclusive license to use Software as described in the applicable Addenda. The limited licenses granted under the applicable Addenda shall continue until the expiration date of Term-Licensed Products or termination in accordance with Section 12 below, whichever occurs first. Mentor Graphics does NOT grant Customer any right to (a) sublicense or (b) use Software beyond the scope of this Section without first signing a separate agreement or Addenda with Mentor Graphics for such purpose.

3.2. License Type. The license type shall be identified in the applicable Addenda.

3.2.1. Development License: During the Term, if any, Customer may modify, compile, assemble and convert the applicable Embedded Software Source Code into Linkable Object Code and/or Executable Code form by the number of Developers specified, for the Processor(s), Customer's Product(s) and at the Development Location(s) identified in the applicable Addenda.

3.2.2. End-User Product License: During the Term, if any, and unless otherwise specified in the applicable Addenda, Customer may incorporate or embed an Executable Code version of the Embedded Software into the specified number of copies of Customer's Product(s), using the Processor Unit(s), and at the Development Location(s) identified in the applicable Addenda. Customer may manufacture, brand and distribute such Customer's Product(s) worldwide to its End-Users.

3.2.3. Internal Tool License: During the Term, if any, Customer may use the Development Tools solely: (a) for internal business purposes and (b) on the specified number of computer work stations and sites. Development Tools are licensed on a per-seat or floating basis, as specified in the applicable Addenda, and shall not be distributed to others or delivered in Customer's Product(s) unless specifically authorized in an applicable Addenda.

3.2.4. Sourcery CodeBench Professional Edition License: During the Term specified in the applicable Addenda, Customer may (a) install and use the Proprietary Components of the Software (i) if the license is a node-locked license, by a single user who uses the Software on up to two machines provided that only one copy of the Software is in use at any one time, or (ii) if the license is a floating license, by the authorized number of concurrent users on one or more machines provided that only the authorized number of copies of the Software are in use at any one time, and (b) distribute the Redistributable Components of the Software in Executable Code form only and only as part of Customer's Object Code developed with the Software that provides substantially different functionality than the Redistributable Component(s) alone.

3.2.5. Sourcery CodeBench Standard Edition License: During the Term specified in the applicable Addenda, Customer may (a) install and use the Proprietary Components of the Software by a single user who uses the Software on up to two machines provided that only one copy of the Software is in use at any one time, and (b) distribute the Redistributable Component(s) of the Software in Executable Code form only and only as part of Customer's Object Code developed with the Software that provides substantially different functionality than the Redistributable Component(s) alone.

3.2.6. Sourcery CodeBench Personal Edition License: During the Term specified in the applicable Addenda, Customer may (a) install and use the Proprietary Components

of the Software by a single user who uses the Software on one machine, and (b) distribute the Redistributable Component(s) of the Software in Executable Code form only and only as part of Customer Object Code developed with the Software that provides substantially different functionality than the Redistributable Component(s) alone.

3.2.7. Sourcery CodeBench Academic Edition License: During the Term specified in the applicable Addenda, Customer may (a) install and use the Proprietary Components of the Software for non-commercial, academic purposes only by a single user who uses the Software on one machine, and (b) distribute the Redistributable Component(s) of the Software in Executable Code form only and only as part of Customer Object Code developed with the Software that provides substantially different functionality than the Redistributable Component(s) alone.

3.3. Mentor Graphics may from time to time, in its sole discretion, lend Products to Customer. For each loan, Mentor Graphics will identify in writing the quantity and description of Software loaned, the authorized location and the Term of the loan. Mentor Graphics will grant to Customer a temporary license to use the loaned Software solely for Customer's internal evaluation in a non-production environment. Customer shall return to Mentor Graphics or delete and destroy loaned Software on or before the expiration of the loan Term. Customer will sign a certification of such deletion or destruction if requested by Mentor Graphics.

4. **Beta Code.**

4.1. Portions or all of certain Products may contain code for experimental testing and evaluation ("Beta Code"), which may not be used without Mentor Graphics' explicit authorization. Upon Mentor Graphics' authorization, Mentor Graphics grants to Customer a temporary, nontransferable, nonexclusive license for experimental use to test and evaluate the Beta Code without charge for a limited period of time specified by Mentor Graphics. This grant and Customer's use of the Beta Code shall not be construed as marketing or offering to sell a license to the Beta Code, which Mentor Graphics may choose not to release commercially in any form.

4.2. If Mentor Graphics authorizes Customer to use the Beta Code, Customer agrees to evaluate and test the Beta Code under normal conditions as directed by Mentor Graphics. Customer will contact Mentor Graphics periodically during Customer's use of the Beta Code to discuss any malfunctions or suggested improvements. Upon completion of Customer's evaluation and testing, Customer will send to Mentor Graphics a written evaluation of the Beta Code, including its strengths, weaknesses and recommended improvements.

4.3. Customer agrees to maintain Beta Code in confidence and shall restrict access to the Beta Code, including the methods and concepts utilized therein, solely to those employees and Customer location(s) authorized by Mentor Graphics to perform beta testing. Customer agrees that any written evaluations and all inventions, product improvements, modifications or developments that Mentor Graphics conceived or made during or subsequent to this Agreement, including those based partly or wholly on Customer's feedback, will be the exclusive property of Mentor Graphics. Mentor Graphics will have exclusive rights, title and interest in all such property. The provisions of this Subsection 4.3 shall survive termination of this Agreement.

5. **Restrictions on Use.**

5.1. Customer may copy Software only as reasonably necessary to support the authorized use, including archival and backup purposes. Each copy must include all notices and legends

embedded in Software and affixed to its medium and container as received from Mentor Graphics. All copies shall remain the property of Mentor Graphics or its licensors. Except where embedded in Executable Code form in Customer's Product, Customer shall maintain a record of the number and location of all copies of Software, including copies merged with other software and products, and shall make those records available to Mentor Graphics upon request. Customer shall not make Products available in any form to any person other than Customer's employees, authorized manufacturers or authorized contractors, excluding Mentor Graphics competitors, whose job performance requires access and who are under obligations of confidentiality. Customer shall take appropriate action to protect the confidentiality of Products and ensure that any person permitted access does not disclose or use Products except as permitted by this Agreement. Customer shall give Mentor Graphics immediate written notice of any unauthorized disclosure or use of the Products as soon as Customer learns or becomes aware of such unauthorized disclosure or use.

5.2. Customer acknowledges that the Products provided hereunder may contain Source Code which is proprietary and its confidentiality is of the highest importance and value to Mentor Graphics. Customer acknowledges that Mentor Graphics may be seriously harmed if such Source Code is disclosed in violation of this Agreement. Except as otherwise permitted for purposes of interoperability as specified by applicable and mandatory local law, Customer shall not reverse-assemble, reverse-compile, reverse-engineer or in any way derive any Source Code from Products that are not provided in Source Code form. Except as embedded in Executable Code in Customer's Product and distributed in the ordinary course of business, in no event shall Customer provide Products to Mentor Graphics competitors. Log files, data files, rule files and script files generated by or for the Software (collectively "Files") constitute and/or include confidential information of Mentor Graphics. Customer may share Files with third parties, excluding Mentor Graphics competitors, provided that the confidentiality of such Files is protected by written agreement at least as well as Customer protects other information of a similar nature or importance, but in any case with at least reasonable care. Under no circumstances shall Customer use Products or allow their use for the purpose of developing, enhancing or marketing any product that is in any way competitive with Products, or disclose to any third party the results of, or information pertaining to, any benchmark.

5.3. Customer may not assign this Agreement or the rights and duties under it, or relocate, sublicense or otherwise transfer the Products, whether by operation of law or otherwise ("Attempted Transfer"), without Mentor Graphics' prior written consent, which shall not be unreasonably withheld, and payment of Mentor Graphics' then-current applicable relocation and/or transfer fees. Any Attempted Transfer without Mentor Graphics' prior written consent shall be a material breach of this Agreement and may, at Mentor Graphics' option, result in the immediate termination of the Agreement and/or the licenses granted under this Agreement. The terms of this Agreement, including without limitation the licensing and assignment provisions, shall be binding upon Customer's permitted successors in interest and assigns.

5.4. Notwithstanding any provision in an OSS license agreement applicable to a component of the Sourcery CodeBench Software that permits the redistribution of such component to a third party in Source Code or binary form, Customer may not use any Mentor Graphics trademark, whether registered or unregistered, in connection with such distribution, and may not recompile the Open Source Software components with the --with-pkgversion or --with-bugurl configuration options that embed Mentor Graphics' trademarks in the resulting binary.

5.5. The provisions of this Section 5 shall survive the termination of this Agreement.

6. **Support Services.**

   6.1. Except as described in Sections 6.2, 6.3 and 6.4 below, and unless otherwise specified in any applicable Addenda to this Agreement, to the extent Customer purchases support services, Mentor Graphics will provide Customer updates and technical support for the number of Developers at the Development Location(s) for which support is purchased in accordance with Mentor Graphics' then-current End-User Software Support Terms located at http://supportnet.mentor.com/about/legal/.

   6.2. To the extent Customer purchases support services for Sourcery CodeBench Software, support will be provided solely in accordance with the provisions of this Section 6.2. Mentor Graphics shall provide updates and technical support to Customer as described herein only on the condition that Customer uses the Executable Code form of the Sourcery CodeBench Software for internal use only and/or distributes the Redistributable Components in Executable Code form only (except as provided in a separate redistribution agreement with Mentor Graphics or as required by the applicable Open Source license). Any other distribution by Customer of the Sourcery CodeBench Software (or any component thereof) in any form, including distribution permitted by the applicable Open Source license, shall automatically terminate any remaining support term. Subject to the foregoing and the payment of support fees, Mentor Graphics will provide Customer updates and technical support for the number of Developers at the Development Location(s) for which support is purchased in accordance with Mentor Graphics' then-current Sourcery CodeBench Software Support Terms located at http://www.mentor.com/codebench-support-legal.

   6.3. To the extent Customer purchases support services for Sourcery VSIPL++, Mentor Graphics will provide Customer updates and technical support for the number of Developers at the Development Location(s) for which support is purchased solely in accordance with Mentor Graphics' then-current Sourcery VSIPL++ Support Terms located at. http://www.mentor.com/vsipl-support-legal.

   6.4. To the extent Customer purchases support services for Mentor Embedded Linux, Mentor Graphics will provide Customer updates and technical support for the number of Developers at the Development Location(s) for which support is purchased solely in accordance with Mentor Graphics' then-current Mentor Embedded Linux Support Terms located at http://www.mentor.com/mel-support-legal.

7. **Third Party and Open Source Software.** Products may contain Open Source Software or code distributed under a proprietary third party license agreement. Please see applicable Products documentation, including but not limited to license notice files, header files or source code for further details. Please see Section B.2.2, “Components” for additional rights and obligations governing your use and distribution of Open Source Software. Customer agrees that it shall not subject any Product provided by Mentor Graphics under this Agreement to any Open Source Software license that does not otherwise apply to such Product. In the event of conflict between the terms of this Agreement, any Addenda and an applicable OSS or proprietary third party agreement, the OSS or proprietary third party agreement will control solely with respect to the OSS or proprietary third party software component. The provisions of this Section 7 shall survive the termination of this Agreement.

8. **Limited Warranty.**

   8.1. Mentor Graphics warrants that during the warranty period its standard, generally supported Products, when properly installed, will substantially conform to the functional specifications set forth in the applicable user manual and/or specification. Mentor Graphics does not warrant that Products will meet Customer's requirements or that operation of Products will be uninterrupted or error free. The warranty period is 90 days starting on the 15th day after

delivery or upon installation, whichever first occurs. Customer must notify Mentor Graphics in writing of any nonconformity within the warranty period. For the avoidance of doubt, this warranty applies only to the initial shipment of Products under an Order and does not renew or reset, for example, with the delivery of (a) Software updates or (b) authorization codes. This warranty shall not be valid if Products have been subject to misuse, unauthorized modification or improper installation. MENTOR GRAPHICS' ENTIRE LIABILITY AND CUSTOMER'S EXCLUSIVE REMEDY SHALL BE, AT MENTOR GRAPHICS' OPTION, EITHER (A) REFUND OF THE PRICE PAID UPON RETURN OF THE PRODUCTS TO MENTOR GRAPHICS OR (B) MODIFICATION OR REPLACEMENT OF THE PRODUCTS THAT DO NOT MEET THIS LIMITED WARRANTY, PROVIDED CUSTOMER HAS OTHERWISE COMPLIED WITH THIS AGREEMENT. MENTOR GRAPHICS MAKES NO WARRANTIES WITH RESPECT TO: (A) SERVICES; OR (B) PRODUCTS PROVIDED AT NO CHARGE, WHICH ARE PROVIDED "AS IS" UNLESS OTHERWISE AGREED IN WRITING.

8.2. THE WARRANTIES SET FORTH IN THIS SECTION 8 ARE EXCLUSIVE TO CUSTOMER AND DO NOT APPLY TO ANY END-USER. NEITHER MENTOR GRAPHICS NOR ITS LICENSORS MAKE ANY OTHER WARRANTIES, EXPRESS, IMPLIED, OR STATUTORY, WITH RESPECT TO PRODUCTS OR OTHER MATERIAL PROVIDED UNDER THIS AGREEMENT. MENTOR GRAPHICS AND ITS LICENSORS SPECIFICALLY DISCLAIM ALL IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NON-INFRINGEMENT OF INTELLECTUAL PROPERTY.

9. **LIMITATION OF LIABILITY.** EXCEPT WHERE THIS EXCLUSION OR RESTRICTION OF LIABILITY WOULD BE VOID OR INEFFECTIVE UNDER APPLICABLE LAW, AND EXCEPT FOR EITHER PARTY'S BREACH OF ITS CONFIDENTIALITY OBLIGATIONS, CUSTOMER'S BREACH OF LICENSING TERMS OR CUSTOMER'S OBLIGATIONS UNDER SECTION 10, IN NO EVENT SHALL: (A) EITHER PARTY OR ITS RESPECTIVE LICENSORS BE LIABLE FOR INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES (INCLUDING LOST PROFITS OR SAVINGS) WHETHER BASED ON CONTRACT, TORT OR ANY OTHER LEGAL THEORY, EVEN IF SUCH PARTY OR ITS LICENSORS HAVE BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES; AND (B) EITHER PARTY OR ITS RESPECTIVE LICENSORS' LIABILITY UNDER THIS AGREEMENT, INCLUDING, FOR THE AVOIDANCE OF DOUBT, LIABILITY FOR ATTORNEYS' FEES OR COSTS, EXCEED THE GREATER OF THE FEES PAID OR OWING TO MENTOR GRAPHICS FOR THE PRODUCT OR SERVICE GIVING RISE TO THE CLAIM OR $500,000 (FIVE HUNDRED THOUSAND U.S. DOLLARS). NOTWITHSTANDING THE FOREGOING, IN THE CASE WHERE NO AMOUNT WAS PAID, MENTOR GRAPHICS AND ITS LICENSORS SHALL HAVE NO LIABILITY FOR ANY DAMAGES WHATSOEVER. THE PROVISIONS OF THIS SECTION 9 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

10. **Hazardous Applications.**

10.1. Customer agrees that Mentor Graphics has no control over Customer's testing or the specific applications and use that Customer will make of Products. Mentor Graphics Products are not specifically designed for use in the operation of nuclear facilities, aircraft navigation or communications systems, air traffic control, life support systems, medical devices or other applications in which the failure of Mentor Graphics Products could lead to death, personal injury, or severe physical or environmental damage ("Hazardous Applications").

10.2. CUSTOMER ACKNOWLEDGES IT IS SOLELY RESPONSIBLE FOR TESTING PRODUCTS USED IN HAZARDOUS APPLICATIONS AND SHALL BE SOLELY

LIABLE FOR ANY DAMAGES RESULTING FROM SUCH USE. NEITHER MENTOR GRAPHICS NOR ITS LICENSORS SHALL BE LIABLE FOR ANY DAMAGES RESULTING FROM OR IN CONNECTION WITH THE USE OF PRODUCTS IN ANY HAZARDOUS APPLICATIONS.

10.3. CUSTOMER AGREES TO INDEMNIFY AND HOLD HARMLESS MENTOR GRAPHICS AND ITS LICENSORS FROM ANY CLAIMS, LOSS, COST, DAMAGE, EXPENSE OR LIABILITY, INCLUDING REASONABLE ATTORNEYS' FEES, ARISING OUT OF OR IN CONNECTION WITH THE USE OF PRODUCTS AS DESCRIBED IN SECTION 10.1.

10.4. THE PROVISIONS OF THIS SECTION 10 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

11. **Infringement.**

11.1. Mentor Graphics will defend or settle, at its option and expense, any action brought against Customer in the United States, Canada, Japan, or member state of the European Union which alleges that any standard, generally supported Product acquired by Customer hereunder infringes a patent or copyright or misappropriates a trade secret in such jurisdiction. Mentor Graphics will pay any costs and damages finally awarded against Customer that are attributable to the action. Customer understands and agrees that as conditions to Mentor Graphics' obligations under this section Customer must: (a) notify Mentor Graphics promptly in writing of the action; (b) provide Mentor Graphics all reasonable information and assistance to settle or defend the action; and (c) grant Mentor Graphics sole authority and control of the defense or settlement of the action.

11.2. If a claim is made under Subsection 11.1 Mentor Graphics may, at its option and expense, and in addition to its obligations under Section 11.1, either (a) replace or modify the Product so that it becomes noninfringing; or (b) procure for Customer the right to continue using the Product. If Mentor Graphics determines that neither of those alternatives is financially practical or otherwise reasonably available, Mentor Graphics may require the return of the Product and refund to Customer any purchase price or license fee(s) paid.

11.3. Mentor Graphics has no liability to Customer if the claim is based upon: (a) the combination of the Product with any product not furnished by Mentor Graphics, where the Product itself is not infringing; (b) the modification of the Product other than by Mentor Graphics or as directed by Mentor Graphics, where the unmodified Product would not infringe; (c) the use of the infringing Product when Mentor Graphics has provided Customer with a current unaltered release of a non-infringing Product of substantially similar functionality in accordance with Subsection 11.2(a); (d) the use of the Product as part of an infringing process; (e) a product that Customer makes, uses, or sells, where the Product itself is not infringing; (f) any Product provided at no charge; (g) any software provided by Mentor Graphics' licensors who do not provide such indemnification to Mentor Graphics' customers; (h) Open Source Software, except to the extent that the infringement is directly caused by Mentor Graphics' modifications to such Open Source Software; or (i) infringement by Customer that is deemed willful. In the case of (i), Customer shall reimburse Mentor Graphics for its reasonable attorneys' fees and other costs related to the action.

11.4. THIS SECTION 11 IS SUBJECT TO SECTION 9 ABOVE AND STATES: (A) THE ENTIRE LIABILITY OF MENTOR GRAPHICS AND ITS LICENSORS AND (B) CUSTOMER'S SOLE AND EXCLUSIVE REMEDY, WITH RESPECT TO ANY ALLEGED PATENT OR COPYRIGHT INFRINGEMENT OR TRADE SECRET MISAPPROPRIATION BY ANY PRODUCT PROVIDED UNDER THIS AGREEMENT.

12. **Termination and Effect of Termination.** If a Software license was provided for limited term use, such license will automatically terminate at the end of the authorized Term.

    12.1. **Termination for Breach.** This Agreement shall remain in effect until terminated in accordance with its terms. Mentor Graphics may terminate this Agreement and/or any licenses granted under this Agreement, and Customer will immediately discontinue use and distribution of Products, if Customer (a) commits any material breach of any provision of this Agreement and fails to cure such breach upon 30-days prior written notice; or (b) becomes insolvent, files a bankruptcy petition, institutes proceedings for liquidation or winding up or enters into an agreement to assign its assets for the benefit of creditors. Termination of this Agreement or any license granted hereunder will not affect Customer's obligation to pay for Products shipped or licenses granted prior to the termination, which amounts shall be payable immediately upon the date of termination. For the avoidance of doubt, nothing in this Section 12 shall be construed to prevent Mentor Graphics from seeking immediate injunctive relief in the event of any threatened or actual breach of Customer's obligations hereunder.

    12.2. **Effect of Termination.** Upon termination of this Agreement, the rights and obligations of the parties shall cease except as expressly set forth in this Agreement. Upon termination or expiration of the Term, Customer will discontinue use and/or distribution of Products, and shall return Hardware and either return to Mentor Graphics or destroy Software in Customer's possession, including all copies and documentation, and certify in writing to Mentor Graphics within ten business days of the termination date that Customer no longer possesses any of the affected Products or copies of Software in any form, except to the extent an Open Source Software license conflicts with this Section 12.2 and permits Customer's continued use of any Open Source Software portion or component of a Product. Upon termination for Customer's breach, an End-User may continue its use and/or distribution of Customer's Product so long as: (a) the End-User was licensed according to the terms of this Agreement, if applicable to such End-User, and (b) such End-User is not in breach of its agreement, if applicable, nor a party to Customer's breach.

13. **Export.** The Products provided hereunder are subject to regulation by local laws and United States government agencies, which prohibit export or diversion of certain products, information about the products, and direct or indirect products thereof, to certain countries and certain persons. Customer agrees that it will not export Products in any manner without first obtaining all necessary approval from appropriate local and United States government agencies. Customer acknowledges that the regulation of product export is in continuous modification by local governments and/or the United States Congress and administrative agencies. Customer agrees to complete all documents and to meet all requirements arising out of such modifications.

14. **U.S. Government License Rights.** Software was developed entirely at private expense. All Software is commercial computer software within the meaning of the applicable acquisition regulations. Accordingly, pursuant to US FAR 48 CFR 12.212 and DFAR 48 CFR 227.7202, use, duplication and disclosure of the Software by or for the U.S. Government or a U.S. Government subcontractor is subject solely to the terms and conditions set forth in this Agreement, except for provisions which are contrary to applicable mandatory federal laws.

15. **Third Party Beneficiary.** For any Products licensed under this Agreement and provided by Customer to End-Users, Mentor Graphics or the applicable licensor is a third party beneficiary of the agreement between Customer and End-User. Mentor Graphics Corporation, Mentor Graphics (Ireland) Limited, and other licensors may be third party beneficiaries of this Agreement with the right to enforce the obligations set forth herein.

16. **Review of License Usage.** Customer will monitor the access to and use of Software. With prior written notice, during Customer's normal business hours, and no more frequently than

once per calendar year, Mentor Graphics may engage an internationally recognized accounting firm to review Customer's software monitoring system, records, accounts and sublicensing documents deemed relevant by the internationally recognized accounting firm to confirm Customer's compliance with the terms of this Agreement or U.S. or other local export laws. Such review may include FlexNet (or successor product) report log files that Customer shall capture and provide at Mentor Graphics' request. Customer shall make records available in electronic format and shall fully cooperate with data gathering to support the license review. Mentor Graphics shall bear the expense of any such review unless a material non-compliance is revealed. Mentor Graphics shall treat as confidential information all Customer information gained as a result of any request or review and shall only use or disclose such information as required by law or to enforce its rights under this Agreement. Such license review shall be at Mentor Graphics' expense unless it reveals a material underpayment of fees of five percent or more, in which case Customer shall reimburse Mentor Graphics for the costs of such license review. Customer shall promptly pay any such fees. If the license review reveals that Customer has made an overpayment, Mentor Graphics has the option to either provide the Customer with a refund or credit the amount overpaid to Customer's next payment. The provisions of this Section 16 shall survive the termination of this Agreement.

17. **Controlling Law, Jurisdiction and Dispute Resolution.** This Agreement shall be governed by and construed under the laws of the State of California, USA, excluding choice of law rules. All disputes arising out of or in relation to this Agreement shall be submitted to the exclusive jurisdiction of the state and federal courts of California, USA. Nothing in this section shall restrict Mentor Graphics' right to bring an action (including for example a motion for injunctive relief) against Customer or its Subsidiary in the jurisdiction where Customer's or its Subsidiary's place of business is located. The United Nations Convention on Contracts for the International Sale of Goods does not apply to this Agreement.

18. **Severability.** If any provision of this Agreement is held by a court of competent jurisdiction to be void, invalid, unenforceable or illegal, such provision shall be severed from this Agreement and the remaining provisions will remain in full force and effect.

19. **Miscellaneous.** This Agreement contains the parties' entire understanding relating to its subject matter and supersedes all prior or contemporaneous agreements, including but not limited to any purchase order terms and conditions. This Agreement may only be modified in writing, signed by an authorized representative of each party. Waiver of terms or excuse of breach must be in writing and shall not constitute subsequent consent, waiver or excuse.

Rev. 120305, Part No. 252061

B.2. Licenses for Sourcery CodeBench Lite Components

The table below lists the major components of Sourcery CodeBench Lite for ARM EABI and the license terms which apply to each of these components.

B.2.1. Mentor Graphics Proprietary Components

Components of the Software that are owned and/or licensed by Mentor Graphics and are not subject to a “free software” or “open source” license, such as the GNU Public License. The Mentor Graphics Proprietary Components of the Software include, without limitation, the Sourcery CodeBench Installer, any Sourcery CodeBench Eclipse plug-ins, the CodeSourcery C Library (CSLIBC), and any Sourcery CodeBench Debug Sprite.

B.2.2. Components

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

Component	**License**
GNU Compiler Collection	GNU General Public License 3.0 http://www.gnu.org/licenses/gpl.html
GNU Binary Utilities	GNU General Public License 3.0 http://www.gnu.org/licenses/gpl.html
GNU Debugger	GNU General Public License 3.0 http://www.gnu.org/licenses/gpl.html
CodeSourcery Common Startup Code Sequence	Mentor Graphics License
Newlib C Library	BSD License. For the text of the license and a complete list of copyright holders, see Section B.3.2, “Newlib”.
GNU Make	GNU General Public License 2.0 http://www.gnu.org/licenses/old-licenses/gpl-2.0.html
GNU Core Utilities	GNU General Public License 2.0 http://www.gnu.org/licenses/old-licenses/gpl-2.0.html
Cloud Sourcery Tools	GNU General Public License 3.0 http://www.gnu.org/licenses/gpl.html

Important

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

Sourcery CodeBench Lite may include some third party example programs and libraries in the `share/sourceryg++-arm-none-eabi-examples` subdirectory. These examples are not covered by the Sourcery CodeBench Software License Agreement. To the extent permitted by law, these examples are provided by CodeSourcery as is with no warranty of any kind, including implied warranties of merchantability or fitness for a particular purpose. Your use of each example is governed by the license notice (if any) it contains.

B.3. Attribution

This version of Sourcery CodeBench Lite may include code based on work under the following copyright and permission notices:

B.3.1. Android Open Source Project

```
/*
 * Copyright (C) 2008 The Android Open Source Project
 * All rights reserved.
 *
 * Redistribution and use in source and binary forms, with or without
```

```
 * modification, are permitted provided that the following conditions
 * are met:
 *  * Redistributions of source code must retain the above copyright
 *    notice, this list of conditions and the following disclaimer.
 *  * Redistributions in binary form must reproduce the above copyright
 *    notice, this list of conditions and the following disclaimer in
 *    the documentation and/or other materials provided with the
 *    distribution.
 *
 * THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS
 * "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT
 * LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS
 * FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE
 * COPYRIGHT OWNER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT,
 * INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING,
 * BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS
 * OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED
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