ST40 Micro Toolset User Manual

30 September 2005

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Preface

Comments on this manual should be made by contacting your local STMicroelectronics sales office or distributor.

Document identification and control

Each book carries a unique ADCS identifier of the form:

ADCS *nnnnnnnx*

where *nnnnnnn* is the document number, and *x* is the revision.

Whenever making comments on this document, quote the complete identification ADCS *nnnnnnnx*.

License information

The ST40 Micro Toolset is based on a number of open source packages. Details of the licenses that cover all these packages can be found on the CD in the file **`license.htm`**. This file is located in the **`doc`** subdirectory and can be accessed from **`index.htm`**.

ST40 documentation suite

The ST40 documentation suite comprises the following volumes:

ST40 Micro Toolset User Guide

ADCS 7379953. This manual describes the ST40 Micro Toolset and provides an introduction to OS21. It covers the various code and cross development tools that are provided in the toolset, how to boot OS21 applications from ROM and how to port applications which use STMicroelectronics' OS20 operating systems. Information is also given on how to build the open source packages that provide the compiler tools, base run-time libraries and debug tools and how to set up an ST Micro Connect.

OS21 User Manual

ADCS 7358306. This manual describes the generic use of OS21 across the supported platforms. It describes all the core features of OS21 and their use and details the OS21 function definitions. It also explains how OS21 differs from OS20, the API targeted at ST20 platforms.

OS21 for ST40 User Manual

ADCS 7358673. This manual describes the use of OS21 on ST40 platforms. It describes how specific ST40 facilities are exploited by the OS21 API. It also describes the OS21 board support packages for ST40 platforms.

32-Bit RISC Series, SH-4 CPU Core Architecture

ADCS 7182230. This manual describes the architecture and instruction set of the SH4-1xx (previously known as ST40-C200) core as used by STMicroelectronics.

32-Bit RISC Series, SH-4, ST40 System Architecture

This manual describes the ST40 family system architecture. It is split into four volumes:

ST40 System Architecture - Volume 1 System - *ADCS 7153464*.

ST40 System Architecture - Volume 2 Bus Interfaces - *ADCS 7181720*.

ST40 System Architecture - Volume 3 Video Devices - *ADCS 7225754*.

ST40 System Architecture - Volume 4 I/O Devices - *ADCS 7225755*.

Conventions used in this guide

General notation

The notation in this document uses the following conventions:

- **`sample code`**, **`keyboard input`** and **`file names`**,
- *variables*, ***`code variables`*** and *`code comments`*,
- `equations` and `math`,
- **screens**, **windows**, **dialog boxes** and **tool names**,
- **instructions**.

Hardware notation

The following conventions are used for hardware notation:

- REGISTER NAMES and FIELD NAMES,
- PIN NAMES and SIGNAL NAMES.

Software notation

Syntax definitions are presented in a modified Backus-Naur Form (BNF) unless otherwise specified.

- Terminal strings of the language, that is those not built up by rules of the language, are printed in teletype font. For example, `void`.
- Nonterminal strings of the language, that is those built up by rules of the language, are printed in italic teletype font. For example, ***name***.
- If a nonterminal string of the language starts with a nonitalicized part, it is equivalent to the same nonterminal string without that nonitalicized part. For example, **vspace-*name***.
- Each phrase definition is built up using a double colon and an equals sign to separate the two sides (‘`::=`’).
- Alternatives are separated by vertical bars (‘`|`’).
- Optional sequences are enclosed in square brackets (‘`[`’ and ‘`]`’).
- Items which may be repeated appear in braces (‘`{`’ and ‘`}`’).

Introducing the ST40 Micro Toolset

1.1 Toolset overview

The ST40 Micro Toolset is a cross-development system for developing and debugging C and C++ embedded applications on STMicroelectronics' ST40 range of products integrating the SuperH SH-4 core. All ST40 devices include the UDI user debug interface, available through the JTAG port of the device, which provides on-chip emulation capabilities such as: code and data breakpoints, watchpoints and memory peeking and poking.

The ST40 Micro Toolset provides an integrated set of tools to support the development of embedded applications.

1.1.1 Toolset features

- Supported platforms
  The toolset is available on Windows 2000, Windows XP, Red Hat Linux Enterprise Workstation Version 3 and on Sun Solaris 2.8 platforms.
- Code development tools (assembler, linker and compiler)
  Program development is supported by the GNU C compiler, the GNU C++ compiler, assembler, linker and archiver (librarian) tools.
- The SuperH simulator
  This provides an accurate software simulation of the entire family of STMicroelectronics' SH-4 CPU cores.

- Cross development with GDB
  The GNU debugger (GDB) supports both the SuperH simulator and the hardware development boards. GDB also includes a text user interface and the Insight GUI as a graphical user interface on all supported host platforms. The **sh4xrun** tool is also available to provide a command line driven interface to simplify downloading and running applications on the supported targets using GDB.
- Eclipse Integrated Development Environment (IDE)
  The Eclipse framework is extended using the CDT (C/C++ Development Tools) and ST40 specific plug-ins which provide a fully functional C and C++ IDE for the Eclipse platform. This allows the user to develop, execute and debug ST40 applications interactively.
- OS21 real-time kernel
  The software design of embedded systems is supported by a real-time kernel (OS21) which facilitates the decomposition of a design into a collection of communicating tasks and interrupt handlers.
- A C/C++ run-time system
  The **newlib** C library provides ANSI C/C++ run-time functions including support for C I/O using the facilities of the host system. The C++ run-time system is provided by the GNU GCC **libstdc++** library which includes support for the STL and **iostream** ISO C++ standard libraries.
- File I/O is provided as well as terminal I/O.
- Trace and statistical data analysis tools
  Used to visualize performance information from the SuperH simulator.
- Flash ROM examples
  Several Flash ROM examples are provided. These create applications which are able to boot from ROM on the supported targets.
- Support for the ST Micro Connect
  Provides the download route to the board via the JTAG interface. The ST Micro Connect supports download via Ethernet from any host machine, and via USB from Microsoft Windows hosts. The ST Micro Connect interface is connected to the UDI port of the target device, which is used to control and communicate with the device during development.

The targets supported by this toolset are:

- STMicroelectronics development boards
  These boards provide development platforms for the STMicroelectronics system-on-chip devices which use the SH-4 core.
- GDB simulator
  GNU GDB has a built-in simulator target for the SH-4 family of CPU cores. The GDB simulator is a user-mode-only basic instruction set simulator, with no support for memory management, executing privileged instructions, nor any of the extra facilities that the SuperH simulator provides.
- SuperH simulator
  This provides an accurate simulation of the SuperH CPU cores and comes in two forms.
  - Functional simulator
    Simulates the CPU core accurately, but ignoring the internal details such as pipelines.
  - Performance simulator
    Simulates the CPU core in detail in order to model the performance.

Note: In the text of this document the term SuperH simulator is used when referring to features that are common to both the functional and the performance simulators.

1.2 The SuperH configuration

The GNU tools, maintained by the Free Software Foundation (FSF) and the open-source community, provide a complete toolset supporting the SH-4 CPU.

The traditional configuration (the non-SuperH configuration of the GNU tools) for SH-4, is identified by the target triplet[1] **sh-elf**, or sometimes by the target triplet **sh-hitachi-elf** (which is an alias).

The SuperH configuration of the GNU tools is identified by the target triplet **sh-superh-elf**.

This configuration is the only configuration supported by STMicroelectronics for the ST40 Micro Toolset.

1.2.1 Traditional and SuperH configuration differences

There are several changes that have been made to the traditional configuration to create the SuperH configuration.

- The default endianness has changed from big to little endian.
- Board support has been added. This allows the same tools to create executables for different target boards and SuperH simulators.
- Run-time support has been added. This allows the same tools to create executables for different operating systems and for different I/O interfaces (for example, debug link and simulator traps).
- ANSI C I/O over the debug link has been added. This is provided by the Data Transfer Format (DTF), a low-level communication mechanism.
- SH4-400 and SH4-500 support added.

1. The GNU tools support many platforms, operating systems and vendor configurations. The tools are configured by means of a triplet, the second part of which is optional. As an example, STMicroelectronics uses the triplet **sh-superh-elf** to represent the SuperH configuration of the tools for the **sh** platform using generic **elf** files (as used by bare machines).

1.3 Distribution content

1.3.1 Tools

From the binutils GNU package

sh4as	GNU assembler
sh4ld	GNU linker
sh4addr2line	Convert addresses into file names and line numbers
sh4ar	Create, modify, and extract from archives
sh4c++filt	Demangle encoded C++ symbols
sh4gprof	GNU profiler
sh4nm	List symbols from object files
sh4objcopy	Copy and translate object files
sh4objdump	Display information from object files
sh4ranlib	Generate index to archive contents
sh4readelf	Display the contents of ELF format files
sh4size	List file section sizes and total size
sh4strings	List printable strings from files
sh4strip	Discard symbols

From the GCC GNU package

sh4c++	GNU C++ compiler
sh4cpp	GNU C/C++ preprocessor
sh4g++	GNU C++ compiler
sh4gcc	GNU C compiler
sh4gcov	GNU test coverage tool

From the GDB/Insight GNU package

sh4gdb	GNU target debugger
sh4insight	Graphical User Interface for the debugger
sh4gdbtui	Text user interface[1] for the debugger
sh4run	GNU SH-4 simulator

From the GNU make package

make	GNU make

Others

sh4xrun	SuperH target loader
sh4sim	SuperH SH-4 simulator
censpect	View statistical data files
trcview	View trace files
os21prof	OS21 profiler (implemented as a Perl script)
sh4rltool	Relocatable library tool (implemented as a Perl script)

1.3.2 Libraries

The libraries are supplied for each of the possible target configurations supported by GCC: one version for each permutation of the SuperH specific compiler options that affect code generation and for the Application Binary Interface (ABI), such as floating-point and endianness. Therefore, whatever permutation a user program is compiled against, a library with the same permutation (except for optimizations) exists and is automatically selected by the compiler driver.

From the newlib package

An ISO/ANSI C run-time library (**libc** and **libm**) and header files. The run-time libraries also provide support for low-level I/O and additional maths functions. The low-level I/O is implemented by the Data Transfer Format library (**libdtf**), see *Section 1.4.3: The data transfer format (DTF) library on page 26*.

1. This is sometimes referred to as a terminal user interface.

An alternative I/O library (**libgloss**, see *Section 1.4.4 on page 27*) is provided for building applications to run on the GNU GDB SH-4 simulator (**sh4run**) and a run-time library (**libprofile**) is also provided to support profiling with **sh4gprof**.

From the GNU GCC package

A compiler intrinsics library (**libgcc**) and a run-time library (**libgcov**) are also provided. These support code coverage with **sh4gcov**.

From the libstdc++ subpackage of the GNU GCC package

An ISO/ANSI C++ run-time library (**libstdc++**) and header files supporting I/O streams and the standard templates library (the **STL**).

Others

The OS21 real-time kernel library and header files, and OS21 board support libraries for the various supported platforms.

The relocatable loader library and header files.

1.3.3 Configuration scripts

A full set of GDB command scripts are supplied for the configuration of the various supported platforms (used in conjunction with **sh4gdb**, **sh4insight**, **sh4gdbtui** and **sh4xrun**).

1.3.4 Sources

Full sources for the OS21 real-time kernel library are included in the package. The GNU and newlib sources can be found on the CD in the `gnu_sources` directory.

1.3.5 Examples

Various example applications including those using OS21 and illustrating the construction of Flash ROM systems are supplied. See *Section 1.5.3: The examples directory on page 32* for more information on the examples supplied.

1.4 Libraries delivered

ANSI/ISO C and C++ run-time libraries and header files are shipped with the ST40 Micro Toolset supporting both OS21 and bare machine applications for various target application configurations.

Note: A bare machine application is a non-OS21 application built without real-time kernel libraries.

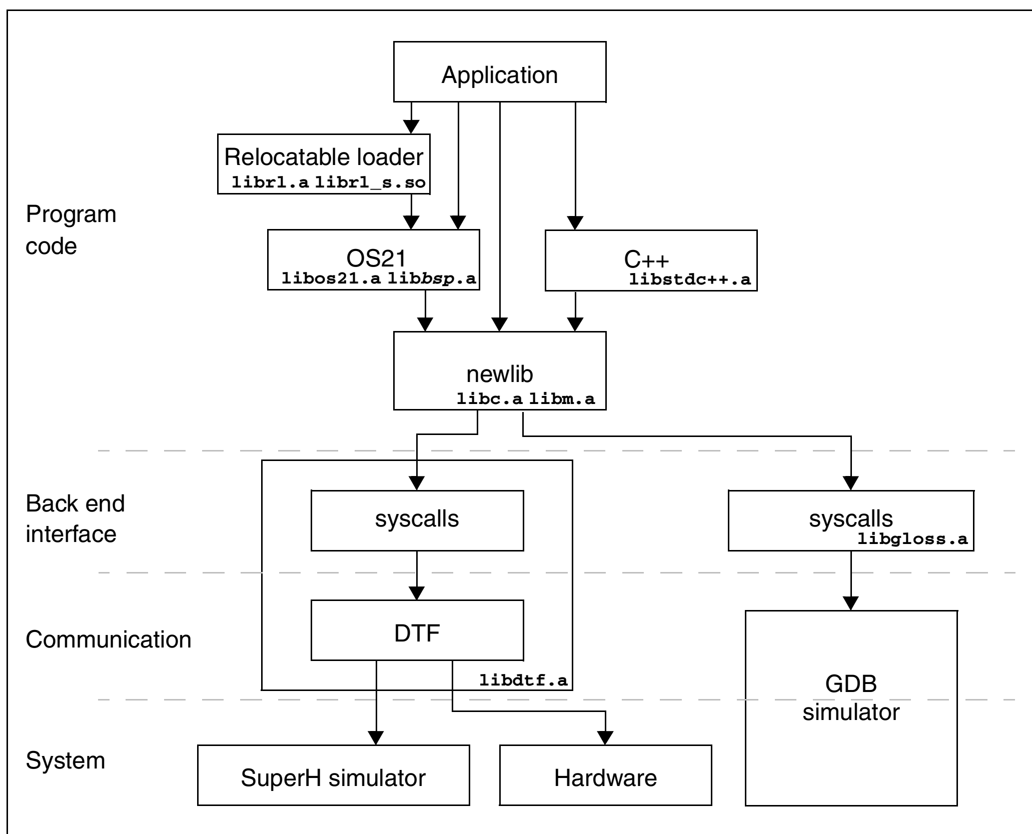


Figure 1: The relationship between the libraries

The header files shipped with the toolset are located in the subdirectory **sh-superh-elf/include** under the release installation directory and include the header files for OS21 support. The OS21 header files are located under **sh-superh-elf/include/os21**.

The libraries shipped with the toolset are located in the subdirectory **`sh-superh-elf/lib`** under the release installation directory, which is structured as described below.

- Little endian libraries with double precision FPU support pervading (the default, or optionally selected by the GCC compiler's **`-ml`** option):

  `sh-superh-elf/lib`

- Little endian libraries with no FPU support (selected by the GCC compiler's **`-m4-nofpu`** option and optionally the **`-ml`** option):

  `sh-superh-elf/lib/m4-nofpu`

- Little endian libraries with single precision FPU support pervading (selected by the GCC compiler's **`-m4-single`** option and optionally the **`-ml`** option):

  `sh-superh-elf/lib/m4-single`

- Little endian libraries with single precision FPU support only (SH-3e ABI) (selected by the GCC compiler's **`-m4-single-only`** option and optionally the **`-ml`** option):

  `sh-superh-elf/lib/m4-single-only`

- Big endian libraries[1] with double precision FPU support pervading (selected by the GCC compiler's **`-mb`** option):

  `sh-superh-elf/lib/mb`

- Big endian libraries[1] with no FPU support (selected by the GCC compiler's **`-mb`** and **`-m4-nofpu`** options):

  `sh-superh-elf/lib/mb/m4-nofpu`

- Big endian libraries[1] with single precision FPU support pervading (selected by the GCC compiler's **`-mb`** and **`-m4-single`** options):

  `sh-superh-elf/lib/mb/m4-single`

- Big endian libraries[1] with single precision FPU support only (SH-3e ABI) (selected by the GCC compiler's **`-mb`** and **`-m4-single-only`** options):

  `sh-superh-elf/lib/mb/m4-single-only`

---

1. Some ST40 products might not be validated for use in big endian mode, please see the relevant silicon product documentation for details.

1.4.1 The C library (newlib)

newlib implements a version of the C library which is suitable for use in embedded systems. **newlib** supports the most common functions used in C programs, but not the more specialized features available in standard operating systems, such as networking support.

*Note: Wide character support is not enabled in the supplied version of **newlib**.*

newlib assumes a minimal set of OS interface functions (the **syscalls** API). These provide all the I/O, and process entry and exit control functions required by programs using **newlib**. The syscalls API is implemented either by the **libdtf** DTF library (for SuperH simulator or silicon) or by the **libgloss** library (for GDB simulator).

1.4.2 The C++ library (libstdc++)

The C++ library is part of GNU Compiler Collection and uses the underlying C library for its basic functionality.

1.4.3 The data transfer format (DTF) library

The DTF library implements the POSIX I/O mechanism used with the ST Micro Connect or the SuperH simulator. It implements most of the basic file I/O features required by the C library. The I/O is performed via the debug link and requires the correct host side software to be present (this is handled automatically by the supplied GDB connection commands).

It is not usually necessary for applications to call the DTF library directly since this is handled by the **newlib** C library low-level I/O interface (see *Section 1.4.5: The syscalls low-level I/O interface on page 27*).

Note: The DTF library assumes that GDB is present in order to provide the I/O services for the target. If GDB is not present, for example in boot from ROM systems, then the application waits indefinitely on an I/O transaction that never completes.

In order to allow applications linked with the DTF library (the default) to operate correctly in these circumstances, the DTF library provides a mechanism for disabling communication with GDB. In your application, define the global variable `_SH_DEBUGGER_CONNECTED` to `0`, for example, in the “C” namespace:

```
int _SH_DEBUGGER_CONNECTED = 0;
```

The Flash ROM examples do this automatically (see the `rombootram` example `readme.txt` file for further details).

1.4.4 The libgloss library

libgloss is intended to be the **newlib** backend library (so called because it glosses over the system details). It implements the interface between **newlib** and the underlying system, whatever that may be, in order to allow access to I/O and other system resources via a standardized trap interface recognized by the GNU GDB simulator.

1.4.5 The syscalls low-level I/O interface

The **syscalls** low-level I/O interface consists of 30 functions. These functions provide all the I/O, entry and exit, and process control routines that **newlib** requires. The full list of these functions is:

`__setup_argv_and_call_main`, **`_chmod`**, **`_chown`**, **`_close_r`**, **`_creat`**, **`_execv`**, **`_execve_r`**, **`_exit`**, **`_fork_r`**, **`_fstat_r`**, **`_getpid_r`**, **`_gettimeofday_r`**, **`_kill_r`**, **`_link_r`**, **`_lseek_r`**, **`_open_r`**, **`_pipe`**, **`_raise`**, **`_read_r`**, **`_rename`**, **`_sbrk_r`**, **`_stat_r`**, **`_times_r`**, **`_unlink_r`**, **`_utime`**, **`_wait_r`**, **`_write_r`**, **`ftruncate`**, **`isatty`**, **`truncate`**.

There are two versions of this interface implemented:

- **DTF**
  This is for use with the SuperH simulator and the ST Micro Connect. Not all functions are implemented. See *Section 1.4.3*.
- **libgloss**
  This is for use with the GNU GDB simulator. Not all functions are implemented. See *Section 1.4.4*.

An example is provided with the toolset containing minimal implementations of the functions, sufficient to compile, link and execute an application (see *syscalls example on page 32*). However, the application cannot perform I/O or utilize any of the services that these functions provide until the stub versions provided in the example have been implemented.

The example implementation provides an overview of each function but for further information the POSIX standard should be used as a reference.

Note: *It is not required for all functions to be implemented.*

1.4.6 Threading

The C (**newlib**) and C++ (**libstdc++**) libraries both provide support for thread-safe operation (although by different mechanisms).

The C library ensures thread-safe operation by using per-task re-entrancy structures and guards around critical regions (as described in the **newlib** source documentation). If OS21 tasks are not being used then the C libraries use a single re-entrancy structure for the application and no guards whereas the OS21 versions use a re-entrancy structure per task and OS21 mutexes as guards.

The C++ library relies on the generic GNU threading interface provided by the STMicroelectronics' version of the GNU Compiler Collection. The implementation of the generic threading interface in the GNU Compiler Collection only provides support for bare machine applications; the default implementation does not provide thread-safe operation (and hence the C++ library is not thread safe). However, the implementation of the generic threads interface provides a mechanism whereby the default implementation may be overridden via function pointers. Therefore the generic GNU threading interface provides a technique for supporting different OS implementations without requiring a different GNU Compiler Collection for each OS.

The function pointer overrides provided by the generic GNU threads interface are as follows:

```
int (*__generic_gxx_active_p)(void);
int (*__generic_gxx_once)(__gthread_once_t *once, void (*func)(void));
int (*__generic_gxx_key_create)(__gthread_key_t *key, void (*dtor)(void
*));
int (*__generic_gxx_key_dtor)(__gthread_key_t key, void *ptr);
int (*__generic_gxx_key_delete)(__gthread_key_t key);
void * (*__generic_gxx_getspecific)(__gthread_key_t key);
int (*__generic_gxx_setspecific)(__gthread_key_t key, const void *ptr);
void (*__generic_gxx_mutex_init)(__gthread_mutex_t *mutex);
int (*__generic_gxx_mutex_lock)(__gthread_mutex_t *mutex);
int (*__generic_gxx_mutex_trylock)(__gthread_mutex_t *mutex);
int (*__generic_gxx_mutex_unlock)(__gthread_mutex_t *mutex);
void (*__generic_gxx_recursive_mutex_init) (__gthread_recursive_mutex_t
*mutex);
int (*__generic_gxx_recursive_mutex_lock) (__gthread_recursive_mutex_t
*mutex);
int (*__generic_gxx_recursive_mutex_trylock)
(__gthread_recursive_mutex_t *mutex);
int (*__generic_gxx_recursive_mutex_unlock) (__gthread_recursive_mutex_t
*mutex);
```

These function pointers are defined in the GNU Compiler Collection and initialized to **NULL**. However, the OS21 library replaces the GNU Compiler Collection definitions of these function pointers with its own definitions. These definitions are initialized to OS21 implementations to ensure thread safe operation of the generic GNU threading interface, and therefore the C++ library.

The **__generic_gxx_active_p** function returns a status value indicating whether threading is active (**1**) or not (**0**). All other functions return a status value which indicates either success (**1**), failure (**0**) or not supported (**-1**).

The definitions of the types in the generic GNU threading interface in the GNU Compiler Collection are as anonymous pointers. The actual definitions of the types are determined by the implementations of the function pointers.

The functions correspond closely to those in the POSIX **pthread** library. Refer to the POSIX documentation for implementation details.

1.5 Release directories

The installation procedure creates the directory structure shown in *Table 1*. Some of these directories are described in more detail in the following sections.

As well as including the directories shown in *Table 1*, the release installation directory also includes the file, **index.htm**. This file can be used to navigate the documentation supplied with the installation.

Directory	Contents
bin	The tools.
doc	The documentation set.
include	C/C++ library header files.
lib	Library files.
libexec	C/C++ compiler executables.
man	man(1) manual pages.
microprobe	The ST Micro Connect target application.
share	GDB GUI configuration files.

Table 1: The release directories

Directory	Contents
sh-superh-elf/bin	Subset of the compiler tools in **bin**.
sh-superh-elf/examples	Example applications.
sh-superh-elf/include	OS21 and C library header files.
sh-superh-elf/lib	Run-time library files.
sh-superh-elf/src	OS21 source files.
sh-superh-elf/stdcmd	GDB command script files.

Table 1: The release directories

1.5.1 GDB command scripts directory

The directory **sh-superh-elf/stdcmd** contains GDB command script files for a selection of target evaluation boards supplied by STMicroelectronics. These files may be used for accessing the target boards, and as examples in writing script files for other boards.

1.5.2 The documents directory

Several HTML files are provided to navigate the documentation. These can all be accessed from the **index.htm** file in the release installation directory and the main pages are summarized in *Table 2*.

File	Description
acknow.htm	The acknowledgements page.
acroread.htm	Instructions on installing and using Acrobat Reader.
cdmap.htm	A map of the information provided.
docbug.htm	Instructions on how to get support on the toolset and report problems in the documentation.

Table 2: The HTML files in the doc directory

File	Description
`docs.htm`	A list of the documentation supplied with the toolset. Each document can be accessed from this page by clicking on the relevant link. A link is also provided to the training documentation. This documentation is supplied as a reminder for people that have attended an ST40 training course.
`issues.htm`	Information on bugs outstanding and resolved in this release.
`license.htm`	Links to each of the license files that the software is shipped under.

Table 2: The HTML files in the doc directory

The **`doc`** directory also contains the supporting documentation supplied with the toolset. There are three subdirectories provided in the **`doc`** directory:

Directory	Description
`images`	The images used in the documentation.
`hyper`	The HTML and Microsoft Compiled Help versions of the documentation. These can be accessed from the `docs.htm` file.
`pdf`	The printable documentation supplied as one file per document. These can be accessed from the `docs.htm` file.

Table 3: The doc subdirectories

1.5.3 The examples directory

The examples are held in the **sh-superh-elf/examples** directory. Each example has a **readme.txt** file describing the example and makefiles to build the example.

Also supplied is a sample implementation of the low-level I/O interface provided in the **libdtf** and **libgloss** libraries.

Getting started examples

The **bare/getstart** subdirectory of the **examples** directory contains two simple examples of bare machine programs. These examples can be used as confidence tests for the hardware and the toolset. There is a simple “Hello World” application, and one to display part of the Fibonacci sequence.

Hardware configuration registers

The **bare/sh4reg** subdirectory of the **examples** directory provides C/C++ header files. These header files define the locations of the memory mapped configuration registers for the core and other commonly accessed peripherals of the ST40 and other SH-4 CPUs.

syscalls example

The **syscalls** subdirectory of the **examples** directory contains a sample implementation of the **syscalls** low level I/O interface (see *Section 1.4.5: The syscalls low-level I/O interface on page 27*).

Census example

The **census** subdirectory of the **examples** directory contains the implementation of the API that allows you to control performance data collection on a simulated ST40 from within the source (see *Section 8.3.3: Dynamic control on page 163*).

OS21 examples

The **os21** subdirectory of the **examples** directory contains some examples of programs using the features of OS21.

- The **os21/autostart** subdirectory contains an example of how to start OS21 before any C++ static constructors or **main()** is called.
- The **os21/dynamic** subdirectory contains an example illustrating how to build a simple application which loads a dynamic library from the host file system.

- The **os21/mandelbrot** subdirectory contains a multi-tasking example generating a Mandelbrot pattern.
- The **os21/os21demo** subdirectory contains an example of using tasks to animate a graphical display.
- The **os21/rombootram** and **os21/rombootrom** subdirectories contains examples of how to program Flash ROM, and how to build applications which can be booted out of Flash ROM.
- The **os21/romdynamic** subdirectory shows how to use the Relocatable Loader Library to load a dynamic library from Flash ROM from an application which is booted out of Flash ROM.
- The **os21/sh4ubc** subdirectory contains an example illustrating using the SH-4 UBC to perform run-time debugging of an application without the use of a debugger (see the *ST40 System Architecture - Volume 1, System*). The example contains the source for the UBC library and a small test program which uses the library.
- The **os21/soaktest** subdirectory contains a simple stress test program, designed to act as a confidence test for OS21 running on the target platform.
- The **os21/stb7100loader** subdirectory contains an example showing how the ST40 processor on an STB7100 or STb7109 device can boot the ST231 processors. This example requires the ST200 Toolset R4.1 or later.
- The **os21/stb7100multiboot** subdirectory contains an example showing how the ST40 and ST231 co-processors on an STb7100 or STb7109 device can boot from Flash ROM. This example requires the ST200 Toolset R4.1 or later.
- The **os21/sti5528dualboot** subdirectory contains an example showing how both the ST40 and ST20 processors on the STi5528 device can boot from Flash ROM. This example requires the ST20 Toolset R1.9.6 patch 7 or later.
- The **os21/sti5528loader** subdirectory contains an example showing how the ST40 processor on the STi5528 device can boot the ST20 processor. This example requires the ST20 Toolset R1.9.6 patch 7 or later.
- The **os21/stm8000loader** subdirectory contains an example showing how the ST40 processor on the STm8000 device can load executable images for the ST220 co-processors, and boot them. This example requires the ST200 Toolset R3.1 or later.

- The **os21/stm8000multiboot** subdirectory contains an example showing how the ST40 and ST220 co-processors on the STm8000 device can boot from Flash ROM. This example requires the ST200 Toolset R3.1 or later.
- The **os21/timer** subdirectory contains an example showing how the OS21 API can be used to implement a simple timer. Tasks are able to create timer objects, which have a programmable duration, and can run in one shot or periodic mode. When a timer fires, a user supplied callback function is called in the context of a high priority task. The example contains the source for the timer library, and a small test program which uses the library.

1.6 Installation

The following sections describe how to install the toolset on Windows, Linux and Solaris. For each toolset, an example is provided showing how to run a getting started program on a target board and a simulator, see *Section 1.6.1.4 on page 36*, *Section 1.6.2.3 on page 38* and *Section 1.6.3.3 on page 39*.

1.6.1 Windows installation

The Windows release is installed using the self-extracting installation program, **stm-st40.311-3.1.1-MSWin32-x86.exe**. Details on installing the Windows release are provided in the installation notes shipped with the release (**install.htm**). These notes can be accessed from **index.htm** on the CD.

On successful completion of the installation, no further setting up is required in order to use the toolset. The ST Micro Connect USB drivers may now be installed by following the instructions in *Appendix F: ST Micro Connect setup on page 307*. The following sections provide details on the changes to the environment by the installation program.

As part of the installation process a batch file called **st40.bat** is created in the **bin** subdirectory of the release installation directory which sets up the environment to run the tools from a command prompt. The installation process also offers the option to update the environment in the system properties.

Under Windows 2000 and Windows XP, if the user installing the toolset has system administrator privileges then, if selected, the environment for all users (that is, the system environment) is updated, instead of just the environment for the user installing the toolset.

The **STM Tools** menu is added to the **Start** button on the task bar that contains a number of shortcuts to various tools in the toolset, and a shortcut to a command prompt which is set up to run the **st40.bat** batch file automatically when it is opened.

1.6.1.1 Setting up your path

To be able to use the tools, the **bin** subdirectory of the release installation directory is added to your **PATH**. For example, using **C:\STM\ST40R3.1.1** as the installation directory:

```
set PATH=C:\STM\ST40R3.1.1\bin;%PATH%
```

PATHEXT is also updated to ensure that **.pl** is present. This allows the tools **os21prof** and **sh4rltool** to be invoked without requiring the **.pl** extension to be explicitly specified. For example:

```
set PATHEXT=%PATHEXT%;.pl
```

The **os21prof** and **sh4rltool** tools are implemented as Perl scripts and rely on a Windows association existing between a Perl interpreter and files with the **.pl** extension. The **assoc** and **ftype** commands of the Windows/DOS command shell syntax can be used to determine if an association exists for the **.pl** extension. For example:

```
assoc .pl
ftype Perl
```

Alternatively, the **File Types** page in the **Folder Options** control (found in the **Tools** menu of the Windows Explorer or in the Windows Control Panel) can also be used to determine if an association exists.

*Note: A suitable version of Perl (version 5.6.1 or greater) is required in order to use the **os21prof** and **sh4rltool** Perl scripts. A suitable version can be obtained from* www.activestate.com.

1.6.1.2 Setting environment variables

The environment variable **HOME** should be set to specify the location of your home directory. For example:

```
set HOME=C:\
```

Under Windows 2000 and Windows XP, the value of the environment variable **HOME** may be derived from the environment variables **HOMEDRIVE** and **HOMEPATH** (which are set by the operating system) as follows:

```
set HOME=%HOMEDRIVE%%HOMEPATH%
```

1.6.1.3 Setting up the target interface

The Windows release supports an ST Micro Connect via Ethernet or USB to the target system.

A CD-ROM is supplied with the ST Micro Connect which includes all necessary device drivers, and any necessary Windows upgrades. Once this software has been installed on your PC, no further action is needed to set up the target interface.

1.6.1.4 Checking the installation

You can check your installation by running the getting started example program. The following procedure describes running the program on an STMediaRef-Demo platform.

1. Change directories to the getting started example directory. For example, using **C:\STM\ST40R3.1.1** as the installation directory:

   ```
   cd C:\STM\ST40R3.1.1\sh-superh-elf\examples\bare\getstart
   ```

   This contains several files including **hello.c**.

2. Compile and link:

   ```
   sh4gcc hello.c -g -mboard=mediarefp1
   ```

   The output file should be called **a.out**.

3. Run the program on an STMediaRef-Demo platform connected to an ST Micro Connect called **stmc**:

   ```
   sh4xrun -c mediaref -t stmc -e a.out
   ```

   The program should display the message:

   ```
   Hello World
   ```

Alternatively, the program may be run on the simulator configured as an STMediaRef-Demo platform as follows:

1 Follow step 1 above.

2 Compile and link:

```
sh4gcc hello.c -g -mboard=mediarefsim
```

The output file should be called **a.out**.

3 Run the program on the simulator:

```
sh4xrun -c mediarefsim -e a.out
```

The program should display the message:

```
Hello World
```

1.6.2 Linux installation

The Linux release is installed using the **rpm** archive, **stm-st40.311-3.1.1-1.i386.rpm**. Details on installing the Linux release are provided in the installation notes shipped with the release (**install.htm**). These notes can be accessed from **index.htm** on the CD.

Having installed the release there are several environment variables to be set up before you can use any of the tools.

1.6.2.1 Setting up your paths

To be able to use the tools, the **bin** subdirectory of the release installation directory must be added to your **PATH**:

sh or compatible

```
PATH=/opt/STM/ST40R3.1.1/bin:$PATH
export PATH
```

csh or compatible

```
setenv PATH /opt/STM/ST40R3.1.1/bin:$PATH
```

*Note: A suitable version of Perl (version 5.6.1 or greater) is required. In order to use the Perl scripts **os21prof** and **sh4rltool**, Perl must be available on your* **PATH**. *A suitable version can be obtained from www.activestate.com.*

1.6.2.2 Setting environment variables

The environment variable **$HOME** is used to specify the user's home directory and is normally correctly set automatically by the system on login.

1.6.2.3 Checking the installation

You can check your installation by running the getting started example program. The following procedure describes running the program on an STMediaRef-Demo platform.

1. Change directories to the getting started example directory. For example, using the installation directory of **/opt/STM/ST40R3.1.1**:

   ```
   cd /opt/STM/ST40R3.1.1/sh-superh-elf/examples/bare/getstart
   ```

   This contains several files including **hello.c**.

2. Compile and link:

   ```
   sh4gcc hello.c -g -mboard=mediarefp1
   ```

   The output file should be called **a.out**.

3. Run the program on an STMediaRef-Demo platform connected to an ST Micro Connect called **stmc**:

   ```
   sh4xrun -c mediaref -t stmc -e a.out
   ```

   The program display the message:

   ```
   Hello World
   ```

Alternatively, the program may be run on the simulator configured as an STMediaRef-Demo platform as follows:

1. Follow step 1 above.

2. Compile and link:

   ```
   sh4gcc hello.c -g -mboard=mediarefsim
   ```

   The output file should be called **a.out**.

3. Run the program on the simulator:

   ```
   sh4xrun -c mediarefsim -e a.out
   ```

   The program should display the message:

   ```
   Hello World
   ```

1.6.3 Solaris installation

The Solaris release is installed using the compressed **tar** archive, **stm-st40.311-3.1.1-sun4-solaris.tar.gz**. Details on installing the Solaris release are provided in the installation notes shipped with the release (**install.htm**). These notes can be accessed from **index.htm** on the CD.

Having installed the release there are several environment variables to be set up before you can use any of the tools.

1.6.3.1 Setting up your paths

To be able to use the tools, the **bin** subdirectory of the release installation directory must be added to your **PATH**:

sh or compatible

```
PATH=/opt/STM/ST40R3.1.1/bin:$PATH
export PATH
```

csh or compatible

```
setenv PATH /opt/STM/ST40R3.1.1/bin:$PATH
```

Note: A suitable version of Perl (version 5.6.1 or greater) is required. In order to use the Perl scripts ***os21prof*** *and* ***sh4rltool****, Perl must be available on your* **PATH***. A suitable version can be obtained from www.activestate.com.*

1.6.3.2 Setting environment variables

The environment variable **$HOME** is used to specify the user's home directory and is normally correctly set automatically by the system on login.

1.6.3.3 Checking the installation

You can check your installation by running the getting started example program. The following procedure describes running the program on an STMediaRef-Demo platform.

1 Change directories to the getting started example directory. For example, using the installation directory of **/opt/STM/ST40R3.1.1**:

```
cd /opt/STM/ST40R3.1.1/sh-superh-elf/examples/bare/getstart
```

This contains several files including **hello.c**.

2 Compile and link:

```
sh4gcc hello.c -g -mboard=mediarefp1
```

The output file should be called **a.out**.

3 Run the program on an STMediaRef-Demo platform connected to an ST Micro Connect called **stmc**:

```
sh4xrun -c mediaref -t stmc -e a.out
```

The program should display the message:

```
Hello World
```

Alternatively, the program may be run on the simulator configured as an STMediaRef-Demo platform as follows:

1 Follow step 1 above.

2 Compile and link:

```
sh4gcc hello.c -g -mboard=mediarefsim
```

The output file should be called **a.out**.

3 Run the program on the simulator:

```
sh4xrun -c mediarefsim -e a.out
```

The program should display the message:

```
Hello World
```

1.6.4 GDB setup

sh4gdb, **sh4insight**, **sh4gdbtui** and **sh4xrun** (which internally invokes **sh4gdb**) use GDB command scripts in order to connect and configure ST40 targets connected to an ST Micro Connect.

A GDB startup script file (**.shgdbinit**) is provided in the subdirectory **sh-superh-elf/stdcmd** of the release installation directory to make these scripts available. This file is automatically read by **sh4gdb**, **sh4insight**, **sh4gdbtui** and **sh4xrun**.

More information on **sh4gdb** and **sh4xrun** is provided in *Chapter 4: Cross development tools on page 63*. Information on **sh4insight** is provided in *Chapter 6: Using Insight on page 111* and information on **sh4gdbtui** is provided in the GNU *Debugging with GDB* manual.

2 Introducing OS21

OS21 is a royalty-free, lightweight, multi-tasking operating system developed by STMicroelectronics. It is based on the existing OS20 API and is intended for applications where small footprint and excellent real-time responsiveness are required. It provides a multi-priority preemptive scheduler, with low context switch and interrupt handling latencies.

OS21 assumes an unprotected, single address-space model and is designed to be easily portable between chip architectures.

OS21 provides an OS20 compatible API to handle task, memory, messaging, synchronization and time management. In addition, OS21 enhances the OS20 memory API and introduces API extensions to control mutexes, event flags and target-specific APIs for interrupts and caches.

OS21 is built using the GNU toolset for the given target. OS21 aware debugging is available through GDB.

Multi-tasking is widely accepted as an optimal method of implementing real-time systems. Applications may be broken down into a number of independent tasks which co-ordinate their use of shared system resources, such as memory and CPU time. External events arriving from peripheral devices are made known to the system via interrupts.

The OS21 real-time kernel provides comprehensive multi-tasking services. Tasks synchronize their activities and communicate with each other via semaphores, event flags, mutexes and message queues. Real world events are handled via interrupt routines and communicated to tasks using semaphores and event flags. Memory allocation for tasks is selectively managed by OS21, the C run-time library or the user. Tasks may be given priorities and are scheduled accordingly. Timer functions are provided to implement time and delay functions.

An OS21 application is built as a single executable image[1], which can be loaded on the target via a debug port, or from Flash ROM. This single executable is typically written in C, and statically linked with the C run-time library, the OS21 library and the OS21 board support library. The application author has control of initializing the OS21 kernel, and switching on pre-emptive multi-tasking support. Once the OS21 kernel has been started, the full OS21 API can be used, for example, to manipulate tasks, semaphores, messages.

A very simple OS21 application (**test.c**) is shown below:

```
#include <os21.h>
#include <os21/st40.h>
#include <stdio.h>

void my_task (char * message)
{
  printf("Hello from the child task.\nMessage is '%s'\n", message);
}

int main (void)
{
  task_t * task;

  kernel_initialize(NULL);
  kernel_start();

  printf("Hello from the root task\n");

  task = task_create((void (*)(void*))my_task,
                     "Hi ya!",
                     OS21_DEF_MIN_STACK_SIZE,
                     MAX_USER_PRIORITY,
                     "my_task",
                     0);

  task_wait(&task, 1, TIMEOUT_INFINITY);

  printf("All tasks ended. Bye.\n");

  return 0;
}
```

1. This executable may load relocatable libraries. See *Chapter 12: Relocatable loader library on page 203*.

To compile and run this program on an STMediaRef-Demo platform connected to an ST Micro Connect called **stmc**:

```
sh4gcc test.c -mruntime=os21 -mboard=mediaref
sh4xrun -t stmc -c mediaref -e a.out
```

The output should be:

```
Hello from the root task
Hello from the child task.
Message is 'Hi ya!'
All tasks ended. Bye.
```

Further information on OS21 is provided in the *OS21 User Manual* and the *OS21 for ST40 User Manual*.

2.1 OS21 features

The following list summarizes the key features of OS21.

- Simple royalty free multi-tasking package.
- Single address space and single name space (application is contained in one executable image).
- 256 level priority based FIFO scheduler.
- Optional timeslicing.
- Inter-task synchronization.
- Counting semaphores:
  - can be initialized to any count,
  - can be signalled from interrupts,
  - FIFO semaphores - the longest waiting task gets the semaphore,
  - Priority semaphores - the highest priority task gets the semaphore.
- Mutexes:
  - create critical sections between tasks,
  - can be recursively acquired by the owning task without deadlock,
  - FIFO mutexes - the longest waiting task gets the mutex,
  - Priority mutexes - the highest priority task gets the mutex. Supports priority inheritance to avoid priority inversion.

- Event flags:
    - tasks can poll, or wait for all or any event flag within a group,
    - events can be posted from a task or interrupt.
- Inter-task communication - simple FIFO message queues.
- User installable interrupt handlers.
- Extensive cache API.
- Memory management:
    - heaps,
    - fixed block allocator,
    - simple (non-freeable) allocator,
    - user definable allocators,
    - system heap managed by OS21 or C run-time.
- Task aware profiling. The OS21 profiler allows profiling of a single task, a single interrupt level or the system as a whole.
- Board Support Package (BSP) libraries allow customization for new boards.
- Based on GNU toolset, using **newlib** C run-time library.

Code development tools

3.1 Introduction to the code development tools

The code development tools are based on the GNU development tools and have been modified in various ways from the standard GNU base tools. These modifications are referred to as the SuperH configuration, see *Section 1.2 on page 20*. These changes specialize the tools for SH-4 and provide integration with the SuperH simulators and ST40 target boards.

3.2 The GNU compiler (GCC)

GCC is the GNU Compiler Collection (formerly called the GNU C Compiler). It has support for a number of languages including C, C++, Objective C, Fortran, Ada and Java. Only the C and C++ compilers are provided and supported by STMicroelectronics.

GCC consists of the tools listed below.

- **sh-superh-elf-gcc**
  The C compiler without board support.
- **sh4gcc**
  Short form of **sh-superh-elf-gcc** enables board and run-time support.
- **sh-superh-elf-g++**
  The C++ compiler without board support.
- **sh4g++**
  Short form of **sh-superh-elf-g++** enables board and run-time support.

- **sh-superh-elf-c++**
  Another name for the C++ compiler without board support.
- **sh4c++**
  Short form of **sh-superh-elf-c++** enables board and run-time support.

All the tools accept the same compiler options and work in exactly the same way. The board and run-time support packages are only enabled when using the short forms of the tools.

The short forms of the tools may also set up the environment or provide additional functionality. These should always be used in preference to the long form versions, even if the board support or run-time support packages are not required.

Note: These tools are compiler drivers. The actual compilers are called ***cc1*** *and* ***cc1plus*** *and are invoked by the compiler drivers for each C and C++ file. The compiler driver may also invoke the assembler and linker tools as necessary.*

3.2.1 GCC command line quick reference

Table 4 lists many of the most useful, generic, options to the compiler driver (which may also call the assembler and linker).

Option	Description
-o ***file***	Use ***file*** as the output file.
-c	Compile and assemble only - no linking.
-l*library*	Link against ***library***.
-L ***directory***	Search ***directory*** for libraries.
-I ***directory***	Search ***directory*** for header files.
-isystem ***directory***	Search ***directory*** for system header files (included with **<>** not **""**).
-S	Do not assemble. Generate **.s** files containing assembly code instead.
-E	Preprocess only. Output preprocessed file to standard output or the file specified by **-o** if supplied.

Table 4: sh4gcc command line quick reference

Option	Description
-save-temps	Do full compile unless otherwise directed, but do not remove intermediate files. Preprocessed C output to **.i** files, preprocessed C++ output to **.ii** files, assembler code to **.s** files and object code to **.o** files.
-Wa,*optionlist*	Pass options to the assembler. Use commas instead of spaces within the option list (or use quotes).
-Wp,*optionlist*	Pass options to the preprocessor.
-Wl,*optionlist*	Pass options to the linker.
-Wl,-Map,*mapfile*	Generate a linker map file whose name is ***mapfile***.
-v	Verbose output mode. This is useful for viewing the programs the compiler driver is invoking. If given as the first parameter with a short form of the tool, any additional options and environment variables set are also displayed.
--help	Provide help on the command line options.
--help -v	Provide help on all the options available on all the programs which the compiler driver may invoke (for example, the assembler and linker).
-g	Insert debug information into the output files.
-pg	Enable function profiling.
-O0	Do not optimize the output code. This is the default optimization setting if **-O** is not specified.
-O1	Do some optimizations. This is the default optimization setting if **-O** is specified without a level. Some optimizations enabled by **-O1** can decrease the ease of debugging.
-O2	Do most optimizations. Some optimizations enabled by **-O2** can severely impact the ease of debugging.
-O3	Do all **-O2** optimizations plus function inlining.
-Os	Do optimizations designed to reduce code size (and skip optimizations that often increase code size).

Table 4: sh4gcc command line quick reference

Option	Description
-funroll-loops	Enable loop unrolling; not enabled by default with **-O1**, **-O2** or **-O3**. Only unroll when the iteration count is known.
-funroll-all-loops	Enable loop unrolling for all loops; not enabled by default with **-O1**, **-O2** or **-O3**.
-fomit-frame-pointer	Remove unnecessary frame pointers; not enabled by default with **-O1**, **-O2** or **-O3**. This option may impede the ability to debug.
-Wall	Give all but the most unusual warnings.
-pedantic	Give all warnings required by the ISO C standard.
-D*macro*[=*value*]	Define a preprocessor ***macro*** (same as **#define**). If **=*value*** is not given then the default is **1**.

Table 4: sh4gcc command line quick reference

Table 5 lists all the generic SH-4 options that are common to all the CPU core families and do not rely on the SuperH configuration.

Option	Description
-ml	Create little endian programs (default in SuperH configuration).
-mb	Create big endian programs (default in traditional configuration).
-mrelax	Do special linker optimizations (use consistently for all of the compile, assemble and link steps to be effective).

Table 5: sh4gcc SH-4 specific options

For more SH-4 specific options, see *Table 45: SH-4 specific GCC options on page 271*. For SH-4 optimization recommendations, see *Section B.1.8: Speed and space optimization options on page 281*.

3.2.2 GCC SuperH configuration specific options

Table 6 lists all the options added by the SuperH configuration.

Option	Description
-mboard=*board*	This option is used by the board support package. The board support package allows the same toolchain to build executables for a number of different hardware and simulation platforms (not including OS platforms). This option **must** be specified when linking. The value of ***board*** determines what memory location the linker places the program and the stack, and therefore with which boards it works. For a list of the valid values see *Section 3.6: Board support on page 54*. For instructions on setting up a custom board see *Section 3.6.1: GCC board support setup on page 56*.
-mruntime=*runtime*	This option is used by the run-time support package to select the I/O interface and to select between bare machine and OS21 applications. The default is to compile for the bare machine versions using DTF. For a list of the valid values, see *Section 3.7: Run-time support on page 59*. For instructions on setting up a custom run-time, see *Section 3.7.1: GCC run-time support setup on page 59*.
-rlib	This option is used to build a relocatable library, see *Section 12.5: Writing and building a relocatable library and main module on page 234*. In almost all cases this should be used in conjunction with the **-nostdlib** option.
-rmain	This option is used to build an executable which can load relocatable libraries, see *Section 12.5: Writing and building a relocatable library and main module on page 234*.

Table 6: sh4gcc SuperH configuration specific options

3.3 The GNU assembler

It is not usually necessary to invoke the assembler directly since the GNU compiler driver calls the assembler automatically when an assembler source file is specified. However, there may be occasions when it is necessary to invoke the assembler directly.

The tools provided are listed below.

- **sh-superh-elf-as**
  The assembler.
- **sh4as**
  Short form of **sh-superh-elf-as**.
- **as** (in **`sh-superh-elf/bin`**)
  Same as **sh-superh-elf-as**. Used by the compiler driver instead of **sh-superh-elf-as**.

The short form is provided for convenience and is to be used in preference.

The SuperH configuration of the GNU assembler is identical to the traditional configuration (including the default endianness which is big).

3.3.1 GNU assembler command line quick reference

Table 7 lists the most useful options to the assembler.

Option	Description
`-little`	Assemble for a little endian target.
`-big`	Assemble for a big endian target. This is the default setting.
`-o` ***`name`***	Set the output file name. The default is **`a.out`**.
`-relax`	Place special information in the object file, allowing some additional optimizations to be performed by the linker. This is only useful if the relaxation options of the compiler and linker are also used. The **`-mrelax`** option to the compiler driver does this automatically (if the compile, assemble and link steps are done all in one operation).

Table 7: GNU assembler command line quick reference

3.4 The GNU linker

As with the assembler, it is generally unnecessary to use the linker directly since the GCC compiler driver calls it automatically (via a program called **collect2** which, in turn, calls **ld**).

The tools provided are listed below.

- **sh-superh-elf-ld**
  The linker.
- **sh4ld**
  Short form of **sh-superh-elf-ld**.
- **ld** (in **`sh-superh-elf/bin`**)
  Same as **sh-superh-elf-ld**. Used by the compiler driver instead of **sh-superh-elf-ld**.

The short form is provided for convenience and is to be used in preference.

The SuperH configuration is different from the traditional configuration in the set of supported emulations. These emulations support board support packages (see *Section 3.6: Board support on page 54*).

3.4.1 GNU linker command line quick reference

Table 8 lists many of the most useful linker options.

Option	Description
`-l`*`library`*	Specify a library. The linker searches its search path for a file named **`lib`*`library`*`.a`**. Only the first one found on the path is used.
`-L` ***`path`***	Add ***`path`*** to the library search path.
`-m` ***`emulation`***	Use ***`emulation`*** to link the files. The emulation selects a linker script file from the standard set.
`-EL`	Link for little endian. Outside of the SuperH configuration a little endian emulation is also required. (Default in SuperH configuration.)

Table 8: sh4ld command line quick reference

Option	Description
-EB	Link for big endian. Outside of the SuperH configuration a big endian emulation is also required. (Default in traditional configuration.)
-t	Output trace information of the link process. This allows the dependencies to be traced, which is useful for diagnosing link failures.
-T *script_file*	Provide a custom linker script file. This overrides the linker script from the emulation.
-r	Create a relocatable object file as output. Used for partial links.
-M	Output map information from the link to standard output.
-Map *file*	Output map information from the link to ***file***.
-s	Strip all symbols from the output. Reduces the output file size, but cannot be debugged.
-S	Strip debugging symbols from the output.
--relax	Do relaxation optimizations (requires that the inputs are compiled and assembled with the relaxation options).
--defsym *s=v*	Define symbol ***s*** to value ***v***. This option is used by the board support mechanism to set the top and bottom of memory.

Table 8: sh4ld command line quick reference

3.5 Profiling with the sh4gcov and sh4gprof utilities

sh4gcov is used for testing the coverage of a program. This has two main purposes:

- to identify how much of the program code has been tested,
- to identify the most-used parts of the program.

To use **sh4gcov**, the entire application must first be instrumented by compiling with the **`-fprofile-arcs`** and **`-ftest-coverage`** compiler options.

When the application is executed a file named ***program*.gcda** is created in the same directory as the object file, for each source file. This file can then be read by **sh4gcov**:

```
sh4gcov program.c
```

sh4gcov creates a file named ***program*.c.gcov** which records the number of times each line was executed. Lines that were not executed are marked with **####**. The **-f** option provides a summary-per-function to the console:

```
sh4gcov -f program.c
```

The counts are cumulative. Therefore if the application is run multiple times, the execution counts in ***program*.gcda** are added to those of previous runs. This allows testing of all possible paths through the application.

The **-b** option provides information about how many times each branch was taken:

```
sh4gcov -b program.c
```

This provides a summary to the console and also records specific information in the **.gcov** file.

sh4gprof is used for profiling the application. For best results, the entire application should be instrumented by compiling with the **-pg** option.

When the application is executed the file named **gmon.out** is created which provides the profiling information. **sh4gprof** can then be used to examine this data.

There are several options for viewing different aspects of the data. For information on these refer to the GNU *Using the GNU Compiler Collection* manual.

3.6 Board support

The board support mechanism specifies the memory map that is used to link the program. This defines the start of memory and the start of the stack.

The default memory layout places the data and text (code) sections of the program at the lowest available address and places the stack at the highest available address. The heap is placed after the data and text sections and grows towards the stack.

The set of board specifications for a particular release is contained within the **boardspecs** file (see *Section 3.6.1: GCC board support setup*) and is selected with the **-mboard** GCC option. For example, the option **-mboard=mediaref** selects the memory map for the STMediaRef-Demo platform.

The SH-4 memory space is divided into several memory areas (**P0**, **P1**, **P2** and **P3**) all of which have different cache and translation behaviors. By default, programs are linked into area **P1** (cached), however, a different area can be selected by adding the appropriate **p*x*** suffix (where ***x*** is the region number) to the board support package name. *Table 9* lists the recognized board support packages for the SH-4, the addresses listed are the physical addresses for the base of the memory region for which the application is linked.

Board support package	Address	Size	Use
gdbsim	**0x00000000**	16M	GDB's built-in simulator
db457	**0x04000000**	32M	ST40STB1-ODrive board[a]
espresso **espressolmi**	**0x04000000** **0x04000000**	64M 128M	STi5528-Espresso board
mb293 **mb293emi**	**0x08000000** **0x03000000**	32M 16M	ST40RA HARP board[a]
mb317a	**0x08000000**	64M	ST40GX1 Evaluation board (Revision A)[a]
mb317b	**0x08000000**	64M	ST40GX1 Evaluation board (Revision B)[a]

Table 9: Recognized board support packages

Board support package	Address	Size	Use
mb350 **mb350emi**	**0x08000000** **0x03000000**	32M 16M	ST40RA Extended HARP board[a]
mb360	**0x08000000**	32M	ST40RA-Eval board
mb374	**0x08000000**	64M	ST40RA-Starter board[a]
mb376 **mb376emi** **mb376lmi**	**0x04000000** **0x03800000** **0x04000000**	64M 8M 128M	STi5528-Mboard
mb379 **mb379emi** **mb379lmi**	**0x08000000** **0x01000000** **0x08000000**	32M 32M 64M	STm8000-Demo board
mb392 **mb392lmi**	**0x08000000** **0x08000000**	32M 64M	ST220-Eval development board
mb411 **mb411vid** **mb411sys** **mb411lmivid** **mb411lmisys**	Synonym for **mb411sys** **0x10000000** **0x04000000** **0x10000000** **0x04000000**	 32M 32M 64M 64M	STb7100-Mboard
mb411stb7109 **mb411stb7109vid** **mb411stb7109sys** **mb411stb7109lmivid** **mb411stb7109lmisys**	Synonym for **mb411stb7109sys** **0x10000000** **0x04000000** **0x10000000** **0x04000000**	 32M 32M 64M 64M	STb7100-Mboard
mb422 **mb422lmi1** **mb422lmi2**	Synonym for **mb422lmi1** **0x09000000** **0x10000000**	 112M 112M	DTV100-DB board

Table 9: Recognized board support packages

Board support package	Address	Size	Use
mediaref	**0x08000000**	112M	STMediaRef-Demo reference platform
stb7100ref	Synonym for **stb7100refsy**		STb7100-Ref board
stb7100refvid	**0x10000000**	32M	
stb7100refsys	**0x04000000**	32M	
stb7100reflmivid	**0x10000000**	64M	
stb7100reflmisys	**0x04000000**	64M	

Table 9: Recognized board support packages

a. The ST40STB1-ODrive, ST40RA HARP, ST40GX1 Evaluation, ST40RA Extended HARP and ST40RA-Starter boards are no longer in production.

3.6.1 GCC board support setup

The GCC **-mboard** option is controlled by the GCC specs file **boardspecs**. This file is located in the subdirectory **lib/gcc/sh-superh-elf/3.4.3** under the release installation directory. A description of the format of a GCC specs file may be found in *Section 3.15* of the *Using the GNU Compiler Collection* manual (updated 23 May 2004 for GCC 3.4.3).

The primary objective of the **boardspecs** file is to provide to the linker the location of the top of memory (via the **_start** symbol) and bottom of memory (via the **_stack** symbol) for the given board. See *Section 3.6.2* for details of the linker command line.

The **boardspecs** file works by defining a spec string named **board_link**. This spec string must, directly or indirectly, specify the linker options defining the memory available to the application for the target board.

An example of the simplest **boardspecs** file is as follows:

```
*board_link:
--defsym _start=0xA8001000 --defsym _stack=0xAEFFFFFC
```

This defines the memory for a MediaRef-Demo board in the P2 region. The first line (and it **must** be the first line) describes that it is defining or re-defining the **board_link** spec-string. The second line (and it **must** be the second line) is the definition of the spec-string. The string is inserted into the linker command line when the spec-strings are interpreted by the GNU GCC compiler driver.

This example directly defines the memory for a single board with no option for any other board.

An example of defining the memory indirectly is as follows:

```
*mediaref:
--defsym _start=0xA8001000 --defsym _stack=0xAEFFFFFC

*board_link:
%(mediaref)
```

This technique allows more than one configuration to be defined (although in this example the **board_link** spec string still has to be manually altered in order to switch between them).

An example of using the **-mboard=** option is as follows:

```
*mediaref:
--defsym _start=0xA8001000 --defsym _stack=0xAEFFFFFC

*mb360:
--defsym _start=0xA8001000 --defsym _stack=0xA9FFFFFC

*board_link:
%(mboard=mediaref:%(mediaref)) \
%(mboard=mb360:%(mb360)) \
%(!mboard=*:%(mediaref))
```

This defines that ‘if the option **mboard=mediaref** was given then use spec string **mediaref**’. The next line defines exactly the same but for **mb360**. These two entries are not exclusive, if the option were given twice both might be true. This technique can be scaled up to any number of boards. It then goes on to define that ‘if there are no options given matching **mboard=*** then use spec string **mediaref**’. This is the default action for when no value is given.

An example of adding memory region support is as follows:

```
*mediarefp0:
--defsym _start=0x08001000 --defsym _stack=0x0EFFFFFC

*mediarefp1:
--defsym _start=0x88001000 --defsym _stack=0x8EFFFFFC

*mediarefp2:
--defsym _start=0xA8001000 --defsym _stack=0xAEFFFFFC

*mediarefp3:
--defsym _start=0xC8001000 --defsym _stack=0xCEFFFFFC

*board_link:
%(mboard=mediaref:%(mediarefp2)) \
%(mboard=mediarefp0:%(mediarefp0)) \
%(mboard=mediarefp1:%(mediarefp1)) \
%(mboard=mediarefp2:%(mediarefp2)) \
%(mboard=mediarefp3:%(mediarefp3))
```

This is similar to adding new boards except that instead of specifying a default board, a default memory region (P2) is specified.

3.6.2 Linker board support

The board support mechanism (available only in the SuperH configuration) permits the location of the top and bottom of memory to be specified on the command line by defining the symbols **_start** and **_stack** to the location of the bottom and top of memory respectively. For example:

```
sh4ld --defsym _start=0x1000 --defsym _stack=0x30000 ...
```

These symbols are used by the default linker script to position the final executable in memory.

The start address (**_start**) should be near the beginning of memory, but a small buffer (about **0x1000**) is required to allow for the small, but variable, amount of data the linker places before this symbol.

The stack address (**_stack**) specifies the initial location of the stack for the application and is the location of the top of memory (the SH-4 uses a falling stack).

Note: The address should be 1 word less than the top of memory since the location must be a legal address.

The GCC compiler driver passes these options automatically when it is used to perform the link. See *Section 3.6.1 on page 56* for more detailed information on how this is performed using the **-mboard** option of GCC.

3.7 Run-time support

The run-time support mechanism allows GCC to link programs for each recognized run-time system. The run-time is specified using the **-mruntime** option (see *Section 3.7.1: GCC run-time support setup*).

Table 10 lists the recognized run-time systems.

Supported run-time systems	Comment
bare	Bare machine (default)
os21	OS21
os21_d	OS21 debug

Table 10: Recognized run-time systems

3.7.1 GCC run-time support setup

The GCC **-mruntime** option is controlled by the GCC specs file **runtimespecs**. This file is located in the subdirectory **lib/gcc/sh-superh-elf/3.4.3** under the release installation directory. A description of the format of a GCC specs file may be found in *Section 3.15* of the *Using the GNU Compiler Collection* manual (updated 23 May 2004 for GCC 3.4.3).

The SuperH configuration places five spec strings in the standard GCC **specs** file (located in the same directory as the **runtimespecs** file). They are named **asruntime** (assembler), **cppruntime** (C preprocessor), **cc1runtime** (compiler), **ldruntime** (linker) and **libruntime** (libraries). These spec strings can be overridden in the **runtimespecs** file in order to specify a new run-time environment setup.

An example of the simplest **runtimespecs** file is as follows:

```
*asruntime:
                (line intentionally blank)

*cppruntime:
-D__BARE_BOARD__

*cc1runtime:
                (line intentionally blank)

*ldruntime:
                (line intentionally blank)

*libruntime:
-lc -ldtf
```

This sets the run-time environment to that of a bare application (that is, an application without an operating system) using the Data Transfer Format (DTF) I/O transport. It does not provide information about which board is targeted. There is one entry for each of the five spec strings.

Each of the five spec strings is inserted respectively into the command lines of the assembler, preprocessor, compiler and linker (general linker options and library options).

There is an implicit **-lc** placed at the end of the library spec string **libruntime**. However, if a file or library listed in the **libruntime** string provides a symbol required by the C library (such as those found in **libgloss** or **libdtf**) then it is necessary to place an additional **-lc** first. The final line of the example shows **-lc** is listed before **-ldtf**.

The previous example allows only one run-time to be defined and ignores the **-mruntime** option. A simple example supporting both bare machine and OS21 applications is as follows:

```
*as_bare:
                (line intentionally blank)

*cpp_bare:
-D__BARE_BOARD__

*cc1_bare:
                (line intentionally blank)
```

```
*ld_bare:
                (line intentionally blank)

*lib_bare:
-lc -ldtf

*libgcc_bare:
-lgcc

*as_os21:
                (line intentionally blank)

*cpp_os21:
-D__os21__ -D__OS21_BOARD__

*cc1_os21:
                (line intentionally blank)

*ld_os21:
                (line intentionally blank)

*lib_os21:
%(lib_bare) -los21 -l%(lib_os21bsp_base) -los21 %(lib_bare)

*libgcc_os21:
-los21 %(libgcc_bare)

*asruntime:
%{!mruntime=*:%(as_bare)}\
%{mruntime=bare:%(as_bare)}\
%{mruntime=os21:%(as_os21)}\

*cppruntime:
%{!mruntime=*:%(cpp_bare)}\
%{mruntime=bare:%(cpp_bare)}\
%{mruntime=os21:%(cpp_os21)}\

*cc1runtime:
%{!mruntime=*:%(cc1_bare)}\
%{mruntime=bare:%(cc1_bare)}\
%{mruntime=os21:%(cc1_os21)}\
```

```
*ldruntime:
%{!mruntime=*:%(ld_bare)}\
%{mruntime=bare:%(ld_bare)}\
%{mruntime=os21:%(ld_os21)}\

*libruntime:
%{!mruntime=*:%(lib_bare)}\
%{mruntime=bare:%(lib_bare)}\
%{mruntime=os21:%(lib_os21)}\

*libgcc:
%{!mruntime=*:%(libgcc_bare)}\
%{mruntime=bare:%(libgcc_bare)}\
%{mruntime=os21:%(libgcc_os21)}\
```

Again, there is one line to describe which spec string is being defined (or redefined), one (possibly blank) line defining the spec string (after escape processing) and one blank line between rules.

The example supports the compiler driver options:

```
-mruntime=bare
-mruntime=os21
```

Cross development tools

4.1 Introduction to the cross development tools

The cross development tools allow an executable that has been created by the code development tools (see *Chapter 3: Code development tools on page 45*), to run on a variety of simulator and hardware platforms via the GNU debugger (GDB).

GDB has been enhanced in the SuperH configuration (see *Section 1.2 on page 20*) to provide better support for the SuperH simulator and silicon targets.

Before using any of the STMicroelectronics boards it is necessary to set up the hardware correctly. See *Appendix F: ST Micro Connect setup on page 307* for details.

4.2 The GNU debugger

The GNU debugger (GDB) supports the downloading and debugging of applications on:

- silicon (using the ST Micro Connect via Ethernet or, for Windows users, via USB),
- the SuperH functional simulator,
- the SuperH performance simulator,
- the GDB built-in simulator.

Although the GDB supplied includes the text user interface (TUI) and the Insight GUI, this section describes only the standard command line interface. Details of the TUI are provided in the GNU *Debugging with GDB* manual and the Insight GUI is described in *Chapter 6: Using Insight on page 111*.

GDB consists of the following tools:

- **sh-superh-elf-gdb**
  The debugger, without support for silicon or SuperH simulator.
- **sh4gdb**
  Short form of **sh-superh-elf-gdb**, provides support for the SuperH simulators and silicon.
- **sh-superh-elf-insight**
  The debugger graphical user interface, without support for silicon or SuperH simulator.
- **sh4insight**
  Short form of **sh-superh-elf-insight**, provides support for the SuperH simulators and silicon.
- **sh-superh-elf-gdbtui**
  The debugger text user interface, without support for silicon or SuperH simulator.
- **sh4gdbtui**
  Short form of **sh-superh-elf-gdbtui**, provides support for the SuperH simulators and silicon.

sh4insight is identical to **sh4gdb** except that it defaults to starting the Insight GUI instead of the command line interface (the same is also true for **sh-superh-elf-insight**). Therefore, wherever **sh4gdb** is referenced the same also applies to **sh4insight** (and similarly for **sh-superh-elf-gdb** and **sh-superh-elf-insight**).

sh4gdbtui is identical to **sh4gdb** except that it defaults to starting the text user interface (TUI), instead of the command line interface (the same is also true for **sh-superh-elf-gdbtui**). As for Insight, references to **sh4gdb** also apply to **sh4gdbtui**. The TUI provides simple source and register display windows and one-key shortcuts, in addition to the normal command line interface, suitable for use in text terminals such as **xterm**. For more information see the GNU GDB documentation.

Launching the debugger using the long name, **sh-superh-elf-gdb**, **sh-superh-elf-insight** or **sh-superh-elf-gdbtui** provides no support for the SuperH simulators or silicon, however it is possible to enable this support using a customized **`.shgdbinit`** file (see *Section 4.2.2*).

4.2.1 Using GDB

Although the GDB supplied by STMicroelectronics includes the Insight GUI, this section describes only the command line interface. See *Chapter 6: Using Insight on page 111* for a description of the Insight GUI.

GDB can be used to execute any program, but it can only be used effectively to debug programs compiled with debugging information (using the **-g** compilation option).

Once the program has been properly compiled, start GDB as follows:

sh4gdb *executable*

GDB then responds with a short message describing its version and configuration followed by a command prompt **(gdb)**.

There are many GDB commands available. For full instructions on all these commands use the GDB **help** command or refer to the GNU *Debugging with GDB* manual.

All of the commands may be abbreviated to the shortest name that is still unique. The GDB command line supports auto-completion of both commands and, where possible, parameters. In addition, many of the most common commands have single letter aliases.

Most of the commands serve no purpose until GDB has connected to and initialized a target.

Connecting to a target

There are a range of different target types that can be used to debug the executable. The connection command varies according to this type.

- The GDB simulator is built in to GDB and is connected to using the **target sim** command.
- The SuperH simulators and silicon (using ST Micro Connect) are connected using specialist commands, see *sh4targets.cmd, sh4targets-board.cmd on page 93*. These commands are only available when the short form of GDB (**sh4gdb**) is used. For example connecting to a standard SuperH simulator setup for the MediaRef-Demo board:

  (gdb) mediarefsim

Executing the program

If the program is executed immediately, it simply runs until it reaches completion or an error. In many cases it is desirable to set a breakpoint so that the program stops at the point of interest and allows inspection or single-stepping of the program state.

Breakpoints can be set on specific functions, lines or addresses using the **break** command, for example:

```
(gdb) break main
(gdb) break 42
(gdb) break *0x08002000
```

Once ready, download and start the program on the target by invoking the **run** command.

Note: It is possible to specify arguments to the **run** *command. These arguments are passed to the target program, which may read them through* **argc** *and* **argv** *as usual.*

For the GDB simulator target, the **load** command must be used to download the program onto the target before the **run** command is used. For local targets, only the **run** command is required. However, in all cases **continue** must be used to restart the program after it has stopped.

The program runs until it completes, hits a breakpoint, is interrupted by the user with a **Ctrl+C**, or encounters an error. At this point, a short explanatory message is displayed and the GDB prompt returns.

The following commands are provided to step execution a line, or a machine instruction at a time:

- the **step** command (abbreviated to **s**) moves on to the next source line (even if it is in a different function),
- the **stepi** command (abbreviated to **si**) moves on a single machine instruction before pausing the program again,
- the **next** command (abbreviated to **n**) is the same as **step**, but moves to the next line in the current function, rather than the next line in the program, stepping over any function calls,
- the **nexti** command is the machine code equivalent of **next**, it moves to the next instruction in the sequence even if the current one is a call.

Examining the target

All the GDB commands for interrogating targets are available.

The register set can be viewed with the **info registers** command or for a more compact display use the **regs** command.

The current function can be disassembled using the **disassemble** command. The current instruction can be disassembled using:

```
(gdb) x/i $pc
```

Memory can also be inspected using the **x** (examine) command:

```
(gdb) x 0x1000
```

The **/** modifier can also be used for other formats. For example, strings:

```
(gdb) x/s 0x08001234
```

Any variable currently in scope can be viewed by name with the **print** (or **p**) command. It can also be used with expressions, for example:

```
(gdb) p foo+bar*2
```

The **printf** command is also available to provide the capability to format the displayed information:

```
(gdb) printf "%s %d %d\n", 0x8001234, foo, foo+bar*2
```

Changing the state of the program

Memory locations, registers and variables can be altered using the **set** command:

```
(gdb) set variable i = 0
```

The expression syntax is much the same as C (or C++ depending what is being debugged), but there are some extensions. Refer to the GNU *Debugging with GDB* manual for details.

Exiting GDB

When the debug session is complete, exit GDB using the **quit** (or **q**) command.

4.2.2 The .shgdbinit file

On startup GDB searches for a file named **.shgdbinit**, first in the home directory and then in the current working directory. If either or both of these files exist GDB sources their contents.

The GDB **-nx** option prevents GDB from sourcing any of these files.

Note: Any commands in the **.shgdbinit** *files that require confirmation assume affirmative responses. Any line beginning with* **#** *will be ignored.*

Additionally, if GDB is launched using the **sh4gdb**, **sh4insight** or **sh4gdbtui** tool, a default **.shgdbinit** file is sourced before any other file. This file enables support for the SuperH simulator and silicon targets. The **-nx** option has no effect on this file.

Using the sh4gdb, sh4insight or sh4gdbtui tools

When GDB is launched using the **sh4gdb**, **sh4insight** or **sh4gdbtui** tool there is no requirement to create any additional **.shgdbinit** files. However, the **.shgdbinit** files are still useful for setting up user preferences and defaults.

Using the sh-superh-elf-gdb, sh-superh-elf-insight tools or sh-superh-elf-gdbtui

When GDB is launched using the **sh-superh-elf-gdb**, **sh-superh-elf-insight** or **sh-superh-elf-gdbtui** tool, the SuperH simulator and silicon support can be enabled from a user **.shgdbinit**. Use the **source** command to source the default **.shgdbinit** (in **sh-superh-elf/stdcmd** under the release installation directory).

The default **.shgdbinit** file assumes that the **sh-superh-elf/stdcmd** directory is on the GDB search path, which can be displayed using the GDB **show directories** command and set using the GDB **dir** command.

The standard command files, containing the SuperH configuration and target connection mechanisms, are also located in the **sh-superh-elf/stdcmd** directory and can be identified by the **.cmd** extension.

4.2.3 GDB command line reference

Table 11 lists some of the most useful command line options.

Option	Description
-nw | -nowindows	Disable the Insight GUI and use the command line interface. Equivalent to the option **-interpreter=console**.
-n | -nx	Prevent GDB from sourcing any **.shgdbinit** files or reading the **.gdbtkinit** file (if they exist).
-w | -windows	Enable the Insight GUI instead of the command line interface, see *Chapter 6: Using Insight on page 111*. Equivalent to the option **-interpreter=insight**.
-tui	Enable the GDB text user interface (TUI) instead of the command line interface. Equivalent to the option **-interpreter=tui**.
-args *exe args*	Debug the program (***exe***) and pass the command line arguments ***args*** to the program (***exe***).
-batch	Process the command line options (including any scripts from the **-command** option) and then exit.
-command *file* **-x *file***	Source the commands in ***file***. This is useful for setting up functions or automating downloads.
-interpreter *interface* **-ui *interface*** **-i *interface***	Set the GDB user interface to ***interface***. Standard user interfaces are **console**, **tui**, **insight** and **mi**.

Table 11: sh4gdb command line options

4.2.4 GDB SuperH configuration specific options

Table 12 lists the options added by the SuperH configuration.

Option	Description
-nx-except-gdbtkinit	This option is similar to **-nx** except that it does not prevent GDB from reading the **.gdbtkinit** file (if there is one). It only prevents GDB from sourcing any **.shgdbinit** files.
-batch-silent	This option is similar to **-batch** except that the debugger will suppress all normal output messages other than errors.
-eval-*command* **-ex *command***	Execute the specified GDB command, ***command***. This option may be specified multiple times to execute multiple commands. When used in conjunction with **-command**, the commands and scripts will be executed in the order specified on the command line.
-return-child-result	The return value given by GDB will be the return value from the target application (unless an explicit value is given to the GDB **quit** command, or an error occurs).

Table 12: sh4gdb SuperH configuration specific options

4.2.5 GDB command quick reference

Table 13 lists some of the most useful GDB commands. It does not include any of the additional commands for connecting and controlling targets that have been added in the SuperH configuration, see *Section 4.2.6: SuperH specific GDB commands on page 74*. The *Debugging with GDB* manual provides further details on GDB commands and the GNU debugger.

Command	Description
backtrace *n* [full]	Print a backtrace of all the stack frames (function calls). If ***n*** is specified and is positive then give the top ***n*** frames. If ***n*** is specified and is negative then give the bottom ***n*** frames. If the word **full** is given then it also prints the values of the local variables. The **bt** command may be used as an alias for **backtrace**.
break *function* |*line*|*file:line* |address***	Set a breakpoint on the specified function, line or address.
clear *function* |*line*|*file:line* |address***	Clear a breakpoint on the specified function, line or address.
continue	Continue execution of the program.
delete [*number*]	Delete the numbered breakpoint or all breakpoints.
disable [*number*]	Disable the numbered breakpoint or all breakpoints.
disassemble [*add1*] [*add2*]	Disassemble the machine code between the addresses ***add1*** and ***add2***. If one address is omitted then the code around the one given is disassembled. If both are omitted then it uses the program counter as the address to use.
file *file*	Use ***file*** as the program to be debugged.
finish	Complete current function.
help	GDB commands assistance.
info all-registers	Print the contents of all the registers.
info breakpoints	List all breakpoints.

Table 13: sh4gdb command quick reference

Command	Description
info registers	Print the contents of the registers. This provides more information than **regs**.
list	List next ten source lines.
list -	List previous ten source lines.
list ***function*** |***line***|***file:line*** |****address*** |***file:function***	List specific source code. Any two arguments separated by a comma are required to specify a range.
load [*file*]	Download the ***file*** to the target. If no ***file*** is given, the executable from the GDB command line or the **file** (or **exec-file**) command is used.
next [*n*]	Continue execution to next source line, stepping over functions. If ***n*** is specified, do this ***n*** times.
nexti [*n*]	Execute exactly one instruction, stepping over subroutine calls. If ***n*** is specified, do this ***n*** times.
print ***exp***|***$r***	Print the value of the expression ***exp*** or contents of the register ***$r*** (for example, **$r0** or **$pc**).
printf "*format*", ***arg1, ..., argn***	Same as **print** but with a format-string. Allows more than one parameter to be printed. Parameters must be separated by commas.
quit [*code*]	Exit GDB with the return value ***code***, if specified. If ***code*** is not specified, GDB will exit with the return value of 0. Note that the GDB convenience variable **$_exitcode** is set to the return value of the target application and therefore may be used as the value for ***code***, for example **quit $_exitcode**.
rbreak ***regexp***	Set a breakpoint on all functions that match ***regexp***.
regs	Print the contents of the registers. **info registers** provides more information.
run [*file*] *args*	Run the program. The program must already have been downloaded (using **load**) when using the GDB simulator. If an executable was given on the command line then ***file*** must not be given here.

Table 13: sh4gdb command quick reference

Command	Description
set args *args*	Set the command line for the program. Used before starting the program.
set variable *var* = *exp*	Set the value of a variable or register.
step [*n*]	Continue execution to next source line. If ***n*** is specified, do this ***n*** times.
stepi [*n*]	Execute exactly one instruction. If ***n*** is specified, do this ***n*** times.
target sim	Use the GDB built-in simulator instead of the SuperH simulator or silicon target.
tbreak *function* | *line* | *file:line* | **address*	Set a temporary (one time only) breakpoint on the specified function, line or address.
watch *exp*	Set a watchpoint for the expression ***exp***.
where *n* [full]	This is identical to the **backtrace** command.

Table 13: sh4gdb command quick reference

4.2.6 SuperH specific GDB commands

There are several additional features in the supplied GDB not found in the standard version from the Free Software Foundation (FSF). These are not specific to the SuperH configuration, but are generic features that have been added in order to provide better support for the implementation of the GDB scripts used for connecting to SuperH simulators and silicon. These additional commands are listed in *Table 14*.

Table 15 lists the additional features in the supplied GDB that are specific to the SuperH configuration.

Command	Description
fork *program arg1* [*arg2 ... argn*]	Start ***program*** with the specified arguments (***arg1*** to ***argn***). The program actually starts with: ***program fdout fdin arg1 arg2 ... argn*** where: ***fdout*** is the file descriptor of a writable pipe. Anything written to this pipe is interpreted as commands by GDB. ***fdin*** is the file descriptor of the read end of the same pipe.
init-if-undefined *var* = *exp*	The same as the GDB **set *var*** command except that it does not overwrite an existing value. The variable ***var*** must be a GDB convenience variable.
keep-variable *var*	Prevent the **file** (or **symbol-file**) command from removing the GDB convenience variable ***var***. Advantageous for scripting.
set backtrace abi-sniffer on|off	Use the ABI frame analyzer for back tracing (in addition to the DWARF2 debug information). Use this to obtain back traces when debug information is not available. The default is **off**.
set debug commandtrace on|off	Enable the tracing of GDB commands. Primarily used by **sh4xrun**. The default is **off**.
show backtrace abi-sniffer	Display the current state of the ABI analyzer.

Table 14: SuperH sh4gdb specific commands

Command	Description
show debug commandtrace	Display the current state of debug command trace.
sleep *time1* [*time2*]	Sleep for the specified time. ***time1*** is given in seconds and ***time2*** (optional) is given in microseconds.

Table 14: SuperH sh4gdb specific commands

Command	Description
console on|off	Display the output from the target program in a separate console window, or in the same console as GDB. The console may be turned on or off at any time. The default is **on**. Refer to *Section 4.2.8: Console settings on page 102*.
msglevel *opt*	Set the target debug interface message level. Use **help msglevel** for a list of valid options.
rtos on|off	Enables and disables RTOS awareness (useful in boot from ROM debug). The default is **on**. See *Section A.6.3: Debugging OS21 boot from ROM applications on page 261*.
targetargs "*arg0* *args* ..."	Set the command line for the program. This command is retained only for backward compatibility and may be removed from future releases.
target shtdi	Use the SuperH target debug interface to connect to a target. Used by the GDB connection commands.

Table 15: SuperH sh4gdb configuration specific commands

The following additional features have been added or enhanced:

- **$argc** GDB variable
  This GDB convenience variable is automatically defined at the start of every user defined GDB command. This allows a command to test how many parameters have been passed by the user. Beware that **$argc** is a global, updated at the start of every user defined command, and therefore does not retain its value across command calls.
- Directory search path
  The **directory** command is usually used by GDB to locate files (such as C source files). It has been extended so that it can also be used to locate GDB command files sourced using the **source** command.

There are also a number of commands that are defined when GDB sources the **sh-superh-elf/stdcmd** files. These files are automatically sourced when **sh4gdb**, **sh4insight** and **sh4gdbtui** are used. However if **sh4gdb**, **sh4insight** and **sh4gdbtui** are not used, they must be sourced by a **.shgdbinit** file in order to be available. The commands can be listed using the **help user-defined** command.

4.2.7 GDB command script files

The following GDB command script files are supplied in the subdirectory **sh-superh-elf/stdcmd** under the release installation directory and define user commands to connect to SH-4 targets; either simulated targets or connected to an ST Micro Connect.

Additional help is provided for many of these commands using the **help** command. For example, to display the help for **mb360**, use the command **help mb360**.

register40.cmd

Defines commands which define symbolically the locations of the memory mapped configuration registers on all SH-4 and ST40 silicon variants supported by the ST40 Micro Toolset. The user commands listed below are defined.

st40ra_si_regs	Define ST40RA configuration registers.
st40gx1_si_regs	Define ST40GX1 configuration registers.
stb7100_si_regs	Define STb7100 configuration registers.
stb7109_si_regs	Define STb7109 configuration registers.
std2000_si_regs	Define STd2000 configuration registers.
sti5528_si_regs	Define STi5528 configuration registers.
stm8000_si_regs	Define STm8000 configuration registers.

display40.cmd

Defines commands which display the contents of the memory mapped configuration registers for all SH-4 and ST40 silicon variants support by the ST40 Micro Toolset. The user commands listed below are defined.

st40ra_display_si_regs	Display ST40RA configuration registers.
st40gx1_display_si_regs	Display ST40GX1 configuration registers.
stb7100_display_si_regs	Display STb7100 configuration registers.
stb7109_display_si_regs	Display STb7109 configuration registers.
std2000_display_si_regs	Display STd2000 configuration registers.
sti5528_display_si_regs	Display STi5528 configuration registers.
stm8000_display_si_regs	Display STm8000 configuration registers.

st40gx1.cmd

Defines commands describing the core memory regions and other attributes of an ST40GX1. The user commands listed below are defined.

st40gx1_define	Define ST40GX1 core memory map.
st40gx1_fsim_core_setup	Configure the SuperH SH-4 functional simulator.
st40gx1_psim_core_setup	Configure the SuperH SH-4 performance simulator.

st40ra.cmd

Defines commands describing the core memory regions and other attributes of an ST40RA. The user commands listed below are defined.

st40ra_define	Define ST40RA core memory map.
st40ra_fsim_core_setup	Configure the SuperH SH-4 functional simulator.
st40ra_psim_core_setup	Configure the SuperH SH-4 performance simulator.

stb7100.cmd

Defines commands describing the core memory regions and other attributes of an STb7100. The user commands listed below are defined.

stb7100_define	Define STb7100 core memory map.
stb7100_fsim_core_setup	Configure the SuperH SH-4 functional simulator.
stb7100_psim_core_setup	Configure the SuperH SH-4 performance simulator.

stb7109.cmd

Defines commands describing the core memory regions and other attributes of an STb7109. The user commands listed below are defined.

stb7109_define	Define STb7109 core memory map.
STb7109_fsim_core_setup	Configure the SuperH SH-4 functional simulator.
STb7109_psim_core_setup	Configure the SuperH SH-4 performance simulator.

std2000.cmd

Defines commands describing the core memory regions and other attributes of an STd2000. The user commands listed below are defined.

std2000_define	Define STd2000 core memory map.
std2000_fsim_core_setup	Configure the SuperH SH-4 functional simulator.
std2000_psim_core_setup	Configure the SuperH SH-4 performance simulator.

sti5528.cmd

Defines commands describing the core memory regions and other attributes of an STi5528. The user commands listed below are defined.

sti5528_define	Define STi5528 core memory map.
sti5528_fsim_core_setup	Configure the SuperH SH-4 functional simulator.
sti5528_psim_core_setup	Configure the SuperH SH-4 performance simulator.

stm8000.cmd

Defines commands describing the core memory regions and other attributes of an STm8000. The user commands listed below are defined.

stm8000_define	Define STm8000 core memory map.
stm8000_fsim_core_setup	Configure the SuperH SH-4 functional simulator.
stm8000_psim_core_setup	Configure the SuperH SH-4 performance simulator.

db457.cmd

Defines commands which set the configuration registers for the ST40RA on an STMicroelectronics ST40STB1-ODrive board[1]. The user commands listed below are defined.

db457_setup	Set ST40STB1-ODrive board configuration registers.
db457sim_setup	Set simulated ST40STB1-ODrive board configuration registers.
db457_display_registers	Display ST40STB1-ODrive board configuration registers.

1. The ST40STB1-ODrive, ST40RA HARP, ST40GX1 Evaluation, ST40RA Extended HARP and ST40RA-Starter boards are no longer in production.

db457_sim_memory_define	Define memory regions for the ST40STB1-ODrive board to the SuperH SH-4 simulator.

espresso.cmd

Defines commands which set the configuration registers for the STi5528 on an STMicroelectronics STi5528-Espresso board. The user commands listed below are defined.

espresso_setup	Set STi5528-Espresso board configuration registers.
espressosim_setup	Set simulated STi5528-Espresso board configuration registers.
espresso_display_registers	Display STi5528-Espresso board configuration registers.
espresso_sim_memory_define	Define memory regions for the STi5528-Espresso board to the SuperH SH-4 simulator.

mb293.cmd

Defines commands which set the configuration registers for the ST40RA on STMicroelectronics ST40RA HARP and ST40RA Extended HARP boards[1]. The user commands listed below are defined.

mb293_setup	Set ST40RA HARP board configuration registers.
mb350_setup	Set ST40RA Extended HARP board configuration registers.
mb293sim_setup	Set simulated ST40RA HARP board configuration registers.
mb350sim_setup	Set simulated ST40RA Extended HARP board configuration registers.

1. The ST40STB1-ODrive, ST40RA HARP, ST40GX1 Evaluation, ST40RA Extended HARP and ST40RA-Starter boards are no longer in production.

mb293_display_registers	Display ST40RA HARP board configuration registers.
mb350_display_registers	Display ST40RA Extended HARP board configuration registers.
mb293_sim_memory_define	Define memory regions for the ST40RA HARP board to the SuperH SH-4 simulator.
mb350_sim_memory_define	Define memory regions for the ST40RA Extended HARP board to the SuperH SH-4 simulator.

mb317.cmd

Defines commands which set the configuration registers for the ST40GX1 on an STMicroelectronics ST40GX1 Evaluation board (revision A and B variants)[1]. The user commands listed below are defined.

mb317a_setup	Set ST40GX1 Evaluation board Rev A configuration registers.
mb317b_setup	Set ST40GX1 Evaluation board Rev B configuration registers.
mb317asim_setup	Set simulated ST40GX1 Evaluation board Rev A configuration registers.
mb317bsim_setup	Set simulated ST40GX1 Evaluation board Rev B configuration registers.
mb317a_display_registers	Display ST40GX1 Evaluation board Rev A configuration registers.
mb317b_display_registers	Display ST40GX1 Evaluation board Rev B configuration registers.
mb317a_sim_memory_define	Define memory regions for the ST40GX1 Evaluation board Rev A to the SuperH SH-4 simulator.

1. The ST40STB1-ODrive, ST40RA HARP, ST40GX1 Evaluation, ST40RA Extended HARP and ST40RA-Starter boards are no longer in production.

mb317b_sim_memory_define	Define memory regions for the ST40GX1 Evaluation board Rev B to the SuperH SH-4 simulator.

mb360.cmd

Defines commands which set the configuration registers for the ST40RA on an STMicroelectronics ST40RA-Eval board. The user commands listed below are defined.

mb360_setup	Set ST40RA-Eval board configuration registers.
mb360sim_setup	Set simulated ST40RA-Eval board configuration registers.
mb360_display_registers	Display ST40RA-Eval board configuration registers.
mb360_sim_memory_define	Define memory regions for the ST40RA-Eval board to the SuperH SH-4 simulator.

mb374.cmd

Defines commands which set the configuration registers for the ST40RA on an STMicroelectronics ST40RA-Starter board[1]. The user commands listed below are defined.

mb374_setup	Set ST40RA-Starter board configuration registers.
mb374sim_setup	Set simulated ST40RA-Starter board configuration registers.
mb374_display_registers	Display ST40RA-Starter board configuration registers.
mb374_sim_memory_define	Define memory regions for the ST40RA-Starter board to the SuperH SH-4 simulator.

1. The ST40STB1-ODrive, ST40RA HARP, ST40GX1 Evaluation, ST40RA Extended HARP and ST40RA-Starter boards are no longer in production.

mb376.cmd

Defines commands which set the configuration registers for the STi5528 on an STMicroelectronics STi5528-Mboard. The user commands listed below are defined.

mb376_setup	Set STi5528-Mboard configuration registers.
mb376sim_setup	Set simulated STi5528-Mboard configuration registers.
mb376_display_registers	Display STi5528-Mboard configuration registers.
mb376_sim_memory_define	Define memory regions for the STi5528-Mboard to the SuperH SH-4 simulator.

mb379.cmd

Defines commands which set the configuration registers for the STm8000 on an STMicroelectronics STm8000-Demo board. The user commands listed below are defined.

mb379_setup	Set STm8000-Demo board configuration registers.
mb379sim_setup	Set simulated STm8000-Demo board configuration registers.
mb379_display_registers	Display STm8000-Demo board configuration registers.
mb379_sim_memory_define	Define memory regions for the STm8000-Demo board to the SuperH SH-4 simulator.

mb392.cmd

Defines commands which set the configuration registers for the ST220 on an STMicroelectronics ST220-Eval development board. The user commands listed below are defined.

mb392_setup	Set ST220-Eval development board configuration registers.
mb392sim_setup	Set simulated ST220-Eval development board configuration registers.

mb392_display_registers	Display ST220-Eval development board configuration registers.
mb392_sim_memory_define	Define memory regions for the ST220-Eval development board to the SuperH SH-4 simulator.

mb411.cmd

Defines commands which set the configuration registers for the STb7100 on an STMicroelectronics STb7100-Mboard. The user commands listed below are defined.

mb411_setup	Set STb7100-Mboard configuration registers.
mb411sim_setup	Set simulated STb7100-Mboard configuration registers.
mb411_display_registers	Display STb7100-Mboard configuration registers.
mb411_sim_memory_define	Define memory regions for the STb7100-Mboard to the SuperH SH-4 simulator.
mb411bypass_setup	Set the STb7100-Mboard to bypass to the ST40 via **stb7100_bypass_setup** (see *stb7100jtag.cmd on page 93*). Used by the **mb411bypass** and **mb411bypassusb** commands, see *Table 22* and *Table 23*.
mb411stmmx_setup	Set the STb7100-Mboard for use with the ST MultiCore/MUX device allowing simultaneous access to the ST40 and other CPUs on the STb7100 via **stb7100_stmmx_setup** (see *stb7100jtag.cmd on page 93*). Used by the **mb411stmmx** and **mb411stmmxusb** commands, see *Table 22* and *Table 23*.

mb411stb7109.cmd

Defines commands which set the configuration registers for the STb7109 on an STMicroelectronics STb7100-Mboard. The user commands listed below are defined.

mb411stb7109_setup	Set STb7100-Mboard configuration registers.
mb411stb7109sim_setup	Set simulated STb7100-Mboard configuration registers.
mb411stb7109_display_registers	Display STb7100-Mboard configuration registers.
mb411stb7109_sim_memory_define	Define memory regions for the STb7100-Mboard to the SuperH SH-4 simulator.
mb411stb7109bypass_setup	Set the STb7100-Mboard to bypass to the ST40 via **stb7100_bypass_setup** (see *stb7100jtag.cmd on page 93*). Used by the **mb411stb7109bypass** and **mb411stb7109bypassusb** commands, see *Table 22* and *Table 23*.
mb411stb7109stmmx_setup	Set the STb7100-Mboard for use with the ST MultiCore/MUX device allowing simultaneous access to the ST40 and other CPUs on the STb7109 via **stb7100_stmmx_setup** (see *stb7100jtag.cmd on page 93*). Used by the **mb411stb7109stmmx** and **mb411stb7109stmmxusb** commands, see *Table 22* and *Table 23*.

mb422.cmd

Defines commands which set the configuration registers for the STd2000 on an STMicroelectronics DTV100-DB board. The user commands listed below are defined.

mb422_setup	Set DTV100-DB board configuration registers.
mb422sim_setup	Set simulated DTV100-DB board configuration registers.
mb422_display_registers	Display DTV100-DB board configuration registers.
mb422_sim_memory_define	Define memory regions for the DTV100-DB board to the SuperH SH-4 simulator.

mediaref.cmd

Defines commands which set the configuration registers for the ST40GX1 on an STMediaRef-Demo reference platform. The user commands listed below are defined.

mediaref_setup	Set STMediaRef-Demo configuration registers.
mediarefsim_setup	Set simulated STMediaRef-Demo configuration registers.
mediaref_display_registers	Display STMediaRef-Demo configuration registers.
mediaref_sim_memory_define	Define memory regions for the STMediaRef-Demo board to the SuperH SH-4 simulator.

stb7100ref.cmd

Defines commands which set the configuration registers for the STb7100 on an STMicroelectronics STb7100-Ref board. The user commands listed below are defined.

stb7100ref_setup	Set STb7100-Ref board configuration registers.
stb7100refsim_setup	Set simulated STb7100-Ref board configuration registers.
stb7100ref_display_registers	Display STb7100-Ref board configuration registers.
stb7100ref_sim_memory_define	Define memory regions for the STb7100-Ref board to the SuperH SH-4 simulator.
stb7100refbypass_setup	Set the STb7100-Ref board to bypass to the ST40 via **stb7100_bypass_setup** (see *stb7100jtag.cmd on page 93*). Used by the **stb7100refbypass** and **stb7100refbypassusb** commands, see *Table 22* and *Table 23*.
stb7100refstmmx_setup	Set the STb7100-Ref board for use with the ST MultiCore/MUX device allowing simultaneous access to the ST40 and other CPUs on the STb7100 via **stb7100_stmmx_setup** (see *stb7100jtag.cmd on page 93*). Used by the **stb7100refstmmx** and **stb7100refstmmxusb** commands, see *Table 22* and *Table 23*.

shsimcmds.cmd

Defines commands to control the internal configuration of the SuperH SH-4 simulator shipped with the ST40 Micro Toolset. The user commands listed below are defined.

sim_addmemory	Define a memory region for the simulator.
sim_branchtrace	Enable/disable branch instruction tracing.
sim_census	Enable/disable census information.
sim_command	Send a generic command to the simulator.
sim_config	Send a configuration command to the simulator.
sim_insttrace	Enable/disable instruction tracing.
sim_reset	Resets the internal state of the SuperH simulator. For correct operation, it is required that this command is executed after every configuration change.
sim_trace	Enable/disable trace information.

sh4connect.cmd

Defines commands to connect to a target via an ST Micro Connect, or to connect to a simulated target using the SuperH simulator, and optionally to configure the target.

Table 16 lists the user commands for connecting to a target.

Command	Description
connectsh4be	Connect to a SH-4 silicon target (big endian). See *Table 22 on page 95* and *Table 23 on page 97*.
connectsh4usbbe	
connectsh4le	Connect to a SH-4 silicon target (little endian). See *Table 22 on page 95* and *Table 23 on page 97*.
connectsh4usble	

Table 16: Target user commands

These commands take three arguments; the first specifies the name or IP address of the ST Micro Connect (for **connectsh4usble** and **connectsh4usbbe** this is the USB target name), the second specifies the command to be invoked after connecting to the ST Micro Connect in order to configure the target and the third specifies the configuration command for the ST Micro Connect and UDI connection.

Table 17 lists the configuration commands available for configuring the ST Micro Connect and UDI connection.

The configuration commands must be specified as a string (that is, enclosed within double quotes if they contain spaces) and may be combined using a space to separate each command.

Command	Description
-inicommand *command*[,*arg*]	Execute the GDB command ***command*** to initialize the target (see *Appendix E: JTAG control on page 299*) before connecting to the ST40. ***command*** may take optional arguments by appending them to the command name using a comma as a separator without spaces. Note that ***command*** will normally be a user defined GDB command.
jtagclk=internal |external	Set the reference clock source for the JTAG TCK signal. The default is **internal**.
jtagpinout=default |hitachi|st40 |stmmx	Set the style of pinout from the ST Micro Connect to the target board JTAG connector. **default** is a synonym for **hitachi** and is the default pinout style for ST40 targets. **st40** is the natural pinout style used by the STb7100/STb7109 based platforms. **stmmx** is the pinout style used for connections to the ST MultiCore/Mux device.
linkspeed=*speed*	Set the target link speed to ***speed***. This is the same as the **linkspeed** user command (see *linkspeed on page 101*).
linktimeout=*time*	Set the target link timeout period to ***time*** seconds. This is the same as the **linktimeout** user command (see *linktimeout on page 101*).
msglevel=none |warning|info |debug|all	Set the reporting level of diagnostic messages displayed by the ST Micro Connect on its console (which is available when connected to the ST Micro Connect over telnet or via a serial line). The default is **none**.

Table 17: ST Micro Connect configuration commands

Command	Description
ondisconnect=none |reset|restart	Set the action to perform on disconnecting from the target. **none** does nothing when disconnecting. **reset** resets the target before disconnecting. This is not compatible with the **jtag** reset type. **restart** restarts the target from where it was last stopped.
resetdelay=*time*	Set the delay, in ***time*** milliseconds, used when performing a **softreset** or **hardreset** of the target. The delay is performed during each transition of the reset sequence and should be set to the longest delay required. The default is 20 milliseconds.
resettype=soft|hard |jtag|break **softreset** **hardreset** **jtagreset** **breakreset**	Set the reset type when connecting to the target. **soft** performs a UDI reset. This is the same as the **softreset** configuration command. **hard** performs a board level reset. This is the same as the **hardreset** configuration command. **jtag** does not perform an implicit reset of the target; instead reset should be performed explicitly using a **jtag** command (see *Appendix E: JTAG control on page 299*) via a target initialization command (see **-inicommand** configuration option). This is the same as the **jtagreset** configuration command. **break** attaches to a running target without performing a reset and therefore leaves the target state intact. This is the same as the **breakreset** configuration command. This configuration command should normally be used in conjunction with the **ondisconnect=restart** configuration command to ensure that the target is restarted on disconnecting and so allowing the target to be re-attached in the future. The default is **soft**.
tdidelay=*delay*	Set the delay in TCK clock cycles for the JTAG TDI signal (ST Micro Connect perspective). The default is **0**.

Table 17: ST Micro Connect configuration commands

Table 18 lists the user commands for connecting to a simulator.

Command	Description
connectsh4simle	Connect to a SuperH SH-4 functional simulator (little endian). See *Table 24 on page 99*.
connectsh4psimle	Connect to a SuperH SH-4 performance simulator (little endian, cycle accurate). See *Table 25 on page 100*.
connectsh4simbe	Connect to a SuperH SH-4 functional simulator (big endian).
connectsh4psimbe	Connect to a SuperH SH-4 performance simulator (big endian, cycle accurate).

Table 18: Simulator user commands

These commands take three arguments specifying the commands to be invoked after connecting to the simulator. The first configures the simulator, the second is the command to configure the simulated target and the third specifies the configuration command string for the SuperH simulator (see *Table 19*).

Table 19 lists the commands available for configuring the SuperH simulator. Only one configuration command can be specified and it must be specified as a string (that is, enclosed within double quotes).

Command	Description
+DMM *delay*	Set the memory access delay (in cycles) to ***delay*** (SuperH SH-4 performance simulator only). Default is 1 cycle.
+SCIF *mode*	Enable (***mode*** is **1**) or disable (***mode*** is **0**) a simulated serial port. The simulator displays a TCP/IP port number and waits for 30 seconds for the user to connect to the network port using, for example, telnet.

Table 19: Simulator configuration commands

st40clocks.cmd

Defines commands to change the frequencies of the various internal clocks of ST40 silicon. The user commands listed below are defined.

st40_cpu<*f*>bus<*f*>mem<*f*>per<*f*>

Set the internal clock frequencies where **<*f*>** is the frequency in MHz. Several versions of the command are defined.

st40_displayclocks	Display the internal clock frequencies and PLL configuration register settings.

stb7100clocks.cmd

Defines commands to display the frequencies of the various internal clocks of an STb7100/STb7109. The user command listed below is defined.

stb7100_displayclocks	Display the internal clock frequencies and PLL configuration register settings.

sti5528clocks.cmd

Defines commands to display the frequencies of the various internal clocks of an STi5528. The user command listed below is defined.

sti5528_displayclocks	Display the internal clock frequencies and PLL configuration register settings.

stm8000clocks.cmd

Defines commands to display the frequencies of the various internal clocks of an STm8000. The user command listed below is defined.

stm8000_displayclocks	Display the internal clock frequencies and PLL configuration register settings.

stb7100jtag.cmd

Defines commands for configuring the connection between an ST Micro Connect and the ST40 CPU of an STb7100/STb7109. The user commands listed below are defined.

stb7100_bypass_setup Configure the ST Micro Connect for a direct connection to the ST40 CPU.

stb7100_bypass_setup_attach Similar to **stb7100_bypass_setup** except that the STb7100/STb7109 is not reset and instead a reset type of **breakreset** is performed (see *Table 17: ST Micro Connect configuration commands on page 89*).

stb7100_stmmx_setup Configure the ST Micro Connect for a connection to the ST40 CPU using an ST Multicore/MUX device allowing simultaneous access to the ST40 and other CPU's on the STb7100/STb7109.

Note: The **$STb7100ResetDelay** *GDB convenience variable is used by the above user commands to set the delay (in milliseconds) when performing a reset of the target (see also* **resetdelay** *in Table 17: ST Micro Connect configuration commands on page 89). The default is 20 milliseconds. To override the default, set this variable before connecting to the STb7100/STb7109, for example the following sets a 200 ms delay:*

```
set $STb7100ResetDelay=200
```

sh4targets.cmd, sh4targets-*board*.cmd

Defines commands for connecting to all the targets supported by the ST40 Micro Toolset including simulated targets. These commands are listed in *Table 20*.

Command	Target
sh4be*suffix*	Generic SH-4 target (big endian)
sh4le*suffix* **sh4*suffix***	Generic SH-4 target (little endian)
db457*suffix*	ST40STB1-ODrive board[a]

Table 20: Target connect commands

Command	Target
espresso*suffix*	STi5528-Espresso board
mb293*suffix*	ST40RA HARP board[a]
mb317a*suffix*	ST40GX1 Evaluation board (Revision A)[a]
mb317b*suffix*	ST40GX1 Evaluation board (Revision B)[a]
mb350*suffix*	ST40RA Extended HARP board[a]
mb360*suffix*	ST40RA-Eval board
mb374*suffix*	ST40RA-Starter board[a]
mb376*suffix*	STi5528-Mboard
mb379*suffix*	STm8000-Demo board
mb392*suffix*	ST220-Eval development board
mb411*suffix*	STb7100-Mboard
mb411stb7109*suffix*	STb7100-Mboard
mb422*suffix*	DTV100-DB board
mediaref*suffix*	STMediaRef-Demo reference platform
stb7100ref*suffix*	STb7100-Ref board

Table 20: Target connect commands

a. The ST40STB1-ODrive, ST40RA HARP, ST40GX1 Evaluation, ST40RA Extended HARP and ST40RA-Starter boards are no longer in production.

Each command in *Table 20* has a number of variants which are represented in the command ***suffix***, these are shown in *Table 21*.

Command suffix and parameters	Comment
command target **[*opt*]**	(No suffix) Connect to a silicon target via Ethernet.
command*usb *target **[*opt*]**	Connect to a silicon target via USB.
***command*sim [*opt*]**	Connect to the SuperH functional simulator.
***command*psim [*opt*]**	Connect to the SuperH performance simulator.

Table 21: Connect command variants

In *Table 21*, ***target*** is the name (or IP address) of the ST Micro Connect and ***opt*** is an optional configuration command string for the ST Micro Connect or SuperH simulator connection. Refer to *Table 17 on page 89* for the available ST Micro Connect configuration commands and *Table 19 on page 91* for the available SuperH simulator configuration commands.

The equivalent **connectsh4be** and **connectsh4le** commands are listed in *Table 22* and the equivalent **connectsh4usbbe** and **connectsh4usble** commands are listed in *Table 23*.

Note: *In Table 22,* **$arg0** *is the name (or IP address) of the ST Micro Connect and in Table 23,* **$arg0** *is the name of the ST Micro Connect assigned during installation.*

Command	connectsh4be/connectsh4le equivalent
sh4be	**connectsh4be $arg0 echo ""**
sh4le **sh4**	**connectsh4le $arg0 echo ""**
db457	**connectsh4le $arg0 db457_setup "hardreset"**
espresso	**connectsh4le $arg0 espresso_setup "hardreset"**
mb293	**connectsh4le $arg0 mb293_setup "hardreset"**
mb317a	**connectsh4le $arg0 mb317a_setup "hardreset"**
mb317b	**connectsh4le $arg0 mb317b_setup "hardreset"**

Table 22: ST40 connectsh4be and connectsh4le equivalents

Command	connectsh4be/connectsh4le equivalent
mb350	connectsh4le $arg0 mb350_setup "hardreset"
mb360	connectsh4le $arg0 mb360_setup "hardreset"
mb374	connectsh4le $arg0 mb374_setup "hardreset"
mb376	connectsh4le $arg0 mb376_setup "hardreset"
mb379	connectsh4le $arg0 mb379_setup "hardreset"
mb392	connectsh4le $arg0 mb392_setup "hardreset"
mb411	connectsh4le $arg0 mb411_setup "jtagpinout=st40 hardreset"
mb411bypass	connectsh4le $arg0 mb411_setup "jtagpinout=st40 jtagreset -inicommand mb411bypass_setup"
mb411stmmx	connectsh4le $arg0 mb411_setup "jtagpinout=stmmx jtagreset tdidelay=1 -inicommand mb411stmmx_setup"
mb411stb7109	connectsh4le $arg0 mb411stb7109_setup "jtagpinout=st40 hardreset"
mb411stb7109bypass	connectsh4le $arg0 mb411stb7109_setup "jtagpinout=st40 jtagreset -inicommand mb411stb7109bypass_setup"
mb411stb7109stmmx	connectsh4le $arg0 mb411stb7109_setup "jtagpinout=stmmx jtagreset tdidelay=1 -inicommand mb411stb7109stmmx_setup"
mb422	connectsh4le $arg0 mb422_setup "hardreset"
mediaref	connectsh4le $arg0 mediaref_setup "hardreset"
stb7100ref	connectsh4le $arg0 stb7100ref_setup "jtagpinout=st40 hardreset"

Table 22: ST40 connectsh4be and connectsh4le equivalents

Command	connectsh4be/connectsh4le equivalent
stb7100refbypass	connectsh4le $arg0 stb7100ref_setup "jtagpinout=st40 jtagreset -inicommand stb7100refbypass_setup"
stb7100refstmmx	connectsh4le $arg0 stb7100ref_setup "jtagpinout=stmmx jtagreset tdidelay=1 -inicommand stb7100refstmmx_setup"

Table 22: ST40 connectsh4be and connectsh4le equivalents

Command	connectsh4usbbe/connectsh4usble equivalent
sh4usbbe	connectsh4usbbe $arg0 echo ""
sh4usble sh4usb	connectsh4usble $arg0 echo ""
db457usb	connectsh4usble $arg0 db457_setup "hardreset"
espressousb	connectsh4usble $arg0 espresso_setup "hardreset"
mb293usb	connectsh4usble $arg0 mb293_setup "hardreset"
mb317ausb	connectsh4usble $arg0 mb317a_setup "hardreset"
mb317busb	connectsh4usble $arg0 mb317b_setup "hardreset"
mb350usb	connectsh4usble $arg0 mb350_setup "hardreset"
mb360usb	connectsh4usble $arg0 mb360_setup "hardreset"
mb374usb	connectsh4usble $arg0 mb374_setup "hardreset"
mb376usb	connectsh4usble $arg0 mb376_setup "hardreset"
mb379usb	connectsh4usble $arg0 mb379_setup "hardreset"
mb392usb	connectsh4usble $arg0 mb392_setup "hardreset"
mb411usb	connectsh4usble $arg0 mb411_setup "jtagpinout=st40 hardreset"

Table 23: ST40 connectsh4usble and connectsh4usbbe equivalents

Command	connectsh4usbbe/connectsh4usble equivalent
`mb411bypassusb`	`connectsh4usble $arg0 mb411_setup "jtagpinout=st40 jtagreset -inicommand mb411bypass_setup"`
`mb411stmmxusb`	`connectsh4usble $arg0 mb411_setup "jtagpinout=stmmx jtagreset tdidelay=1 -inicommand mb411stmmx_setup"`
`mb411stb7109usb`	`connectsh4usble $arg0 mb411stb7109_setup "jtagpinout=st40 hardreset"`
`mb411stb7109bypassusb`	`connectsh4usble $arg0 mb411stb7109_setup "jtagpinout=st40 jtagreset -inicommand mb411stb7109bypass_setup"`
`mb411stb7109stmmxusb`	`connectsh4usble $arg0 mb411stb7109_setup "jtagpinout=stmmx jtagreset tdidelay=1 -inicommand mb411stb7109stmmx_setup"`
`mb422usb`	`connectsh4usble $arg0 mb422_setup "hardreset"`
`mediarefusb`	`connectsh4usble $arg0 mediaref_setup "hardreset"`
`stb7100refusb`	`connectsh4usble $arg0 stb7100ref_setup "jtagpinout=st40 hardreset"`
`stb7100refbypassusb`	`connectsh4usble $arg0 stb7100ref_setup "jtagpinout=st40 jtagreset -inicommand stb7100refbypass_setup"`
`stb7100refstmmxusb`	`connectsh4usble $arg0 stb7100ref_setup "jtagpinout=stmmx jtagreset tdidelay=1 -inicommand stb7100refstmmx_setup"`

Table 23: ST40 connectsh4usble and connectsh4usbbe equivalents

The user commands listed in *Table 24* and *Table 25* are defined for the SuperH SH-4 simulators. These commands take a single optional argument specifying the configuration command string for the SuperH SH-4 simulator.

The equivalent **`connectsh4simle`** commands are listed in *Table 24* and the equivalent **`connectsh4psimle`** commands are listed in *Table 25*.

Command	connectsh4simle equivalent
`db457sim`	`connectsh4simle db457_fsim_core_setup db457sim_setup ""`
`espressosim`	`connectsh4simle espresso_fsim_core_setup espressosim_setup ""`
`mb293sim`	`connectsh4simle mb293_fsim_core_setup mb293sim_setup ""`
`mb317asim`	`connectsh4simle mb317a_fsim_core_setup mb317asim_setup ""`
`mb317bsim`	`connectsh4simle mb317b_fsim_core_setup mb317bsim_setup ""`
`mb350sim`	`connectsh4simle mb350_fsim_core_setup mb350sim_setup ""`
`mb360sim`	`connectsh4simle mb360_fsim_core_setup mb360sim_setup ""`
`mb374sim`	`connectsh4simle mb374_fsim_core_setup mb374sim_setup ""`
`mb376sim`	`connectsh4simle mb376_fsim_core_setup mb376sim_setup ""`
`mb379sim`	`connectsh4simle mb379_fsim_core_setup mb379sim_setup ""`
`mb392sim`	`connectsh4simle mb392_fsim_core_setup mb392sim_setup ""`
`mb411sim`	`connectsh4simle mb411_fsim_core_setup mb411sim_setup ""`
`mb411stb7109sim`	`connectsh4simle mb411stb7109_fsim_core_setup mb411stb7109sim_setup ""`
`mb422sim`	`connectsh4simle mb422_fsim_core_setup mb422sim_setup ""`
`mediarefsim`	`connectsh4simle mediaref_fsim_core_setup mediarefsim_setup ""`
`stb7100refsim`	`connectsh4simle stb7100ref_fsim_core_setup stb7100refsim_setup ""`

Table 24: ST40 connectsh4simle equivalents

Command	connectsh4psimle equivalent
`db457psim`	`connectsh4psimle db457_psim_core_setup db457sim_setup ""`
`espressopsim`	`connectsh4psimle espresso_psim_core_setup espressosim_setup ""`
`mb293psim`	`connectsh4psimle mb293_psim_core_setup mb293sim_setup ""`
`mb317apsim`	`connectsh4psimle mb317a_psim_core_setup mb317asim_setup ""`
`mb317bpsim`	`connectsh4psimle mb317b_psim_core_setup mb317bsim_setup ""`
`mb350psim`	`connectsh4psimle mb350_psim_core_setup mb350sim_setup ""`
`mb360psim`	`connectsh4psimle mb360_psim_core_setup mb360sim_setup ""`
`mb374psim`	`connectsh4psimle mb374_psim_core_setup mb374sim_setup ""`
`mb376psim`	`connectsh4psimle mb376_psim_core_setup mb376sim_setup ""`
`mb379psim`	`connectsh4psimle mb379_psim_core_setup mb379sim_setup ""`
`mb392psim`	`connectsh4psimle mb392_psim_core_setup mb392sim_setup ""`
`mb411psim`	`connectsh4psimle mb411_psim_core_setup mb411sim_setup ""`
`mb411stb7109psim`	`connectsh4psimle mb411stb7109_psim_core_setup mb411stb7109sim_setup ""`
`mb422psim`	`connectsh4psimle mb422_psim_core_setup mb422sim_setup ""`
`mediarefpsim`	`connectsh4psimle mediaref_psim_core_setup mediarefsim_setup ""`
`stb7100refpsim`	`connectsh4psimle stb7100ref_psim_core_setup stb7100refsim_setup ""`

Table 25: ST40 connectsh4psimle equivalents

sh4commands.cmd

Defines commands for use with the targets. The user commands listed below are defined.

linkspeed	Set the target linkspeed (for example, **20MHz**, **10MHz**, **5MHz**). The default is **10MHz**. Use **help linkspeed** to display the complete range of values. See also *Section A.8: Changing ST40 clock speeds on page 264*.
linktimeout	Set the target link timeout period in seconds. The default is **1** second.
memory-add	Add a memory region to the target.
ondisconnect	Set the action to perform on disconnecting from the target. This is the same as the **ondisconnect** configuration command, see *Table 17: ST Micro Connect configuration commands on page 89*.
posixconsole	Specify whether the console window should be created (see *Section 4.2.8: Console settings on page 102*) by calling **console on|off**. **posixconsole** takes a boolean value of **0** or **1** (the default is **1**). This command is retained only for backward compatibility and may be removed from future releases.
stmcmsglevel	Set the reporting level of diagnostic messages displayed by the ST Micro Connect console. This is the same as the **msglevel** configuration command (see *Table 17 on page 89*).
use-watchpoint-access-size	Specify whether the access size is checked when matching watchpoints. The default is **on**. See *Section B.2.3: Silicon specific commands on page 286*.

allcmd.cmd

Sources all the GDB script files supplied with the ST40 Micro Toolset; the main purpose of which is to make available all commands defined by the scripts supplied with the ST40 Micro Toolset.

4.2.8 Console settings

A target console (separate to the GDB console) is provided for the target application. The target console window may be switched on or off at any time using the **console** command with either the **on** or **off** option.

When **console on** is specified, the console window is opened and all target I/O is redirected to the new window. When the target program completes, the console window remains open. The console window closes when GDB is shut down.

When **console off** is specified, the console window is closed (if open) and all target I/O is redirected to the same console as GDB. **stdout** and **stderr** are displayed in the GDB command console and **stdin** is read from the GDB command console.

4.3 Using sh4xrun

sh4xrun provides a simple batch mode interface to GDB. This allows users to connect and configure a target system, and to load and execute an application on the target system. **sh4xrun** invokes GDB with all of the options and scripts required to execute the program.

4.3.1 Setting the environment

The setup of **sh4xrun** is identical to the setup of GDB. Instructions on how to set up GDB are found in *Section 1.6.4: GDB setup on page 40*.

4.3.2 sh4xrun command line reference

To display the help, invoke **sh4xrun** with the **-h** option.

Usage

sh4xrun [-c *procedure* [-t *target*]] [-i *file*] [-e *file*] [-d *directory*] [-g *gdb*] [-x *file*] [-f] [-v] [-h] [-V] [-a *arguments*]

Note: The command order is important, **-a** *must always be the last option.*

Option	Description
-c *procedure*	Specify the target configuration procedure (GDB command) to be invoked. The configuration procedure must be compatible with the target being used.
-t *target*	Specify the target with which to be connected. This can be the target name or IP address. This option is not required for simulator targets.
-e *file*	Specify the executable file to be loaded onto the target.
-d *directory*	Add a directory to GDB's search path. The command **dir *directory*** is issued to GDB. This option can be specified more than once.
-i *file*	Execute the GDB script file ***file***. The command **source *file*** is issued to GDB. The *Debugging with GDB* manual provides examples of script file syntax. This option can be specified more than once.
-g *gdb*	Specify the full path to the GDB executable to be used. This should be a version compatible with the version of GDB supplied by STMicroelectronics.
-x *file*	Execute ***file*** as the default startup script instead of **.shgdbinit**.
-f	Ignore errors and continue execution.
-v	Display verbose information.
-h	Display the help for **sh4xrun**.
-V	Display the version of **sh4xrun**.
-a *arguments*	Specify that the remainder of the command line arguments are to be passed as arguments to the target application. This option can only be specified at the end of the command line.

Table 26: sh4xrun command line options

4.3.3 sh4xrun examples

To run **hello.out** on a silicon target, enter the following command:

```
sh4xrun -c mediaref -t stmc -e hello.out
```

To run **hello.out** on the SuperH SH-4 simulator, enter the following command:

```
sh4xrun -c mediarefsim -e hello.out
```

To run **hello.out** using a script file, enter the following command:

```
sh4xrun -i load.rc
```

Where the contents of the script file, **load.rc**, could be:

```
file hello.out
mediaref stmc
load
c
```

To run **hello.out** with target program arguments, type the following command:

```
sh4xrun -c mediaref -t stmc -e hello.out -a arg1 arg2 arg3 arg4
```

5 Using Eclipse

This chapter describes how to use the Eclipse Integrated Development Environment (IDE) for the ST40 Micro Toolset. Eclipse is available on all supported host platforms.

The Eclipse framework can be extended using plug-ins. One such plug-in is CDT (C/C++ Development Tools) which provides a fully functional C and C++ IDE for the Eclipse platform. This allows the user to develop, execute and debug applications interactively.

The Eclipse development environment and all the related information are available at the Eclipse website http://www.eclipse.org. Information on CDT can be found at http://www.eclipse.org/cdt.

5.1 Eclipse installation

The instructions for installing Eclipse can be found in the HTML introduction pages (**`index.htm`**) of the installation CD.

5.2 Getting started with Eclipse

To start Eclipse, run the **`eclipse`** executable (on Linux and Solaris) or **`eclipse.exe`** (on Windows).

Eclipse for ST40 should be launched with the **`-clean`** command option whenever the plug-ins for ST40 have been (re)installed. This guarantees their correct behavior.

Eclipse should always be launched with the **-configuration** command option whenever a shared installation of Eclipse is being used. This ensures that each developer has their own configuration settings. For example:

- under Windows add the option **-configuration "%USERPROFILE%\eclipse\STEclipseR3.0.2"**,
- under Solaris and Linux add the option **-configuration $HOME/.eclipse/STEclipseR3.0.2**.

When Eclipse is launched, the **Workspace Launcher** dialog is displayed (see *Figure 2*). Use this dialog to enter or select the location of the workspace. The workspace is the directory where the project data, files and directories are stored.

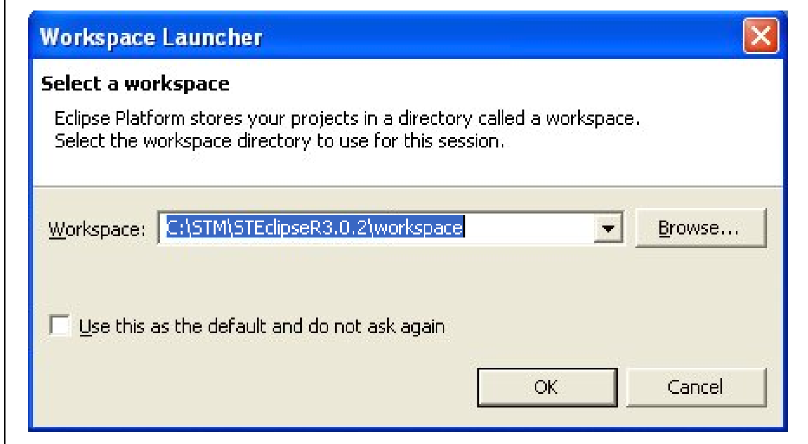


Figure 2: Workspace Launcher

*Note: The workspace can be changed at any time by selecting **Switch Workspace** from the **File** menu.*

After choosing the workspace location, a single **Workbench** is displayed. A **Workbench** offers one or more perspectives. A perspective contains editors and views, such as the **Navigator**. Multiple **Workbenches** can be opened simultaneously.

Initially, in the first **Workbench** that is opened, the **Resource** perspective is displayed, with only the **Welcome** view visible.

Close the **Welcome** view by clicking on the **x** icon circled in *Figure 3*. You can return to the **Welcome** view at any time by selecting **Help > Welcome**.

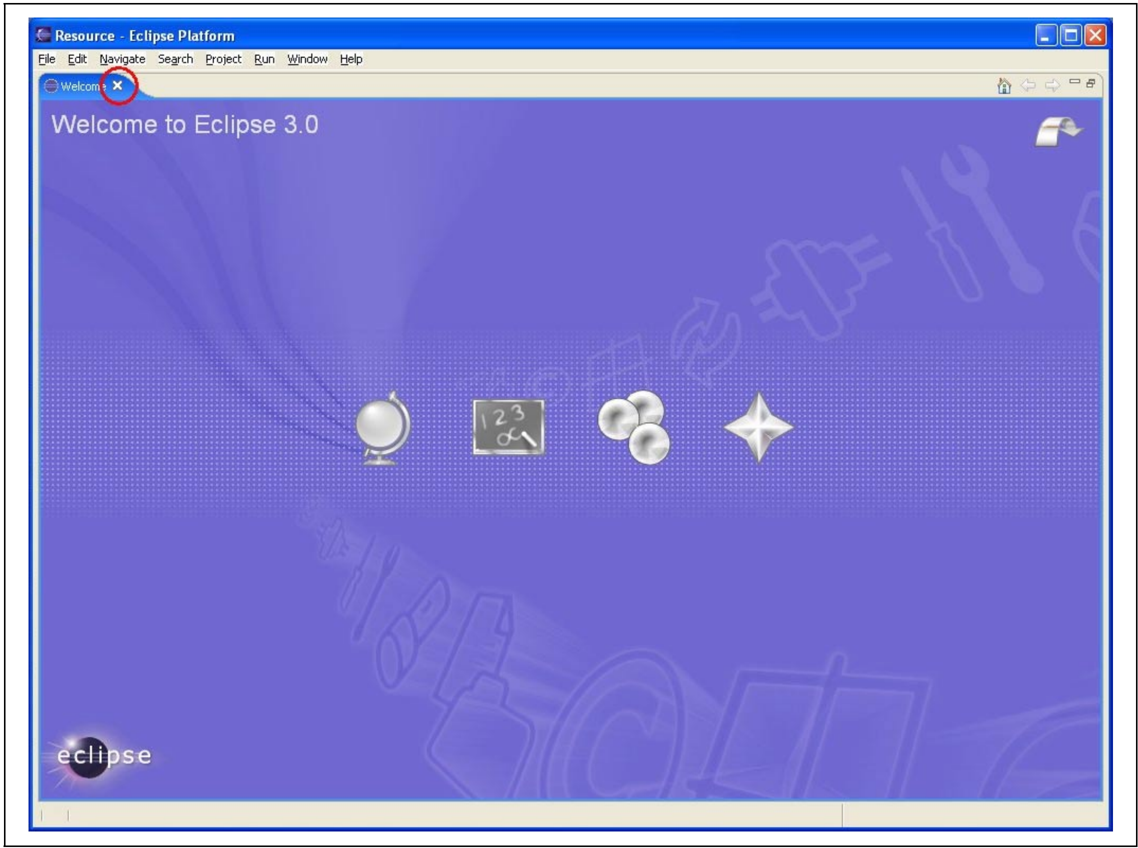


Figure 3: Welcome view

5.2.1 The Eclipse workbench

Before using Eclipse, it is important to become familiar with the various elements of the workbench. A workbench consists of:

- perspectives,
- views,
- editors.

A perspective is a preset group of views and editors in the **Workbench**. A perspective is designed to include all the views necessary for carrying out a specific task. For example, the **C/C++** perspective contains views required for C/C++ development (including the **C/C++ Projects** view and the **Outline** view) and the **Debug** perspective contains views required when debugging (including the **Debug**, **Variables** and **Breakpoints** views). One or more perspectives can exist in a single workbench. Each perspective contains one or more views and editors. Each perspective may have a different set of views but all perspectives share the same set of editors.

A view is a window within the workbench. It is typically used to navigate through a hierarchy of information (such as the resources in the workbench), open an editor, or display properties for the active editor. Modifications made in a view are saved immediately. Normally, only one instance of a particular type of view may exist within a **Workbench**.

The title bar of the **Workbench** indicates which perspective is active. In *Figure 3*, the **Resource** perspective is in use.

Changing a perspective

The views that make up a perspective can be changed. For example, to add the **Disassembly** view to the **Debug** perspective, follow the steps below.

1. If necessary, change to the **Debug** perspective by selecting **Window > Open Perspective > Debug**.
2. Select **Window > Show View > Disassembly** to display the **Disassembly** view.
3. Select **Window > Save Perspective As...**. The **Save Perspective As...** dialog is displayed.

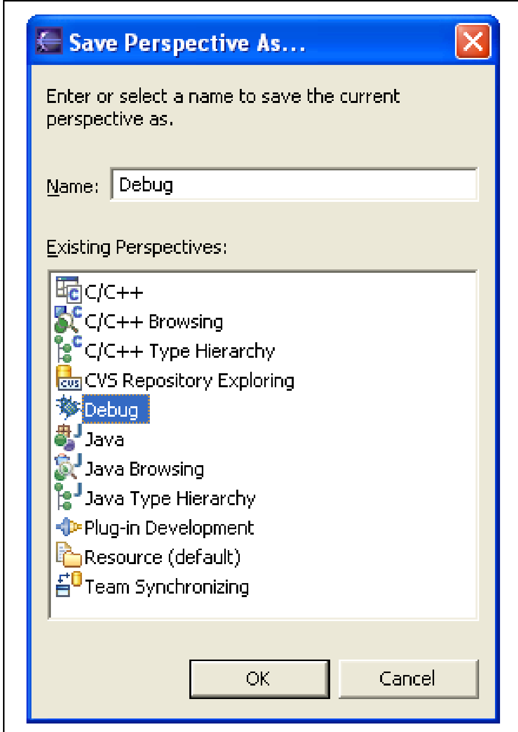


Figure 4: Save Perspective As... dialog

4 Select **Debug** in the **Existing Perspectives** list and click on **OK**.

You are prompted:

A perspective with the name 'Debug' already exists. Do you want to overwrite?

5 Click on **Yes**, to save the **Debug** perspective with the currently open views.

5.3 Eclipse tutorials

There are several tutorials included in the ST40 Eclipse distribution. The tutorials can be accessed through the Eclipse help system by selecting **Help > Help Contents > ST40 Micro Toolset** menu.

On completion of each of the building and importing tutorials, you will have built an ST40 application ready to run or debug.

Building a Managed Make C project

This tutorial describes how to build a simple OS21 application using Eclipse’s Managed Make Project facility which creates a make file automatically.

Building a Standard Make C project

This tutorial describes how to build a simple application using Eclipse’s Standard Make Project facility. This method requires the user to create a makefile which Eclipse uses to build the application.

Importing existing code into a Managed Make project

This tutorial describes the process of importing existing source code into a Eclipse’s Managed Make Project. Eclipse will create a makefile automatically to build this project.

Importing existing code into a Standard Make project

This tutorial describes the process of importing existing source code into Eclipse’s Standard Make Project. This method requires the user to create a make file which Eclipse uses to build the application.

Debugging C/C++ applications

This tutorial describes the process of starting an ST40 debug session with a previously built application. Common debugging steps are described including modifying breakpoints, examining variables, call stacks and tasks.

Running C/C++ applications

This tutorial describes the process of running an ST40 application.

6 Using Insight

6.1 Introduction to Insight

Insight is a Graphical User Interface for GDB available on all supported host platforms. It allows the user to execute and debug applications interactively. The command line interface for GDB is described in *Section 4.2: The GNU debugger on page 63*.

Insight can also be used to display several windows containing source and assembly level code together with a range of system information. A **Console Window** is also available so that GDB commands can be entered on the command line.

Insight has the following features:

- many parts of the window have a context sensitive menu displayed by clicking the right-hand mouse button,
- a tooltip is displayed when the mouse pointer hovers over a button,
- when Insight is invoked, it restores the configuration and open windows from the state saved in the user's home directory (specified by the **HOME** environment variable) in a file named **.gdbtkinit** on UNIX, or **gdbtk.ini** on Windows. This state is saved whenever the Insight GUI is closed.

6.2 Launching Insight

To launch the Insight GUI, enter either **sh4gdb -w** or **sh4insight** on the command line. Under Windows, Insight can also be launched by clicking on the **Start** button and selecting **Programs**, **STM Tools**, **ST40 Micro Toolset**, **Insight**.

When Insight is launched for the first time, the **Source Window** is displayed. This window is described in *Section 6.3*.

6.3 Using the Source Window

The **Source Window** is the main window that is displayed when Insight is launched. The menus available on the menu bar are described in *Section 6.3.1* and the toolbar buttons are described in *Section 6.3.2*.

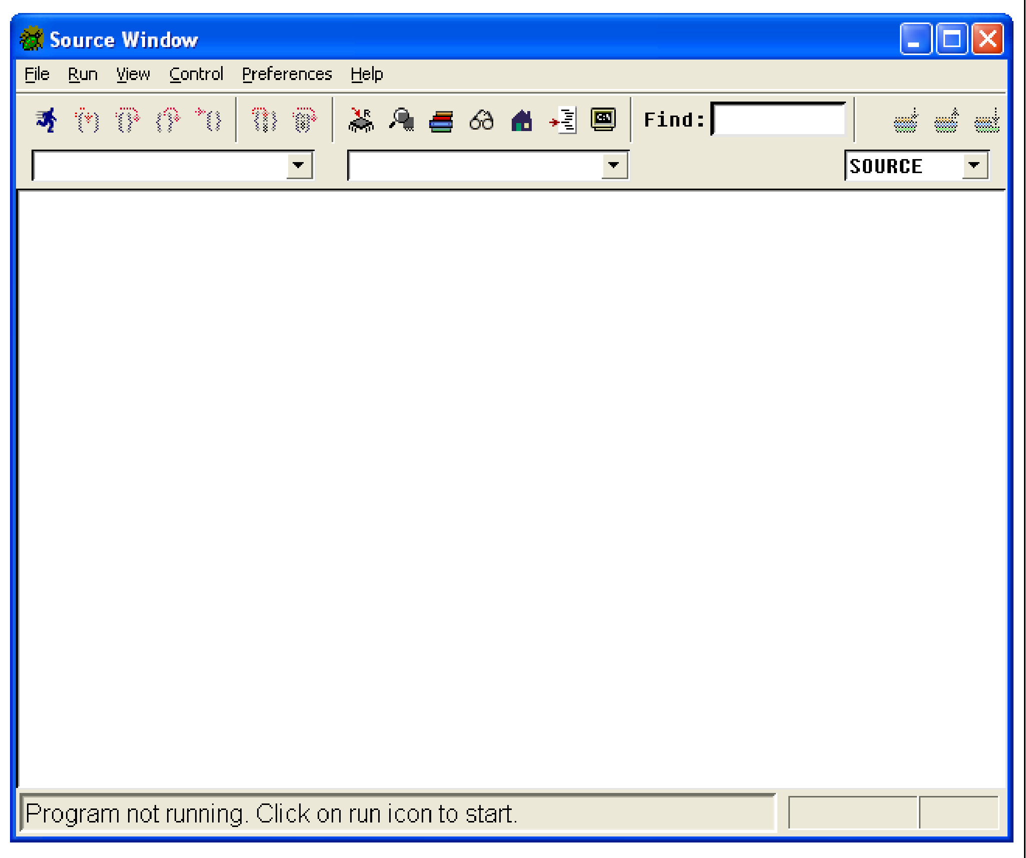


Figure 5: Source Window

6.3.1 Source Window menus

File menu

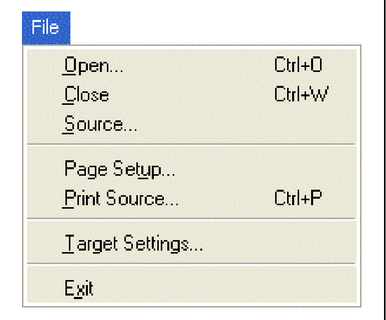


Figure 6: File menu

Open...	Load a program executable.
Close	Close the program executable.
Source...	Select a GDB command file to source.
Page Setup...	Display a dialog to select the paper size, the paper source and page orientation (landscape or portrait).
Print Source...	Display a dialog to select the printer, what to print and the number of copies to be printed.
Target Settings...	Display the **Target Selection** window to select and configure the target.
Exit	Close the Insight GUI.

Run menu

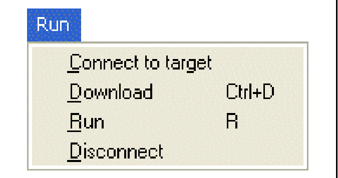


Figure 7: Run menu

Connect to target Connect to the selected target. If no target is selected, the **Target Selection** window is displayed so that the target can be set up as required.

Download Download the program to the target.

Run Download and execute the program. If no target is selected, the **Target Selection** window is displayed so that the target can be set up as required.

Disconnect Close the connection to the target.

View menu

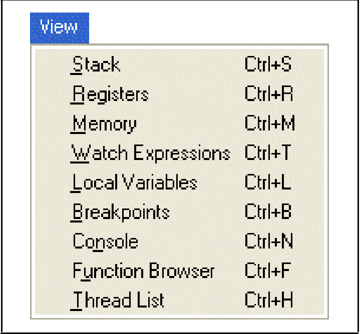


Figure 8: View menu

Stack Display the **Stack** window.

Registers Display the **Registers** window.

Memory Display the **Memory** window.

Watch Expressions Display the **Watch Expressions** window.

Local Variables	Display the **Local Variables** window.
Breakpoints	Display the **Breakpoints** window.
Console	Display the **Console Window**.
Function Browser	Display the **Function Browser** window.
Thread List	Display the **Processes** window.

Control menu

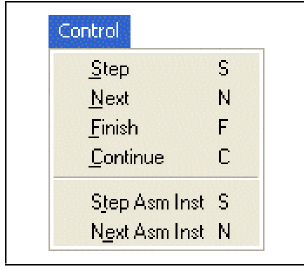


Figure 9: Control menu

Step	Step into the next statement.
Next	Step over the next statement.
Finish	Step out of the current function.
Continue	Continue the program after a breakpoint.
Step Asm Inst	Step one instruction.
Next Asm Inst	Step one instruction and proceed through subroutine calls.

Preferences menu

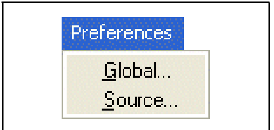


Figure 10: Preferences menu

Global... Display the **Global Preferences** window.

Source... Display the **Source Preferences** window.

Help menu

Figure 11: Help menu

Help Topics Display the online help window.

About GDB... Display version and copyright information for the Insight GUI.

6.3.2 Source Window toolbar

The following table provides a brief explanation of each of the buttons available on the **Source Window** toolbar.

Button	Name	Description
	Run (R)	Start the program executing.
	Step (S)	Step into the next statement.
	Next (N)	Step over the next statement.
	Finish (F)	Step out of the current function.
	Continue (C)	Continue the program after a breakpoint.
	Step Asm Inst (S)	Step one instruction.
	Next Asm Inst (N)	Step over the next instruction.
	Registers (Ctrl+R)	Display the **Registers** window.
	Memory (Ctrl+M)	Display the **Memory** window.
	Stack (Ctrl+S)	Display the **Stack** window.
	Watch Expressions (Ctrl+W)	Display the **Watch Expressions** window.
	Local Variables (Ctrl+L)	Display the **Local Variables** window.
	Breakpoints (Ctrl+B)	Display the **Breakpoints** window.

Table 27: The Source Window buttons

Button	Name	Description
	Console (Ctrl+N)	Display the **Console Window**.
	Down Stack Frame	Move to the stack frame called by the current frame.
	Up Stack Frame	Move to the stack frame that called the current frame.
	Go To Bottom of Stack	Move to the bottom most stack frame.

Table 27: The Source Window buttons

6.3.3 Context sensitive menus

The right mouse button provides several context sensitive menus. For example, right clicking on a breakpoint position (shown as a hyphen) displays a context sensitive menu containing the options listed below.

Continue to Here Continue the application and stop at the selected line.

Jump to Here Jump directly to the specified line[1]. This does not operate in the same way as the Continue option since only the Program Counter is modified. This option is advantageous for going backward after the contents of a variable has been manually modified, or for skipping over defective code.

Set Breakpoint Set a breakpoint on the selected line. The breakpoint is displayed as a red square.

Set Temporary Breakpoint

Set a temporary (one time only) breakpoint on the selected line. The breakpoint is displayed as an orange square.

1. In optimized code, this may not work as expected due to the compiler reordering code.

Set Breakpoint on Thread(s)...

Set a breakpoint on the thread. If more than one thread is available the **Thread Selection** window is displayed to select the required threads. The breakpoint is displayed as a pink square.

6.4 Debugging a program

The following procedure demonstrates debugging a program using the getting started example that was compiled when testing the installation, see *Section 1.6: Installation on page 34*.

1 Launch Insight as described in *Section 6.2 on page 111*.

2 Click on or select **Run** from the **Run** menu.

The **Load New Executable** dialog is displayed.

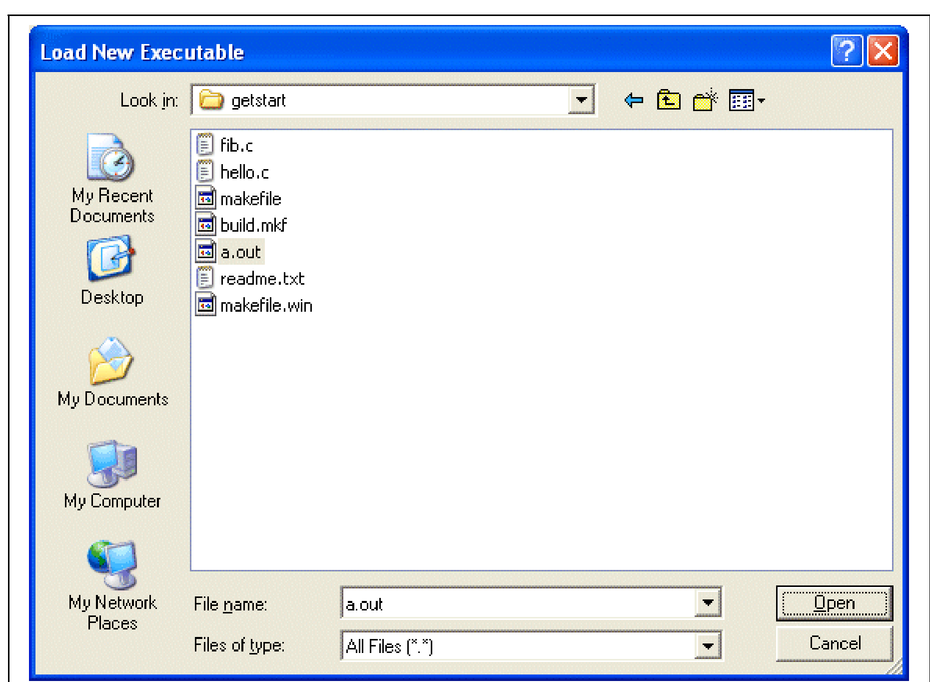


Figure 12: Load New Executable dialog

3 Select the executable file and click on **Open**.

The **Target Selection** window is displayed.

4 Complete this window as described in *Section 6.5: Changing the target*.

The program is launched and stopped at the breakpoint set at the **`main()`** function. See *Figure 13*.

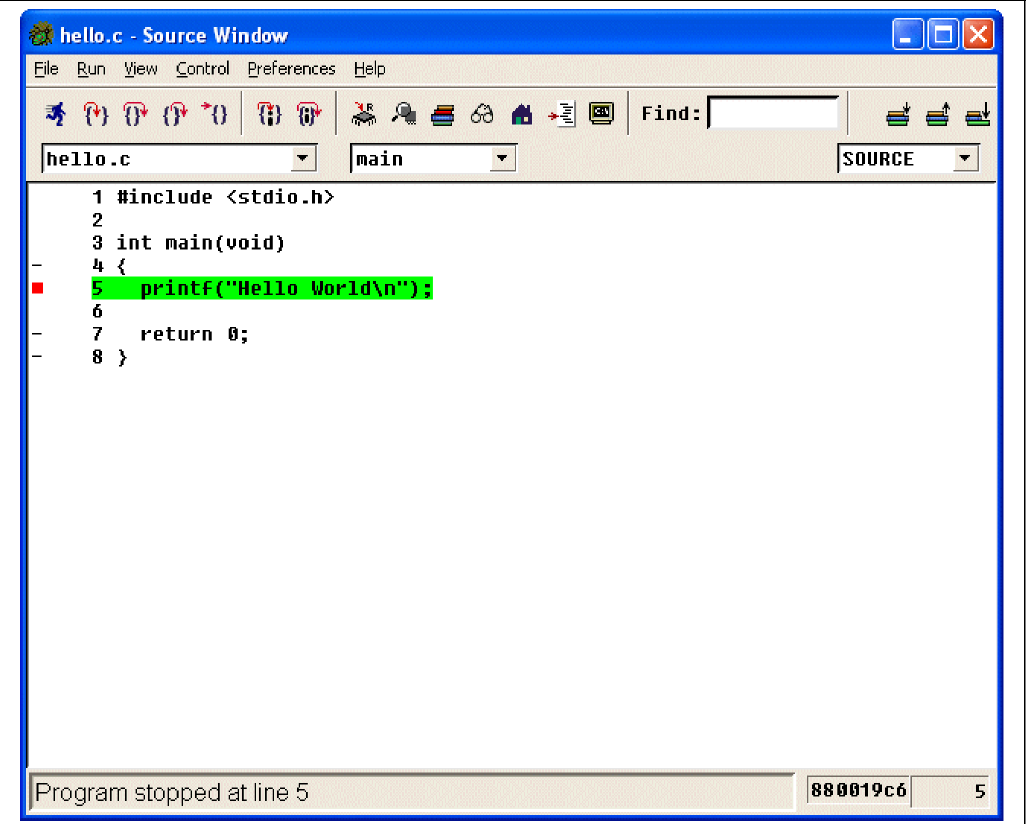


Figure 13: hello.c stopped at breakpoint

5 Debug the program using the menu and toolbar options as described in *Section 6.3.1 on page 113* and *Section 6.3.2 on page 117*.

To toggle breakpoints on and off, click on the hyphen symbols to the left of the code. Breakpoints are shown as red squares.

6.5 Changing the target

1. Select **Target Settings...** from the **File** menu. The **Target Selection** window is displayed, see *Figure 14*.
2. Select **Remote/SH** in the **Target** option.
3. Specify any **Options** required, for example, enter **`mediaref stmc`** to run the example on an STMediaRef-Demo board connected to an ST Micro Connect with a network name of **`stmc`**, or enter **`mediarefsim`** to run the example on the SuperH SH-4 simulator configured as an STMediaRef-Demo board.
4. Click on **OK**.

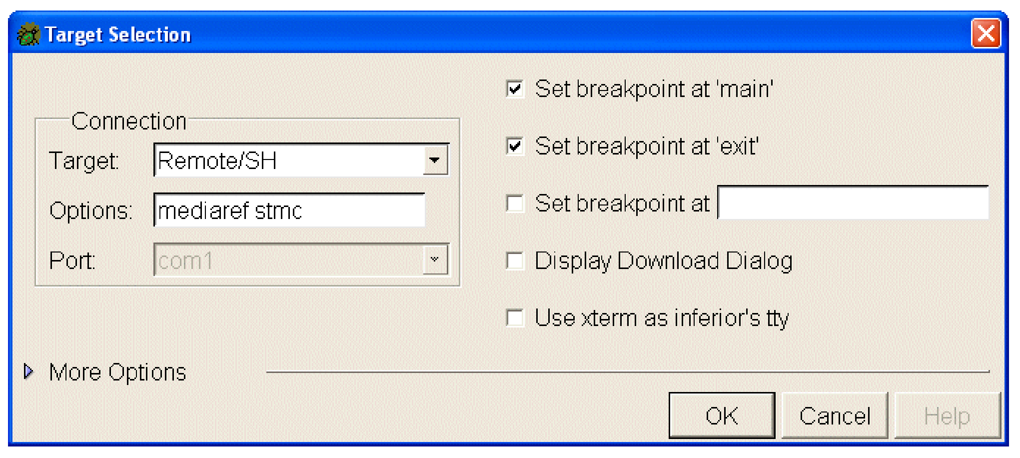


Figure 14: Target Selection window

6.6 Configuring breakpoints

Once a program has started running, it continues as far as the first breakpoint which, if you selected **Set breakpoint at 'main'** in the **Target Selection** window, is set to the first real line of the program.

```
      2
      3 int main(void)
-     4 {
■     5   printf("Hello World\n");
      6
-     7   return 0;
-     8 }
```

Figure 15: Breakpoint examples

The red square in the left-hand margin indicates where a breakpoint has been set. The hyphens indicate valid positions for potential breakpoints.

The green highlighting indicates the position of the current Program Counter (PC). Orange highlighting indicates the current position in that stack frame (the real position being at the top of the stack).

If the mouse pointer hovers over a variable or function name, the type and current value of that variable is displayed. Variables and types have a context sensitive menu (available by right-clicking on the item) containing various actions such as setting watchpoints and dumping memory.

To set a breakpoint, click on the hyphen next to the line of code. The breakpoint is displayed as a red square.

Right click on a breakpoint position (shown as a hyphen) to display the context sensitive menu containing the options listed below to configure breakpoints.

Set Breakpoint Set a breakpoint on the selected line. The breakpoint is displayed as a red square.

Set Temporary Breakpoint

Set a temporary (one time only) breakpoint on the selected line. The breakpoint is displayed as an orange square.

Set Breakpoint on Thread(s)...

Set a breakpoint on the thread. If more than one thread is available the **Thread Selection** window is displayed to select the required threads. The breakpoint is displayed as a pink square.

Right clicking on an existing breakpoint, replaces the three **Set Breakpoint** options with **Disable Breakpoint** and **Delete Breakpoint** options. Disabled breakpoints are displayed as black squares.

6.6.1 The Breakpoints window

Breakpoints can also be controlled using the **Breakpoints** window. To open the **Breakpoints** window, either:

- click on , or
- select **Breakpoints** from the **View** menu in the **Source Window**.

*Note: The **Breakpoints** window does not allow the creation of new breakpoints, but does permit existing ones to be viewed and edited.*

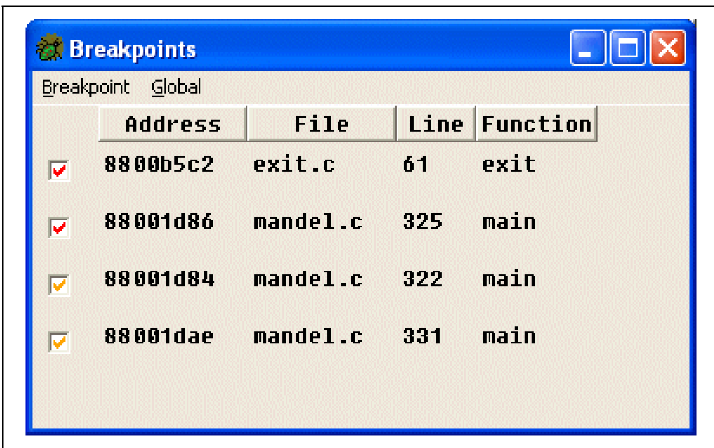


Figure 16: Breakpoints window

Click on a breakpoint to select it. The breakpoint can then be amended using the check boxes and the **Breakpoint** and **Global** menus.

Breakpoint menu

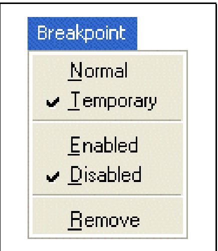


Figure 17: Breakpoint menu

Normal, Temporary	Set the breakpoint to be normal (permanent) or temporary (one-time).
Enabled, Disabled	Enable or disable the breakpoint.
Remove	Delete the selected breakpoint.

Global menu

Figure 18: Global menu

Show Threads	Add an additional column to the window showing the threads the breakpoint is set on.
Disable All, Enable All	Disable or enable all of the breakpoints.
Remove All	Delete all of the breakpoints.
Store Breakpoints...	Save the breakpoints to a file.
Restore Breakpoints...	Restore breakpoints from a file.

6.7 Using the help

Additional information is available in the help files supplied with the Insight GUI. To access the help files, select **Help Topics** from the **Help** menu.

6.8 Using the Stack window

The **Stack** window contains a list of all the frames currently on the stack.

To open the **Stack** window, either:

- click on , or
- select **Stack** from the **View** menu in the **Source Window**.

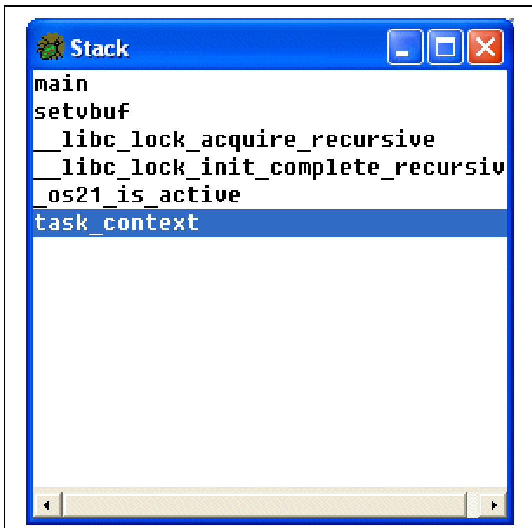


Figure 19: Stack window

To select a frame, click on the appropriate frame line. The line is highlighted in yellow and the associated data is displayed in the **Registers** and **Local Variables** windows and the **Source Window** is updated to display the associated source line. See *Figure 20*, *Figure 25* and *Figure 5* respectively.

6.9 Using the Registers window

The **Registers** window displays the content of all the registers.

To open the **Registers** window, either:

- click on , or
- select **Registers** from the **View** menu in the **Source Window**.

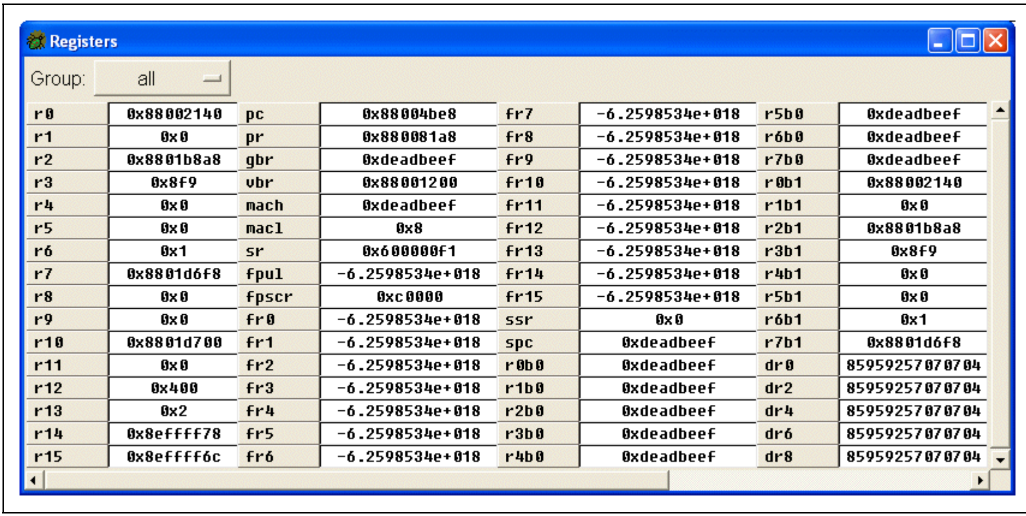


Figure 20: Registers window

Click on a register to select it. A register value can be modified by editing its value in the **Registers** window. A register can be operated upon by right clicking on it to display the context sensitive menu containing the options.

Hex, Decimal, Unsigned	Change the format in which the information is displayed.
Open Memory Window	Open a **Memory** window at the location specified by the currently selected register, see *Section 6.10*.
Add to Watch	Add the selected register to the **Watch** window, see *Section 6.11 on page 130*.
Remove from Display	Delete the selected register from the window.

Display all Registers Restore all registers that have been removed from the display.

Help Displays the online help window.

Close Close the **Registers** window.

The **Group** selection box can be used to view only the registers belonging to a specific group; **general**, **float**, **system**, **vector**, **all**.

6.10 Using the Memory window

The **Memory** window allows the current state of memory on the target to be viewed and modified. The window can be resized to view more memory information. To open the **Memory** window, either:

- click on , or
- select **Memory** from the **View** menu in the **Source Window**.

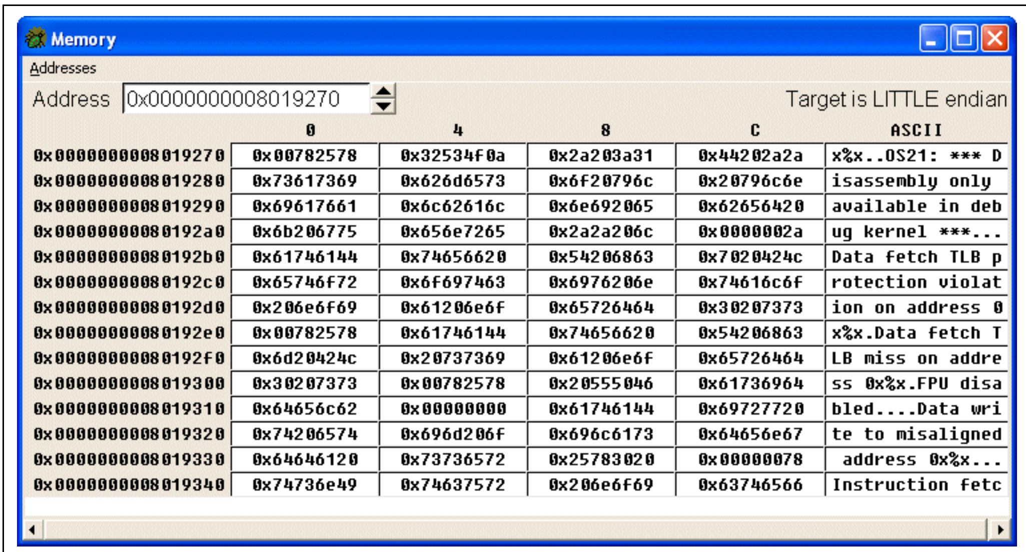


Figure 21: Memory window

Click on a memory location to amend the contents. The display can be customized by using the **Addresses** menu.

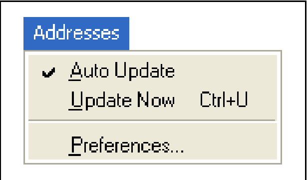


Figure 22: Addresses menu

Auto Update	If the state of the target changes, the memory information is updated automatically. (Default.)
Update Now	Manually override the auto-update to display the memory state at that instant.
Preferences...	Display the **Memory Preferences** window, see *Figure 23*. This window can be used to select the size of the cells, format the memory display, select the number of bytes to be displayed, select or enter (and then press **Return**) the number of bytes per row, select whether to display the memory as ASCII text, and select the character to use for non-ASCII characters (normally ‘**.**’).

Additional options can also be selected by right clicking on a memory location. The options are:

Go To ...	Display the selected memory location.
Open New Window at ...	Open an additional **Memory** window displaying the selected memory location.

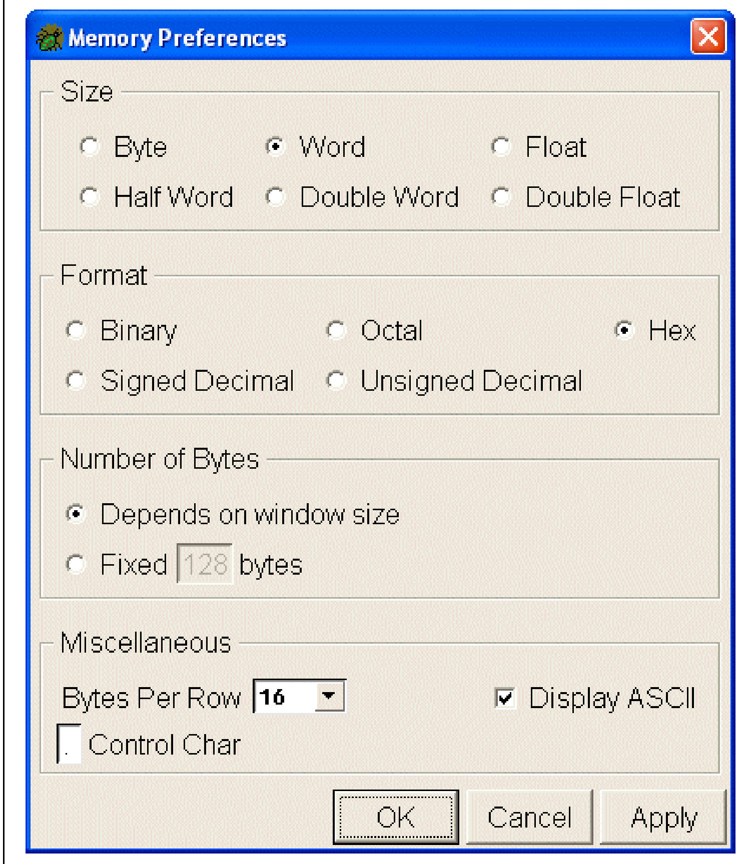


Figure 23: Memory Preferences window

6.11 Using the Watch window

The **Watch** window is used to set and edit user-specified expressions. Each time the program is halted the expressions are reevaluated and the result displayed. This allows the user to see, at a glance, all the program state of interest.

Watch expressions are not the same as watchpoints. Watchpoints must be set via the console window. See *Section B.2.3: Silicon specific commands on page 286*.

To open the **Watch** window, either:

- click on , or
- select **Watch Expressions** from the **View** menu in the **Source Window**.

Figure 24: Watch window

There are two ways that expressions can be added to the **Watch** window, either:

- type an expression into the field at the bottom of the window and click on **Add Watch** (or press **Return**), or
- select the expression in the **Source Window** or **Registers** window and add it to the **Watch** window using the right click menu.

Note: The expression must use the same syntax as the language being debugged. For example, to watch for **`fred`** *being assigned the value* **`42`** *when debugging a C application, enter* **`fred==42`**. *Using assignment operators by mistake, for example,* **`fred=42`**, *changes the value of the variable in the program.*

Click on a watch expression to select it. It can then be operated upon by right clicking on it to display the context sensitive menu containing the following options:

Format	Change the format to **Hex**, **Decimal**, **Binary**, **Octal** or **Natural** (mantissa and exponent for floating-point values).
Edit	Edit the expression value.
Delete	Delete the highlighted expression from the list.
Dump Memory at ...	Displays the selected watch expression in the **Memory** window.
Help	Displays the online help window.
Close	Close the **Watch** window.

The display of values can also be adjusted by normal C type casting. Structures and classes can be expanded as a tree.

6.12 Using the Local Variables window

The **Local Variables** window displays all the variables in the current stack frame. To open the **Local Variables** window, either:

- click on , or
- select **Local Variables** from the **View** menu in the **Source Window**.

```
Local Variables
⊞ fp =  (FILE *) 0x10
⊟ buf =  (char *) 0x8801d1f0 ""
   └*buf =  (char) 0 '\0'
  mode =  (int) -2013210464
  size =  (size_t) 2281820652
  ret =  (int) -2013177208
```

Figure 25: Local Variables window

Click on a variable to select it. It can then be amended by right clicking on it to display the context sensitive menu containing the options.

Format	Change the format of the variable. It can be **Hex**, **Decimal**, **Octal**, **Binary** or **Natural** (mantissa and exponent for float variables).
Edit	Edit the value of the selected variable.
Delete	Delete the highlighted expression from the list.
Dump Memory at ...	Displays the selected variable in the **Memory** window.

Help Displays the online help window.

Close Close the **Local Variables** window.

Click on the plus (**+**) sign to expand the structure of a variable. Similarly, click on the minus (**-**) sign to collapse the structure.

6.13 The Console Window

The **Console Window** is the underlying GDB console and allows commands to be issued directly to GDB.

To open the **Console Window**, either:

- click on , or
- select **Console** from the **View** menu in the **Source Window**.

```
Console Window
The target is assumed to be little endian
The target architecture is assumed to be sh4
0xa0000000 in ?? ()
Loading section .init, size 0x36 lma 0x88001000
Loading section .text, size 0x17940 lma 0x88001100
Loading section .fini, size 0x2a lma 0x88018a40
Loading section .rodata, size 0x128c lma 0x88018a6c
Loading section .eh_frame, size 0x94 lma 0x88019d78
Loading section .ctors, size 0x8 lma 0x88019e0c
Loading section .dtors, size 0x8 lma 0x88019e14
Loading section .jcr, size 0x4 lma 0x88019e1c
Loading section .data, size 0x1ea8 lma 0x88019e20
Loading section .got, size 0xc lma 0x8801bcc8
Start address 0x88001100, load size 109448
Transfer rate: 875584 bits in <1 sec, 10944 bytes/write.

Breakpoint 5, main () at mandel.c:325

(gdb)
```

Figure 26: Console Window

When the **Console Window** is open, the output of a command is displayed whenever a GDB command is issued, for example the **`load`** command.

Note: Insight GUI commands such as **`continue`** *or* **`step`** *are not visible in the* ***Console Window*** *unless they are issued directly at the* ***Console Window*** *prompt.*

The display output of the Insight GUI is synchronized with the GDB console commands.

The console can be used to view the SuperH simulator instruction trace data or to switch the performance data gathering of the simulator on or off.

Any GDB command may be issued to GDB via this window.

Note: If **`console off`** *is used then the program output is visible, not in the console window, but on the terminal from which Insight was launched. For this reason, it is better to use* **`console on`** *in conjunction with Insight.*

6.14 Function Browser window

The **Function Browser** window is used to search for functions in the application and display the source code for that function. This makes it easy to add breakpoints throughout the code.

To open the **Function Browser** window, select **Function Browser** from the **View** menu in the **Source Window**.

The following fields are available to search for functions.

Function Filter Use this to search for an expression. Select **starts with** to list all functions which start with the expression entered, **contains** to list all functions which contain the expression entered, **ends with** to list all functions which end with the expression entered and **matches regexp** to list all functions which match the regular expression entered.

Files This displays all of the files within the application. Only the selected files are searched for the expression entered.

Functions This displays all of the functions within the selected files. Use the **Delete BP** and **Set BP** buttons to delete and set breakpoints at the start of each function.

The source code for the selected function is displayed in the lower section of the window. Breakpoints can be set and removed using the same method as for the **Source Window**, see *Section 6.6 on page 122*.

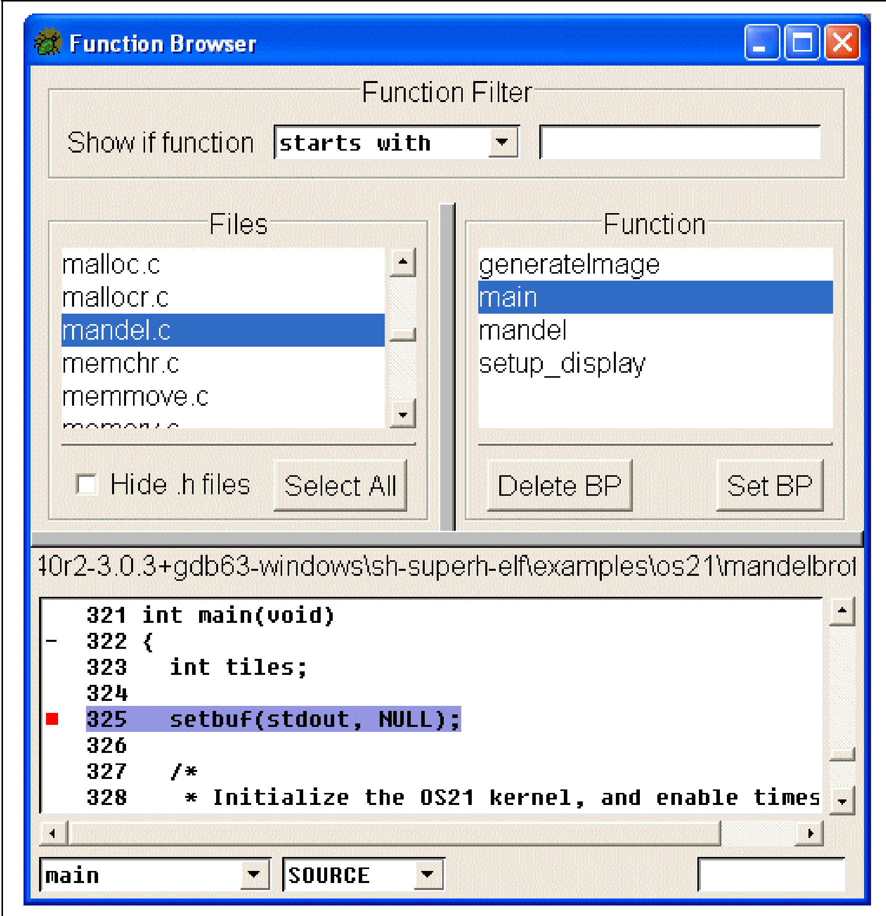


Figure 27: Function Browser window

6.15 The Processes window

The **Processes** window displays the active threads. To open the **Processes** window, select **Thread List** from the **View** menu in the **Source Window**.

```
Processes
 7 Thread 7 ("task4" (terminated) [0x880371f8])  _md_kernel_syscall (
 6 Thread 6 ("task3" (terminated) [0x88032ce0])  _md_kernel_syscall (
 5 Thread 5 ("task2" (terminated) [0x8802e7c8])  _md_kernel_syscall (
 4 Thread 4 ("task1" (terminated) [0x8802a2b0])  _md_kernel_syscall (
 3 Thread 3 ("task0" (unknown state) [0x88025d98])  _md_kernel_syscal
 2 Thread 2 ("Idle Task" (active) [0x88023880])  _md_kernel_task_laur
 1 Thread 1 ("Root Task" (active & running) [0x8801b314])  task_delet
```

Figure 28: Processes window

The **Processes** window displays the thread number and details of the thread, such as current status. Click on a thread to set that thread as the current thread. This causes the debugger to switch contexts and updates all windows.

Building open sources

7.1 Introduction to open sources

The ST40 toolset is based on a number of open source packages which provide the compiler tools, base run-time libraries and debug tools.

The open source packages are as follows:

- GNU binutils (version 2.15.94.0.1),
- GNU GCC (version 3.4.3),
- GNU GDB/Insight (GDB version 6.3 and Insight version 6.1),
- GNU make (version 3.80),
- newlib (version 1.13.0).

The sources for these packages can be found on the CD in the **`gnu_sources`** directory. These sources have been derived from the publicly available versions of the packages which are available via the GNU project website (http://www.gnu.org), and are all available from Red Hat free software projects website (http://sources.redhat.com).

Note: STMicroelectronics does not provide support for users wishing to build these sources, beyond this short guide.

7.2 Requirements

The open source packages shipped with the ST40 toolset, have been built for the following platforms:

- Red Hat Linux Enterprise Workstation Version 3,
- Sun Solaris 8,
- Microsoft Windows 2000,
- Microsoft Windows XP.

The following sections describe the environment required in order to build the open source packages for each of these platforms.

7.2.1 Linux

The Linux platform should be set up for a developer (including X11 development). The only additional requirement is that the GNU GCC package for backwards compatibility is required (version 2.96).

7.2.2 Solaris

The following additions to the standard Solaris environment are required to build the open source packages for the Solaris platform:

- GNU binutils (2.11.2 or later),
- GNU bison (1.28 or later),
- flex (2.5.4 or later),
- GNU GCC (2.95.2 or later),
- GNU make (3.79.1 or later),
- GNU texinfo (4.0 or later),
- Perl (5.0 or later).

These GNU packages and flex are available via the GNU project home page (http://www.gnu.org).

7.2.3 Windows

To build the open source packages for the Windows platform, the Red Hat Cygwin Unix emulation environment is required.

*Note: Although the Cygwin Unix emulation environment is required to build the packages the resulting executables do not use the Cygwin Unix emulation environment. Instead the resulting executables are standard Win32 executables through the use of the **MinGW** toolkit (Minimum GNU for Windows). The **MinGW** toolkit is available as a Cygwin package and should be installed along with the other required Cygwin packages.*

By default, the installer for Cygwin only installs the core set of packages suitable for an end user environment. This core set may not be sufficient to build the open source packages and so additional packages may need to be installed. The installed packages should include the following (from the **Devel** and **Doc** categories):

- binutils,
- bison,
- flex,
- gcc,
- gcc-mingw,
- make,
- mingw-runtime,
- texinfo.

The Red Hat Cygwin Unix emulation environment is available from the Cygwin home page (http://cygwin.com). The MinGW toolkit is also available as a standalone package (not dependent on Cygwin) from the MinGW home page (http://mingw.org).

Note: The installer for Cygwin does not automatically update the Windows **`PATH`** *environment variable with the locations for the Cygwin tools. The following sections assume that the Cygwin tools are available in the Windows environment and therefore the Windows* **`PATH`** *should be manually updated with the following Cygwin tool locations:*

- ***`<cygwin-install-directory>`*****`\usr\local\bin`**,
- ***`<cygwin-install-directory>`*****`\usr\bin`**,

- ***<cygwin-install-directory>*\bin**,
- ***<cygwin-install-directory>*\usr\X11R6\bin**.

*Where **<cygwin-install-directory>** is the location of the Cygwin installation directory.*

7.3 Building the packages

There are six steps for building the GNU packages and **newlib**.

1. Extract the sources from the source archive for the package; the sources are extracted into a directory with the same name as the archive.
2. Create an empty directory in which the package is to be built. A package should not generally be built in the same directory as the extracted sources.
3. Set up a package specific environment (optional).
4. Configure the package.
5. Build the package.
6. Install the package.

Before any package is built, ensure that the additions to the platform environments are performed (as described in *Section 7.2: Requirements on page 138*) and that if the additions conflict with the standard environments then they take precedence.

Note: The configuration of each package is unique therefore the configure step is specific to the package; however, the build and install steps are typically the same.

The packages must be built in the following order:

1. **binutils**,
2. **GCC** (requires **binutils**),
3. **newlib** (requires **GCC** and **binutils**).

The **insight** and **make** packages are not dependent on any other package and therefore may be built independently of the other packages. However, the **make** package should be built last as it is a Windows version of **make** and cannot be used when building the sources since it will not recognize the Cygwin paths used in the makefiles.

Windows and building for MinGW

Unlike the Linux and Solaris platforms, building the packages for Windows with MinGW requires a slightly different approach. This different approach is a consequence of building for MinGW under the Cygwin Unix emulation environment; it is known as a **canadian cross** configuration.

A canadian cross is a configuration where the build platform (Cygwin) is different from the host platform (MinGW) and the target platform (SH-4/ST40). In a normal cross configuration, the build and host platforms are identical.

The packages that need to be built in a canadian cross configuration are **binutils**, **gcc**, **insight** and **make**. The **newlib** package is built in a normal cross configuration.

In a standard canadian cross configuration, a prerequisite is that the packages must also be built with a normal cross configuration (for the Cygwin build and host platforms). However, since the Cygwin and MinGW platforms are effectively the same platform (Windows), the canadian cross configuration has been simplified to remove this prerequisite.

The simplification of the canadian cross configuration is achieved by overriding the tools to build the MinGW applications when configuring the sources by setting up the environment as follows (in Windows/DOS command shell syntax):

```
set AR=ar
set AS=as
set CC=gcc -mno-cygwin
set CXX=g++ -mno-cygwin
set DLLTOOL=dlltool
set LD=ld
set NM=nm
set RANLIB=ranlib
set WINRES=windres
```

A consequence of the simplified canadian cross configuration is that the MinGW versions of the tools are used to build for the target platform (instead of their Cygwin counterparts used in a standard canadian cross configuration). This is generally not a problem since the MinGW versions of the tools accept Cygwin paths (but only of the form **/cygdrive/*<driver-letter>***, normal mounted file systems are not recognized).

Symbolic links created under Cygwin are problematic since Windows applications are unable to resolve them[1]. It is therefore necessary to disable the Cygwin **ln** command before building the sources since the build may attempt to create symbolic links. The following is one possible solution, which replaces the original **ln** command with a **sh(1)** script using the **cp** command.

1 Rename **ln.exe** to **real-ln.exe** in the Cygwin **/bin** directory (see below for determining the Windows equivalent path).

2 Create a new file named **ln** (with no extension) in the Cygwin **/bin** directory with the following contents:

```
#!/bin/sh
[ "$1" = "-s" ] && shift
cp "$@"
```

Note: The Windows equivalent version of the Cygwin location **/bin** *can be obtained using the Cygwin* **cygpath(1)** *command as follows:* **cygpath -a -w /bin**.

Linux

For compatibility with the tools supplied with the toolset (and older versions of Red Hat Linux) the GCC host compiler used for building the sources must be from the GCC backwards compatibility package (version 2.96). To ensure that the configuration steps select the correct version of GCC, the environment variables **CC** (C compiler) and **CXX** (C++ compiler) should be set to the backwards compatibility versions of the GCC C compiler and C++ compiler. For example:

- for Linux C Shell **csh(1)**:

```
setenv CC gcc296
setenv CXX g++296
```

- for Linux Bourne Shell **sh(1)**:

```
CC=gcc296
CXX=g++296
export CC CXX
```

1. Symbolic links are represented by Cygwin as Windows shortcuts and are not normally interpreted by Windows applications unless specifically designed to do so.

7.3.1 Building binutils

Setup

Create an empty build directory in which to build the **binutils** package.

Environment

Set the Linux environment as described in *Linux on page 142* and the MinGW Windows environment as described in *Windows and building for MinGW on page 141*.

Configure

Configure **binutils** by invoking one of the following from the empty build directory (ensure that you set your current directory to the build directory first):

- For Linux and Solaris:

```
<source-directory>/configure --prefix=<install-directory>
--target=sh-superh-elf
```

- For Windows:

```
sh <source-directory-cygwin>/configure
--prefix=<install-directory-cygwin> --build=i686-pc-cygwin
--host=i686-pc-mingw32 --target=sh-superh-elf
```

Where ***<source-directory>*** is the root directory for the sources of the **binutils** package and ***<install-directory>*** is the root of the directory in which the packages are to be installed. ***<source-directory-cygwin>*** and ***<install-directory-cygwin>*** refer to the same locations as their non ***-cygwin*** counterparts except that they are the Cygwin equivalent versions of the locations.

Note: The Cygwin **cygpath(1)** *command can be used to obtain the Cygwin equivalent version as follows:* **cygpath -a -u *<directory>***.

Build

Build **binutils** by invoking the following from the build directory:

```
make
```

Install

Install **binutils** by invoking the following from the build directory:

```
make install
```

7.3.2 Building GCC

Setup

Create an empty build directory in which to build the GCC package.

Environment

Set the Linux environment as described in *Linux on page 142* and the MinGW Windows environment as described in *Windows and building for MinGW on page 141* with the following additions specific to building the GCC package on Windows (in Windows/DOS command shell syntax):

```
set CC_FOR_BUILD=gcc
set CC_FOR_TARGET=<build-directory-cygwin>/gcc/xgcc ^
        -B<build-directory-cygwin>/gcc ^
        -B<install-directory-cygwin>/sh-superh-elf/bin ^
        -B<install-directory-cygwin>/sh-superh-elf/lib ^
        -isystem <install-directory-cygwin>/sh-superh-elf/include ^
        -isystem <install-directory-cygwin>/sh-superh-elf/sys-include
set CXX_FOR_TARGET=%CC_FOR_TARGET% -shared-libgcc
```

Note: 1 ***<build-directory-cygwin>*** *and* ***<install-directory-cygwin>*** *refer to the same locations as their non* **-cygwin** *counterparts (see below) except that they are the Cygwin equivalent versions of the locations.*

2 *The Cygwin* **cygpath(1)** *command can be used to obtain the Cygwin equivalent version as follows:* **cygpath -a -u *<directory>***.

Update the environment on each platform.

- For Linux/Solaris C Shell **csh(1)**:

```
setenv PATH <install-directory>/bin:$PATH
```

- For Linux/Solaris Bourne Shell **sh(1)**:

```
PATH=<install-directory>/bin:$PATH
export PATH
```

- For Windows:

```
set PATH=<install-directory>\bin;%PATH%
```

Where ***<install-directory>*** is the root of the directory in which the packages are installed and ***<build-directory>*** is the root of the GCC build directory.

Configure

Configure GCC by invoking one of the following from the empty build directory (ensure that you set your current directory to the build directory first):

- For Linux and Solaris:

```
<source-directory>/configure --prefix=<install-directory>
--target=sh-superh-elf --enable-languages=c,c++
--enable-threads=generic --with-newlib
--with-headers=<newlib-source-directory>/newlib/libc/include
--with-gnu-as --with-gnu-ld
```

- For Windows:

```
sh <source-directory-cygwin>/configure
--prefix=<install-directory-cygwin> --build=i686-pc-cygwin
--host=i686-pc-mingw32 --target=sh-superh-elf
--enable-languages=c,c++ --enable-threads=generic
--with-newlib
--with-headers=<newlib-source-directory-cygwin>/newlib/libc/
include --with-gnu-as --with-gnu-ld
```

Where ***<source-directory>*** is the root directory for the sources of the GCC package, ***<newlib-source-directory>*** is the root directory for the sources of the **newlib** package and ***<install-directory>*** is the root of the directory in which the packages are to be installed. ***<source-directory-cygwin>***, ***<newlib-source-directory-cygwin>*** and ***<install-directory-cygwin>*** refer to the same locations as their non ***-cygwin*** counterparts except that they are the Cygwin equivalent versions of the locations.

Note: *The Cygwin* **cygpath(1)** *command can be used to obtain the Cygwin equivalent version as follows:* **cygpath -a -u *<directory>***.

Build

Before building GCC, copy the **gsyslimits.h** header file from the GCC source directory (***<source-directory>*/gcc**) to the **gcc** subdirectory of the GCC build directory.

Build GCC by invoking the following from the build directory:

```
make
```

Install

Install GCC by invoking the following from the build directory:

```
make install
```

7.3.3 Building newlib

Setup

Create an empty build directory in which to build the **newlib** package.

Environment

Update the environment on each platform.

- For Linux/Solaris C Shell **csh(1)**:

  ```
  setenv PATH <install-directory>/bin:$PATH
  ```

- For Linux/Solaris Bourne Shell **sh(1)**:

  ```
  PATH=<install-directory>/bin:$PATH
  export PATH
  ```

- For Windows:

  ```
  set PATH=<install-directory>\bin;%PATH%
  ```

Where ***<install-directory>*** is the root of the directory in which the packages are installed.

Configure

Configure **newlib** by invoking the following from the empty build directory (ensure that you set your current directory to the build directory first):

- For Linux and Solaris:

```
<source-directory>/configure --prefix=<install-directory>
--target=sh-superh-elf --program-prefix=sh-superh-elf-
```

- For Windows:

```
sh <source-directory-cygwin>/configure
--prefix=<install-directory-cygwin> --target=sh-superh-elf
--program-prefix=sh-superh-elf-
```

Where ***<source-directory>*** is the root directory for the sources of the **newlib** package and ***<install-directory>*** is the root of the directory in which the packages are to be installed. ***<source-directory-cygwin>*** and ***<install-directory-cygwin>*** refer to the same locations as their non ***-cygwin*** counterparts except that they are the Cygwin equivalent versions of the locations.

Note: The Cygwin **cygpath(1)** *command can be used to obtain the Cygwin equivalent version as follows:* **cygpath -a -u *<directory>***.

Build

Build **newlib** by invoking the following from the build directory:

```
make
```

Install

Install **newlib** by invoking the following from the build directory:

```
make install
```

7.3.4 Building GDB/Insight

Setup

Create an empty build directory in which to build the **insight** package.

Environment

Set the Linux environment as described in *Linux on page 142* and the MinGW Windows environment as described in *Windows and building for MinGW on page 141*.

In addition, on Windows it is necessary to have the **PDcurses** package in order to build the GDB text user interface. This package is available from http://pdcurses.sourceforge.net. The file **curses.h** must be copied from the **PDcurses** package to the **/usr/include/mingw** directory of your Cygwin installation. Similarly, the file **curses.dll.a** must be copied to the **/lib/mingw** directory. Alternatively, the TUI may be disabled by adding **--disable-tui** to the configure line.

Configure

Configure **insight** by invoking one of the following from the empty build directory (ensure that you set your current directory to the build directory first).

- For Linux:

```
<source-directory>/configure --prefix=<install-directory>
--target=sh-superh-elf --enable-gdbmi=yes
```

- For Solaris:

```
<source-directory>/configure --prefix=<install-directory>
--target=sh-superh-elf --enable-gdbmi=yes
--x-includes=/usr/openwin/include
--x-libraries=/usr/openwin/lib
```

- For Windows:

```
sh <source-directory-cygwin>/configure
--prefix=<install-directory-cygwin> --build=i686-pc-cygwin
--host=i686-pc-mingw32 --target=sh-superh-elf
--enable-gdbmi=yes --disable-nls
```

Where ***<source-directory>*** is the root directory for the sources of the **insight** package and ***<install-directory>*** is the root of the directory in which the packages are to be installed. ***<source-directory-cygwin>*** and ***<install-directory-cygwin>*** refer to the same locations as their non ***-cygwin*** counterparts except that they are the Cygwin equivalent versions of the locations.

Note: The Cygwin **cygpath(1)** *command can be used to obtain the Cygwin equivalent version as follows:* **cygpath -a -u *<directory>***.

Build

Build **insight** by invoking the following from the build directory:

```
make
```

Install

Install **insight** by invoking the following from the build directory:

```
make install
```

7.3.5 Building make

Under Windows, the **make** package should be built last as it is a Windows version of **make** and cannot be used when building the source since it will not recognize the Cygwin paths used in the makefiles. Under Linux and Solaris, the **make** package may be built at any time.

Setup

Create an empty build directory in which to build the **make** package.

Environment

Set the Linux environment as described in *Linux on page 142* and the MinGW Windows environment as described in *Windows and building for MinGW on page 141*.

Configure

Configure **make** by invoking one of the following from the empty build directory (ensure that you set your current directory to the build directory first):

- For Linux and Solaris:

```
<source-directory>/configure --prefix=<install-directory>
```

- For Windows:

```
sh <source-directory-cygwin>/configure
--prefix=<install-directory-cygwin> --build=i686-pc-cygwin
--host=i686-pc-mingw32
```

Where ***<source-directory>*** is the root directory for the sources of the **make** package and ***<install-directory>*** is the root of the directory in which the packages are to be installed. ***<source-directory-cygwin>*** and ***<install-directory-cygwin>*** refer to the same locations as their non ***-cygwin*** counterparts except that they are the Cygwin equivalent versions of the locations.

Note: The Cygwin **cygpath(1)** *command can be used to obtain the Cygwin equivalent version as follows:* **cygpath -a -u *<directory>***.

Build

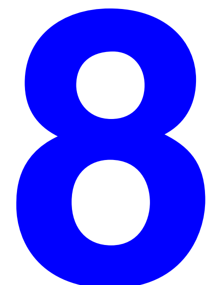
Build **make** by invoking the following from the build directory:

```
make
```

Install

Install **make** by invoking the following from the build directory:

```
make install
```



Core performance analysis guide

8.1 Introduction to core performance analysis

This chapter describes how to analyze the performance of the SH-4 CPU cores using the SuperH simulator. It includes details of how to execute code on the SuperH simulator and produce statistical and trace information from these execution runs. The tools which perform the analysis of the generated data are also described.

GDB provides access to two versions of the SuperH simulator.

- The Functional Simulator provides a simulation of the functionality of the CPU core including full instruction set simulation, memory management (MMU), and system architecture features such as caches.
- The Performance Simulator provides a simulation of the full functionality of the CPU core. In addition, it provides cycle-accurate[1] performance information including instruction latencies, pipeline stalls, and cache behavior. This can be used to generate accurate performance trace and/or statistical information for use by the performance visualization tools.

Each of the SuperH simulators are functionally verified against the regression test database for the respective SH-4 core. The user can therefore be confident that once functionally proven on the SuperH simulator, the silicon behaves in the same way.

1. The performance simulator is not guaranteed to be 100% accurate in all cases.

8.2 Running performance models under GDB

This section provides examples of how to execute programs on the simulators, generate performance data and use the analysis tools.

8.2.1 Example source code

The examples in this chapter use the following program (**velocity.c**).

```
#include <stdio.h>
#include <math.h>

/* functions using basic equations of motion */
int distance(int u, int a, int t)
{
   /* s= ut + 1/2at^2 */
   int inter1, inter2;
   inter1 = u*t;
   inter2 = 0.5 * (a * pow((double)t,2.0));
   return inter1 + inter2;
}

int velocity(int u, int a, int t)
{
   /* v = u + at */
   return ( u + (a * t));
}

float velocity2(int u, int a, int s)
{
   /*  v^2 = u^2 + 2as */
   float inter1, inter2;
   inter1 = pow((double)u,2.0);
   inter2 = 2 * a * s;
   return sqrt(inter1 + inter2);
}
```

```
int main(void)
{
   int t = 10;
   int a = 30;
   int u = 5;
   int s,v;
   float v2;

   v = velocity(u,a,t);
   s = distance(u,a,t);
   v2 = velocity2(u,a,s);

   /*  should be the same */
   printf("Velocity 1 = %d\nVelocity 2 = %f\n",v,v2);

   return 0;
}
```

This can be compiled using the command line:

```
sh4gcc -o velocity.out velocity.c -lm
```

For full debugging information to be included, use the **-g** option:

```
sh4gcc -g -o velocity.out velocity.c -lm
```

8.2.2 Beginning a debug session

To begin a debug session invoke GDB with the command line:

```
sh4gdb velocity.out
```

It is then necessary to select a simulator target. For example, to use the simulator configured as an STMediaRef-Demo platform, enter:

```
mediarefsim
```

Next, load the code to be executed using:

```
load
```

With the code loaded into memory and the start address set, GDB leaves the simulator in a suspended mode.

To run the program use the **continue** command. This may be abbreviated to **c**.

8.2.3 Obtaining performance data

GDB creates a flexible platform from which to collect performance information. Performance logging commands can be controlled from within GDB, therefore it is possible to set breakpoints or watchpoints to turn the profiling information on or off at specific points.

Getting a trace

The following example generates a performance trace for the **velocity2()** function (see the example in *Section 8.2.1*). This requires passing commands to the SuperH simulation models using the following command:

```
sim_trace option
```

where ***option*** can be **on**, **off**, **open** or **close**.

The following example GDB command script loads the executable, opens a trace file and saves the trace information to the file specified.

```
mediarefpsim
load
break velocity2
continue
break *$pr
sim_trace open:velocity
sim_trace on
continue
sim_trace off
continue
quit
```

Note: The command **break *$pr** *sets a breakpoint on the* PR *register which contains the Program Counter (PC) value for the return of the function, effectively setting a breakpoint at the end of the function.*

The **trcview** tool is used to view the generated trace information and is described in *Section 8.5: The trace viewer (trcview) on page 175*.

To produce an instruction trace other than by using **sim_trace**, use the command:

```
sim_insttrace option
```

where ***option*** can be either **on** or **off**. This sends an instruction trace to **stderr** on the console.

Note: With the **sim_insttrace** *command it is not possible to send the trace directly to a file or to analyze it with the* ***trcview*** *tool.*

Collecting census information

The method for collecting the census information is similar to that for obtaining trace information: **sim_census** is used instead of the **sim_trace** command. The following example GDB command script illustrates census information being collected for the **distance** function:

```
mediarefpsim
load
break distance
continue
break *$pr
sim_census open:velocity
sim_census on
continue
sim_census off
sim_census save:results
continue
quit
```

The **censpect** tool is used to inspect the generated census information and is described in *Section 8.4: The census inspector (censpect) on page 164*.

Using software controls

The following example shows how function calls can be used to dynamically control the collection of statistical and trace data. It is based on changing the **main()** function of the **velocity.c** example (see *Section 8.2 on page 152*) to the version below. The set of SuperH simulator dynamic control functions is described in *Section 8.3.3: Dynamic control on page 163*.

```
int main(void)
{
   int t = 10;
   int a = 30;
   int u = 5;
   int s,v;
   float v2;

   TracesOn();
   CensusOn();
```

```
    v = velocity(u,a,t);
    s = distance(u,a,t);
    v2 = velocity2(u,a,s);

    CensusOff();
    TracesOff();
    CensusOutput("Velocity statistics");

    done();
    return 0;
}
```

The example also needs to **#include** the include file **census.h** (which provides declarations for the dynamic control functions) and to be linked with the compiled source file **census.c** (which defines these functions). These files are located in **sh-superh-elf/examples/census** under the release installation directory.

For these dynamic control functions to have an effect, **trace** and **census** files need to be opened.

The following GDB command script example shows the **velocity** example being run with the version of **main** to turn the census on and off dynamically:

```
mediarefpsim
load
sim_census open:velocity
continue
quit
```

Using delayed memory models

The SH-4 SuperH performance simulators support a delayed memory model. This allows the user to specify the number of cycles taken for an external memory request to be serviced by the memory system. With the model disabled, it is assumed that all memory requests are serviced instantly. It should be noted that it is not possible to use this model in conjunction with an uncached model to get “perfect” caching results. This is because the occupancy of the pipeline resources of the CPU core are still occupied as if the accesses were made uncached. For example, there is contention between the I-side and O-side requests for the shared external bus connection.

An additional argument can be supplied when connecting to the performance simulators to enable the delayed memory models, for example:

```
mediarefpsim "+DMM 6"
```

instantiates the delayed memory with a latency of 6 cycles. It is also possible to alter the number of cycles delay by using the GDB command **sim_command**, for example:

```
sim_command "config +DMM.delay=cycles"
sim_reset
mediarefsim_setup
```

This method is not recommended as it requires the simulator to be reset before the change takes effect and therefore discard any previous settings, see *config subcommands on page 162*.

The **sim_command** command above sets the latency but it can also set:

- **DMM.bus_width**, the bus-width in bytes (default is 8),
- **DMM.throughput**, the through-put, in the form of the number of cycles of delay per bus-width word (the default is 1).

However, it is best that these are left at their default values.

Perfect caching

Models with caches enabled support a configuration option which causes the cache to behave as if all accesses hit the cache. It should be noted that this is the only method of collecting performance data that eliminates any influence of the cache. For example, using a zero memory model in conjunction with a cache model does not stop the pipeline interlocks and stalls that are caused by the occurrence of cache misses.

As stated in *config subcommands on page 162*, the **sim_reset** command must be issued after all configuration changes. The GDB commands to enable perfect caching (for both I-cache, and D-cache) are as follows:

```
sim_command "config +cpu.icache.perfect=true"
sim_command "config +cpu.dcache.perfect=true"
```

Setting up custom targets

To ease the configuration of the SuperH simulators, a set of custom targets can be created that contain options for setting-up the caches or enabling census taking.

The following example defines a target that opens files for census and tracing. It also sets up the model to use a 30 cycle delayed memory model. It should be noted that the method for setting-up the delayed memory model is different to the other model configuration options.

```
define mediarefpsim_dmm_cns
   mediarefpsim "+DMM 30"
   sim_census open:census
   sim_trace  open:trace
   sim_census autosave:census
end
```

The following example defines a target that sets up a model that collects tracing information and uses perfect caches. A **sim_command config** command is used and therefore must be followed by a **sim_reset** command (as described in *config subcommands on page 162*) plus any architectural set up files that had already been run (here **mediarefsim_setup**).

```
define mediarefpsim_perfectc_trc
   mediarefpsim
   sim_command "config +cpu.icache.perfect=true"
   sim_command "config +cpu.dcache.perfect=true"
   sim_reset
   delete mem
   mediarefsim_setup
   sim_trace open:trace
end
```

8.3 The SuperH simulator reference

This section provides a reference for all the GDB features specific to SuperH simulator targets.

8.3.1 SuperH simulator targets

A list of all the available simulator targets can be found in *sh4targets.cmd, sh4targets-board.cmd on page 93*.

8.3.2 SuperH simulator back-end commands

The SuperH simulator back-end commands are invoked using **sim_command** and must be enclosed in double quotes, for example:

```
sim_command "census open 'census'"
```

Several back-end commands can be specified in the same **sim_command** command using a space to separate the commands. For example, to open a census file and turn on census taking:

```
sim_command "census open 'census' census on"
```

As an abbreviation, subcommands can be combined using curly braces. The previous command is therefore equivalent to:

```
sim_command "census { open 'census' on }"
```

To avoid overly long command sequences it is recommended that user defined commands are used to simplify the task.

The following back-end commands are available:

```
census open 'file' | on | off | save 'label' | autosave 'label' | reset
trace open 'file' | on | off | close
config +tag=value | load 'file' | save 'file'
```

Note: The **trace** *commands are only available when using the SuperH performance simulator.*

The details of these commands and their options are described in *census subcommands on page 160*, *trace subcommands on page 161* and *config subcommands on page 162*.

Short cuts to these back-end commands are available as GDB user commands. See *shsimcmds.cmd on page 88*.

census subcommands

The **census** subcommands are used to produce files containing statistical data which are visualized using the **censpect** tool, see *Section 8.4: The census inspector (censpect) on page 164*.

Command	Description
open '*file*'	Open a new census file unless a census file is already open. The ***file*** argument is the name of the census file to be created (without the **.cns** extension which is added automatically) and must be enclosed by single quotes. The shortcut for this command is **sim_census open:*file***. Census taking does not commence until a **census on** command.
on	Switch on census taking. Subsequently executed instructions contribute to the statistical data being collected until an **off** command or the program terminates. The shortcut for this command is **sim_census on**.
off	Switch off census taking. Subsequently executed instructions do not contribute to the statistical data being collected until an **on** command. It is not essential to switch off census taking before issuing a **save** command. The shortcut for this command is **sim_census off**.
reset	Reset the census counters. Any census information not already saved is lost. This is required after a **config** command. The shortcut for this command is **sim_census reset**.

Table 28: Census subcommands

Command	Description
save '*label*'	Save the current state of the census counters to the census file. ***label*** specifies the label for the census record that is generated and must be enclosed by single quotes. The shortcut for this command is **sim_census save:*label***.
autosave '*label*'	Set up a delayed save that is performed when the current census file is closed. ***label*** specifies the label for the census record that is generated and must be enclosed by single quotes. The shortcut for this command is **sim_census autosave:*label***.

Table 28: Census subcommands

trace subcommands

The **trace** subcommands are used to produce files containing statistical data which is then visualized using the **trcview** tool described in *Section 8.5: The trace viewer (trcview) on page 175*.

Command	Description
open '*file*'	Open a set of trace files with the base name ***file***. Depending upon the type of simulation being traced, a number of files are created and various extensions added to the trace base name. See the description of the trace file format in *Section 8.6: Trace viewer file formats on page 178* for more details. ***file*** must be enclosed by single quotes. The shortcut for this command is **sim_trace open:*file***. Tracing does not commence until a **trace on** command.
on	Switch on tracing of the simulation. The shortcut for this command is **sim_trace on**.

Table 29: Trace subcommands

Command	Description
off	Switch off tracing of the simulation. The shortcut for this command is **sim_trace off**.
close	Flush and close all the files associated with the current trace. The shortcut for this command is **sim_trace close**.

Table 29: Trace subcommands

config subcommands

The **config** subcommands are used to review or modify the configuration variables of the current SuperH simulation.

A **sim_reset** must be performed after each of these commands in order for changes to take effect.

Command	Description
+tag=value	Modify a configuration variable associated with the model. The available variables and their current values can be determined using the **save** command or by reviewing the **SIM.CONFIG** section of a generated census file.
load '*file*'	Load the configuration variables stored in ***file*.cfg**. The format of the file is described in *Section 8.7: Census file formats on page 181*. ***file*** must be enclosed by single quotes. It is possible to load several configuration files. If any variable is defined more than once then the last value specified for a variable is used.
save '*file*'	Save the current value of the configuration variables in configuration file format (see *Section 8.7: Census file formats on page 181*) to ***file*.cfg**. The saved state of the configuration variables can therefore be restored at anytime by reloading ***file***. ***file*** must be enclosed by single quotes.

Table 30: Config subcommands

8.3.3 Dynamic control

The collection of statistical and trace data can be performed dynamically by adding a pseudo-device, which can control simulator features, to the address space of the CPU core. The code needed to drive this device is encapsulated within C functions that are implemented in **census.c** located in the subdirectory **sh-superh-elf/examples/census** under the release installation directory.

The associated header file **census.h** defines the functions listed below.

int GetClock(void) Return the current clock cycle during a performance simulation and an instruction count during a functional simulation.

void CensusOn(void) Switch on census taking. It is equivalent to setting a breakpoint at that particular point in the code and executing a **census on** command.

void CensusOff(void) Switch off census taking. It is equivalent to setting a breakpoint at that particular point in the code and executing a **census off** command.

void CensusClear(void) Reset the census counters. It is equivalent to setting a breakpoint at that particular point in the code and executing a **census reset** command.

void CensusOutput(char* label)

Save the census counters to the **census** file.

void TracesOn(void) Enable tracing. It is equivalent to setting a breakpoint at that particular point in the code and executing a **trace on** command.

void TracesOff(void) Disable tracing. It is equivalent to setting a breakpoint at that particular point in the code and executing a **trace off** command.

Note: The simulation control is not overly intrusive. Most commands involve executing relatively few instructions and, in most cases, a single write to the dynamic control device. However, the **CensusOutput()** *function involves the execution of significant code, particularly when a string is copied into the dynamic control device. It is therefore highly recommended that a* **CensusOff()** *function is invoked prior to any* **CensusOutput()** *function. This avoids the execution of the* **CensusOutput()** *function appearing in the statistics.*

8.4 The census inspector (censpect)

The census inspector provides a means of visualizing the contents of census files. This section describes it in the context of the census information produced by the SuperH simulators, but it can be used to view the content of any census file that adheres to the format described in *Section 8.7: Census file formats on page 181*.

The tool is called **censpect** and takes a single optional argument which is the name of the configuration file into which configuration data can be loaded and saved. If no argument is specified then the default for the configuration file is used, `~/.censpect.v3.cfg` (`c:\.censpect.v3.cfg` under Windows).

If this is not present, then a configuration file is created based on the default internal configuration. To select the default configuration explicitly, use '**-**' as the argument. If this is used, it is not possible to save any configuration changes.

8.4.1 The Census Inspector window

An example of the **Census Inspector** window is shown in *Figure 29*.

The fields listed in *Table 31* are available in the **Census Inspector** window.

Field	Description
Unselected Files	This contains a list of all the census files that the tool has located in the current directory. To load a file into the tool, click on the appropriate entry. Several files can be loaded at the same time by selecting multiple entries when clicking.
Selected Files	Loaded files are transferred to **Selected Files** and prefixed by the name of the tool or model by which they were generated. To unload a file, click on the appropriate entry.
Groups	Related queries can be assembled into groups whose results are displayed as histograms or 2D plots as appropriate. A number of useful groups are pre-defined and are listed in **Groups**. Generally, only the pre-defined groups with a prefix matching the model/tool type specified in the loaded census file are appropriate. It is recommended that this convention is adopted when adding user defined groupings. The creation of new groups is described in *Section 8.4.4 on page 171*.

Table 31: Fields available in the Census Inspector window

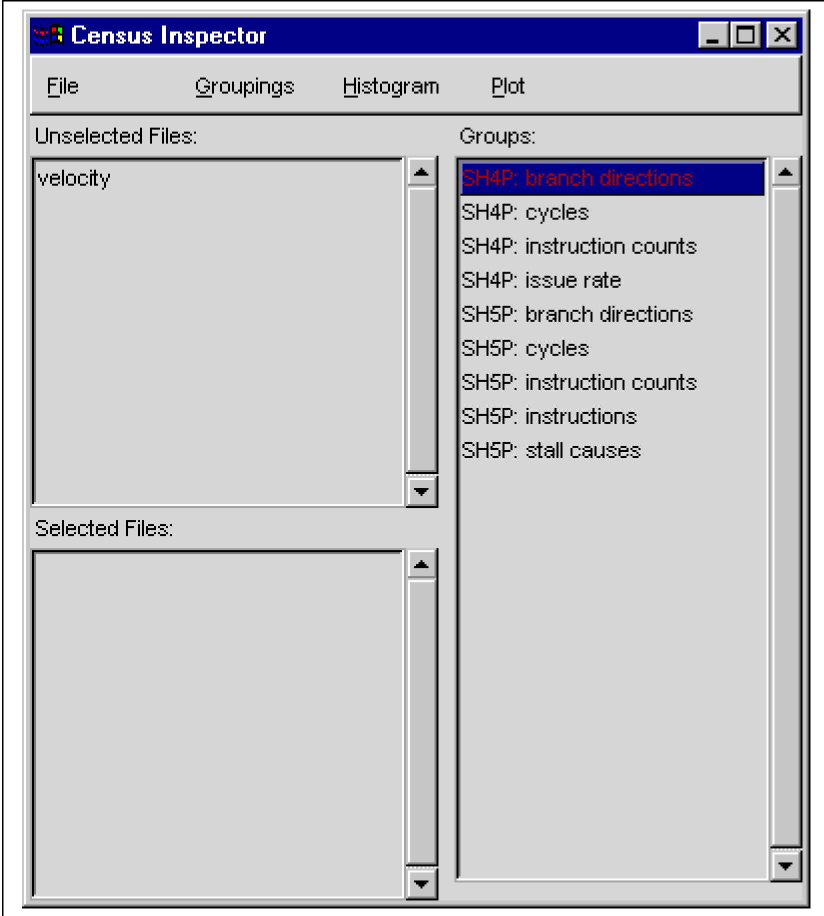


Figure 29: Census Inspector window

To make all census files located below the current directory available for selection, select **Search Subdirectories** from the **File** menu. Selecting the **Follow Links** check box causes the search to traverse any symbolic links that it encounters (not applicable to Windows).

To change the working directory of the tool, select **Change Directory** from the **File** menu.

Any new census files generated while the tool is running do not automatically appear in the **Unselected Files** list. To update this window select **Rescan Directory** from the **File** menu.

8.4.2 Creating histograms

Once a group has been defined and a suitable census file loaded, it is then possible to create a histogram. To do this, double-click on the appropriate entry in the **Group** list. Alternatively select the group with a single click and then select **Display Histogram** from the **Histogram** menu.

The **Display Histogram** function applies each query found in the selected group to the census database and builds a table of queries and associated counts. These results are then displayed on the screen in the form of a bar chart (or histogram).

The pre-defined groups supplied with the tool typically aggregate across all the census records[1] found in the loaded census files. To display specific records from the loaded census files, select **Select Output** from the **Histogram** menu.

The **Select Output** function lists all the census records in the census database by output number and label. Arbitrary numbers of the records can then be selected using the same mechanism as that used for loading files. The results contained within the chosen records can then be merged (by summing the results of applying the same query to each selected record) or displayed separately. If only one label is selected these two options have exactly the same effect.

A number of additional options are also available on the **Histogram** menu (see *Table 32*). These control the way in which the histogram is formatted on the screen.

Menu option	Description
Use Blt Package	Draw the bar charts using a different histogram package. The advantages of this package are that it is capable of marking the ruler with percentages instead of counts, and drawing the labels vertically. This allows more columns to be placed onto the screen. The disadvantages are that bars can only be displayed vertically, charts can be no wider than the screen and there is no cut-off facility so that short bars can be omitted from the display.
Show Zero Bars	If this option is set then a bar continues to be displayed for any queries that return zero.

Table 32: Histogram menu options

1. A census record is defined as the data produced by a simulator each time a CensusOutput command is invoked.

Menu option	Description
Show Count	Display the counts returned by the queries as an annotation to each bar.
Show Files	Display the file names of the census files used to produce the histogram at the top of the window.
Show Query	The histogram displayer takes a table containing the results of queries applied to the database as its input. It determines the label that appears next to each bar by stripping any prefix and any suffix common to all the queries in the table. This option displays these common components of the queries in the form: ***prefixXsuffix***
Show Percentage	Annotate each bar with a percentage. Whether this is a percentage of a summation applied across all the columns or of the highest count is determined by the **Percentage of Sum** and **Percentage of Max** menu entries.
Unsorted	Display the bars in the same order which they appeared in the group.
Sort Labels	Order the bars by breaking up the labels into alphabetic and numeric sequences. The labels are then sorted from left to right using dictionary-order for alphabetic strings and value-order for numeric strings.
Sort Increasing	Organize the bars with the shortest first.
Sort Decreasing	Organize the bars with the tallest first.
Y is Count	Mark the ruler with counts.
Y is % of Sum	Mark the ruler with a percentage of the column sum.
Y is % of Max	Mark the ruler with a percentage of the tallest column.
Y is % of Group	Allow the percentage to be expressed as a count produced when applying a specified group to the census database.
Horizontal Bars	Display the bars of the histogram horizontally instead of vertically. This option is not available when **Use Blt Package** is in use.

Table 32: Histogram menu options

Menu option	Description
Wide Results	If this function is selected and the census query returns more results than can be presented on the screen, a scroll bar is automatically added to the display. This can then be used to navigate to the appropriate part of the chart. If it is not selected, then the counts associated with bars that cannot be displayed are summed and placed in a bar labelled **REST**. This option is not available when **Use Blt Package** is in use.
Select Cutoff	Display the **Set Cutoff Point** window. This window can be used to select the cutoff point by: • clicking on **None** to disable the cutoff mechanism, • clicking on **Accumulate into OTHERS** to add together all columns which contribute less than the cutoff percentage to the column sum and display it in a bar labelled **OTHERS**, • clicking on **Forget OTHERS** to ignore all columns which contribute less than the cutoff percentage, • entering the percentage of the maximum to use as the cutoff point in the **Enter cutoff** field. This facility is not available when **Use Blt Package** is in use.

Table 32: Histogram menu options

8.4.3 2D plots

The census inspection tool supports two modes of graph generation which are selected from the **Plot** menu. These can be based on:

- census record labels,
- changes to the simulator configuration.

Plots based on census record labels

If the **X taken from label** option is selected, plots are produced that are dependent upon the contents of the labels associated with each census record. The X co-ordinate of a point is taken from the label of the record. The Y co-ordinate is produced by using the selected group to query the census record.

Each member of the group is expected to return a single count value[1] which is used to locate the Y co-ordinate for the line. A line is plotted on the graph for every query that appears in the group. When this option is selected, a list of merged labels is supplied. Labels are merged when they differ by only a single token and the differing tokens are numeric. The result of a merge is to produce a single label of the form:

***prefixXsuffix* (for X = *token-list*)**

For example, the following set of labels:

```
Decode Frame 0
Decode Frame 1
Decode Frame 2
Decode Frame 3
```

would be processed into the following merged list:

```
Decode Frame X (for X = 0 1 2 3 4 ...)
```

The required plot is selected by double-clicking on the appropriate entry in the list. The sample plot shown in *Figure 30* displays the range of cycles required to compress a sequence of MPEG frames.

1. This can be achieved by giving the full tag name of a census item and only using a wild card for the **outputN tag** field. See *Census queries on page 172* for more information on queries.

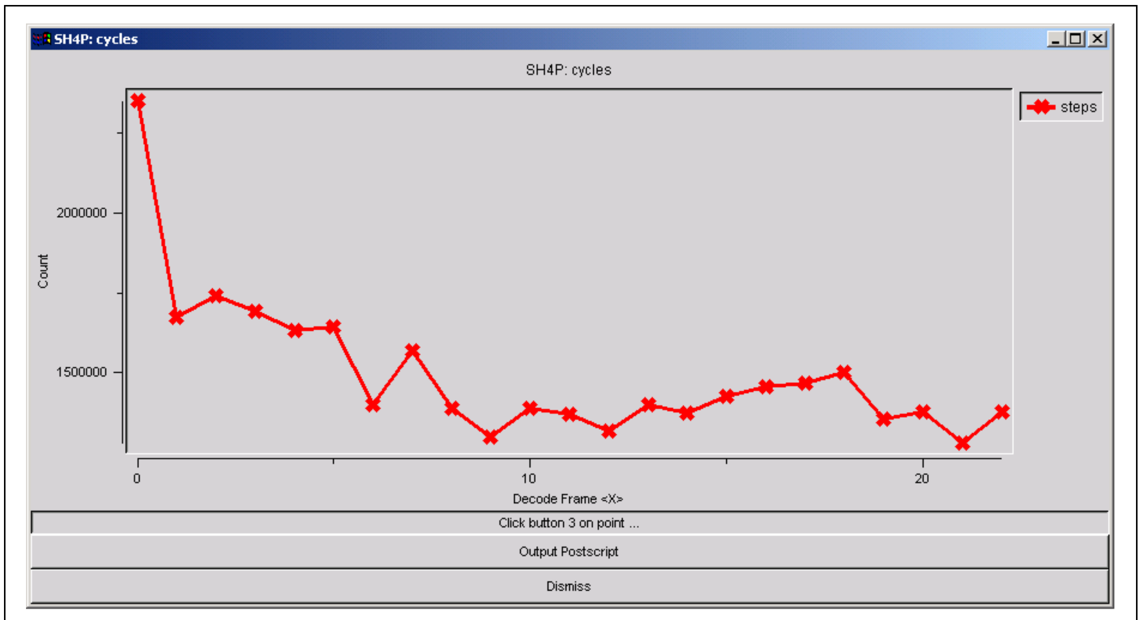


Figure 30: Cycles required to compress a sequence of MPEG frames

Plots based on changes to the simulator configuration

This plotting function is used when the **X taken from configuration** option is selected. It graphically represents the effect of varying the configuration of the simulator on the execution of an application. This function is provided primarily for observing the effects of changes in the architecture and micro-architecture. For example, it is possible to observe the effect of varying the cache size on execution times and miss rates.

Before using this function, it is necessary to generate a set of census files that run the same application but which use different simulator configurations. To avoid repeated intervention from the user, it is advisable to write a script to perform this task.

Once a set of census files have been generated they should be loaded into the tool and **X taken from configuration** selected. This interrogates the configuration information recorded in each of the census files to determine which configuration parameter is varying. A plot is not produced if more than one parameter is found to be changing across the set of census files.

When the varying parameter has been identified, a line is drawn for every result returned by applying the currently selected census group to one of the selected census files. The X co-ordinate identifies the value of the configuration parameter. The Y co-ordinate is the count returned by the associated query.

Plotting options

The options listed in *Table 33* are also available from the **Plot** menu.

Menu option	Description
Unmarked	Do not mark the points that are used to draw the plot.
Circular	Mark the points that are used to draw the plot as circles.
Square	Mark the points that are used to draw the plot as squares.
Diamond	Mark the points that are used to draw the plot as diamonds.
Cross	Mark the points that are used to draw the plot as crosses.
Y is Count	Mark the Y axis ruler in terms of counts.
Y is % of Group	Mark the Y axis ruler in terms of a percentage of a group specified value. The group used to compute this value is chosen using **Select Base Group** on the **Groupings** menu.

Table 33: Plot menu options

8.4.4 Preparing new groups

The preparation of new groups requires an understanding of the format and content of census files and also knowledge of how to query the census database.

Census file format

This section discusses the generic format of census files. Detailed information regarding the content of census files generated by the SuperH simulators can be found in *Section 8.7: Census file formats on page 181*.

A census file entry consists of a tag/value pair where the value can be either an integer or a quoted string of characters. For example:

```
SIM.TYPE "SH4P"
SIM.DATA.CACHE.BYPASS 0
SIM.DATA.CACHE.SETS 64
```

```
SIM.CODE.CACHE.BYPASS 0
SIM.CODE.CACHE.SETS 64
```

The order in which entries appear in the census file is of no consequence to their interpretation, although to improve clarity, related information should be grouped together.

Tag names must start with a character from the set:

```
_ $ # % A-Z a-z
```

In the body of the tag, plus (**+**), minus (**-**) and numerals are also permitted. The census database is case-insensitive. Therefore, **SIM**, **Sim** and **sim** are all equivalent.

Census queries

The least complex form of a census query is a dot-separated list of field names. The query returns every entry that is prefixed by a matching set of field names. Field matching is case-insensitive. This means that the query **sim.data** would return the following entries if applied to the above census database:

```
SIM.DATA.CACHE.BYPASS 0
SIM.DATA.CACHE.SETS 64
```

In addition to prefix matching, there are two operators defined for querying the database that can be used to wildcard a particular field. If the **?** operator is used as a field name, the matching operation on that field is the one that always succeeds. **sim.?.cache.sets** returns:

```
SIM.DATA.CACHE.SETS 64
SIM.CODE.CACHE.SETS 64
```

The **+** operator is used in a similar manner except that the counts returned by the matching entries are summed to return a single result. **sim.+.cache.sets** returns:

```
SIM.+.CACHE.SETS 128
```

Both operators can appear multiple times in any combination within the same query. For example, **sim.+.cache.?** returns:

```
SIM.+.CACHE.BYPASS 0
SIM.+.CACHE.SETS 128
```

8.4.5 Creating and modifying groups

To begin creating a new group, select **New Group** from the **Groupings** menu. The **Add new group** window is displayed, see *Figure 31*. The fields are described in *Figure 34*.

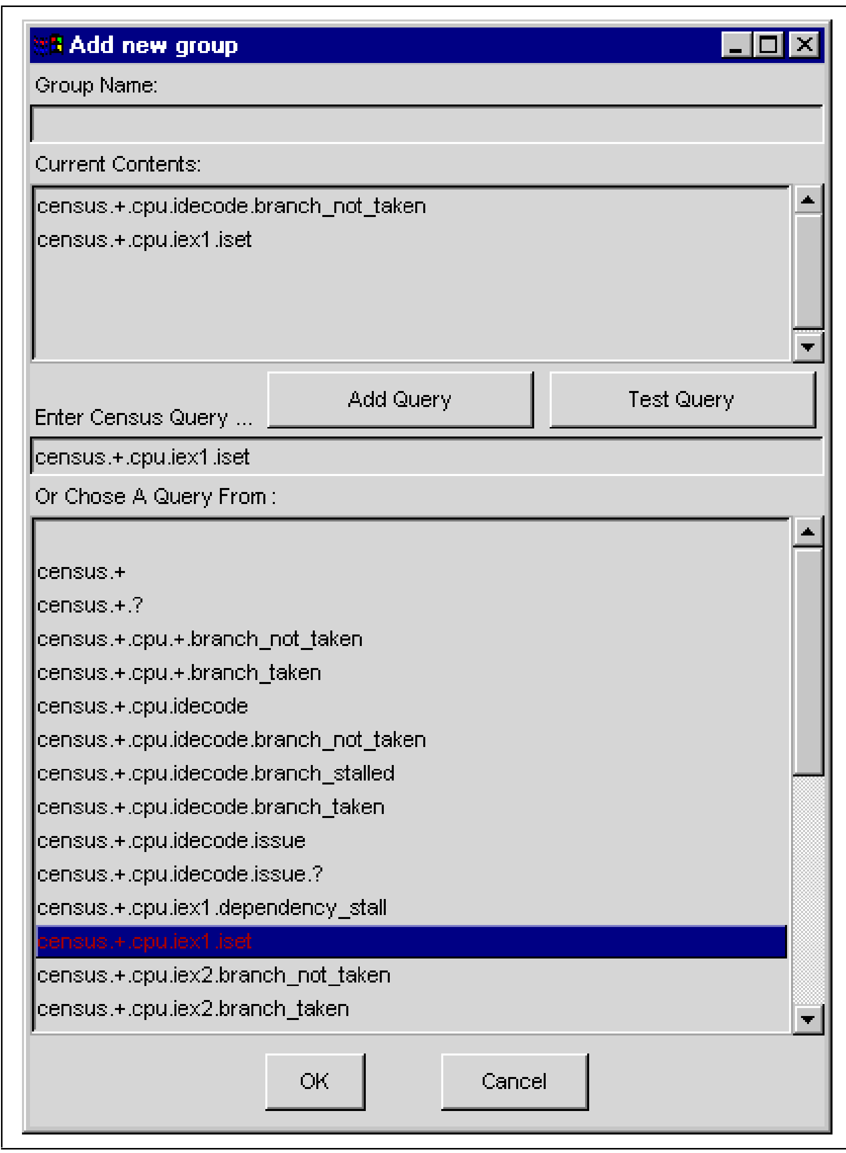


Figure 31: Add new group window

Field	Description
Group Name	Enter the name of the group. By convention it is advisable to prefix the group name with the type information for the tool/model that produces the census files with which it is associated. This information can be found in the census file's **`SIM.TYPE`** field and prefixes a selected census name.
Current Contents	This lists all of the queries in the group. To delete a query from the group double-click on the appropriate entry.
Enter Census Query	Enter the query to add to the group.
Add Query	Click on this button to add the query entered in the **Enter Census Query** field to the group. The query is applied to the currently loaded census files and a table of results is displayed in a new window. Any query which has no match against the loaded census files returns **`0`**. This mechanism is also advantageous for inspecting the contents of a census file. For example, testing **`census.+.cpu0`** lists all census file entries associated with CPU core 0. Most queries should commence **`census.+`** as this makes the default behavior of the query merge the results of every census record found in the database. This behavior can be overridden using the **Select Output** option in the **Histogram** menu to specify arbitrary subsets of the census records for display.
Test Query	Click on this button to test the query entered in the **Enter Census Query** field before adding it to the group. When constructing queries for processing by the census inspector, only census file entries with numeric values are appropriate. Attempting to use queries which return strings as part of a query grouping result in an error.
Or Choose A Query From	This lists a history of all previously used queries[a]. Click on an entry in this box to transfer it to the **Enter Census Query** field. Double-click on an entry to transfer it to the **Current Contents** field. The history list also contains queries of the form **`merge(`*`group-name`*`)`** for each of the groups that are currently defined. A query of this form applies the query group ***`group-name`*** to the census database. The results of this query are accumulated and returned by the merge query as a single result.

Table 34: Add new workgroup window fields

a. To edit the contents of the history list, select **File > Selector Maintenance**.

To save the new group of queries, click on the **OK** button.

To delete a group, select it in the **Census Inspector** window and then select **Delete Group** from the **Groupings** menu. **Modify Group** displays the same dialog box as used for adding a new group, pre-loaded with the contents of the currently selected group. This window can also be opened by double-clicking on an entry in the **Groups** list.

8.5 The trace viewer (trcview)

The trace viewer is invoked as follows:

`trcview` ***`rootname`*****`[.trc]`**

where ***`rootname`*** is the root file name for the trace set to be viewed.

When the trace viewer is invoked, the **Trace File Viewer** window is displayed, see *Figure 32*.

The **Trace File Viewer** window is capable of displaying the following:

- packet traces,
- probe traces.

Packet traces are used for time-stamping the flow of an instruction through a CPU core pipeline.

All information regarding the specifics of the trace are encapsulated within the generated trace files themselves. The number of packet traces generated depends upon the model. A list of traces is displayed at the bottom of the **Options** menu. CPU core traces show the flow of the instructions through each stage of its pipeline. An example of such a trace is given in *Figure 32*.

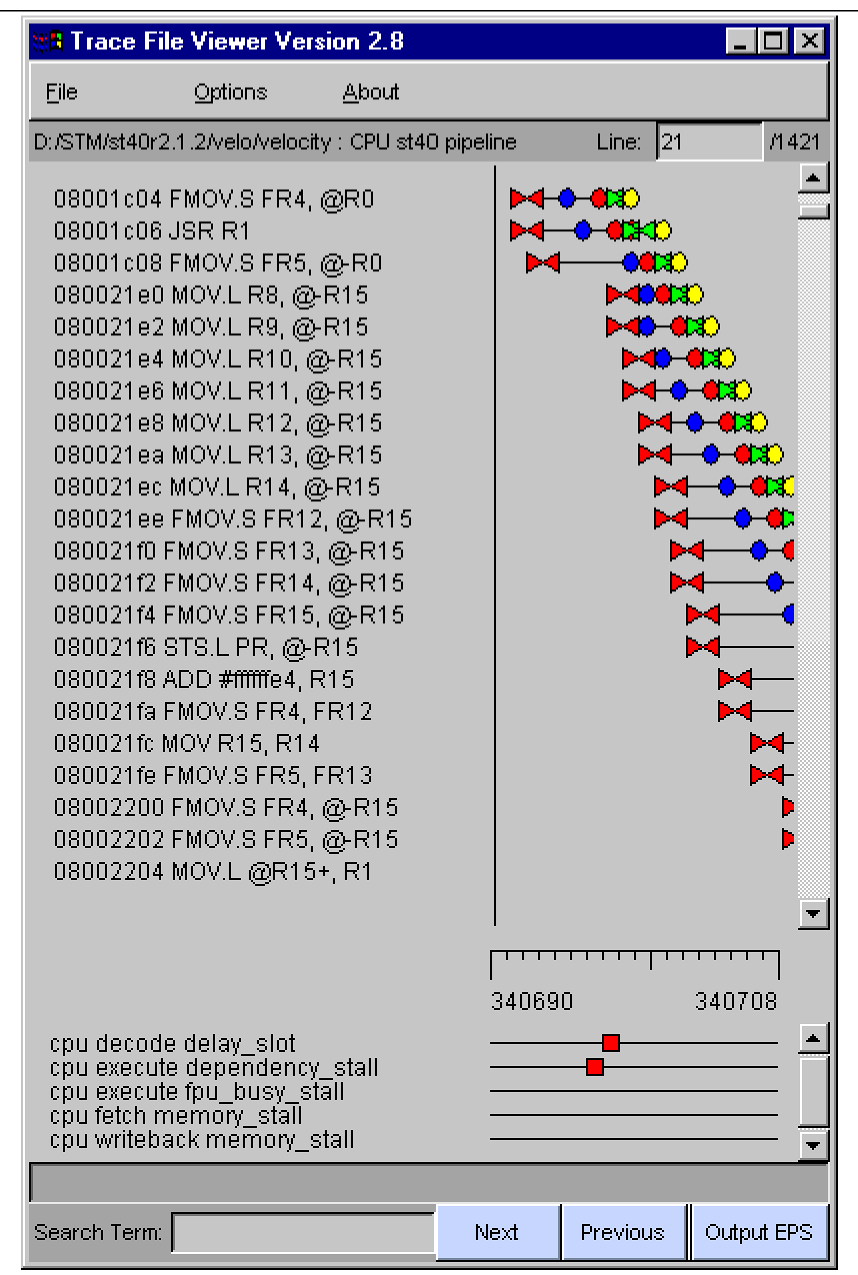


Figure 32: The Trace File Viewer window

Probe traces are used to monitor the state of individual components of the model on a cycle-by-cycle basis. All probes are boolean, for example, a probe can be used to indicate when a queue is empty. However, it cannot be used to indicate how many entries are in the queue unless a probe is allocated for every possible number of queue entries. The purpose of a probe is captured within the trace files. This ensures that the trace viewer does not need to be programmed with information specific to a particular simulation model.

Probes appear at the bottom of the **Trace File Viewer** window but can be disabled by unchecking the **Probes** option in the **Options** menu.

Additional information regarding all the probes can be displayed by selecting **Probe Configure** from the **File** menu. The dialog box displayed allows probes to be hidden, to have the color changed and to be placed on the same line as the previous probe. The latter feature, in combination with a change in color, is advantageous for presenting related signals on a single line. An example of this is the treatment of EMI phases which appear, by default, on a single line with the RAS phase in red, the CAS phase in purple, and any pre-charge phase in blue.

8.6 Trace viewer file formats

This section describes the format required for the files read by the trace viewer (see *Section 8.5: The trace viewer (trcview) on page 175*).

Note: Each file which makes up a trace set has the same file name but with a different extension. The additional extensions are defined in the **.trc** *file (a member of the trace set).*

8.6.1 Trace set files (.trc)

The **.trc** file gives the general structure of the trace set. The types of packet trace used in the set are defined, as are the possible stamps[1] which can be used in each packet trace. The file also contains references to the files containing the values used to construct the traces.

Definitions of trace types

The following construct defines a trace packet type with an entry for each available stamp:

```
DEFINE TRACETYPE type-name
{stamp-name} shape color
{stamp-name} shape color
...
END
```

where:

type-name is the name used to refer to the trace type,

stamp-name is the name that appears in the legend,

shape is the default shape the stamp uses, this can be square, circle, diamond, left arrow, or right arrow,

color is the default color the stamp uses.

A trace type definition must exist for each referenced trace type.

1. A stamp is an event that can occur zero or more times during the course of the trace. For instruction traces, there is one stamp for each of the various decode and execute states of the processor pipeline.

References to associated files

An entry must exist for each packet trace in the set specified by a **TRACE** statement.

TRACE *type-name file-extension "trace-name"*

where:

type-name is the name of the trace type (as defined above),

file-extension is the extension of the file containing the data for this trace,

trace-name is the name of the trace as it appears in the view.

Following each **TRACE** statement there can be any number of **TRACETEXT** statements that refer to files containing additional trace information (see *Section 8.6.3 on page 180*).

TRACETEXT *file-extension*

There must also exist entries for each probe trace file (see *Section 8.6.4 on page 180*), specified by a **PROBE** statement.

PROBE *file-extension*

8.6.2 Packet trace files

Packet trace files are referred to in the **TRACE** statements of a **.trc** file. They must contain a line for each object in the trace. Each line should be structured as follows:

: *descriptive-text* (*values*)

where:

descriptive-text is any arbitrary string up to the **(** character that is displayed next to the trace of the object in the viewer,

values is a list of the time stamps for the object where each stamp can be represented using:

- a single integer value,
- multiple values (these must be enclosed in braces, for example **{1 2 5}**),
- empty braces **{}**.

Each value (or set of braces) must be separated by a space. Using multiple values causes more than one instance of the stamp in the trace.

Note: There is a deprecated form for an entry which has a value before the colon. In the current version, everything before the colon is ignored.

8.6.3 Trace text files

Trace text files contain one line of free text for each line in the packet trace file. The trace viewer displays the text, one line at a time, at the foot of the packet trace. Typically the text contains the same information as the packet trace descriptive text, but with more information (such as register contents).

8.6.4 Probe trace files

Probe trace files contain a header plus the trace data for the probes which is displayed by the trace viewer window. The performance simulator uses these files to represent pipeline stalls.

Header

The header starts with a line containing the word **`PRELUDE`** and then follows one line for each probe type:

`word bit name description`

where:

`word` is the binary word in which the ***`bit`*** is found. The value should be **`0`**, **`1`**, **`2`** and so on.

`bit` is the binary bit (**`0`**, **`1`**, **`2`** and so on) that represents the probe in the data (see the trace data below). It must be between **`0`** and **`15`** (inclusive). More can be used by using a different word.

`name` is the name displayed by the trace viewer.

`description` is a short description of what triggers the probe.

Trace

The trace follows the header and starts with a line containing the word **TRACE** and then follows a series of lines describing the probe data:

value probes ...

where:

> ***value*** corresponds to the values in the packet trace data (see *Section 8.6.2 on page 179*).
>
> ***probes*** indicates which probes were triggered. This is a hexedecimal number (without a **0x** prefix) in which the binary bits represent the probes (as defined in the probe trace file header).
>
> ***...*** is optional and means that if there are multiple words defined in the header (that is, more than 16 probes) then these should be listed, separated by spaces.

8.7 Census file formats

Every census file (**.cns**) generated by the SuperH simulators contains the fields shown in *Table 35*. Census files are read by the census inspector (see *Section 8.4 on page 164*).

Field	Description
SIM.TYPE	The type of model which generated census data.
SIM.VERSION	The version of the model which generated census data.
SIM.ARCH	The model family, usually empty.
SIM.BUILD.DATE	The date the model was built.
SIM.RUN.DATE	The date the model was run.

Table 35: Census file generic fields

These are followed by a series of model specific configuration fields that contain the settings for all the run-time configurable components of the model. They are all prefixed by **SIM.CONFIG**.

The configuration section is followed by a series of counter descriptions of the form:

```
DESCRIPTION.<counter id> "<description>"
```

For example:

```
DESCRIPTION.cpu.decode.branch_taken  "Count of branches predicted to be
taken by the decode pipeline stage"
```

The description section is followed by a series of output sections, one per counter dump performed during simulation. Each entry begins:

```
CENSUS.OUTPUTn
```

where ***n*** begins at 0 and is incremented at the start of each new output section. Each output section contains a **LABEL** field describing its contents as specified during the counter dump. The rest of the entries record the state of all the counters at the time the dump was requested.

Some of this census data is output in the form of a histogram. This type of entry always contains the subfields shown in *Table 36*.

Subfield	Description
total	Sum of all values entered in the histogram.
samples	Number of samples in the histogram.
min	Lowest value entered in the histogram.
max	Highest value entered in the histogram.
mean	Mean of all values entered in the histogram (truncated to an integer).
bins.#-X	Number of values below or equal to **X** entered in the histogram.
bins.#X-Y	Number of values between **X** and **Y**, inclusive, entered in the histogram.
bins.#X	Number of values equal to **X** entered in the histogram.
bins.#X-	Number of values greater than or equal to **X** entered in the histogram.

Table 36: Census file subfields

The number, widths and range of **bins** vary depending upon the data being sampled.

9 OS21 source guide

9.1 Introduction to the OS21 source

The source code for OS21 is included with the toolset release and is located under the release installation directory, in **`sh-superh-elf/src/os21`**.

OS21 may be freely rebuilt for your own purposes, but these uses must be strictly within the terms and conditions of the OS21 Software License Agreement. A copy of this license agreement is located in the top level directory of the OS21 source code (**`LICENSE.htm`**).

There is a **`makefile`** (GNU make compatible) in this directory, which enables OS21 and its board support libraries to be built by issuing the **`make`** command.

This top level **`makefile`** has three build rules.

build Build all of OS21 and its board support libraries (the default rule).

buildbsp Build just the OS21 board support libraries.

clean Remove all built files (object files and libraries).

The resulting libraries are placed in the directory **`sh-superh-elf/src/os21/lib/st40`**.

The source for OS21 is provided so that you may:

- refer to the OS21 source for a clearer understanding of OS21's behavior,
- refer to the OS21 source to aid debugging,
- rebuild OS21 with different compiler options,
- enable configurable options within OS21 which are not enabled in the shipped binaries,
- build your own board support libraries.

Note: In order to build OS21, GNU make and Perl (version 5.6.1) must be available on your system.

9.2 Configurable options

OS21 supports a number of configurable options. These options are selectively enabled at build time by defining preprocessor symbols. *Table 37* lists the preprocessor symbols that are available for configuring OS21 for the ST40.

Symbol name	Description
CONF_CALLBACK_SUPPORT	Enable the callback API.
CONF_DEBUG	Enable debug checking within the OS21 kernel.
CONF_DEBUG_ALLOC	Enable additional debug checking for memory allocators.
CONF_DEBUG_CHECK_EVT	Perform extra validation checks on events.
CONF_DEBUG_CHECK_MTX	Perform extra validation checks on mutexes.
CONF_DEBUG_CHECK_SEM	Perform extra validation checks on semaphores.
CONF_DEBUG_TIMING	STMicroelectronics internal use only.
CONF_DISPLAY_CLOCK_FREQS	OS21 reports certain ST40 clock settings on kernel boot.
CONF_FINE_GRAIN_CLOCK	Program the system clock to operate at as high a frequency as possible, hence yielding greater accuracy.
CONF_FPU_SINGLE_BANK	Restrict FPU save and restore to the bank of FPU registers used by GCC.
CONF_INLINE_FUNCTIONS	Inline certain functions.

Table 37: OS21 configurable options

Symbol name	Description
CONF_NO_FPU_SUPPORT	OS21 does not save/restore FPU registers on context switch.
CONF_TIME_LOGGING	Enable time logging within the OS21 kernel.
CONF_TRACE	Enable tracing of key events within the OS21 kernel.
CONF_TRACE_MASK	Specify which modules to be traced at compile time.
CONF_TRACE_SIZE	Specify the internal size of the OS21 trace buffer.

Table 37: OS21 configurable options

Note: *The file* **makest40.inc** *(located in the subdirectory* **sh-superh-elf/src/os21***) can be amended to alter these options. By default, none of the configuration options in Table 37 are enabled in this file.*

9.2.1 Configurable options in the standard OS21 libraries

The standard OS21 libraries shipped in the distribution (selected with **-mruntime=os21**) have been built with **CONF_INLINE_FUNCTIONS** defined. The debug OS21 libraries (selected with **-mruntime=os21_d**) have been built with **CONF_DEBUG** defined. The OS21 libraries selected when the **-m4-nofpu** compiler option is specified have also been built with **CONF_NO_FPU_SUPPORT** defined.

CONF_CALLBACK_SUPPORT

Defining this preprocessor symbol enables OS21's callback API. This API provides a mechanism for user supplied routines to be called when certain OS21 events occur (for example, context switch). It is intended to provide support for code profiling tools. See the *OS21 User Manual* for a complete explanation of this API.

CONF_DEBUG

Defining this preprocessor symbol produces a debug OS21 kernel. This kernel contains many self checks to ensure internal integrity, and to check that user calls into the kernel are correct.

CONF_DEBUG_ALLOC

Defining this preprocessor symbol produces an OS21 kernel with special checks added to the memory management code including the detection of heap scribbles, and the freeing of bad pointers.

CONF_DEBUG_CHECK_SEM, CONF_DEBUG_CHECK_MTX and CONF_DEBUG_CHECK_EVT

Defining these preprocessor symbols produces an OS21 with extra integrity checks enabled for semaphores, mutexes and event flags respectively. Every time one of these objects is referenced, OS21 performs extra checks to ensure that its structure is not corrupt, and that it has not been previously deleted.

CONF_DISPLAY_CLOCK_FREQS

Defining this preprocessor symbol produces an OS21 kernel which reports certain key ST40 clock frequencies when the kernel is initialized.

CONF_FPU_SINGLE_BANK

Defining this preprocessor symbol produces an OS21 with a restricted FPU context save and restore. OS21 only considers the bank of FPU registers which are used by GCC when saving or restoring a context. This halves the number of FPU registers which need to be saved or restored on context switch, therefore improving context switch time and interrupt latency. This option is safe to use provided that no custom FPU routines which perform FPU bank switching are being used.

CONF_INLINE_FUNCTIONS

Defining this preprocessor symbol produces an OS21 with inlined list manipulation functions. This may yield a slight performance improvement.

CONF_FINE_GRAIN_CLOCK

Defining this preprocessor symbol causes OS21 to program the system clock to operate at as high a frequency as possible, given the prevailing timer input clock. This increases the number of ticks per second, and hence yields greater accuracy when reading the system time, or setting timeouts.

CONF_NO_FPU_SUPPORT

Defining this preprocessor symbol produces an OS21 kernel which disregards the FPU registers when switching context. This improves context switch time and interrupt latency, at the expense of making the use of the FPU task unsafe. It is therefore important that the program is built with the **`-m4-nofpu`** compiler option to ensure that the FPU is not used at all, or that the FPU is just used by a single task.

CONF_TIME_LOGGING

Defining this preprocessor symbol produces a kernel with the time logging API enabled. This allows the kernel to perform simple accounting, in order to record the amount of CPU time given to individual tasks and the kernel. See the *OS21 User Manual* for an explanation of the time logging API.

CONF_TRACE, CONF_TRACE_MASK and CONF_TRACE_SIZE

Together these preprocessor symbols are used to control the internal tracing facilities of OS21. Defining **CONF_TRACE** enables the OS21 trace mechanism. This allows key events inside OS21 to be recorded in a trace buffer. The trace buffer wraps so that the newer entries overwrite the oldest ones. The tracing scheme used is designed to minimize run-time impact.

Each module within OS21 is assigned a bit in a trace mask. The bit values are enumerated in the type **trace_modules_t** in the file **src/os21/include/_debug.h**. The trace points that get logged into the trace buffer are controlled by a global trace mask. This mask can be set at compile time (by giving the **CONF_TRACE_MASK** preprocessor symbol a non-zero value) and at run-time, by the macro **OS21_TRACE_MODULES()**. The default size of the OS21 trace buffer is 64 Kbytes, but this can be overridden by setting the preprocessor symbol **CONF_TRACE_SIZE** to the required size expressed in Kbytes.

Tracing is performed by calling the macro **OS21_TRACE()**. The arguments to this macro are a trace mask, a constant string and up to three additional parameters. The string may contain simple **printf** format conversion character sequences as listed in *Table 38* (width and precision modifiers are not supported).

Format characters	Description
%%	Print a % character.
%c	Print a single character.
%d	Print a signed decimal number.
%u	Print an unsigned decimal number.
%x	Print a hexidecimal number.
%p	Print a pointer.
%s	Print a string.

Table 38: Supported trace format conversions

If the trace mask provided matches any bits in the global trace mask, or is the special value **TRC_FORCED**, then the trace point is recorded by storing the current active task pointer, followed by the string pointer and user supplied parameters in the trace buffer.

The trace buffer is dumped to the screen automatically when OS21 terminates. It can also be dumped at any point during execution by invoking the macro **OS21_TRACE_DUMP()**. Once dumped, the trace buffer is emptied, ready for more trace events to be recorded. OS21 dumps the trace buffer by printing the active task pointer for each trace entry, followed by the expansion of the stored string, using the additional parameters recorded to satisfy the format characters in the string.

An example trace point:

```
OS21_TRACE ((TRC_TASK, "Context switch to task %p", new_taskp));
```

9.3 Building the OS21 board support libraries

The OS21 board support libraries can be built by invoking **make** from the root of the OS21 source tree (**sh-superh-elf/src/os21**) with the target **buildbsp**. Each board support library consists of three object files:

- one for SH-4 CPU support,
- one for chip support,
- one for target board support.

The board support source code is located under the release installation directory, in **sh-superh-elf/src/os21/src/st40/bsp**.

CPU support files

There is a CPU support file for each supported SH-4/ST40 variant:

```
cpu_st40gx1.c
cpu_st40ra.c
cpu_stb7100.c
cpu_stb7109.c
cpu_std2000.c
cpu_sti5528.c
cpu_stm8000.c
```

Each file contains:

- declarations of all the interrupts which can be serviced on this CPU,
- tables enumerating all the interrupts and interrupt groups,
- base addresses of the interrupt controllers on this CPU,
- interrupt controller initialization flags,
- a function to return the name of the CPU.

Platform specific variants of the CPU support files may also exist to support platforms where the external interrupts are not priority encoded (the default).

Chip support files

There is a chip support file for each supported SH-4/ST40 system-on-a-chip part:

chip_st40gx1.c
chip_st40ra.c
chip_stb7100.c
chip_stb7109.c
chip_std2000.c
chip_sti5528.c
chip_stm8000.c

Each file contains:

- a function to return the name of the chip,
- optionally the function **bsp_timer_input_clock_frequency()**, and associated support code to determine the clock frequencies of the part from the CLOCKGEN circuitry.

Target board support files

There is a target board support file for each supported reference platform:

board_db457.c
board_espresso.c
board_mb293.c
board_mb317.c
board_mb350.c
board_mb360.c
board_mb376.c
board_mb379.c
board_mb392.c

```
board_mb411.c
board_mb422.c
board_mediaref.c
board_sh4chess.c
board_stb7100ref.c
```

Each file contains functions that OS21 calls:

- during initialization,
- during startup,
- when processing an unexpected exception,
- on kernel panic,
- when the kernel shuts down,
- to determine the name of the target board,
- when an illegal exception or internal OS error is detected, and the target is not connected to a debugger.

9.3.1 Creating a customized board support library

The following steps show the process of creating a new board support library for a fictitious XYZ board.

1 In the directory **sh-superh-elf/src/os21/src/st40/bsp**, copy one of the supplied target board support files to use as a template, for example, copy **board_mediaref.c** to **board_xyz.c**.

2 Edit it to meet your requirements.

3 In the directory **sh-superh-elf/src/os21**, edit **makest40bsp.inc**.

3.1 Declare a new library name:

```
BSPLIB_XYZ = $(OS21LIBDIR)/libxyz$(LIBSFX).a
```

3.2 Add **$(BSPLIB_XYZ)** to the list defined by **BSPLIBS**.

3.3 Create a definition of the object files to be put in this library. Choose the appropriate CPU support file, based on the processor used on the board, for example:

```
BSPOBJS_XYZ = \
   $(OS21OBJDIR)/st40/bsp/cpu_st40gx1$(OBJSFX).o \
   $(OS21OBJDIR)/st40/bsp/chip_st40gx1$(OBJSFX).o \
   $(OS21OBJDIR)/st40/bsp/board_xyz$(OBJSFX).o
```

3.4 Add **$(BSPOBJS_XYZ)** to the list **BSPOBJS**.

3.5 Add a rule to build the new library:

```
$(BSPLIB_XYZ): $(BSPOBJS_XYZ)
   $(ARBUILD) $(BSPOBJS_XYZ)
   $(RANLIB) $@
```

4 Build the board support library by invoking **make** from the top level OS21 directory, with the target **buildbsp**.

Since by default **LIBSFX** is empty, the resulting library name is **libxyz.a**. It is placed in the directory **sh-superh-elf/src/os21/lib/st40**.

9.3.2 Using the built libraries

After rebuilding the OS21 libraries, the **-L** compiler option must be specified every time the libraries are required to ensure that the linker picks up the new versions:

```
sh4gcc -Linstall-directory/sh-superh-elf/src/os21/lib/st40
```

Debugging the libraries

To debug the libraries using GDB, add the following to the GDB initialization file (**.shgdbinit**):

```
directory install-directory/sh-superh-elf/src/os21
```

This ensures that GDB finds the OS21 source files. If required, optimization can be switched off or reduced in the kernel by specifying **-O0** or **-O1** as the optimization level, for example:

```
make build CCOPTFLAGS=-O0
```

9.4 Adding support for new boards

Once a new board support library has been built as described in *Section 9.3.1*, it has to be registered with the toolset. This means creating a new GCC compiler **specs** file to describe the memory layout of the board, and to inform the compiler driver of the new board support library. This specs file can be placed in:

- the working directory, or
- the release installation directory under **lib/gcc/sh-superh-elf/3.4.3**.

Placing the file in the release installation directory makes it available from wherever the compiler is invoked.

Continuing the example in *Section 9.3.1*, create a specs file called **xyzspecs** in one of the above directories, with the following contents:

```
*xyzp0:
--defsym _start=0x08000000 --defsym _stack=0x0BFFFFFC

*xyzp1:
--defsym _start=0x88000000 --defsym _stack=0x8BFFFFFC

*xyzp2:
--defsym _start=0xA8000000 --defsym _stack=0xABFFFFFC

*xyzp3:
--defsym _start=0xC8000000 --defsym _stack=0xCBFFFFFC

*board_link:
%{mboard=xyzp0:%(xyzp0)}\
%{mboard=xyzp1:%(xyzp1)}\
%{mboard=xyzp2|mboard=xyz:%(xyzp2)}\
%{mboard=xyzp3:%(xyzp3)}

*lib_os21bsp_base:
%{mboard=xyz*:xyz}
```

Note: The values specified for **_start** *and* **_stack** *should reflect the actual memory configuration of the target board. Compiler specs files are very sensitive to spaces and blank lines; make sure that the specs file looks exactly like the example above.*

To use this new specs file, invoke the compiler with the option **-specs=xyzspecs**, along with an appropriate **-mboard** option, for example **-mboard=xyzp1**.

It is now possible to create OS21 applications targeted for the new board. For example:

```
sh4gcc -specs=xyzspecs -o hello.out hello.c -mruntime=os21 -mboard=xyzp1
```

9.5 GDB OS21 awareness support

GDB provides OS21 task aware debugging with the **shtdi** GDB target. The **shtdi** target installs a service which runs on the ST Micro Connect and has knowledge of the data structures used in OS21. A dependency therefore exists between the version of OS21 being used and the version of the **shtdi** server being used.

OS21 is built with static data tables which expose the layout of certain critical data structures to the **shtdi** server. Each data table has a cyclic redundancy check (CRC) calculated for it, and this too is stored statically. These data tables are auto-generated as part of the OS21 build process. At the same time a header file is also auto-generated which is imported into the build of the **shtdi** server. This header file contains the same CRC values, and some key type definitions.

The data tables are offset/size pairs which identify particular fields within OS21 data structures. The tables are indexed by enumerated types, which are the types imported by the **shtdi** server. There is one data table per OS21 data structure type of which the **shtdi** server has to be aware. The CRC value for each table is calculated using the field name, and since it is a CRC, the order in which the fields appear relative to each other is important. If a field changes name between releases, or fields alter position within a data structure (relative to each other), then the CRC for the data table also changes.

When the **shtdi** server examines a target system to determine if it can debug it in OS21 aware mode, it examines the data table CRCs in memory and checks to see if they match the ones it was built with. If they do, then OS21 awareness is enabled, and the **shtdi** server can use the in-memory data tables to determine how to parse the OS21 data structures. If the CRCs do not match, then the **shtdi** server and OS21 were not built from the same source base, and the **shtdi** server cannot operate in OS21 aware mode.

When modifying OS21 you should be aware that changing the relative order of certain fields in key data structures, or renaming them, may render the **shtdi** server unable to debug the resulting OS21 executables with task awareness.

9.5.1 Generation of the shtdi server data tables

The generation of the **shtdi** server data is performed by the Perl script:

`sh-superh-elf/src/os21/scripts/mkgdb.pl`

which is invoked automatically as part of the build process. This Perl script is passed key OS21 header files, which are scanned for special mark-ups. These mark-ups identify which structures, and which fields in those structures, are to be exposed to the **shtdi** server. The mark-ups used are very simple, and are designed to be invisible to the C compiler when the headers are compiled, by using the C preprocessor.

`GDB_STRUCT(`*`struct`*`)`

Declares this structure as containing information required by the **shtdi** server. This decoration triggers the generation of the following data objects:

- an array of offset and size descriptors, given the name ***`struct`*`_descs`**,
- a **`size_t`**, with the value of the number of elements in the above array, given the name ***`struct`*`_descs_size`**,
- an **`unsigned int`** with the value of the calculated CRC for the above array, given the name ***`struct`*`_descs_crc`**.

`GDB_FIELD(`*`enum_prefix, field`*`)`

Declares that a field in the current structure is to be exposed to the **shtdi** server. An enum called ***`enum_prefix_field`*** is generated and stored in the export header file to correspond to this fields index in the array of descriptors.

`GDB_ARRAY_FIELD(`*`enum_prefix, field, field_index, enum_suffix`*`)`

Declares that a particular field in the structure array is to be exposed to the **shtdi** server. An enum called ***`enum_prefix_field_enum_suffix`*** is generated and stored in the export header file to correspond to this field’s index in the array of descriptors.

`GDB_BEGIN_EXPORT, GDB_END_EXPORT`

These two markers are used to identify a section of header file which is to be copied verbatim into the export header file.

10 Booting OS21 from Flash ROM

Examples are provided which show how to boot applications from Flash ROM. In the **rombootram** example, the application is copied to RAM before being run. In the **rombootrom** example, the application is run directly from Flash ROM. The **romdynamic** example shows how to use the Relocatable Loader Library to load a dynamic library from Flash ROM from an application which is booted out of Flash ROM. The **sti5528dualboot** example shows how both the ST40 and ST20 processors on the STi5528 chip can boot from Flash ROM. The **stb7100multiboot** example shows how the ST40 and ST231 co-processors on an STb7100 or STb7109 chip can boot from Flash ROM and the **stm8000multiboot** examples show how the ST40 and ST220 co-processors on the STm8000 chip can boot from Flash ROM.

Additionally examples are supplied illustrating how to generate a ROM image for booting only the co-processors on the STb7100/STb7109 (**stb7100loader**), STm8000 (**stm8000loader**) and STi5528 (**sti5528loader**) under the control of a separately downloaded ST40 application.

These examples are located in the subdirectories of the **sh-superh-elf/examples/os21** subdirectory of the installed release. Full details can be found in the **readme.txt** files in these directories.

10.1 Overview of booting from Flash ROM

The ST40 Micro Toolset provides support for both single CPU and multicore CPU chips where each CPU boots from the same Flash ROM. The chips supported by the Flash tool are listed in *Table 39*.

The Flash ROM is structured by the tools and bootstraps provided in the examples so that it consists of a 16 Kbyte reserved area at the start of Flash ROM, followed by executable image sections. The same structure is used for all chips, regardless of the number of cores present. The reserved area consists of the CPU boot vectors, directories of the bootstraps and applications present in the rest of the Flash ROM. The example directories contain the **flashdir** tool which can display the contents of Flash ROM.

Chip	Cores contained	Comments
ST40GX1	ST40	ST40 boots from offset **0x0** in Flash ROM.
ST40RA	ST40	ST40 boots from offset **0x0** in Flash ROM.
STb7100 and STb7109	ST40 and 2x ST231	ST231 slave CPUs are booted from an address given by the software running on the master ST40 CPU.
STd2000	ST40	ST40 boots from offset **0x0** in Flash ROM.
STi5528	ST40 and ST20	ST40 boots from offset **0x0** in Flash ROM. ST20 boots from **0x7FFFFFFE** in Flash ROM. Hardware in the STi5528 remaps 256 bytes of the physical address space to appear at **0x7FFFFF00** in the ST20 address space.
STm8000	ST40 and 3x ST220	ST40 boots from offset **0x0** in Flash ROM. ST220-1 boots from offset **0x40** in Flash ROM. ST220-2 boots from offset **0x80** in Flash ROM. ST220-3 boots from offset **0xC0** in Flash ROM.

Table 39: Supported chips

Applications can be placed in Flash ROM by the **flasher** Flash ROM programming tool included in the examples. The **flasher** tool can either take component image files (for example, for bootvectors, bootstraps or applications), or a complete Flash ROM image file as its input.

The **`mkimage.pl`** Perl script is provided to convert target executable files into the component image file format. It can process ST40 and ST200 ELF files (executable files and relocatable libraries), as well as ST20 hex and S-record ROM format files. Executable files and relocatable libraries are decomposed into a number of sections, which are placed in the component image file.

Using the **flasher** tool with component image files allows updates to the existing contents of Flash ROM. Any component image file being placed in Flash results in an update to the Flash directory pages. Multiple application images can be stored in Flash. Each image is tagged in the Flash directory with its relevant CPU. A CPU can have multiple application images stored in Flash, but only one is tagged as the boot application for that CPU.

The **`mkbinrom.pl`** Perl script provided with the examples creates a complete binary ROM image in a single file. Like the **flasher** tool it can take component image files as input, but it can also take executable and relocatable library ELF files directly (in which case it calls **`mkimage.pl`** automatically to convert them to component image files). The **flasher** tool can then be used to program the complete binary ROM image to Flash ROM. Complete ROM images cannot be updated, they must be created from all constituent ELF files and/or component image files each time.

The examples provide sample boot vector and bootstrap code for the ST40, which is able to locate the ST40 application in the Flash ROM, and start it. The flow of execution on booting is as follows:

- the ST40 boot vector code is called which then calls the ST40 bootstrap code,
- the ST40 bootstrap code then:
  - configures the clocks, EMI and LMI interfaces,
  - locates the ST40 boot application,
  - moves any sections to RAM which require moving,
  - zeros any sections in RAM which require zeroing,
  - transfers control to the ST40 application.

11 Porting from OS20

11.1 Introduction to porting from OS20

The majority of OS21's API is based on the OS20 operating system for the ST20 processors.

Although the APIs have a great deal in common there are a number of differences between the two operating systems. These differences are presented here in order to show how to port an application from OS20 to OS21.

11.2 Header files

OS20 uses header files with 8.3 (MS-DOS style) names. OS21 is not constrained by this limitation and uses meaningful names, which do not clash with other headers. *Table 40 on page 200* shows the name changes for each header file, however, it is often more convenient to replace all OS20 header files with the more general **`<os21.h>`** and **`<os21/`*`cpu`*`.h>`**, where ***`cpu`*** is the CPU type name, for example **`st40`**.

OS20 header file	OS21 header file
interrup.h	**os21/interrupt.h**
kernel.h	**os21/kernel.h**
message.h	**os21/message.h**
ostime.h	**os21/ostime.h**
partitio.h	**os21/partition.h**
semaphor.h	**os21/semaphore.h**
task.h	**os21/task.h**

Table 40: Header file name changes

11.3 Bringing up the kernel

OS20 provides two means to bring up the kernel: manual and automatic (through the use of the **st20cc -runtime os20** option). OS21 is normally brought up manually, although the **autostart** example shows how to bring it up automatically (see *Section 1.5.3: The examples directory on page 32*).

The following example demonstrates how to bring up the OS21 kernel.

```
int main(void)
{
   /*
   * Initialize the OS21 kernel, and enable timeslicing
   */
   kernel_initialize(NULL);
   kernel_start();
   kernel_timeslice(OS21_TRUE);
   ...
}
```

Note: OS21 ***does not*** *enable timeslicing by default. If timeslicing is required it must be manually enabled after the kernel has started using* **kernel_timeslice()** *as shown in the example above.*

11.4 Statically allocated memory

OS21 does not support the **_init()** family of functions. These functions expose the data structures used by the operating system and their general use can hinder the development of the operating system.

Normally all instances of **_init()** functions would be replaced by **_create()** functions. However, one of the advantages of the **_init()** functions is the flexibility they afford with regard to memory allocation. OS21 takes a different approach to flexible memory management. In addition to all the **_create()** functions there are **_create_p()** functions which take a partition pointer as an additional argument. This allows the application programmer to tightly control where memory is allocated from.

Every instance of the following list of APIs should be replaced with its **_create()** or **_create_p()** equivalent.

- **message_init_queue()**
- **message_init_queue_timeout()**
- **partition_init_fixed()**
- **partition_init_heap()**
- **partition_init_simple()**
- **semaphore_init_fifo()**
- **semaphore_init_fifo_timeout()**
- **semaphore_init_priority()**
- **semaphore_init_priority_timeout()**
- **task_init()**

Note: 1 *OS21 does not differentiate between timeout and non-timeout synchronization primitives. Non-timeout functions are simple macro versions of their timeout equivalents.*

2 *OS21 does not support the ST20 specific* **task_create_sl()**, **task_init_sl()** *and* **task_onexit_set_sl()** *API calls.*

11.5 Interrupts and caches

The OS20 interrupt and cache API is very closely tied to the ST20 interrupt and cache architectures. The rationale for this is to provide complete access to the hardware's functionality. OS21 follows the philosophy of OS20 on this point for caches, and is therefore different for every CPU, and different from the cache API in OS20. The interrupt API provided by OS21 is intended to be generic, and portable between CPUs, so it differs from the API used in OS20.

Full details of the cache API for the ST40 CPU can be found in the *OS21 for ST40 User Manual*. Full details of the OS21 interrupt API can be found in the *OS21 User Manual*.

11.6 Channels and 2D block moves

The channel and 2D block move API present in OS20, provide access to ST20 hardware features. These have been removed from OS21 as they are ST20 specific.

11.7 Time

In OS21, time is represented using a 64-bit integer type (**`osclock_t`**) whereas in OS20, time is represented as a 32-bit integer type (**`clock_t`**).

11.8 New features in OS21

OS21 provides features that OS20 does not provide. These offer more elegant ways to solve certain concurrent design problems and their use is to be encouraged. Applications which require their code base to be built both with OS20 and OS21 should avoid the use of events.

12 Relocatable loader library

12.1 Introduction to the relocatable loader library

The relocatable loader library (**rl_lib**) provides support for the creation and loading of dynamic shared objects (DSOs) in an embedded environment. **rl_lib** implements DSOs (or load modules) as defined in the standard for supporting ELF System V Dynamic Linking.

This relocatable loader library only supports OS21 applications. There is no relocatable loader support for bare machine applications.

12.1.1 Run-time model overview

There are several run-time models which can be supported using the ELF System V ABI of which, only some are suitable for embedded systems without the support of traditional operating system services. The run-time model for an application dictates the method used for linking and loading. *Table 41* lists the different run-time models and *Table 42* summarizes the features supported by each model.

rl_lib only implements the **R_Relocatable** run-time model.

Run-time model	Description
R_Absolute	Absolute run-time model. The application is a single module which is statically linked at a fixed load address.
R_Relocatable	Relocatable run-time model. The application has a main module and several load modules. The main module is statically linked and loaded as for an **R_Absolute** application. The load modules are loaded on demand (by explicit calls to the loader) at run-time. The load modules are loaded at an arbitrary address and dynamic symbol binding is applied by the loader for symbols undefined in the load modules. The dynamic symbol binding traverses the modules bottom up in the hierarchy of loaded modules. See *Section 12.2 on page 205* for details.
R_PIC	System V run-time model. The application has a main module and several load modules. The main module is typically statically linked but may have references to symbols in the load modules. The main module is loaded with support from the dynamic loader that also loads load modules and binds symbols before the application starts. At run-time, the application may also load other modules on demand. The dynamic symbol binding walks the load modules in an order which is defined by the static link order and the run-time loading order. In addition to dynamic loading and linking, the load module's segments can be shared between several applications in a multi-process environment. This model usually relies on file system support and virtual memory management.

Table 41: Run-time models

	R_Absolute	R_Relocatable	R_PIC
Application partitioning	1 single program	1 main module + N load modules	1 main module + N load modules
Static symbol binding	Yes	Yes	Yes
Dynamic loading	No	Startup time: No Run-time: Yes	Startup time: Yes Run-time: Yes
Dynamic symbol binding	No	Main module: No Load modules: Yes	Main module: Yes Load modules: Yes
Explicit module dependencies	N/A	No	Yes

Table 42: Run-time model features

	R_Absolute	R_Relocatable	R_PIC
Dynamic symbol lookup	N/A	Bottom up (from loaded to loader)	Unrestricted order
Symbol preemption	N/A	No	Yes
Segment sharing (across processes)	N/A	No	Yes
Performance impact	N/A	Minimal	Yes
Code size impact	N/A	Minimal	Yes
Application writer impact	N/A	Need explicit loading	No change by default
Build system impact	N/A	Compiler options. Load modules build.	Compiler options. Load modules build.

Table 42: Run-time model features

12.2 Relocatable run-time model

The **R_Relocatable** run-time model as implemented by **rl_lib** has the following features:

- one main module loaded at application startup by the system,
- several load modules that can be loaded at run-time and unloaded after use,
- several modules can be resident at the same time,
- a loaded module, as for the main module, can load and unload other load modules,
- load modules can be loaded anywhere,
- access to symbols in loaded modules from the loader via a call to the loader library,
- dynamic symbol binding is performed by the loader when loading a module and symbols are searched in the load modules hierarchy bottom-up (to the main module),
- sharing of code and data objects between modules is achieved by linking to the objects in a common ancestor,

- the loader library is statically linked with the main module,
- generally, system support archive library should be linked with the main module.

The example in *Figure 33* shows an application which has four load modules A, B, C and D.

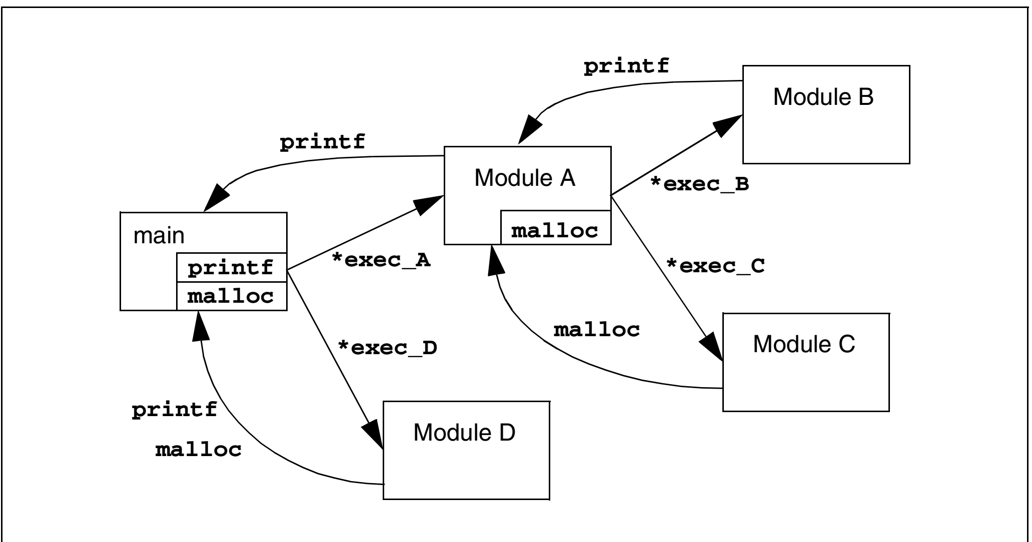


Figure 33: Example of an application with four load modules

In *Figure 33*, curved arrows (from load modules to parent module) represent load time symbol binding performed while the load module is loaded and straight arrows (from loader module to loaded module) represent explicit symbol address resolution performed through the loader library API.

The following points describe a possible scenario.

- At run-time the main module loads into memory the module A using the **rl_load_file()** function.
- The loader, in the process of loading A into memory, binds the symbol **printf** undefined in A to the **printf** function defined in main.
- The main module then retrieves a pointer to the function symbol **exec_A** in A using the **rl_sym()** function.
- As for A, the main module loads the module D and references to **printf** are resolved to the **printf** in main. In addition references to **malloc** in D are also

resolved to the **malloc** in main. The main module then retrieves a pointer to **exec_D** in D using the **rl_sym()** function.

- The main module will then, at some point, invoke the function **exec_A**.
- The **exec_A** function then loads a further two modules B and C.
- The undefined reference to **printf** in B is resolved to the **printf** in main (the loader searches first in A, and then in main).
- The undefined reference to **malloc** in C is resolved to the **malloc** in A (the loader searches for and finds it in A). Note that the **malloc** function called from D (**malloc** of main) is then different from the **malloc** function called from B (or C, or A) which is the **malloc** of A.
- Module A may in turn indirectly call functions or reference data in B and C after retrieving symbol addresses using the **rl_sym()** function.
- At any time, the main module or the module A may unload one of the loaded modules.

12.2.1 The relocatable code generation model

The relocatable code generation model is the same as the code generation model for the System V model with the following differences.

- No symbol can be preempted. Dynamic symbol binding always searches the current module first. This has the effect that a module containing a symbol definition can be sure that it will use this definition. This allows inlining in load modules for example.
- Weak references are treated the same way as undefined references in load modules. Therefore the first definition seen when traversing bottom-up the module tree is taken.

12.3 Relocatable loader library API

The relocatable loader library provides support for loading and unloading a module and for accessing a symbol address in a module by name. The relocatable loader library is provided as a library **librl.a** and its associated header file **rl_lib.h**.

The functions defined in this API are explained in the following sections.

rl_handle_t

All the functions manipulating a load module use a pointer to the **rl_handle_t** type. This is an abstract type for a load module handle.

A load module handle is allocated by the **rl_handle_new()** function and deallocated by the **rl_handle_delete()** function.

The main module handle is statically allocated and initialized in the startup code of the main module.

A module handle references one loaded module at a time. To load another module from the same handle, the previous module must first be unloaded.

rl_handle_new

Allocate and initialize a new handle

Synopsis

```
rl_handle_t *rl_handle_new(
            const rl_handle_t *parent,
            int mode);
```

Arguments

parent	The handle of the parent module.
mode	Reserved for future extensions.

Returns

The newly initialized handle or **NULL** on failure.

Description

This function allocates and initializes a new handle that can be used for loading and unloading a load module.

The handle of the parent module to which the loaded module will be connected is specified by the **parent** argument.

The **mode** argument is reserved for future extensions and must be **0**.

Generally, a load module will be attached to the module using this function, therefore a handle will typically be allocated as follows:

```
rl_handle_t *new_handle = rl_handle_new(rl_this(), 0);
```

rl_handle_delete

Finalize and deallocate a module handle

Synopsis

```
int rl_handle_delete(
            rl_handle_t *handle);
```

Arguments

handle	The handle to deallocate.

Returns

Returns **0** for success, **-1** for failure.

Description

This function finalizes and deallocates a module handle.

The handle must not hold a loaded module. The loaded module must have been first unloaded by **rl_unload()** before calling this function. If successful, the value returned is **0**. Otherwise, the value returned is **-1** and the error code returned by **rl_errno()** is set accordingly.

rl_this

Return the handle for the current module

Synopsis

```
rl_handle_t *rl_this(void);
```

Arguments

None.

Returns

The handle for the current module.

Description

This function returns the handle for the current module. If called from the main module, it returns the handle of the main module. If called from a loaded module, it returns the handle that holds the loaded module.

This function is used when allocating a handle with **rl_handle_new()**. It can also be used, for example, to retrieve a symbol in the current module:

```
void *symbolPtr = rl_sym(rl_this(), "_symbol");
```

rl_parent

Return the handle for the parent of the current handle

Synopsis

```
rl_handle_t *rl_parent(void);
```

Arguments

None.

Returns

The handle for the parent of the current handle, or **NULL** if there is no parent module.

Description

This function returns the handle for the parent of the current handle (as returned by **rl_this()**).

It may be used, for example, to find a symbol in one of the parent modules:

```
void *parentSymbolPtr = rl_sym_rec(rl_parent(), "_symbol");
```

rl_load_addr

Return the memory load address of a loaded module

Synopsis

```
const char *rl_load_addr(
            rl_handle_t *handle);
```

Arguments

handle	The handle for the loaded module.

Returns

The memory load address of the loaded module, or **NULL**.

Description

This function returns the memory load address of a loaded module. It returns **NULL** if the handle does not hold a loaded module or if the handle passed is the main module handle.

rl_load_size

Return the memory load size of a loaded module

Synopsis

```
unsigned int rl_load_size(
            rl_handle_t *handle);
```

Arguments

handle	The handle for the loaded module.

Returns

The memory load size of the loaded module, or **0**.

Description

This function returns the memory load size of a loaded module. It returns **0** if the handle does not hold a loaded module or if the handle passed is the main module handle.

rl_file_name

Return the file name associated with the loaded module handle

Synopsis

```
const char *rl_file_name(
            rl_handle_t *handle);
```

Arguments

handle	The handle for the loaded module.

Returns

The file name associated with the loaded module handle, or **NULL**.

Description

This function returns the file name associated with the loaded module handle. It returns **NULL** if no file name is associated with the current loaded module, if the handle does not hold a loaded module or if the handle passed is the main module handle.

rl_set_file_name

Specify a file name for the handle

Synopsis

```
int rl_set_file_name(
            rl_handle_t *handle,
            const char *f_name);
```

Arguments

handle	The handle for the module.
f_name	The file name to specify for the handle.

Returns

Returns **0** for success, **-1** for failure.

Description

This function is used to specify a file name for the **handle**. The file name is attached to the next module that will be loaded. It can be used to specify a file name for modules loaded from memory or a byte stream, or to force a different file name for a module loaded from a file.

This function returns **0** if the file name was successfully set, or **-1** and the error code returned by **rl_errno()** is set accordingly if a module is already loaded or if the application runs out of memory.

rl_load_buffer

Load a relocatable module into memory

Synopsis

```
int rl_load_buffer(
            rl_handle_t *handle,
            const char *image);
```

Arguments

handle	The handle for the module.
image	The image of the load module.

Returns

Returns **0** for success, **-1** for failure.

Description

This function loads a relocatable module into memory from the image referenced by **image**.

The function allocates the space for the loaded module from the heap, loads the segments from the memory image of the loadable module, links the module to the parent module of the handle and relocates and initializes the loaded module. This function calls the action callback functions for the **RL_ACTION_LOAD** action after loading and before executing any code in the loaded module.

0 is returned if the loading was successful, **-1** is returned on failure and the error code returned by **rl_errno()** is set accordingly.

rl_load_file

Load a relocatable module into memory from a file

Synopsis

```
int rl_load_file(
            rl_handle_t *handle,
            const char *f_name);
```

Arguments

handle	The handle for the module.
f_name	The file from which to load the relocatable module.

Returns

Returns **0** for success, **-1** for failure.

Description

This function loads a relocatable module into memory from the file specified by **f_name**.

This function opens the specified file with an **fopen()** call, allocates space for the loaded module from the heap, loads the segments from the file, links the module to the parent module of the handle, relocates and initializes the loaded module. The file is closed with **fclose()** before returning. This function calls the action callback functions for the **RL_ACTION_LOAD** action after loading and before executing any code in the loaded module.

0 is returned if the loading was successful, **-1** is returned on failure and the error code returned by **rl_errno()** is set accordingly.

rl_load_stream

Load a relocatable module into memory from a byte stream

Synopsis

```
typedef int rl_stream_func_t (
            void *cookie,
            char *buffer,
            int length);

int rl_load_stream(
            rl_handle_t *handle,
            rl_stream_func_t *stream_func,
            void *stream_cookie);
```

Arguments

handle	The handle for the module.
stream_func	The user specified callback function.
stream_cookie	The user specified state.

Returns

Returns **0** for success, **-1** for failure.

Description

This function loads a relocatable module into memory from a byte stream provided via a user specified callback function **stream_func** and the user specified state **stream_cookie**.

The callback function must be of type **rl_stream_func_t**. It is called multiple times by the loader to retrieve the load module data into the buffer **buffer** of length **length** until the module is loaded into memory. The loader will always call the callback function with a buffer length strictly greater than 0. The **stream_cookie** argument passed to **rl_load_stream** is passed to the callback function in its **cookie** parameter. The **cookie** parameter is intended to be used by the callback function to update a private state.

The callback function must return the number of bytes transferred. If the returned value is less than the specified buffer length or is **-1**, **rl_load_stream()** will in turn return an error and the error code returned by **rl_errno()** is set accordingly.

The **rl_load_stream()** function allocates the space for the loaded module from the heap, loads the segments by calling the callback function, links the module to the parent module of the handle, relocates and initializes the loaded module. This function calls the action callback functions for the **RL_ACTION_LOAD** action after loading and before executing any code in the loaded module.

0 is returned if the loading was successful, **-1** is returned on failure and the error code returned by **rl_errno()** is set accordingly.

This function can be used as an alternative to **rl_load_buffer()** or **rl_load_file()** to allow any loading method to be implemented.

The following example illustrates how the **rl_load_file()** function may be implemented using the **rl_load_stream()** function:

```
/* User implementation of the callback function that reads from a
file. */
static int rl_stream_read(FILE *file, char *buffer, int length)
{
   int nbytes;
   nbytes = fread(buffer, 1, length, file);
   return nbytes;
}
...
{
   /* Loads the module from a file.*/
   FILE *file;
   int status;
   file = fopen(f_name, "rb");
   if (file == NULL) { /* ... error ...*/ }
   status = rl_load_stream(handle,
            (rl_stream_func_t *)rl_stream_read, file);
   if (status == -1) { /* ... error ...*/ }
   fclose(file);
}
...
```

rl_unload

Unload a previously loaded relocatable module

Synopsis

```
int rl_unload(
            rl_handle_t *handle);
```

Arguments

handle	The handle for the module.

Returns

Returns **0** for success, **-1** for failure.

Description

This function unloads a previously loaded relocatable module. It finalizes, unlinks, and frees allocated memory for the loaded module. This function calls the action callback functions for the **RL_ACTION_UNLOAD** action before unloading and after having executed finalization code in the module.

The return value is **0** if the unloading is successful, otherwise the return value is **-1** and the error code returned by **rl_errno()** is set accordingly.

rl_sym

Return a pointer reference to the symbol in the loaded module

Synopsis

```
void *rl_sym(
            rl_handle_t *handle,
            const char *name);
```

Arguments

handle	The handle for the loaded module.
name	The symbol in the loaded module.

Returns

The pointer reference to the symbol.

Description

This function returns a pointer reference to the symbol **name** in the loaded module specified by **handle**.

This function searches the dynamic symbol table of the loaded module and returns a pointer to the symbol. The **handle** parameter can be the handle of any currently loaded module, or the handle of the main module.

If the symbol is not defined in the loaded module, **NULL** is returned. It is not generally an error for this function to fail. For example, the user may conditionally call a specific function only if it is defined in the module.

In this function, as well as for the **rl_sym_rec()** function, the **name** parameter must be the mangled symbol name. For SH-4 modules, C names are always mangled by prefixing the name with an underscore (_). For example, to return a reference to the **printf()** function, the symbol name passed to **rl_sym()** will be "**_printf**". Also, to access C++ symbols, the fully mangled name must be passed. The **sh4nm** tool can be used to obtain the mangled names of C and C++ symbols. **sh4c++filt** can be used to obtain the demangled names.

rl_sym_rec

Return a pointer reference to the symbol in the loaded module or one of its ancestors

Synopsis

```
void *rl_sym_rec(
           rl_handle_t *handle,
           const char *name);
```

Arguments

handle	The handle for the loaded module.
name	The symbol in the loaded module.

Returns

The pointer reference to the symbol.

Description

This function returns a pointer reference to the symbol named **name** found in the loaded module specified by **handle** or one of its ancestors.

This function searches the dynamic symbol table of the loaded module and returns a pointer to the symbol if found. If the symbol is not found, the function iteratively searches in the dynamic symbol table of the parent modules until the symbol is found. The **handle** parameter can be the handle of any currently loaded module, or the handle of the main module.

If the symbol is not defined in the loaded module or one of its ancestors, **NULL** is returned.

The **name** parameter must be the mangled symbol name as for the **rl_sym()** function (see *rl_sym on page 222*).

rl_foreach_segment

Iterate over all the segments of loaded module and call the supplied function

Synopsis

```
typedef rl_segment_info_t_ rl_segment_info_t;
typedef int rl_segment_func_t (
            rl_handle_t *handle,
            rl_segment_info_t *seg_info,
            void *cookie);
int rl_foreach_segment(
            rl_handle_t *handle,
            rl_segment_func_t *callback_fn,
            void *callback_cookie);
```

Arguments

handle The handle for the module.

callback_fn The user specified callback function.

callback_cookie

The user specified state.

Returns

Returns **0** for success, **-1** for failure.

Description

This function iterates over all the segments of loaded module specified by **handle** and calls back the user supplied function. For each segment the function **callback_fn** is called with the following parameters:

handle	The handle passed to **rl_foreach_segment()**.
seg_info	The current segment information.
cookie	The **callback_cookie** argument passed to **rl_foreach_segment()**.

The segment information returned in **seg_info** is a pointer to the following structure:

```
typedef unsigned int rl_segment_flag_t;
#define RL_SEG_EXEC         1
#define RL_SEG_WRITE        2
#define RL_SEG_READ         4
struct rl_segment_info_t_ {
   const char *seg_addr;
   unsigned int seg_size;
   rl_segment_flag_t seg_flags;
};
```

The user callback function must return **0** on success or **-1** on error.

In the case where the callback function returns an error, the **rl_foreach_segment()** function returns **-1** and the error code returned by **rl_errno()** is set to **RL_ERR_SEGMENTF**.

rl_add_action_callback

Add a user action callback function to the user action callback list

Synopsis

```
typedef unsigned int rl_action_t;
#define RL_ACTION_LOAD         1
#define RL_ACTION_UNLOAD       2
#define RL_ACTION_ALL          ((rl_action_t)-1)
typedef int rl_action_func_t (
            rl_handle_t *handle,
            rl_action_t action,
            void *cookie);
int rl_add_action_callback(
            rl_action_t action_mask,
            rl_action_func_t *callback_fn,
            void *callback_cookie);
```

Arguments

action_mask The set of actions for which the callback function must be called.

callback_fn The user specified callback function.

callback_cookie

The user specified state.

Returns

Returns **0** for success, **-1** for failure.

Description

This function adds a user action callback function to the user action callback list. It can be called any number of times with different callback functions. The same callback function cannot be added more than once.

For each defined action, each callback function is called in the order it was added to the callback list. The callback functions are not attached to a particular module and are called for any loaded/unloaded modules.

This function returns **0** on success and **-1** on failure. No error code is set. This function can fail if a callback function is already in the callback list or if the program runs out of memory.

The type **rl_action_t** defines the action flags for module loading/unloading and is passed to the action function callback. The action flags can be OR-ed to create an action mask which can be passed to the function **rl_add_action_callback()**. The actions defined are:

RL_ACTION_LOAD	The callback is called just after the module has been loaded in memory and the cache has been synchronized. No module code has been executed.
RL_ACTION_UNLOAD	The callback is called just before the module is unloaded from memory. No module code will be executed after this point.
RL_ACTION_ALL	The callback will be called for any of the above actions.

The type for the user action callback function is **rl_action_func_t**. The parameters passed to the callback function when it is called are:

handle	The handle that performed the action.
action	The action performed.
cookie	The **callback_cookie** parameter passed to **rl_add_action_callback()**.

The callback function returns **0** on success and **-1** on failure, in the case of failure the loading (or unloading) of the module is undone and the error code returned by **rl_errno()** is set to **RL_ERR_ACTIONF**.

rl_delete_action_callback

Remove a user function from the action callback list

Synopsis

```
int rl_delete_action_callback(
            rl_action_func_t *callback_fn);
```

Arguments

callback_fn The user specified callback function.

Returns

Returns **0** for success, **-1** if the callback was not present in the callback list.

Description

This function removes from the action callback list the specified callback function. It returns **0** if the callback was removed, or **-1** if it was not present in the callback list. No error code is set.

rl_errno

Return the error code for the last failed function

Synopsis

```
int rl_errno(rl_handle_t *handle);
```

Arguments

handle The handle for the module.

Returns

The error code for the last failed function.

Description

This function returns the error code for the last failed function. *Table 43* lists the possible codes.

Error code	Diagnostic	Possible error causing functions
RL_ERR_NONE	No previous call has failed.	
RL_ERR_MEM	Ran out of memory (**rl_memalign()** failed).	**rl_load_buffer()**, **rl_load_file()**, **rl_load_stream()**, **rl_set_file_name()**
RL_ERR_ELF	The load module is not a valid ELF file.	**rl_load_buffer()**, **rl_load_file()**, **rl_load_stream()**
RL_ERR_DYN	The load module is not a dynamic library.	**rl_load_buffer()**, **rl_load_file()**, **rl_load_stream()**

Table 43: Errors returned by rl_errno()

Error code	Diagnostic	Possible error causing functions
RL_ERR_SEG	The load module has invalid segment information.	**rl_load_buffer()**, **rl_load_file()**, **rl_load_stream()**
RL_ERR_REL	The load module contains invalid relocations.	**rl_load_buffer()**, **rl_load_file()**, **rl_load_stream()**
RL_ERR_RELSYM	A symbol was not found a load time. **rl_errarg()** returns the symbol name.	**rl_load_buffer()**, **rl_load_file()**, **rl_load_stream()**
RL_ERR_SYM	The symbol is not defined in the module. **rl_errarg()** returns the symbol name.	**rl_sym()**, **rl_sym_rec()**
RL_ERR_FOPEN	The file cannot be opened by **rl_fopen()**.	**rl_load_file()**
RL_ERR_FREAD	Error while reading the file in **rl_fread()**.	**rl_load_file()**
RL_ERR_STREAM	Error while loading the file from a stream.	**rl_load_stream()**
RL_ERR_LINKED	Module handle is already linked.	**rl_load_file()**, **rl_load_buffer()**, **rl_load_stream()**, **rl_handle_delete()**
RL_ERR_NLINKED	Module handle is not yet linked.	**rl_unload()**, **rl_sym()**, **rl_sym_rec()**, **rl_foreach_segment()**
RL_ERR_SEGMENTF	Error in segment function callback.	**rl_foreach_segment()**
RL_ERR_ACTIONF	Error in action function callback.	**rl_load_file()**, **rl_load_buffer()**, **rl_load_stream()**

Table 43: Errors returned by rl_errno()

rl_errarg

Return the name of the symbol that could not be resolved

Synopsis

```
const char *rl_errarg(
            rl_handle_t *handle);
```

Arguments

handle	The handle for the module.

Returns

The name of the symbol that could not be resolved.

Description

If **rl_errno()** returns **RL_ERR_RELSYM** or **RL_ERR_SYM**, this function returns the name of the symbol that could not be resolved.

rl_errstr

Return a string for an error code

Synopsis

```
const char *rl_errstr(
           rl_handle_t *handle);
```

Arguments

handle	The handle for the module.

Returns

A string for the error code.

Description

This function returns a string for the error code reported by **rl_errno()**. For example:

```
...
void *sym = rl_sym(handle, "symbol");
if (sym == NULL) fprintf(stderr, "failed: %s\n", rl_errstr(handle));
...
```

If **symbol** is not defined in the module referenced by **handle** then the following message is displayed:

```
failed: symbol not found: symbol
```

12.4 Customization

The relocatable loader library defines a number of functions which it uses internally for providing services such as heap memory management and file access. These functions may be overridden by the application in the main module to provide custom implementations of these functions.

12.4.1 Memory allocation

```
void *rl_malloc(int size);
void *rl_memalign(int align, int size);
void rl_free(void *ptr);
```

These functions are used to allocate and deallocate space for the loaded module image and for the handle objects.

The default behavior for these functions is to call the standard C library functions **malloc()**, **memalign()** and **free()** respectively.

Note: All three functions must be overridden and linked with the main module if providing a custom implementation.

12.4.2 File management

```
void *rl_fopen(const char *f_name, const char *mode);
int rl_fread(char *buffer, int eltsize, int nelts, void *file);
int rl_fclose(void *file);
```

These functions are used by the **rl_load_file()** function to open, read and close a file handle.

The default behavior for these functions is to call the standard C library functions **fopen()**, **fread()** and **fclose()** respectively.

Note: All three functions must be overridden and linked with the main module if providing a custom implementation.

12.5 Writing and building a relocatable library and main module

12.5.1 Example source code

The following sections use the very simple relocatable library, **rl_hello.c**:

```
#include <stdio.h>
void library_function (void)
{
   printf ("Hello World!\n");
}
```

The following main module, **main.c**, is used to load the library.

```
#include <stdio.h>
#include <rl_lib.h>
int main (void)
{
   rl_handle_t *lib;
   void (*lib_function)();

   kernel_initialize(NULL);
   kernel_start();

   printf ("In main program\n");

   lib = rl_handle_new (rl_this(), 0);
   rl_load_file (lib, "rl_hello.rl");
   lib_function = rl_sym (lib, "_library_function");
   if ( ! lib_function )
   {
      printf ("Error %d: %s (%s)\n", rl_errno(lib), rl_errstr(lib),
               rl_errarg(lib));
      exit(1);
   }
   lib_function();
   return 0;
}
```

Note: *The library requires the* **printf** *symbol to be present in the main module. The* **printf** *symbol is naturally present because the main module also requires the* **printf** *symbol. If this was not the case then steps would have to be taken to ensure that it was linked in or else the relocatable library will fail to load.*

12.5.2 Building a simple relocatable library

To build a relocatable library that can be loaded by the **rl_lib** loader, additional compiler and linker options must be used.

To build a loadable module, the **-fpic** option is required when compiling and the **-rlib** and **-nostdlib** options are required when linking.

The following is a simple example of building a **hello world** loadable module:

```
sh4gcc -o rl_hello.o -fpic -c rl_hello.c
sh4gcc -o rl_hello.rl -mruntime=os21 -nostdlib -rlib rl_hello.o
```

Note: *It is necessary to use* **-nostdlib** *to prevent the C run-time libraries being linked into each loadable module. If it is omitted, the link or subsequent load will fail.*

Alternatively, the relocatable library can be built using a single command:

```
sh4gcc -o rl_hello.rl -fpic -mruntime=os21 -nostdlib -rlib rl_hello.c
```

12.5.3 Building a simple main module

To build a main module suitable for loading a module only the **-rmain** option is required when linking. No special compile time options are required for the main module.

The following is an example of building a main module capable of loading modules for the STMediaRef-Demo target:

```
sh4gcc -o a.out -mboard=mediaref -mruntime=os21 -rmain main.c
```

Note: *This example assumes that the main module provides all the standard library symbols required by the relocatable library.*

12.5.4 Running and debugging the main module

A main module can be loaded into GDB as normal, for example:

```
sh4gdb a.out
```

The debugger will not become aware of symbols in the relocatable libraries until the module has loaded them.

For example, given the previous example in *Section 12.5.1* (compiled with the **-g** option), the following command attempts to set a breakpoint on an, as yet, unknown symbol:

```
(gdb) break library_function
Function "library_function" not defined.
Make breakpoint pending on future shared library load? (y or [n])
```

Answering **y** sets the breakpoint on a symbol of that name, if and when one is loaded.

See *Section 12.6 on page 238* for details on how to debug issues with relocatable library loading and linking.

12.5.5 Importing and exporting symbols

For the relocatable loader system to function, the main module, or a loaded module, must provide services to the other load modules. In order to avoid a load error when loading a module, it is usual for the referenced symbols to be linked into the main module. When the services are present in a library at the time of linking the main module, the referenced symbols must be imported. To import symbols, the linker needs to be provided with an import script.

An import script can be generated by the **sh4rltool** utility. There are two common cases:

- when the required services are well defined, the list of symbols can be passed to the **sh4rltool** utility to generate an import script,
- when the list of services is not defined but the load modules are available, the load modules can be passed to **sh4rltool** so that an import script may be generated from the set of symbols that are required by the load modules.

Note: The **-h** *option of* ***sh4rltool*** *provides help on its command line options.*

To generate an import script from a list of symbols specified in the file **prog_import.lst** (one symbol per line):

```
sh4rltool -i -s -o prog_import.ld prog_import.lst
```

To generate an import script from a list of load modules, **liba.rl** and **libb.rl**, that may be loaded by the main module:

```
sh4rltool -i -o prog_import.ld liba.rl libb.rl
```

Once the import script is created, the main module can then be linked using it, for example:

```
sh4gcc -o a.out -mboard=mediaref -mruntime=os21 -rmain prog_import.ld ...
```

In addition to import scripts, the **sh4rltool** utility can also generate export scripts that can be used to reduce the size of the dynamic symbol table in the main module or the load modules. The export script defines the set of symbols (and only these) that must be exported to the other modules through the dynamic symbol table. These symbols are then accessible by the load time symbol binding process and by the calls to **rl_sym()** and **rl_sym_rec()**. The export script is not mandatory since, by default, all global symbols are exported.

There are two common cases for generating export scripts:

- when an import script is required for the module, the export script can be generated at the same time as the symbols to export are generally the ones that are imported,
- for a load module that has a well known external interface, the export script can be generated from a list of symbols to export.

The following example shows how to generate an export script and import script for a list of modules which is then used when linking the main module. Only the symbols from **liba.rl** and **libb.rl** are imported into the main module and exported by it.

```
sh4rltool -i -e -o prog_import_export.ld liba.rl libb.rl
sh4gcc -o a.out -mboard=mediaref -mruntime=os21 -rmain
       prog_import_export.ld ...
```

To generate an export script for a load module with a well defined interface specified in the file **liba_export.lst** (one symbol per line):

```
sh4rltool -e -s -o liba_export.ld liba_export.lst
sh4gcc -o liba.rl -nostdlib -rlib liba_export.ld ...
```

12.5.6 Optimization options

When compiling a load module with the **-fpic** option, some overhead occurs in the generated code to access functions and data objects.

Fine grain visibility can be specified with the **__attribute__((visibility(...)))** GNU C extension at the source code level.

For detailed information on the visibility specification refer to the compiler options documentation and to the ELF System V Dynamic Linking ABI.

12.6 Debugging support

12.6.1 GDB support

The debugging of dynamically loaded modules is implemented in the same way as for System V dynamic shared objects. The main module debugging information is loaded at load time of the application. The load modules debugging information is loaded at load time of the load modules.

In order for GDB to be able to update its debugging information, the loader maintains a list of loaded modules together with their file names (which contain the debugging information) and the load address of the module. Each time a new module is loaded the loader calls a specific function. GDB sets a breakpoint on this specific function and traverse the list when this breakpoint occurs to find new loaded modules and load the debugging information.

In order to find the file that contains the debug information, the loader must know the location of the load module file. This is automatic in the case of **rl_load_file()** as the file name is specified in the interface. For the **rl_load_buffer()** and **rl_load_stream()** functions, the user must set the file name with a call to the **rl_set_file_name()** function.

The following example enables automatic debugging of a load module loaded with **rl_load_buffer()**:

```
{
   int status;
   rl_handle_t *handle = rl_handle_new(rl_this(), 0);
   if (handle == NULL) { /* error */ }
#ifdef DEBUG_ENABLED
   rl_set_filename(handle, "path_to_the_file_for_the_module");
#endif
   status = rl_load_buffer(handle, module_image);
   if (status == -1) { /* error */ }
   ...
}
```

12.6.2 Verbose mode

The **rl_lib** loader library can be configured to print details of its progress at run time. This is done by setting the **RL_VERBOSE** environment variable.

For example, place the following statement in the main module before using the loader library functions:

```
putenv("RL_VERBOSE=1");
```

12.7 Action callbacks

Action callbacks may be used with a profiling support library, or a user defined package that needs to be informed that a segment has just been loaded or is on the point of being unloaded, by using the user action callback interface.

The following is an example that iterates over the segment list and declares the executable segments to a profiling support library on the loading and unloading of a module.

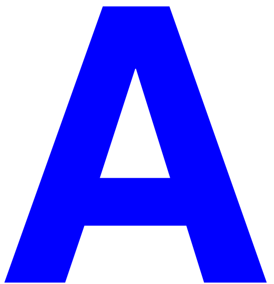
```
static int segment_profile(rl_handle_t *handle, rl_segment_info_t *info,
               void *cookie)
{
   rl_action_t action = *((rl_action_t *)cookie);
   const char *file_name = rl_file_name(handle);
   if (file_name != NULL && (info->seg_flags & RL_SEG_EXEC) {
      if (action == RL_ACTION_LOAD) {
         /* Call profiling interface for adding a code region. */
```

```
            profiler_add_region(file_name, info->seg_addr, info->seg_size);
        }
        if (action == RL_ACTION_UNLOAD) {
            /* Call profiling interface for removing a code region. */
            profiler_remove_region(file_name, info->seg_addr,
                    info->seg_size);
        }
    }
    return 0;
}

static int module_profile(rl_handle_t *handle, rl_action_t action,
             void *cookie)
{
    rl_foreach_segment(handle, segment_profile, (void *)&action);
    return 0;
}

int main()
{
    ...
    if (rl_add_action_callback(RL_ACTION_ALL, module_profile, NULL)==-1){
        fprintf(stderr, "rl_add_Action_callback failed\n");
        exit(1);
    }
    ...
    status = rl_load_file(handle, file_name);
    ...
    return 0;
}
```

Appendices



Toolset tips

A.1 Managing memory partitions with OS21

OS21 allows memory partitions to be created in order to manage areas of memory. For more information, see the *OS21 User Manual* (ADCS 7358306). There are several reasons why this might be required, for example:

- to implement an allocation algorithm which is appropriate to an application (for example, to apply some alignment constraint to allocated blocks),
- to manage a special area of memory not visible to the normal memory managers (for example, on-chip RAM or peripheral device RAM),
- to manage a memory region which has special caching issues.

The first step in managing a memory partition is to know the location of the memory and its size. This may be implicitly known, for instance, the address and size of on-chip RAM is a characteristic of the CPU. To select a pool of memory to manage with an allocator, either declare it statically, or allocate it from another partition or from the general heap:

```
static unsigned char *my_device_RAM = SOME_ADDRESS;
static unsigned char my_static_pool [65536];
       unsigned char *my_alloced_pool = malloc (65536);
```

The next step is to select the allocation strategy to use with the memory. There are three managers provided with OS21:

```
my_pp = partition_create_simple (my_pool, 65536);
my_pp = partition_create_fixed (my_pool, 65536, block_size);
my_pp = partition_create_heap (my_pool, 65536);
```

Alternatively, a special purpose allocator can be used. In order to use a special purpose allocator, a partition which uses the required memory management implementation must be created with the **partition_create_any()** call. This call takes the size of a control structure which the allocator uses to manage the memory, and the addresses of functions which perform allocation, freeing, reallocation and status reporting. In the following example, a simple linear allocator is implemented, with no **free** or **realloc** methods.

```
#include <os21.h>
#include <stdio.h>

/*
 * Declare memory to be managed by our partition
 */
static unsigned char my_memory[65536];

/*
 * Declare the management data we use to control the partition
 */
typedef struct
{
   unsigned char * base;
   unsigned char * limit;
   unsigned char * free_ptr;
} my_state_t;

/*
 * Allocation routine - really simple!
 */
static void *my_alloc(my_state_t *state, size_t size)
{
   void *ptr = NULL;

   if(size && ((state->free_ptr + size) < state->limit))
   {
      ptr = state->free_ptr;
      state->free_ptr = state->free_ptr + size;
   }

   return ptr;
}
```

```
/*
 * Partition status routine
 * Note that status->partition_status_used is not filled
 * in here - partition_status sets this field automatically.
 */
static int my_status(my_state_t *state,
      partition_status_t *status,
      partition_status_flags_t flag)
{
   status->partition_status_state = partition_status_state_valid;
   status->partition_status_type = partition_status_type_user;
   status->partition_status_size = state->limit - state->base;
   status->partition_status_free = state->limit - state->free_ptr;
   status->partition_status_free_largest = state->limit -
          state->free_ptr;
}

/*
 * Initialization routine, called when a partition is created
 */
static void my_initialize(partition_t *pp,
         unsigned char *base,
         size_t size)
{
   my_state_t *state = partition_private_state(pp);

   state->free_ptr = base;
   state->base = base;
   state->limit = base + size;
}

int main(void)
{
   partition_t *pp;
   void *ptr;

   /*
    * Start OS21
    */
   kernel_initialize(NULL);
   kernel_start();
```

```
    /*
     * Create new partition
     */
    pp = partition_create_any(sizeof (my_state_t),
           (memory_allocate_fn)my_alloc,
           NULL, /* no free method */
           NULL, /* no realloc method */
           (memory_status_fn)my_status);

    /*
     * Initialize it
     */
    my_initialize(pp, my_memory, sizeof(my_memory));

    /*
     * Try it out!
     */
    printf("Alloc 16 bytes : %p\n", memory_allocate(pp, 16));
    printf("Alloc 10 bytes : %p\n", memory_allocate(pp, 10));
    printf("Alloc  1 bytes : %p\n", memory_allocate(pp,  1));

    printf("Done\n");

    return 0;
}
```

A.2 Memory managers

The run-time libraries provide several memory managers. These provide heap, simple and fixed block allocators. The heap algorithm used by OS21 is very simple. It maintains a single free list of blocks, and allocates from the first one which can satisfy the request. Blocks added to the free list are coalesced with neighbors to reduce fragmentation.

The partition manager in OS21 can provide extensive run-time checking when OS21 is built with the **-DCONF_DEBUG_ALLOC** option specified. This checking is enabled for all partitions, including those maintained by user supplied routines (see *Section A.1*). With this option enabled, the partition manager over-allocates and places scribble guards above and below the block of memory passed back to the user. These guards are filled with a known pattern when the block is allocated, and are checked when the block is freed in order to detect writes which have occurred outside of the block (for example, writing past the end of an array). When OS21 terminates, the partition manager reports any blocks of memory which have been allocated but not freed.

newlib provides Doug Lea's allocator (version 2.6.4). The design of Doug Lea's allocator is discussed at length in http://gee.cs.oswego.edu/dl/html/malloc.html. The design goals for this widely used allocator include minimizing execution time and memory fragmentation.

newlib can be rebuilt (see *Section 7.3.3: Building newlib on page 146*) with debugging switched on in **malloc_r.c** (**-DDEBUG**) to enable extensive run-time checking. With debugging enabled, calls to **malloc_stats()** and **mallinfo()** attempt to check that every memory block in the heap is consistent.

A.3 OS21 scheduler behavior

The scheduler in OS21 provides priority based preemptive FIFO scheduling, with optional timeslicing. The following list summarizes its behavior.

- 256 priority levels.
- FIFO scheduling within priority level.
- Tasks get preempted when higher priority tasks become runnable.
- Preemption can be disabled and re-enabled with **task_lock()** and **task_unlock()**, see *Section A.4.2.1 on page 250*.
- Preemptions held pending while **task_lock()** is in effect, occur when **task_unlock()** releases the lock.
- Tasks which get preempted are placed at the head of the run queue for their priority level.
- Tasks which yield are placed at the tail of the run queue for their priority level.
- Tasks which become runnable are placed at the tail of the run queue for their priority level.
- Tasks which get timesliced are placed at the tail of the run queue for their priority level.
- Timeslicing is optional (off by default), and can be enabled or disabled by calling **kernel_timeslice()**.
- The default timeslice frequency is 50 Hz.
- The timeslice frequency can be set between 1 and 500 Hz by changing the value of the variable **bsp_timeslice_frequency_hz**, either before calling **kernel_initialize()**, or in the BSP library routine **bsp_initialize()**.

A.4 Managing critical sections in OS21

A critical section is a region of code where exactly one thread of execution can be running at any one time. There are two forms of critical section to consider:

- **task / interrupt**,
- **task / task**.

A.4.1 task / interrupt critical sections

task / interrupt critical sections are implemented within the context of a running task by masking interrupts, so the interrupt handler you are serializing with cannot run. OS21 provides three calls for interrupt masking and unmasking.

A.4.1.1 interrupt_mask(), interrupt_mask_all() and interrupt_unmask()

OS21 provides this API to allow the priority level of the CPU to be raised and lowered. The CPU's interrupt level provides a simple mechanism to mask interrupts from reaching the CPU. Any interrupts which have a priority that is strictly greater than the CPU's interrupt priority can interrupt the CPU. Any interrupts which have a priority less than or equal to the CPU's interrupt priority are masked out and cannot therefore affect the CPU.

The CPU's interrupt level is normally zero, meaning that all interrupts are unmasked. Any interrupt masked by the CPU's interrupt level when it becomes active, is asserted to the CPU when the CPU's interrupt priority is lowered below that of the active interrupts.

To serialize with an interrupt handler which is interrupting at level X, only the interrupts up to level X need to be masked. This stops all interrupts with a priority less than or equal to X from reaching the CPU, but leaves higher priority interrupts unaffected.

`interrupt_mask()` sets the CPU's interrupt level to the value specified, and **`interrupt_mask_all()`** sets the CPU's interrupt level to its maximum.

`interrupt_mask()` and **`interrupt_mask_all()`** also perform an implicit **`task_lock()`**, to prevent pre-emption. This is because if a context switch occurred whilst under an **`interrupt_mask()`**, the CPU's interrupt priority would be changed to the value required by the incoming task, thus breaking the critical section. Care should be taken to ensure that an explicit deschedule does not occur whilst interrupts are masked (for example, blocking on a busy semaphore or mutex).

A.4.2 task / task critical sections

OS21 provides a number of mechanisms for achieving task / task critical sections, each of which has its own cost and benefit.

A.4.2.1 task_lock() and task_unlock()

These calls provide a lightweight mechanism to prevent preemption. With a **task_lock()** in effect, the running task is guaranteed that the scheduler will not preempt it if a higher priority task becomes runnable, or a timeslice interrupt occurs. In addition, any calls to **task_reschedule()** have no effect.

It is possible for the running task to explicitly give up the CPU while a **task_lock()** is active. In fact this is the only way another task can be scheduled while the running task holds a **task_lock()**. Explicit yielding of the CPU occurs when the running task calls **task_yield()** or a blocking OS21 function, for example:

- calls to **task_delay()** or **task_delay_until()** specifying a time in the future,
- waiting on an unposted event flag, busy semaphore or empty message queue with the timeout period not set to **TIMEOUT_IMMEDIATE**,
- waiting for a busy mutex.

When the running task resumes execution, the **task_lock()** is automatically reinstated by OS21. The critical section provided by **task_lock()** and **task_unlock()** has been broken and so, if the task blocks, it is quite weak. If a strong critical section is required when using these calls, care must be taken to ensure that called functions do not block. This is not always possible, for example, when calling a library function.

Advantages

- Light weight.
- No need to allocate a synchronization object.
- Critical sections can nest.

Disadvantages

- Critical sections broken if the running task explicitly blocks.

A.4.2.2 Mutexes

Mutexes in OS21 are designed to provide robust critical sections. The critical section remains in place even if the task in the critical section blocks. Exactly one task is able to own a mutex at any one time. OS21 provides two forms of mutex: FIFO and priority.

FIFO mutexes have the simplest semantics. When tasks try to acquire a busy FIFO mutex they are queued in request order. When a task releases a FIFO mutex, ownership is passed to the task at the head of the waiting queue, and it is unblocked.

Priority mutexes are more complex. When tasks try to acquire a busy priority mutex, they are queued on the mutex in order of descending task priority. In this way, the task at the head of the wait queue is always the one with the highest priority, regardless of when it attempted to acquire the mutex.

Priority mutexes also implement what is known as priority inheritance. This mechanism temporarily boosts the priority of the task that owns a mutex to be the same as the priority of the task at the head of the wait queue. When the owning task releases the mutex, its priority is returned to its original level. This behavior prevents priority inversion, where a low priority task can effectively prevent a high priority task from running. This can happen if a low priority task owns a mutex which a high priority task is waiting for, and a mid level priority task starts running, the low priority task cannot run, and hence cannot release the mutex, causing the high priority task to wait.

Ownership of FIFO or priority mutexes has the effect of making the task immortal, that is, immune to **`task_kill()`**. This is intended to prevent deadlock in the event that a task owning a mutex is killed; the mutex would otherwise be left owned by a dead task, and hence it would be locked out for ever. If **`task_kill()`** is carried out on a mutex owning task, the task remains running until it releases the mutex, at which point the **`task_kill()`** is actioned.

Both forms of mutex can be recursively taken by the owning task without deadlock.

Advantages

- Robust critical section.
- Can be recursively taken without deadlock.
- Tasks are immortal while holding a mutex.
- FIFO mutexes provide strictly fair access to the mutex.
- Priority mutexes provide priority ordered access, with priority inheritance.

Disadvantages

- Mutexes have to be created before they can be used.
- More costly than **`task_lock()`** and **`task_unlock()`**.
- Priority mutexes have a higher cost than FIFO mutexes, due to priority inheritance logic.
- Strictly for task / task interlock. Cannot be used by interrupt handlers.

A.4.2.3 Semaphores

Semaphores in OS21 can be used for a variety of purposes, as discussed in the *OS21 User Manual*. They can be used to provide a robust critical section, in a similar fashion to mutexes, but with some major differences.

- Semaphores cannot be taken recursively; any attempt to do this results in deadlocking the calling task.
- Like mutexes, both FIFO and priority queuing models are provided, but unlike priority mutexes, priority semaphores do not implement priority inheritance.
- Tasks are not automatically made immortal when they acquire a semaphore.
- Semaphores can be used with care from interrupt handlers.

Advantages

- Robust critical section.
- FIFO and priority queuing models are available, but no priority inheritance.
- No difference in cost between a FIFO and a priority semaphore.
- Slightly lower execution cost compared to mutexes, due to simpler semantics.
- Can be used in an interrupt handler, provided **`TIMEOUT_IMMEDIATE`** is used when trying to acquire, and the interrupt handler is written to cope with not acquiring the semaphore.

Disadvantages

- Semaphores have to be created before they can be used.
- More costly than **`task_lock()`** and **`task_unlock()`**.
- Cannot be taken recursively, since the system would deadlock.
- No immortality whilst holding; killing an owning task would be dangerous.

A.4.2.4 Disabling timeslicing

When running with timeslicing enabled, and a very light weight task / task critical section is required (which does **not** involve accessing a synchronization object), it is possible to temporarily disable timeslicing. For example:

```
kernel_timeslice (0);

...critical section...

kernel_timeslice (1);
```

Whilst very efficient, this approach should be used with great care since the **kernel_timeslice()** API has an immediate global effect. This means that if the task blocks in this region (for example, calls **task_delay()**, blocks waiting for a synchronization object, or signals a synchronization object and gets preempted as a result), then timeslicing remains disabled for all other tasks. This can result in deadlock, for instance, if the other tasks are compute bound and rely on timeslicing to share the CPU.

A.5 Debugging with OS21

Note: Further information on debugging can be found in the Debugging with GDB manual.

A.5.1 Understanding OS21 stack traces

Every time OS21 is entered via an interrupt or exception, it captures the context of the CPU on the current stack. If interrupts nest, then there are multiple contexts captured, one for each interrupt. The information stored includes the complete register state of the CPU, details of what caused the context to be saved (interrupt or exception) and the task that was active at the time. More information is captured if the kernel is built with **CONF_DEBUG** defined as is the case when the **-mruntime=os21_d** compiler option is used to build the application, as this enables better stack tracing from debug kernels.

A stack trace is produced whenever an unexpected exception occurs. On the ST40 these stack traces have the following general form:

```
OS21: ============================================================
OS21: Stack trace (<n> of <N>)

OS21: Fatal exception detected: ST40 exception code
OS21: Description of exception, possibly with faulting address

* Disassembly of instructions around faulting instruction

+ OS21: Active Task ID    : task ID
+ OS21: Active Task Stackp: stack pointer
+ OS21: Active Task name  : task name

<Register dump>

* OS21: ============================================================
* OS21: Stack trace (<n+1> of <N>)
*
* OS21: Took interrupt      : <interrupt EVT code>
* + OS21: Active Task ID    : <task ID>
* + OS21: Active Task Stackp: <stack pointer>
* + OS21: Active Task name  : <task name>
*
* <Register dump> ...
```

Note: The lines marked with a '' are only available from debug kernels.*

The lines marked with a '+' are only shown if the stack frame belongs to a task, not if the stack frame belongs to an interrupt handler.

The first stack trace shows the state of the CPU at the time the exception occurred. It should be possible to ascertain the cause of the exception from the description of the exception, reported faulting addresses and the register dump.

For example, consider the following program which creates a task that contains a deliberate misaligned write to memory.

```
#include <os21.h>

void my_task(void *ptr)
{
   *((unsigned int*)ptr) = 0xBA49;
}

int main (void)
{
   kernel_initialize(NULL);
   kernel_start();

   (void)task_create(my_task, (void*)0x12344321, 32768,
      OS21_MAX_USER_PRIORITY, "bang", 0);

   task_delay(time_ticks_per_sec());

   return 0;
}
```

Building this program with the compiler options **-g** and **-mruntime=os21_d**, and running it gives the following output:

```
OS21: ==========================================================
OS21: Stack trace (1 of 1)

OS21: Fatal exception detected: 0x00000100.
OS21: Data write to misaligned address 0x12344321

OS21:     0x880019C8 mov.l      @r14,r2
OS21:     0x880019CA mov.l      (3,pc),r1       ; (0x880019D8) 0x0000BA49
OS21: >>> 0x880019CC mov.l      r1,@r2
OS21:     0x880019CE add        #4,r14
OS21:     0x880019D0 mov        r14,r15
```

```
OS21: Active Task ID    : 0x8802E610
OS21: Active Task Stackp: 0x8803661C
OS21: Active Task name  : bang

OS21: R0:  0x00000000   R1:   0x0000BA49  R2:  0x12344321
OS21: R3:  0x00000003   R4:   0x12344321  R5:  0x12344321
OS21: R6:  0x00000006   R7:   0x00000007  R8:  0x880019C0
OS21: R9:  0x12344321   R10:  0x8800CDA0  R11: 0x0000000B
OS21: R12: 0x0000000C   R13:  0x0000000D  R14: 0x880366FC
OS21: R15: 0x880366FC

OS21: FR0_0:  0xFFFFBAD0   FR1_0:   0xFFFFBAD0  FR2_0:  0xFFFFBAD0
OS21: FR3_0:  0xFFFFBAD0   FR4_0:   0xFFFFBAD0  FR5_0:  0xFFFFBAD0
OS21: FR6_0:  0xFFFFBAD0   FR7_0:   0xFFFFBAD0  FR8_0:  0xFFFFBAD0
OS21: FR9_0:  0xFFFFBAD0   FR10_0:  0xFFFFBAD0  FR11_0: 0xFFFFBAD0
OS21: FR12_0: 0xFFFFBAD0   FR13_0:  0xFFFFBAD0  FR14_0: 0xFFFFBAD0
OS21: FR15_0: 0xFFFFBAD0

OS21: FR0_1:  0xFFFFBAD1   FR1_1:   0xFFFFBAD1  FR2_1:  0xFFFFBAD1
OS21: FR3_1:  0xFFFFBAD1   FR4_1:   0xFFFFBAD1  FR5_1:  0xFFFFBAD1
OS21: FR6_1:  0xFFFFBAD1   FR7_1:   0xFFFFBAD1  FR8_1:  0xFFFFBAD1
OS21: FR9_1:  0xFFFFBAD1   FR10_1:  0xFFFFBAD1  FR11_1: 0xFFFFBAD1
OS21: FR12_1: 0xFFFFBAD1   FR13_1:  0xFFFFBAD1  FR14_1: 0xFFFFBAD1
OS21: FR15_1: 0xFFFFBAD1

OS21: FPSCR: 0x000C0000   FPUL:   0xDEADBABE

OS21: GBR:   0x00000000   PC:     0x880019CC   SR:   0x40000000
OS21: MACH:  0xDEADBABE   MACL:   0xDEADBABE   PR:   0x88009D82

OS21: Aborted.
```

The exception has been decoded as a misaligned write to memory, and the bad address is **0x12344321**. It can be seen from the disassembly that the instruction causing the error is:

```
OS21: >>> 0x880019CC mov.l      r1,@r2
```

Looking at the register state for this stack frame we can see that the register R1 contains **0x0000BA49**, and R2 contains **0x12344321** as expected.

A.5.2 Identifying the function which took the exception

It is not possible to identify directly from an OS21 stack trace, the function that generated an exception. There are several ways to establish the function.

Using GDB

By placing a breakpoint on OS21's unexpected exception handler, it is possible to catch the exception in GDB, for example:

```
(gdb) break _kernel_exp_handler
Breakpoint 1 at 0x88001aaa: file src/os21/kernel/kernel.c, line 67.
(gdb) c
Continuing.
[Switching to Thread 2147483647]

Breakpoint 1, _kernel_exp_handler (exp_code=256, contextp=0x8803661c) at
src/os21/kernel/kernel.c:67
67      src/os21/kernel/kernel.c: No such file or directory.
        in src/os21/kernel/kernel.c
(gdb) info threads
  4 Thread 3 ("bang" (active & interrupted) [0x8802e610])  0x880019cc in
my_task (ptr=0x12344321) at test.c:5
  3 Thread 2 ("Idle Task" (active) [0x8802c1f0])  _md_kernel_task_launch
(entry_point=0x8, datap=0x9) at src/st40/kernel/kernel.c:164
  2 Thread 1 ("Root Task" (active) [0x88023c28])  _md_kernel_syscall
(functionp=0x880024a0 <_scheduler_context_switch>)
    at src/st40/kernel/syscall.c:42
* 1 Thread 2147483647 ("OS21 System Task" (active & running) [PSEUDO])
_kernel_exp_handler (exp_code=256, contextp=0x8803661c)
    at src/os21/kernel/kernel.c:67

Program received signal SIGTRAP, Trace/breakpoint trap.
[Switching to Thread 2147483647]
0x88019f64 in _asebrk () at dtf/dbgtrap.c:4
4       dtf/dbgtrap.c: No such file or directory.
        in dtf/dbgtrap.c
(gdb)
```

In this example, the thread which hit the breakpoint is a pseudo thread called **OS21 System Task**. This is fabricated by GDB to allow it to present the state of the system.

Thread 4 is indicated as being interrupted as it was running when the exception occurred. To examine the state of this thread, simply change context to that thread:

```
(gdb) thread 4
[Switching to thread 4 (Thread 3)]#0  0x880019cc in my_task
(ptr=0x12344321) at test.c:5
5         *((unsigned int*)ptr) = 0xBA49;
(gdb) print /x ptr
$1 = 0x12344321
(gdb)
```

Using sh4objdump

From the OS21 stack trace, note the value of the PC register of the first stack trace. In the example above, this is **0xA80019CC**. Next, generate a disassembly of the program using **sh4objdump**, starting and stopping, just before and just after, this address. This should reveal the name of the function which generated the exception. If it does not, start the disassembly a little further back. For example:

```
sh4objdump -d -j .text --start-address=0X880019C0
--stop-address=0X880019D0 a.out

a.out:     file format elf32-shl

Disassembly of section .text:

880019c0 <_my_task>:
880019c0:     e6 2f       mov.l   r14,@-r15
880019c2:     fc 7f       add     #-4,r15
880019c4:     f3 6e       mov     r15,r14
880019c6:     42 2e       mov.l   r4,@r14
880019c8:     e2 62       mov.l   @r14,r2
880019ca:     03 d1       mov.l   880019d8 <_my_task+0x18>,r1   ! 0xba49
880019cc:     12 22       mov.l   r1,@r2
880019ce:     04 7e       add     #4,r14
```

Using sh4addr2line

sh4addr2line provides the source file and line number for a specified address. Taking the PC to be the same as above (**0xA80019CC**), pass it to **sh4addr2line**, for example:

```
sh4addr2line -e a.out -f 0x880019CC
my_task
source-directory/test.c:5
```

Note: The program must contain debug information.

A.5.3 Catching program termination with GDB

The normal exit path for an application is to call **exit()**, so a breakpoint on this function catches typical application exit scenarios.

However, if OS21 detects an internal error, it panics. This involves calling the function **_kernel_panic()** with a string describing the situation. This function is a good place for a breakpoint to catch abnormal kernel situations. **_kernel_panic()** calls down to **bsp_panic()**, which provides a hook for your own panic handler, should you want to provide one.

Ultimately all exit paths go via the internal run-time library function **_SH_posix_Exit()**, so a breakpoint here catches every exit path.

A.6 General tips for GDB

A.6.1 Handling target connections

When debugging using the command line interface to GDB, you can avoid typing a sequence of commands by using a simple script and invoking it with **-x**:

```
sh4gdb -x script.cmd
```

For each target board, a set of user defined commands can be defined in your **.shgdbinit** file. Each command connects to the named target ready for debugging. The following example sets up a command which connects to a board known as **target1** (in this case an STMediaRef-Demo board), and loads the program specified, ready for debugging:

```
define target1
   file $arg0
   mediaref target1
   load
end
```

A.6.2 Path names on Windows

Windows allows a great deal of flexibility with path names, to the extent that it permits spaces to appear within path names. The GNU tools do not tolerate path names that contain spaces, so it is advisable not to follow this practice.

When using autocomplete, GDB does not recognize the usual DOS path name separator, the backslash (****), instead use the UNIX style forward slash (**/**).

Windows permits file names to have 2-byte (wide) characters. Mostly this is not a problem, because although the tools do not understand them, they just pass them through and Windows still recognizes them. However, some wide characters contain, as one of their two bytes, the directory separator character '****' or '**/**'. These are correctly interpreted by Windows, but in some cases are misinterpreted by the GNU tools, leading to malformed paths and apparently missing files and directories.

A.6.3 Debugging OS21 boot from ROM applications

When debugging boot from ROM applications built with the **flasher** Flash tool supplied with the Flash ROM examples (see *Chapter 10: Booting OS21 from Flash ROM on page 195*), it is necessary to disable OS21 awareness while debugging the ROM bootstrap. This is necessary as before control is passed to the main application by the ROM bootstrap, the application is relocated by the bootstrap from Flash ROM to main memory. Until the application is relocated into main memory, the OS21 awareness support in GDB extracts an undefined state from the target, resulting in undefined behavior.

The OS21 awareness in GDB may be enabled and disabled using the **rtos** GDB command (see *Table 15 on page 75*). To disable OS21 awareness, use **rtos off** and to enable it, use **rtos on**. Therefore to safely debug an OS21 boot from ROM application, **rtos off** should be specified until execution has transferred control from the ROM bootstrap to the start of the application (defined by the symbol **_start**) at which point OS21 awareness can be safely enabled by specifying **rtos on**.

Note: When debugging boot from ROM applications, it is generally inadvisable to configure the target using the standard connection commands as the ROM bootstraps will also configure the target, and configuring a target twice is not always reliable. GDB therefore provides the **sh4** *and* **sh4usb** *basic connection commands to connect to a target without configuring it.*

The following example illustrates connecting to a target (in this case an STMediaRef-Demo reference platform) which has been programmed with a boot from ROM application, and debugging the ROM bootstrap until control is passed to the application.

1 Connect to a target ready to debug a boot from ROM application and disable OS21 awareness.

```
(gdb) file a.out               Main application
(gdb) rtos off                 Disable OS21 awareness
(gdb) sh4 stmc "hardreset"     Connect to target stmc
```

2 Set up the memory mapped registers for the target.

```
(gdb) source registers40.cmd Define register setup commands
(gdb) source display40.cmd   Define register display commands
(gdb) st40gx1_si_regs        Define registers for the target
```

3 Debug the boot from ROM bootstraps. Only the **stepi** and **hbreak** commands may be used for stepping and setting breakpoints until execution has transferred from the ROM to main memory.

4 Start debugging the main application. It is possible to set software breakpoints in the main application at any time (as normal). However, if the debugger inserts the breakpoint into memory before the ROM bootstrap has completed relocating the application from ROM to main memory, the bootstrap will overwrite and effectively disable the breakpoint. This does not apply to hardware breakpoints. The debugger will reinsert all the software breakpoints the next time the program is interrupted, by a hardware breakpoint, user interrupt (**Control+C**) or any other means. The following procedure demonstrates one way to solve the problem. Re-enable OS21 awareness after hitting the breakpoint in the main application.

(gdb) hbreak *&_start	*Set hardware breakpoint on the first instruction in application*
(gdb) continue	*Continue execution until application breakpoint*
(gdb) rtos on	*Enable OS21 awareness*

Note: 1 Only a limited number of hardware breakpoints are available.

2 Depending on the target platform, different configuration commands may need to be specified to the **sh4** *connection command.*

A.7 Polling for keyboard input

The following function has been provided to allow host keyboard polling from an application running on the target.

Synopsis

```
int _SH_posix_PollKey(int *keycode);
```

Arguments

keycode	The address of an **int** to receive the ASCII keycode of the pressed key.

Results

0 if no key was pressed, **1** if a key was pressed.

Errors

None

Description

_SH_posix_PollKey() polls the host keyboard for a keypress. If no keypress is detected, the function returns **0**. If a keypress is detected then the function returns **1**, and the **int** pointed to by **keycode** receives the ASCII keycode of the key that was pressed.

A.8 Changing ST40 clock speeds

The GDB command script files **`st40clocks.cmd`**, **`sti5528clocks.cmd`**, **`stb7100clocks.cmd`** and **`stm8000clocks.cmd`** (see *Section 4.2.7: GDB command script files on page 76*) define user commands which allow the user a simplified mechanism to change the clock frequencies of the various subsystems of the ST40 (for example, CPU, STBus, memory and peripheral subsystems).

The general mechanism by which the user commands change the clock frequencies is as follows:

- stop the PLL,
- set the PLL ratios and setup mode,
- restart the PLL,
- wait for the PLL to lock.

In general, when changing the internal clock frequencies, it is PLL1 of the primary ST40 CLOCKGEN subsystem that is reprogrammed. As a consequence of stopping this PLL, the ST40 reverts to using the external clock as its reference clock frequency. This has the effect of setting the internal clock frequencies to be a ratio of the external clock frequency as defined by the CPG.FRQCR register or the CLOCKGEN.PLL1CR1 register (see the *ST40 System Architecture, Volume 1: System*).

The effect on the internal clocks, of stopping PLL1, may break the constraint that the frequency of the ST40 UDI clock (DCK) must be less than the peripheral clock frequency (see the *ST40 System Architecture, Volume 1: System*).

Since the default UDI clock frequency adopted by the ST40 Micro Toolset is 10 MHz then it is likely that the above constraint will be broken when changing the internal clock frequencies. This is because the standard external clock frequency on STMicroelectronics' boards is 27 MHz and the standard peripheral clock ratios are 1/3, 1/6 and 1/8 of the reference clock frequency, that is, a peripheral clock frequency of 9 MHz, 4.5 MHz or 3.4 MHz respectively.

In order to support the changing of ST40 clock frequencies, the user command **`linkspeed`** is provided to allow the UDI clock frequency used by GDB to be changed in order to comply with the above constraint.

The **linkspeed** command is invoked as follows:

```
linkspeed speed
```

where ***speed*** is the UDI clock frequency to select and may be one of the following: **20MHz**, **10MHz**, **5MHz**, **2.5MHz** **1.25MHz**, **625KHz**, **312.4KHz**, **156.25KHz**, **78.125KHz**, **39.062KHz**, **19.531KHz**, **9.765KHz**, **4.882KHz**, **2.441KHz**, **1.220KHz** and **610.3Hz**.

The following user commands are defined in **st40clocks.cmd** to set the ST40 clocks to the standard reset mode frequencies (see the relevant CPU datasheet for details):

- **st40_cpu100bus50mem50per25** (mode 0),
- **st40_cpu133bus88mem88per44** (mode 1),
- **st40_cpu150bus100mem100per50** (mode 2),
- **st40_cpu166bus110mem110per55** (mode 3),
- **st40_cpu200bus100mem100per50** (mode 4),
- **st40_cpu250bus125mem125per62** (mode 5).

The following example illustrates changing the clock frequencies of a target to mode 3 (assuming that it is currently in mode 0):

```
linkspeed 2.5MHz
st40_cpu166bus110mem110per55
linkspeed 10MHz
```

Where **linkspeed 2.5MHz** changes the UDI clock frequency to below that of the peripheral clock frequency (of 3.4 MHz assuming the target is in mode 0 and a 27 MHz external clock) and **linkspeed 10MHz** returns the UDI clock frequency back to the default.

The GDB command script files, **stb7100clocks.cmd**, **sti5528clocks.cmd** and **stm8000clocks.cmd**, define the user commands for configuring CLOCKGEN of the STb7100/STb7109, STi5528 and STm8000 respectively. These user commands must be used instead of those defined in **st40clocks.cmd** to program the STb7100/STb7109, STm8000 and STi5528 CLOCKGEN. See *stb7100clocks.cmd on page 92*, *sti5528clocks.cmd on page 92* and *stm8000clocks.cmd on page 92* for the commands that are available for programming CLOCKGEN for the STb7100/ STb7109, STi5528 and STm8000.

A.9 Just in time initialization

A common problem when writing a library is performing just in time initialization. It is usually accepted that the first thread to call a library function is responsible for initializing it. This often requires allocating memory or synchronization objects like semaphores. The problem is how to ensure that this is atomic, that is, the initialization is performed precisely once. Since allocation can result in the caller blocking, special consideration has to be given as to how to achieve this atomic initialization. The following describes a simple strategy which guarantees this atomicity.

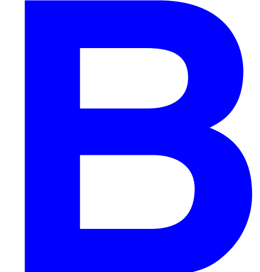
Consider a library where initialization consists of creating a semaphore which is used to serialize access to the library resources, and has to be created by the first caller. The following code (which omits error condition checking to aid clarity) guarantees that the semaphore is created precisely once:

```
static semaphore_t *volatile library_sem;
...

if (library_sem == NULL)
{
   semaphore_t *local_sem = semaphore_create_fifo (1);
   task_lock ();
   if (library_sem == NULL)
   {
      library_sem = local_sem;
   }
   task_unlock ();
   if (library_sem != local_sem)
   {
      semaphore_delete (local_sem);
   }
}
```

When this code completes, the library semaphore has been created if necessary. The first check, which occurs unlocked, is to see if the semaphore already exists. If it does, then there is nothing more to do. If it does not, then the code allocates a new semaphore, but keeps the address of the semaphore in a local variable. If the task was descheduled whilst creating the semaphore, it is possible for another task to enter this routine. It too would see that no library semaphore exists, and would similarly attempt to create a new one. When the task returns from creating the semaphore, it locks the scheduler to prevent pre-emption. Under this lock it again checks the library semaphore. If it still does not exist, the library semaphore is assigned the address of the semaphore just created. The scheduler is now unlocked.

The lock ensured that precisely one of the competing tasks assigned a non-zero value to the library semaphore pointer. Once out of the lock the library semaphore is checked against the local one. If they are identical, then it is known that the local semaphore was used, and nothing more needs to be done. If they are different, then another task assigned the library semaphore pointer. In this case, the local semaphore must be discarded; it is not needed as the library semaphore already exists.



Development tools reference

This chapter provides a reference for the development tools features which are specific to the SH-4 cores.

B.1 Code development tools reference

B.1.1 Preprocessor predefines and asserts

The compiler provides a set of predefined preprocessor options (built-ins) which are listed in *Table 44*. These are in addition to the standard GNU C Compiler (GCC) options (such as defining the version of GCC). For details of these refer to the *Using and Porting the GNU Compiler Collection* manual.

Predefine or Assert	Compiler option
cpu=sh (Assert)[a]	**<<always>>** [b]
machine=sh (Assert)[a]	**<<always>>** [b]
`__BARE_BOARD__`	`-mruntime=bare` [b]
`__BIG_ENDIAN__`	`-mb`
`__LITTLE_ENDIAN__`	`-ml` [b]
`__os21__` `__OS21_BOARD__`	`-mruntime=os21` `-mruntime=os21_d`

Table 44: Preprocessor predefines and asserts

Predefine or Assert	Compiler option
__sh__	<<always>> [b]
__sh3__ [c] __SH3__	-m4-nofpu -m4-100-nofpu -m4-200-nofpu -m4-400 -m4-500
__SH4__	-m4 [b] -m4-100 -m4-200
__SH4_100__	-m4-100 -m4-100-single -m4-100-single-only -m4-100-nofpu
__SH4_200__	-m4-200 -m4-200-single -m4-200-single-only -m4-200-nofpu
__SH4_400__	-m4-400
__SH4_500__	-m4-500
__SH4_NOFPU__	-m4-nofpu -m4-100-nofpu -m4-200-nofpu
__SH4_SINGLE__	-m4-single -m4-100-single -m4-200-single
__SH4_SINGLE_ONLY__	-m4-single-only -m4-100-single-only -m4-200-single-only

Table 44: Preprocessor predefines and asserts

a. GCC assertions are deprecated, and should not be used.

b. Default option.

c. The SH-4 variants without an FPU use the SH-3 ABI (for parameter passing) and define __SH3__ rather than __SH4__. Programs should not confuse the ABI definition with the processor variant as they are not the same.

B.1.2 SH-4 specific GCC options

The GCC options listed in *Table 45* are specific to the SH-4 core family.

Option	Use	Supported
-m4 [a]	Compile for a generic SH-4 processor.	Yes
-m4-100	Compile for an SH4-100 series processor.	Yes
-m4-200	Compile for an SH4-200 series processor.	Yes
-m4-400	Compile for an SH4-400 series processor. All FPU and MMU related instructions are disallowed, including those in assembler inserts. Floating-point calculations will be software emulated.	No
-m4-500	Compile for an SH4-500 series processor. All FPU instructions are disallowed, even in assembler inserts. Floating-point calculations will be software emulated.	No
-m4-nofpu	SH-4 series with the FPU disabled. All floating-point calculations will be software emulated. Note that assembler inserts may still utilize FPU operations, but that the standard C run-time system will not enable the FPU.	Yes
-m4-100-nofpu	This is the same as **-m4-nofpu** but for the SH4-100 series.	Yes
-m4-200-nofpu	This is the same as **-m4-nofpu** but for the SH4-200 series.	Yes
-m4-single	Pervading precision is single. The default is double precision.	Yes
-m4-100-single	This is the same as **-m4-single** but for the SH4-100 series.	Yes
-m4-200-single	This is the same as **-m4-single** but for the SH4-200 series.	Yes
-m4-single-only	SH-4 series with double precision disabled. Double precision arithmetic and variables will be downgraded to single precision.	Yes

Table 45: SH-4 specific GCC options

Option	Use	Supported
-m4-100-single-only	This is the same as **-m4-single-only** but for the SH4-100 series.	Yes
-m4-200-single-only	This is the same as **-m4-single-only** but for the SH4-200 series.	Yes
-mb	Generate big endian code.	Yes
-mbigtable	Use 4-byte fields for switch tables.	Yes
-mboard=*board*	Use board support package ***board***.	Yes
-mdalign	Align doubles on 8-byte boundary.	Yes
-mfmovd	Use double (8-byte) floating-point loads.	No
-mhitachi	Hitachi ABI (Differences in save/restore policy).	No
-mieee	Better IEEE conformance (NaN Support).	Yes
-misize	Annotate assembler listing with estimated address.	Yes
-ml [a]	Generate little endian code[a].	Yes
-mno-ieee [a]	Use SH-4 floating-point instructions with no IEEE fixup[a].	Yes
-mnomacsave [a]	Do not save mac registers over function calls.	No
-mpadstruct	Pad structs up to multiples of 4 bytes.	Yes
-mprefergot	Use **GOT** not **GOTOFF** (pic code).	Yes
-mrelax	Use linker relaxation.	Yes
-mruntime=*runtime*	Use the run-time library ***runtime***.	Yes
-mspace	Optimize for space.	Yes
-musermode	Assume code to be executed in user mode.	Yes

Table 45: SH-4 specific GCC options

a. Default

B.1.3 GCC assembler inserts

GCC enables assembler code to be embedded in C functions by using the **asm** statement extension. The format for this statement is:

```
asm ("code" [: [outputs] [: [inputs] [: clobbers]]] )
```

The ***code*** is the assembler code to be inserted in the output file. The remaining parameters describe the effects of the code insert on the machine and program state. The code insert uses **printf** style parameter names to refer to the parameters which are listed in the ***inputs*** and ***outputs*** sections, for example, **%0** refers to the first value, and **%1** refers to the second value. ***outputs*** is the list of objects modified by ***code***. ***inputs*** is the list of objects read by ***code***. ***clobbers*** is the list of values which are modified by ***code***, and are not listed in the ***outputs*** section. For further details (in general, and for the constraints and qualifiers in particular), refer to the section *Constraints for asm Operands* in *Using and Porting the GNU Compiler Collection* manual.

Each operand is of the form ***qualifier(operand)***. For example:

```
asm ("mov %1, %0" : "=r"(i) : "r"(j)); /* i=j; No clobbers */
```

The set of qualifiers (operand constraints) pertaining to the SH-4 are listed in *Table 46*. The **=** means that this operand is write-only for this instruction, the previous value is discarded and replaced by output data. Any letters that are not listed correspond to “no register”. The following is an example of the use of these qualifiers:

```
asm ("or #0xFF, %0" : "+z"(x)); /* x |= 0xff; No inputs or clobbers */
```

This ensures that **x** is loaded into R0 as required by the instruction. The **+** means that the register is both input (read) and output (written to).

Qualifier (Assembler register names)	Use (Corresponding SH-4 register)
`"c"`	FPSCR
`"d"`	Double FP register
`"f"`	FP register
`"l"`	PR register

Table 46: SH-4 qualifiers (operand constraints)

Qualifier (Assembler register names)	Use (Corresponding SH-4 register)
`"r"`	General purpose register
`"t"`	T bit - use to indicate side effecting T bit
`"w"`	FP0 (also known as FR0)
`"x"`	MAC register (MACH and MACL)
`"y"`	FPUL (FP communication register)
`"z"`	R0

Table 46: SH-4 qualifiers (operand constraints)

The SuperH configuration defines special characters that are useful for SH-4 code, these are listed in *Table 47* and examples are provided below.

Character	Description
`O`	Substitute a constant without the `#`. This is useful to emit a constant with `.long`. The value must be a constant or an expression that evaluates to a constant. The example below uses a function pointer.
`R`	Substitute the register name corresponding to the least significant 32 bits of a 64-bit value (irrespective of the endianness).
`S`	Substitute the register name corresponding to the most significant 32 bits of a 64-bit value (irrespective of the endianness).
`T`	Substitute the register name corresponding to the second 32-bit word of the 64-bit value (the same as `R` in big endian mode, and the same as `S` in little endian mode).

Table 47: SH-4 inline assembler template characters

In the following examples, note how the template characters are placed between the `%` and the number. They may be used for parameters of any type, whether they be registers or memory addresses.

Example of %R and %S

This example demonstrates how to express the C expression **shreg = shreg << 1** in assembler, where **shreg** is of type **long long** (64 bit).

```
asm ("shll %R0; rotcl %S0" : "+r" (shreg) : : "t");
```

Example of %T

This example demonstrates the C expression **result = flag == 0** in assembler, where **flag** is of type **long long** (64 bit).

```
asm ("mov %1,%0; or %T1,%0; tst %0,%0 ; movt %0"
     : "=r" (result) : "r" (flag) : "t");
```

Note: **%1** *and* **%T1** *both refer to the same 64-bit variable,* **flag***, each corresponding to a different 32-bit word.*

Example of %O

This example demonstrates a method of implementing the C expression **for (;;) fun ()** in assembler.

```
asm __volatile__ ("mov.l 0f, r1\n\t"
                  ".balign 4\n\t"
                  "mova 0f, r0\n\t"
                  "add r1, r0\n\t"
                  "braf r1\n\t"
                  "lds r0, pr\n"
                  "0: .long %O0 - 0b"
                  : : "i" (fun));
```

B.1.4 Compiler pragmas and attributes

The compiler supports the following pragmas and attributes. Note some pragmas can also be written as attributes.

Note: These pragmas and attributes should not be used in OS21 applications as OS21 manages interrupts and traps.

Pragma interrupt

This pragma specifies that the specified function is an interrupt handler, for example:

```
#pragma interrupt(fred)
int fred(int i);
```

The compiler alters the generated code as follows:

- uses **rte** as the function return instruction (instead of **rts**),
- executes an extended context save and restore to save the registers normally considered as scratch registers.

Note: This pragma must be specified before any of the following interrupt handler related attributes are used.

interrupt_handler attribute

This is equivalent to the **interrupt** pragma and is specified as follows:

```
int fred(int i) __attribute__((interrupt_handler));
```

sp_switch attribute

This is used in conjunction with the **interrupt_handler** attribute to specify that the handler should be executed on an alternative stack. The compiler generates code to switch to and from this stack on function entry and exit respectively. The stack is named as a parameter to the **sp_switch** attribute as follows:

```
extern void *VBR_STACK;
int fred(int i) __attribute__((interrupt_handler,
      sp_switch("VBR_STACK")));
```

This specifies that **VBR_STACK** is to be used as the interrupt stack.

trap_exit attribute

The compiler generates a **trapa** instruction to exit the function rather than a standard **rte** exit (the **trap_exit** attribute only applies to interrupt handlers). It also saves all registers before using them, even registers defined to be caller save.

```
#pragma interrupt(fred)
int fred(int i) __attribute__((trap_exit(42)));
```

The number is the parameter to the **trapa** instruction (the trap number).

Pragma trapa

This is equivalent to the **interrupt** pragma, except that it does not save extra registers.

```
#pragma trapa(fred)
int fred(int i);
```

B.1.5 Assembler specifics

The SH-4 assembler recognizes the command line options listed in *Table 48* in addition to the standard assembler options.

Option	Description
-isa=sh4	Assemble for an SH-4 core. This also allows the assembler to do SH-4 specific optimizations (in conjunction with **-relax**). The assembler might determine this for itself, but only if there is an SH-4 specific instruction in the code.
-isa=sh4-nofpu	Assemble for an SH-4 without an FPU. This is useful for the SH4-500 series CPUs. Any FPU instructions will be rejected with an error.
-isa=sh4-nommu-nofpu	As for **-isa=sh4-nofpu** but MMU instructions are also rejected. This is useful for the SH4-400 series CPUs.

Table 48: Assembler command line options

Table 48 lists the most useful SH-4 **-isa** options. The **-isa** option allows any supported architecture variant to be selected.

When the **-isa** option is not specified, the assembler selects the most appropriate architecture for an object file based on the instructions used. Therefore, if no SH-4 specific instructions are used, it is quite normal for an SH-4 object file to be set as **sh4-nofpu**, **sh3** or an even earlier variant.

Although the assembler may set the architecture for an inferior CPU, it should be noted that the compiled code still implements the ABI of the originally intended, superior processor. In general, it is not the case that two object files purporting to be for the same architecture are compatible. For example, an object file intended for use with the **sh4-nofpu** architecture will use a different ABI to an object file intended for use with an SH-4 with an FPU, but does not happen to use any floating-point instructions (and is therefore also set to the **sh4-nofpu** architecture).

Note: The linker will almost always link such object files without error, and in some limited cases, the resultant application may even run successfully.

The SH-4 assembler recognizes the pseudo-opcodes listed in *Table 49*.

Pseudo opcodes	Action
.long ***value*** **.int** ***value***	Allocate 4 bytes.
.word ***value*** **.short** ***value***	Allocate 2 bytes.
.big	Specify big endian.
.little	Specify little endian.
.heading "*name*"	Specify ***name*** as name of listing file.
.page	New page in listing file.
.uses	Used to label a call instruction for linker relaxation. (Used by compiler to support **-mrelax**).
.uaword ***value*** **.2byte** ***value***	Unaligned 2-byte allocation.
.ualong ***value*** **.4byte** ***value***	Unaligned 4-byte allocation.
.uaquad ***value*** **.8byte** ***value***	Unaligned 8-byte allocation.

Table 49: Specific pseudo-operations

The assembler supports the assembler syntax as defined in the *SH-4 32-bit CPU Core Architecture* manual, in addition lower case instructions and register names are supported. It should be noted that for the SH-4 CPU family of cores, numeric literals must be prefixed by a **#**.

Table 50 lists the register names recognized by the assembler.

Register name	Use
R0 to R15	General purpose registers.
FR0 to FR15	Floating-point registers.
DR0, DR2, DR4, DR6, DR8, DR10, DR12, DR14	Double-precision floating-point registers.
SR, GBR, SSR, SPC, SGR, DBR	Control registers.
R0_BANK to R7_BANK	Register in other (non selected) bank.
XF0 to XF15	Floating-point extended registers.
FV0, FV4, FV8, FV12	Floating-point register vectors, 4-way.
XD0, XD2, XD4, XD6, XD8, XD10, XD12, XD14	Double-precision extended registers.
XMTRX	4x4column, single-precision matrix.
MACH, MACL, PC, FPUL, PR, FPSCR	System registers.

Table 50: Recognized register names

The assembler supports the following pseudo-instructions.

mov.l *symbol*, *rn* If ***symbol*** is a label that is reachable from this instruction, the instruction is expanded to a PC-relative **mov.l** instruction. That is, an instruction in the format:

```
mov.l @(disp,pc), rn
```

The ***symbol*** must be 4-byte aligned as this is a requirement for the encoding of this instruction.

mov.w *symbol*, *rn* If **symbol** is a label that is reachable from this instruction, it is expanded to a PC-relative **mov.w** instruction. The ***symbol*** must be 2-byte aligned.

B.1.6 Linker relaxation

This is a process carried out by the linker to shorten branches between code in different compilation units. Linker relaxation applies to conditional (with and without delay slots) and unconditional jumps. This option is used to reduce code size and to improve code performance.

It is important that the relaxation option, **`-mrelax`**, is applied to all compilations in addition to the final link.

B.1.7 Floating-point behavior

When executing floating-point instructions, the precision of the operation (either single-precision or double-precision) is controlled by setting the PR bit in the floating-point status/control register, FPSCR. This is in contrast to other architectures where the precision is indicated by the floating-point instructions that are used.

The default bootstrap sets the initial value of the precision to double. This is known as the **pervading precision**. When single-precision operations are required, the compiler must generate code to switch to single-precision. This behavior is inefficient when the majority of floating-point operations are single-precision, therefore the default behavior can be overridden using one of the following options:

`-m4-single`
`-m4-100-single`
`-m4-200-single`

When these options are used, the pervading precision is set to single and the compiler generates code to switch it to double when necessary.

It is also possible to ignore double-precision altogether using one of the following options:

`-m4-single-only`
`-m4-100-single-only`
`-m4-200-single-only`

These options cause the compiler to convert all variables of **`double`** type to **`float`** type. Obviously this can have a serious effect on the accuracy of the calculations, but can also improve the performance of the program.

Note: All of these options change the ABI and therefore all object files and libraries in an application must be compiled with the same option. Additionally, the same options must be supplied to GCC at link time as well as at compile time to ensure that the correct run-time libraries are selected.

The default bootstrap does not set the ENABLE bit in the FPSCR register. Therefore, by default, no floating-point unit (FPU) exceptions are generated. Instead, the FPU selects a suitable value, such as INF (infinity) or NaN (not a number). The FPSCR register may still be queried as described in the architecture manual.

B.1.8 Speed and space optimization options

For the SH-4 core to obtain the fastest possible code, the compiler and linker options listed below are used.

`-O3`	All compiler global and local optimizations.
`-fomit-frame-pointer`	R14 will not be used as a frame pointer where possible, therefore avoiding some calculations and making the register available for general use. The use of this option can inhibit debugging.
`-funroll-loops` **`-funroll-all-loops`**	(Some experimentation may be required to find which is preferable). These unroll loops and provide longer straight-line code sequences that are more suitable for compiler optimization.
`-mrelax`	Used to shorten branches. The option must be used consistently for each of the compile, assemble and link phases in order to have effect.

For minimal code size the options listed below should be used.

`-Os`	This instructs the compiler to optimize for space
`-fomit-frame-pointer`	R14 will not be used as a frame pointer.
`-mrelax`	Used to shorten branches.

B.2 Cross development tools reference

B.2.1 Command script files supplied

The GDB command script files provide the required configuration information in order for GDB to connect to a target (either silicon or simulator).

Table 51 lists all of the GDB command files supplied with the toolset. They are located in the **sh-superh-elf/stdcmd** directory on the installed toolset, for more information on these files, see *Section 4.2.7: GDB command script files on page 76*.

GDB command file	Usage
allcmd.cmd	Sources all the GDB script files supplied with the ST40 Micro Toolset; the main purpose of which is to make available all commands defined by the scripts supplied.
brtrace.cmd	Defines the commands for controlling the SH-4 hardware branch trace buffer (see *Section D.3: The branchtrace command on page 296*).
db457.cmd	Defines commands which set the configuration registers for the ST40RA on an STMicroelectronics ST40STB1-ODrive board[a].
display40.cmd	Defines commands which display the contents of the memory mapped configuration registers for all SH-4 and ST40 silicon variants support by the ST40 Micro Toolset.
espresso.cmd	Defines commands which set the configuration registers for the STi5528 on an STMicroelectronics STi5528-Espresso board.
jtag.cmd	Defines the commands for controlling the ST40 UDI (see *Section E.2: The jtag command on page 299*).
mb293.cmd	Defines commands which set the configuration registers for the ST40RA on STMicroelectronics ST40RA HARP and ST40RA Extended HARP boards[a].
mb317.cmd	Defines commands which set the configuration registers for the ST40GX1 on an STMicroelectronics ST40GX1 Evaluation board (revision A and B variants)[a].

Table 51: GDB command files

GDB command file	Usage
mb360.cmd	Defines commands which set the configuration registers for the ST40RA on an STMicroelectronics ST40RA-Eval board.
mb374.cmd	Defines commands which set the configuration registers for the ST40RA on an STMicroelectronics ST40RA-Starter board[a].
mb376.cmd	Defines commands which set the configuration registers for the STi5528 on an STMicroelectronics STi5528-Mboard.
mb379.cmd	Defines commands which set the configuration registers for the STm8000 on an STMicroelectronics STm8000-Demo board.
mb392.cmd	Defines commands which set the configuration registers for the STm8000 on an STMicroelectronics ST220-Eval development board.
mb411.cmd	Defines commands which set the configuration registers for the STb7100 on an STMicroelectronics STb7100-Mboard.
mb411stb7109.cmd	Defines commands which set the configuration registers for the STb7109 on an STMicroelectronics STb7100-Mboard.
mb422.cmd	Defines commands which set the configuration registers for the STd2000 on an STMicroelectronics DTV100-DB board.
mediaref.cmd	Defines commands which set the configuration registers for the ST40GX1 on an STMediaRef-Demo reference platform.
perfcount.cmd	Defines the commands for controlling the SH-4 hardware performance counters (see *Section C.3: The perfcount command on page 293*).
plugins.cmd	Sources all the plugin GDB script files (**brtrace.cmd**, **jtag.cmd** and **perfcount.cmd**).
register40.cmd	Defines commands which define symbolically the locations of the memory mapped configuration registers on all SH-4 and ST40 silicon variants supported by the ST40 Micro Toolset.
sh4commands.cmd	Defines commands for use with the targets.
sh4connect.cmd	Defines commands to connect to a target via an ST Micro Connect, or to connect to a simulated target, and to set up the target CPU type and endianness and optionally to configure the target.

Table 51: GDB command files

GDB command file	Usage
sh4targets-*board*.cmd	Defines commands for connecting to all the targets of type board (both silicon and simulated targets).
sh4targets.cmd	Defines commands for connecting to all the targets supported by the ST40 Micro Toolset including simulated targets. Sources all the **sh4targets-*board*.cmd** GDB script files and the **sh4commands.cmd** GDB script file.
shsimcmds.cmd	Defines commands to control the internal configuration of the SuperH SH-4 simulator shipped with the ST40 Micro Toolset.
stb7100ref.cmd	Defines commands which set the configuration registers for the STb7100 on an STMicroelectronics STb7100-Ref board.
st40clocks.cmd	Defines commands to change the frequencies of the various internal clocks of ST40 silicon.
st40gx1.cmd	Defines commands describing the core memory regions and other attributes of an ST40GX1.
st40ra.cmd	Defines commands describing the core memory regions and other attributes of an ST40RA.
stb7100.cmd	Defines commands describing the core memory regions and other attributes of an STb7100.
stb7100clocks.cmd	Defines commands to display the frequencies of the various internal clocks of an STb7100 or an STb7109.
stb7100jtag.cmd	Defines commands for configuring the connection between an ST Micro Connect and the ST40 CPU of an STb7100 or an STb7109.
stb7109.cmd	Defines commands describing the core memory regions and other attributes of an STb7109.
std2000.cmd	Defines commands describing the core memory regions and other attributes of an STd2000.
sti5528.cmd	Defines commands describing the core memory regions and other attributes of an STi5528.
sti5528clocks.cmd	Defines commands to display the frequencies of the various internal clocks of an STi5528.

Table 51: GDB command files

GDB command file	Usage
stm8000.cmd	Defines commands describing the core memory regions and other attributes of an STm8000.
stm8000clocks.cmd	Defines commands to display the frequencies of the various internal clocks of an STm8000.

Table 51: GDB command files

a. The ST40STB1-ODrive, ST40RA HARP, ST40GX1 Evaluation, ST40RA Extended HARP and ST40RA-Starter boards are no longer in production.

B.2.2 Memory mapped registers

The user commands for connecting to a target also define, as GDB convenience variables, symbolic names for the memory mapped registers of the target. All SH-4 core support peripheral memory mapped registers are defined plus all the peripherals configured during connection and a selection of other common peripherals (for example, LMI, EMI and PCI). These symbolic names may be used (after connecting to the target) interactively or by GDB user defined commands to read from and write to the memory mapped registers instead of explicitly specifying their address.

The symbolic names for the memory mapped registers use a standard naming convention, where the register name is composed of the peripheral group name followed by the register name (separated by an underscore). For example, the SH-4 cache control register CCR, which is a member of the CCN peripheral group, is defined as **$CCN_CCR**. The register name is prefixed with **$** to indicate that the symbol is a GDB convenience variable and not a symbol in an application.

Note: 1 *The list of register names is located in the file* **sh-superh-elf/stdcmd/register40.cmd** *in the release installation directory.*

2 *The GDB* **show convenience** *command can be used to display the currently defined convenience variables.*

Reading a memory mapped register

The following example illustrates using the GDB **x** command to read the SH-4 cache control register via the pre-defined GDB convenience variable.

```
(gdb) x/wx $CCN_CCR
```

Writing to a memory mapped register

The following example illustrates using the GDB **set** command to change the SH-4 cache control register via the pre-defined GDB convenience variable:

```
(gdb) set *$CCN_CCR = (int)0x00000909
```

The pointer dereference (*****) operator is required since the GDB **set** command has to dereference the pointer **$CCN_CCR** and assign a value to it.

Note: The GDB variable containing the address of a memory mapped register is not read-only and will be changed if the ***** *is omitted.*

B.2.3 Silicon specific commands

GDB hardware breakpoints and watchpoints are only supported on silicon and not in a simulation environment. However, they are limited by the available debug hardware within the SH-4.

Hardware breakpoint support

A hardware breakpoint is set using the **hbreak** command. The **hbreak** command is identical to the **break** command (which sets software breakpoints) for example:

hbreak ***function*|*line*|*file*:*line*|**address***

A maximum of three hardware breakpoints can be set at once as the physical hardware does not support more than three. If used in conjunction with hardware watchpoints it is only possible to have a combined total of three breakpoints and watchpoints at any one time.

Note: The number of software breakpoints is not limited by the hardware.

Hardware breakpoints should be used when debugging applications running from ROM as software breakpoints are not usable.

Hardware watchpoint support

To set a hardware watchpoint, use one of the commands listed in *Table 52*. Where ***location*** is a location expression (for example, an address or a symbolic object name).

Command	When triggered
rwatch *location*	Read accesses only.
watch *location*	Write accesses only.
awatch *location*	Both read and write accesses.

Table 52: Hardware watchpoint commands

A maximum of three hardware watchpoints can be set simultaneously as the physical hardware does not support more. If used in conjunction with hardware breakpoints it is only possible for a combined total of three hardware breakpoints and watchpoints to be set at any time.

Additionally, the SH-4 hardware watchpoints have the ability to watch only for an access to ***location*** of the same size as the location being watched (1, 2 or 4 bytes). Accesses to ***location*** of sizes other than the location size are ignored. The size of a location is inferred from the type of the symbol at that location. This is enabled using the following command (the default is **on**):

```
use-watchpoint-access-size on
```

GDB also supports software watchpoints, however using software watchpoints reduces program performance significantly.

B.3 Embedded features

B.3.1 Default bootstrap

The default bootstrap carries out a number of actions to set-up the SH-4 for program execution and to shut-down the program after execution. The steps below are carried out by the default bootstrap.

1. Set up stack pointer (R15) from the value of the symbol **`_stack`**.
2. Zero the **`bss`**. (Global data is initialized to zero.)
3. Set FPSCR, the floating-point control register, according to the pervading precision.
4. Set up the exception handlers by setting VBR and by setting the status register (SR) to allow exception handlers to be called. By default, the power on value of the status register blocks exceptions causing them to be vectored to the reset address. Trap handlers are set for general exceptions.

Note: For OS21 applications, once OS21 has started, all exceptions are handled using the OS21 exception handler and these embedded features no longer apply (see also Section B.3.2).

5. Call **`main`**.

Note: The bootstrap does not set up any virtual address mapping.

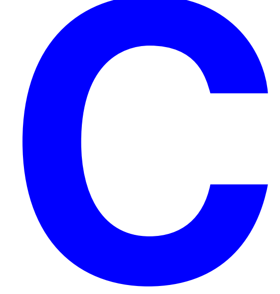
On return from the program the **`exit`** function is called with the return code from the program.

B.3.2 Trap handling

When a general exception occurs and when it is vectored through the default exception handlers, the bootstrap returns the exception code as the return value of the program.

It is possible to use the debugger to catch the exception by setting a breakpoint on the function **`_superh_trap_handler`**. The debugger is then able to provide a stack trace to the location of the exception.

The trap handler function has one parameter that can be examined in the debugger. This is the value of the EXPEVT register at the point of the exception and provides the reason for the exception.



Performance counters

C.1 Introduction to performance counters

Performance counters are an SH-4 hardware feature to aid the debugging and analysis of an application, by providing the ability to count execution cycles or the occurrences of several different kinds of events during the execution of an application.

The SH-4 hardware provides a pair of 48-bit binary counters, designated as **`counter1`** and **`counter2`**. These counters can be configured to count the occurrence of a variety of useful events, or to count cycles while the CPU is in certain states.

The counters can be either started and stopped manually from GDB or automatically by specifying start and stop triggering addresses, which when the instructions at these addresses are executed, start and stop the counters.

Each counter can be individually configured to start and stop automatically at these triggering addresses. However, the SH-4 hardware only supports a single pair of start and stop trigger addresses which are shared between both performance counters. As a consequence both counters start and stop at the same triggering addresses if configured to start and stop automatically.

The counters can be individually configured to count any one of the 34 different events or states listed in *Section C.2*, where the type of event or state is identified by either its numeric code or its corresponding symbolic name (which is a mnemonic for the event).

The counter modes (see *Section C.2*) in which the counter counts in cycles instead of discrete events, support the following two forms of cycle counting.

CPU The counter counts the number of CPU clock cycles (**ICLK**) where the count is incremented by 1 for every CPU clock cycle while the relevant condition applies.

BUS The counter counts the number of BUS clock cycles. This is defined as the inverse ratio of the CPU clock (**ICLK**) to the bus clock (**BCLK**) multiplied by 24 (**BCLK/ICLK * 24**). The BUS clock increment is therefore dependent on the **ICLK** to **BCLK** ratio and will be 12 for a 2:1 ratio, 8 for a 3:1 ratio, 6 for a 4:1 ratio, 4 for a 6:1 ratio and 3 for an 8:1 ratio. These increments approximate to real time **T** where **T=(BCLK period)/24*count**.

Note: The performance counters do not have any impact on CPU performance.

The performance counter features are accessible though the GDB **perfcount** command.

C.2 Performance counter modes

The performance counter modes and their symbolic names (which are case sensitive) are listed in *Table 53*.

Code	Symbol	Countable event	Count or Cycle	Notes
0	**nop**	(nop)	N/A	
1	**oar**	Operand Access (Read with cache)	Count	
2	**oaw**	Operand Access (Write with cache)	Count	
3	**utlb**	UTLB miss	Count	
4	**ocrm**	Operand Cache Read Miss	Count	
5	**ocwm**	Operand Cache Write Miss	Count	
6	**if**	Instruction Fetch (with cache)	Count	Instructions fetched in pairs

Table 53: Performance counter modes

Code	Symbol	Countable event	Count or Cycle	Notes
7	**itlb**	Instruction TLB miss	Count	
8	**icm**	Instruction Cache miss	Count	
9	**aoa**	All Operand Access	Count	
10	**aif**	All Instruction Fetch	Count	Instructions fetched in pairs
11	**ram**	On-chip RAM operand access	Count	
12	**io**	On-chip IO space access	Count	
13	**oarw**	Operand Access (Read & Write with cache)	Count	Equivalent to **oar + oaw**
14	**ocrwm**	Operand Cache (Read & Write) Miss	Count	Equivalent to **ocrm + ocwm**
15	**bi**	Branch instruction issued	Count	
16	**bt**	Branch taken	Count	
17	**bsr**	BSR/BSRF/JSR instruction issued	Count	
18	**ii**	Instruction issued	Count	
19	**2ii**	Two instructions issued simultaneously	Count	
20	**fpu**	FPU instruction issued	Count	
21	**int**	Interrupt (normal)	Count	
22	**nmi**	Interrupt (NMI)	Count	
23	**trapa**	TRAPA instruction executed	Count	
24	**ubca**	UBC-A channel match	Count	
25	**ubcb**	UBC-B channel match	Count	
26	**icf**	Instruction Cache Fill	Cycle	
27	**ocf**	Operand Cache Fill	Cycle	
28	**time**	Elapsed TIME	Cycle	

Table 53: Performance counter modes

Code	Symbol	Countable event	Count or Cycle	Notes
29	**pfi**	Pipeline Freeze due to cache miss Instruction	Cycle	
30	**pfo**	Pipeline Freeze due to cache miss Operand	Cycle	
31	**pfb**	Pipeline Freeze due to Branch instruction	Cycle	
32	**pfr**	Pipeline Freeze due to CPU register	Cycle	
33	**pff**	Pipeline Freeze due to FPU resource	Cycle	

Table 53: Performance counter modes

The **oar**, **oaw**, **oarw** and **if** modes are only applicable for accesses and fetches in cacheable areas of the address map while caches are enabled. They are undefined when the TLB controls the caches.

The **icm** mode includes fetches from noncacheable memory (effectively this counts instruction fetches taking >1 cycle).

The **bi** and **bt** modes count all branch instructions (BF, BF/S, BT, BT/S, BRA, BRAF and JMP), except for the special case of a BF or BT instruction with a displacement of zero.

For the **ii** and **fpu** modes, the count is incremented by 2 for a pair of (floating point) instructions simultaneously dual-issued.

The **pfb** mode counts all branch instructions regardless of displacement. The count is 1 cycle per branch except when a delay slot instruction avoids the pipeline stall. If the target instruction is not in the cache, stalls due to instruction cache refill cycles are counted with **pfi**.

The **pfi** and **pfo** modes also count the wait time for on-chip RAM and I/O space accesses. The counts also include freeze cycles for accesses and fetches performed without caches.

The **pff** mode only counts when no instructions are issued due to FPU resource contention. If one instruction can be issued in a given cycle the count is not incremented.

The counts in all modes must be considered approximate as they may contain errors. For example, the presence of exceptions causes overestimation in the count. In addition there may be a mis-counting of events at the start and the end of the performance measurement. For these reasons the counts are unreliable if performed over a short period or application range.

C.3 The perfcount command

The **perfcount** command is enabled by issuing the GDB user command **enable_performance_counters** (defined in the **perfcount.cmd** GDB command script file).

perfcount *command options*

This command controls the performance counter function specified by ***command*** and ***options***.

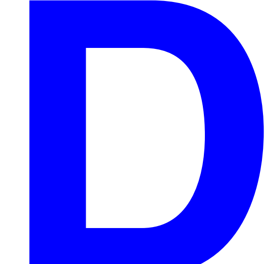
The subcommands supported by the **perfcount** command are listed in *Table 54*.

Command	Options	Description
help	***[command]***	Display help for the **perfcount** command. If a ***command*** is specified then more detailed help for ***command*** is displayed.
status	**counter1|counter2|all**	Display the configuration for the specified counter or all counters.
enable	**counter1|counter2|all**	Enable counting for the specified counter or all counters.
disable	**counter1|counter2|all**	Disable counting for the specified counter or all counters.
trigger	**counter1|counter2|all|none *start_addr stop_addr***	Set the start and stop trigger addresses of the specified counter or all counters to ***start_addr*** and ***stop_addr***. Alternatively, if **none** is specified, remove any previously specified addresses. When **none** is specified, the counter is always on if enabled or off if disabled.

Table 54: perfcount subcommands

Command	Options	Description
mode	**counter1|counter2|all *mode***	Set the mode of the specified counter or all counters to ***mode***, where ***mode*** is one of the numeric codes or its corresponding symbolic name listed in *Table 53 on page 290*. If ***mode*** is not recognized then **nop** is assumed.
display	**counter1|counter2|all**	Display the value of the specified counter or all counters.
reset	**counter1|counter2|all**	Reset the value of the specified counter or all counters to zero.
return	**counter1|counter2 *variable***	Return the value of the specified counter to a GDB convenience variable or target variable named ***variable***.
clock	**counter1|counter2|all cpu|bus**	Set the cycle count mode of the specified counter or all counters to **cpu** or **bus**.

Table 54: perfcount subcommands



Branch trace buffer

D.1 Introduction to the branch trace buffer

The branch trace buffer is an SH-4 hardware feature intended to aid debugging, showing the flow of control during execution of a program by recording the non-sequential updates of the program counter (PC).

The SH-4 branch trace buffer is an 8-level deep FIFO buffer, which stores the source and destination addresses for the last eight branches. The branch trace buffer can be configured for all branches, a class of branches or a combination of branch classes. The branch classes defined are general, subroutine and exception (see *Section D.2: Branch trace buffer modes* for further details).

Note: The collection of branch information does not have any impact on CPU performance and by default the branch trace buffer is disabled.

The branch trace buffer features are accessible though the GDB **`branchtrace`** command.

D.2 Branch trace buffer modes

The branch trace buffer can be configured to trace all branches or any combination of the traceable branch classes. The traceable branch classes and their symbolic names are listed in *Table 55*.

Traceable event	Symbol	Description
General branches	**gn**	BF, BT, BF/S, BT/S, BRAF and JMP.
Subroutine branches	**sb**	BSR, BSRF, JSR and RTS.
Exception branches	**ex**	All exceptions, interrupts and RTE.
All branches	**all**	All branch classes traced.
No branches	**none**	Trace nothing.

Table 55: Traceable branch classes

The branch trace classes **gn**, **sb** and **ex** can be combined using the **+** operator when configured using the **branchtrace** command. For example, use **gn+ex** to trace general and exception branches; or **sb+gn** to trace subroutine branches and general branches.

Note: **all** *is equivalent to* **gn+sb+ex**.

D.3 The branchtrace command

The **branchtrace** command is enabled by issuing the GDB user command **enable_branch_trace** (defined in the **brtrace.cmd** GDB command script file).

branchtrace *command options*

This command controls the branch trace buffer function specified by ***command*** and ***options***.

Note: *For convenience, the* **branchtrace** *command is aliased to the* **brt** *command.*

The subcommands supported by the **branchtrace** command are listed in *Table 56*.

Command	Options	Description
help	***[command]***	Display help for the **branchtrace** command. If a ***command*** is specified then more detailed help for the ***command*** is displayed.
status		Display the configuration for the branch trace buffer.
mode	***mode***	Set the mode of the branch trace buffer, where ***mode*** is one of the symbols in *Table 55* (or a combination of symbols concatenated with **+**).
display		Display the branch trace buffer contents.
reset		Reset the branch trace buffer contents.

Table 56: Branchtrace subcommands

JTAG control

E.1 Introduction to JTAG

JTAG is an acronym for the Joint Test Access Group which specified the *IEEE 1149.1 Test Access Port and Boundary-Scan Architecture*. The ST40 User Debug Interface (UDI) conforms to the IEEE 1149.1 standard and uses all five signals defined in the standard (TCK, TMS, TDI, TDO, and NOT_TRST) plus NOT_ASEBRK/BRKACK which is an additional signal specific to the ST40 UDI debug emulation function.

On some ST40 system-on-chip (SOC) devices, the TCK signal for the ST40 UDI may be provided separately to the TCK signal used by the Test Access Port (TAP) for the SOC. In these instances, the TCK signal for the ST40 UDI is normally referred to as DCK however, in this appendix, the signal name TCK is used to refer to the ST40 UDI signal.

See the *User Interface Debug (UDI)* chapter in the *SH-4, ST40 System Architecture, Volume 1: System* manual for further details about the ST40 UDI implementation.

E.2 The jtag command

The **`jtag`** command is enabled by issuing the GDB user command **`enable_jtag`** (defined in the **`jtag.cmd`** GDB command script file).

`jtag` ***`commands`***

This command enables access to the ST40 UDI for manual control of the standard IEEE 1149.1 TAP and NOT_ASEBRK signals plus the NOT_RESET signal of the target platform. Also, when used with a target which is connected via an ST MultiCore/Mux device, the **`jtag`** command provides control of the signal to switch between the TAP of the target and the TAP of the ST MultiCore/Mux.

The subcommands supported by the **jtag** command are listed in *Table 57*.

Command	Description
asebrk=*signal*	Specify the NOT_ASEBRK signal sequence.
help	Display help for the **jtag** command.
mode=*mode*	Set the mode of the TAP, where ***mode*** is one of the modes listed in *Table 58: JTAG modes*.
nrst=*signal*	Specify the NOT_RESET signal sequence.
ntrst=*signal*	Specify the NOT_TRST signal sequence.
stmmx=*signal*	Specify the signal sequence to switch between the TAP of the ST MultiCore/Mux and the TAP of the target.
tck=*signal*	Specify the TCK signal sequence. Only valid when **mode** is set to **manual** otherwise the signal is ignored.
tdi=*variable*	Return a numerical representation of the TDI signal sequence into a GDB convenience variable. This is the signal received by the ST Micro Connect's TDI signal from the TDO of the target TAP. See *Section E.2.3: TDI signal capture on page 304* for details on the representation of the TDI signal in ***variable***.
tdo=*signal*	Specify the TDO signal sequence. This is the signal sent by the ST Micro Connect's TDO signal to the TDI of the target TAP.
tms=*signal*	Specify the TMS signal sequence.

Table 57: jtag subcommands

The **asebrk**, **nrst**, **ntrst**, **tck**, **tdi**, **tdo**, **tms** and **stmmx** signal subcommands of the **jtag** command may be combined with each other (using space separation) whereas the **mode** and **help** subcommands may not be combined with any other **jtag** subcommand. The syntax of ***signal*** is described in *Section E.2.2: Signal specification*.

*Note: 1 The **stmmx** signal subcommand only has an effect when the **jtagpinout** configuration command has been set to **stmmx** (see Table 17: ST Micro Connect configuration commands on page 89).*

*2 When **jtagpinout** is set to **stmmx** the **asebrk** signal subcommand has no effect.*

E.2.1 TAP modes

The modes of the TAP supported by the **mode** subcommand are listed in *Table 58*.

Mode	Description
normal	Release manual control of the TAP and return to GDB sole control of the ST40. All further manual control of the TAP is disabled until the mode is changed to one of the other modes listed in this table. This is the default mode.
manual	Set the TAP to manual control. GDB no longer has control of the ST40 and care must be taken to ensure GDB does not attempt to access the ST40 until the TAP has been returned to **normal** mode (as this will result in undefined behavior). In **manual** mode, the TCK signal has to be explicitly specified via the **tck** signal subcommand (unlike the **singleshot** and **continuous** modes).
singleshot	The same as **manual** mode except that the TCK signal is automatically clocked 1 cycle for each signal specified by the **jtag** command. The TDI signal is captured a short period after the falling edge of TCK. The **tck** signal subcommand is ignored in this mode.
continuous	The same as **singleshot** mode except that the TCK signal is continuously clocked until the TAP mode is changed. All the signal subcommands are ignored until the TAP is returned to **manual** or **singleshot** mode.

Table 58: JTAG modes

Note: *The TCK clock speed in the* **singleshot** *and* **continuous** *modes is determined by the target link speed as set by the* **linkspeed** *configuration command (see Table 17: ST Micro Connect configuration commands on page 89) or the* **linkspeed** *user command (see linkspeed on page 101).*

The TCK clock speed in **manual** *mode is determined by the signal sequence specified by the* **tck** *subcommand and the speed at which the ST Micro Connect can transmit the signal up to a maximum of the target link speed.*

E.2.2 Signal specification

The BNF for the signal sequence specified by the ***signal*** argument to the **tck**, **tms**, **tdo**, **ntrst**, **nrst**, **asebrk** and **stmmx** signal subcommands is as follows:

```
signal ::= signal-element
         | signal signal-element

signal-element ::= signal-group
                 | signal-list

signal-group ::= ( signal-list * signal-repeat )

signal-repeat ::= decimal-constant

signal-list ::= signal-level
              | signal-list signal-level

signal-level ::= 0
               | 1
```

where ***decimal-constant*** is a literal unsigned decimal constant. Alternatively, using the notation of a regular expression, the syntax for a signal sequence may be expressed as ([**01**] | **(**[**01**]+*****_repeat_**)**)+ where *repeat* is a decimal constant ([**0-9**]+). No white space characters are allowed in a signal sequence specification.

The ***signal-group*** syntax is provided in order to express, in a compact notation, a repeating ***signal-list*** sequence. That is, a ***signal-group*** specification is equivalent to specifying a ***signal-list*** for ***signal-repeat*** times as a single contiguous ***signal-list***.

Examples specifying TMS signals to the **jtag** command to perform simple TAP state machine transitions are as follows:

- explicit sequence to enter the Run-Test-Idle state (after Tap-Logic-Reset):

  ```
  jtag tms=111110
  ```

- alternative sequence using grouping to enter the Run-Test-Idle state:

  ```
  jtag tms=(1*5)0
  ```

- sequence to read (and write) a 32-bit value from the TAP data register leaving the TAP in the Run-Test-Idle state:

  ```
  jtag tms=(1*5)010(0*32)110
  ```

where **(1*5)** takes the TAP to the Test-Logic-Reset state, **0** to Run-Test-Idle, **1** to Select-DR, **0** to Capture-DR, **(0*32)** to Shift-DR for 32 iterations, **1** to Exit1-DR, **1** to Update-DR, and **0** to Run-Test-Idle.

If a signal subcommand is not specified to the **jtag** command then the level for the signal is left unchanged from the final level of its last specified signal sequence (or if never specified, its initial level as defined in *Table 59*). Also, if a signal sequence is specified in a signal subcommand which is shorter than any other specified signal sequences then the level of the signal is also left unchanged from its final level (in the sequence) while the remainder of the other signal sequences are transmitted (and in any future **jtag** command if not specified).

The initial levels of the TAP signals when switching to manual control of the TAP for the first time are listed in *Table 59*.

Signal	Initial level	Comment
tck	0	The clocking of TCK is assumed to generate a clock signal which first presents a rising-edge for TCK and then a falling-edge for TCK (guaranteed when in **singleshot** and **continuous** modes).
tms	1	The TAP is always guaranteed to return to the Test-Logic Reset state after 5 TCK clock cycles when TMS is set to 1.
tdo	0	The ST Micro Connect's TDO is connected to the target's TDI.
ntrst	1	The TAP is reset when NOT_TRST is 0.
nrst	1	The target is reset when NOT_RESET is 0.
asebrk	1	The debug emulation function of the ST40 UDI is activated when NOT_ASEBRK is 0.
stmmx	1	The TAP of the ST MultiCore/Mux is selected when the **stmmx** signal is set to 0.

Table 59: Initial signal levels

Note: The initial signal levels have been chosen to ensure that the target is not affected when switching to manual control of the TAP *signals. When switching from* **manual** *mode to any other mode the* TCK *signal is always reset to its initial level of 0. In* **singleshot** *and* **continuous** *modes,* TCK *always returns to the initial level of 0 after every clock cycle. All other signals retain their levels when switching between modes.*

E.2.3 TDI signal capture

The ST Micro Connect's TDI signal from the TDO of the target TAP can be captured by the **jtag** command by specifying the **tdi** subcommand with a GDB convenience variable name template into which the numerical representations of the TDI signal levels are saved. A target application variable cannot be used directly for capturing the TDI signal as GDB has no access to the ST40 in order to save the captured signal while the TAP is under manual control. Instead a GDB convenience variable can be used to store the captured signal until the mode is returned to **normal**, at which point the GDB convenience variable can be used to set the target application variable.

The **jtag** command sets several variables derived from the GDB convenience variable name template, ***variable***, specified by the **tdi** subcommand.

variable_n This variable is set to the number of bits required to represent the TDI signal levels captured by the **jtag** command. The number of bits indicates the number of 32-bit variables (see below) that were set by the **jtag** command in order to hold the numerical representation of the captured TDI signal.

variable_0 This variable is set to the first 32 bits of the captured TDI signal where each bit represents a TDI signal level (0 or 1). The bits representing the TDI signal levels are packed such that the least significant bit of the variable is the first captured TDI signal level and the most significant bit is the last captured TDI signal level.

variable_x If the TDI signal captured by the **jtag** command requires more than 32 bits in order to be represented then other numbered 32-bit variables (counting monotonically) are set in order to represent the complete captured TDI signal.

The last TDI signal level captured by the **jtag** command is in the most significant valid bit in the ***variable_x*** with the greatest numerical count ***x***. The remaining bits are set to **0**.

The following example shows how a TDI signal of 35 bits is represented.

	31	30	29	28...5	4	3	2	1	0
variable_0	1	1	1	1...1	1	1	1	1	1
variable_1	0	0	0	0...0	0	0	1	1	1

E.2.4 Using the jtag command

The **jtag** command is typically used in a user command invoked by the **-inicommand** configuration command (see *Table 17: ST Micro Connect configuration commands on page 89*) when connecting to a target that requires configuration of the target via the TAP. However, the use of the **jtag** command is not limited to being invoked via a **-inicommand** user command, and may be used at any point as long as GDB does not attempt to access the ST40 while the TAP is under manual control.

Table 60 lists the target connection commands which use a **-inicommand** configuration command to configure the target TAP and the GDB command script file in which it is defined.

Target command	TAP configuration command	Command file
mb411bypass	**mb411bypass_setup**	**mb411.cmd**
mb411stmmx	**mb411stmmx_setup**	**mb411.cmd**
mb411bypassusb	**mb411bypass_setup**	**mb411.cmd**
mb411stmmxusb	**mb411stmmx_setup**	**mb411.cmd**
mb411stb7109bypass	**mb411stb7109bypass_setup**	**mb411stb7109.cmd**
mb411stb7109stmmx	**mb411stb7109stmmx_setup**	**mb411stb7109.cmd**
mb411stb7109bypassusb	**mb411stb7109bypass_setup**	**mb411stb7109.cmd**
mb411stb7109stmmxusb	**mb411stb7109stmmx_setup**	**mb411stb7109.cmd**
stb7100refbypass	**stb7100refbypass_setup**	**stb7100ref.cmd**
stb7100refstmmx	**stb7100refstmmx_setup**	**stb7100ref.cmd**
stb7100refbypassusb	**stb7100refbypass_setup**	**stb7100ref.cmd**
stb7100refstmmxusb	**stb7100refstmmx_setup**	**stb7100ref.cmd**

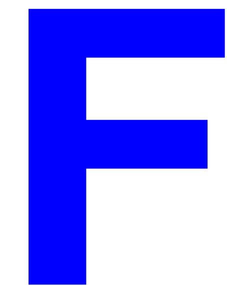
Table 60: TAP configuration commands

See *Table 22 on page 95* and *Table 23 on page 97* for more details of these commands.

Additional examples of using the **jtag** command to configure and query the TAP of a target are defined in the GDB command script files listed in *Table 61*. These script files are located in the subdirectory **sh-superh-elf/stdcmd** under the release installation directory.

Command file	Usage
jtaghudi.cmd	Defines commands for querying and configuring the ST40 UDI.
jtagstmmx.cmd	Defines commands for querying and configuring the ST MultiCore/Mux device.
jtagtmc.cmd	Defines commands for querying and configuring the TAP Mode Controller (TMC) of the STb7100/STb7109.

Table 61: TAP command files



ST Micro Connect setup

F.1 Overview of ST Micro Connect

In order for a host system to communicate with a hardware target, a dedicated ST Micro Connect is required to provide the host/target interface functionality. It is necessary to configure the ST Micro Connect before using it for the first time. This appendix explains how this configuration is achieved. Full details on the ST Micro Connect may be found in the *ST Micro Connect Datasheet* (ADCS 7154764).

Table 62 provides an overview of sockets and connectors on the ST Micro Connect.

Label	Connector	Purpose
TARGET	26-pin IDC box header	Carry the signals from the ST Micro Connect to the target board. The cable to the board may differ from board to board. That is, different boards may have different connectors on them, and may require a different cable. Please ensure the correct cable is used for the target board.
SERIAL	9-pin D-type female	RS-232 serial connection to a host system. This is used for configuring the ST Micro Connect, and for viewing diagnostics. A 9-pin male to 9-pin female straight (not crossed) cable is normally required.

Table 62: ST Micro Connect connectors

Label	Connector	Purpose
ETHERNET	RJ-45 female	This is a standard 10 MBd/s Ethernet connection. A standard RJ-45 Cat-5 cable is required to connect the ST Micro Connect to the network.
USB	USB type-B	A standard type-A to type-B USB cable is required to connect the adaptor to the host PC.
PARALLEL	25-pin D-type	Not used
PWR	5-pin DIN female	5 V power. The power supply unit provided with the ST Micro Connect should be used.

Table 62: ST Micro Connect connectors

The ST Micro Connect can be used with the toolset via Ethernet or USB. Ethernet allows many users to share the networked device, while the USB connection provides a direct connection to a single machine. The serial interface is used only for configuring the ST Micro Connect and the parallel port is not supported for use. When using the Ethernet interface, the ST Micro Connect has to be configured for use on the network while the USB support works out of the box without any configuration. Whether in use via USB or Ethernet only one host machine may use the device at one time.

F.2 Ethernet connectivity

F.2.1 Preliminary configuration

Connect and plug in the power supply unit and the serial cable. Do not connect a network cable. It is recommended that ST Micro Connect is not connected to the network until it has been configured. The host end of the serial cable is connected to a VT100-type terminal, or a COM/Serial port on a standard PC, Sun or Linux host. The host end of the serial cable is referred to as a 'terminal' which may be a real terminal (for example, VT100) or a terminal emulator. Please consult the appropriate documentation to configure the terminal.

The terminal serial interface must be set to the following parameters:

- 9600 Baud,
- 8 data bits,
- no parity,
- 1 stop bit,
- no flow control.

When the above preliminary steps have been completed, power-on the ST Micro Connect. As it is initialized, the three LEDs adjacent to the TARGET connector illuminate in sequence.

When the ST Micro Connect has been powered-up, a two-line banner is displayed on the terminal. To test bidirectional serial connectivity, press **Return** several times on the terminal. Each time a **>** prompt should be offered. If not, the configuration and connectors must be checked. Alternatively, test against a good, known system.

A list of the commands that the ST Micro Connect supports are displayed by entering the **help** command.

Each command is executed on receipt of the **Return** key. Useful commands include:

status
config
ping
reboot

F.2.2 Configuring network information

To configure the ST Micro Connect, the following network information is required:

- Adaptor Internet Address (IP),
- Subnet Mask (Netmask),
- Gateway Address,
- Adaptor Network Name (corresponding to the Adaptor IP Address).

A network name or IP address may be used to communicate with the ST Micro Connect.

A system or network administrator must be consulted for suitable values of these parameters. Using incorrect values can have a detrimental effect on the network.

Assuming that the values given are:

192.168.1.200	*network address*
255.255.255.0	*netmask*
192.168.1.1	*gateway address*
stmc	*adapter network name*

enter the following at the terminal:

```
ipaddr 192.168.1.200
subnet 255.255.255.0
gateway 192.168.1.1
config
```

After the **config** command, the newly entered values are displayed. They have not as yet been activated and have not been copied into non-volatile memory. The values displayed should be carefully checked to ensure that they are the values expected. Assuming that the values appear to be correct, the parameters should then be written into the non-volatile memory, so that on a subsequent power-up, the same configuration values apply. Enter the following commands at the terminal:

```
nvsave
reboot
```

After the reboot, connect the network cable, and attempt to ping another machine on the network from the ST Micro Connect using, for example:

```
ping 192.168.1.1
```

If this is successful, then attempt to ping the ST Micro Connect from a host machine using:

```
ping 192.168.1.200          use IP address
ping stmc                   use network name
```

Finally, attempt to telnet into the adaptor by typing:

```
telnet stmc                 telnet into adaptor
help                        adaptor command
quit
```

F.2.3 Commissioning

After following the instructions in *Section F.2.2: Configuring network information*, the configuration is complete, and the ST Micro Connect is now usable as a network device.

It is recommended that the ST Micro Connect is powered-down, and the serial cable removed. Boot the ST Micro Connect to ensure that the new configuration is preserved in non-volatile memory. To verify the network configuration has been preserved, after booting, check the configuration by using **telnet** to connect with the adaptor:

```
telnet stmc
config
quit
```

If it is necessary to change the network configuration in the future, this can be achieved using **telnet** from any host to make the changes, rather than using the serial interface. The serial cable may still be used to make configuration changes, but it is no longer needed to make subsequent configuration changes. If network changes are made that result in the ST Micro Connect being non-functional, then the serial cable is required to re-configure it.

Once the ST Micro Connect has been successfully commissioned, it may be connected to the target board using the appropriate cable. The recommended way of testing the functionality of the board using the adaptor is run a program on the target. For more information, see *Section 1.6: Installation on page 34*.

F.3 USB connectivity

USB connectivity to the ST Micro Connect is currently only supported from a Microsoft Windows host. The USB connection to the ST Micro Connect is very simple to commission as it requires no additional configuration to be made to the ST Micro Connect itself.

Connect and plug in the power supply unit (PSU) and the type-B USB connector to the ST Micro Connect. Next plug the type-A connector into the host USB connector that will communicate with the ST Micro Connect. The operating system will then detect that a new device has been added and attempt to find the drivers to install it. The drivers are shipped with the ST40 Micro Toolset, and are located in the **`microprobe/usb-driver`** subdirectory of the installation directory. In this directory, select the driver file **`htiusb.inf`** for installation and proceed.

When the driver has been installed, the ST Micro Connect will have been assigned a name and will be ready for use. The name assigned by the installation process is the name the debug and download tools will need to use to connect to the ST Micro Connect. The assigned name of the ST Micro Connect can be obtained from Windows by clicking on the **Unplug** or **Eject Hardware** icon in the Windows system tray which will then display a list of removable devices.

When an ST Micro Connect is connected for the first time to a Windows host that has not had an ST Micro Connect connected before, it is allocated the name **HTI1**. This enumeration is stored in the registry and associated with the unique Ethernet MAC address for the ST Micro Connect. As other ST Micro Connect devices are connected to the host they are given ascending numbers (for example, **HTI2** and **HTI3**). As long as the registry entries are maintained, each ST Micro Connect is always associated with its original number enumerated on that particular host. If however an ST Micro Connect is used on a different host it will be enumerated afresh and may be associated with a different number. If only one ST Micro Connect is connected to the host then the name **usb** may be used as alternative to the allocated **HTI***n* name.

Once the ST Micro Connect has been successfully commissioned, it may be connected to the target board using the appropriate cable. The recommended way of testing the functionality of the board using the ST Micro Connect is to run a program on the target.

Revision history

Reference	Change
Version J	
Throughout	Completely updated for R3.1 Product release of the toolset. Updated to GDB 6.3 and Insight 6.1. Added support for STb7109 and STb7100-Ref.
Introducing the ST40 Micro Toolset chapter	Added details of sh4gdbtui, the text user interface for the debugger. Updated details of the os21prof and sh4rltool tools.
Cross development tools chapter	Added details of sh4gdbtui, the text user interface for the debugger. Updated the list of GDB SuperH configuration specific options and SuperH specific GDB commands. The register40.cmd commands no longer require an additional argument for endianness.
Using Eclipse	Added new chapter to introduce Eclipse.
Building open sources chapter	Updated to provide more information for building sources, particularly on Windows.
Reloctable loader library chapter	The section on writing and building a relocatable library or main program has been updated.

Reference	Change
Version I	
Throughout	Completely updated for R3.0.3 Product release of the toolset. All chapters have been updated. The JTAG control appendix has been completed.
Version H	
Throughout	Completely updated for R3.0.2 Beta release of the toolset. All chapters have been updated. The Relocatable loader library chapter and the Performance counters and Branch trace buffer appendices have been added. The JTAG control appendix has been added and will be completed for the product release. The Toolset changes since R2.0.5 appendix has been moved to the CD-ROM.
Version G	
Throughout	Minor rephrasing and grammatical changes. Details of the ST220-Eval development board have been added. Replaced UDI with H-UDI.
Code development tools chapter	Updated list of recognized boards.
Version F	
Throughout	Carried out minor rephrasing and grammatical changes. Added details of SH-4 202 support. Updated ST40 version number to 2.1.3.
Introducing the ST40 Micro Toolset chapter	Added details of the sti5528loader example
OS21 source guide chapter	Replaced GDB_START and GDB_END with GDB_BEGIN_EXPORT and GDB_END_EXPORT in the GDB OS21 awareness support section.
Toolset tips appendix	Added the section Just in time initialization.
Toolset changes since R2.0.5 appendix	Changed OS21 version to V2.1.

Reference	Change
Version E	
Throughout	The entire manual has been restructured and the following new chapters and appendices have been added: Code development tools, Cross development tools, Core performance analysis guide, Development tools reference, ST Micro Connect setup, Toolset changes since R2.0.5. In addition the following changes have been made: Added Windows XP to the supported Windows versions. Updated ST40 version number to 2.1.2. Updated GCC version number to 3.2.1. Replaced ST40RA166 with ST40RA. Renamed STLite/OS20 to OS20.
Preface	Added the section Conventions used in this guide.
Introducing the ST40 Micro Toolset chapter	Updated list of Libraries delivered and added subsections for the C library, C++ library and threading. Added descriptions of the new OS21 examples.
Using Insight chapter	Chapter has been rewritten.
OS21 source guide chapter	Updated the options described in the Configurable options section. Updated details of the support files in the Building the OS21 board support libraries section.
Booting OS21 from ROM chapter	Chapter has been rewritten.
Porting from OS20 chapter	Updated location of interrupt.h OS21 header file. Updated Interrupts and caches.
Toolset tips appendix	Added the section Memory managers. Managing critical sections in OS21: The section task / interrupt critical sections has been rewritten. Debugging with OS21: The examples have been replaced.

Reference	Change
Version D	
Throughout	Changed document title to ST40 Micro Toolset User's Guide. Added the chapters Using sh4xrun, Using Insight, Building open sources and OS21 for ST40 source guide. Added the appendix, Toolset tips. Changed the term "include files" to "header files". Added details of the simulator.
Preface	Added License information section.
Introducing the ST40 Micro Toolset chapter	Changed name from Introducing the GNU tools. Added details of where the GNU sources are located on the CD. Added footnote relating to big-endian versions of the libraries. Added introductory paragraph to the Installation section. Added sh4chess to list of tools. Expanded note explaining library locations in the Libraries delivered section. Changed the description of the getting started examples in the section, The examples directory. Corrected the location of the st40.bat file. Added details of Cygwin to the Windows installation description. Corrected the names of display40.cmd commands. Updated list of commands in sh4targets.cmd. Added how to access the help for the GDB script files.
Version C	
Throughout	Added details of os21/soaktest example. Corrected ST40RA166 Overdrive board to ST40STB1-ODrive board. Replaced minor typing and grammatical errors.

Reference	Change
Version B	
Throughout	Removed details of unsupported boards. Updated version numbering. Added Index.
Introducing the GNU tools chapter	Added definition of bare machine application. Updated details of the documents directory. Added footnotes for boards that are no longer in production. Replaced board codes with full production names. Removed references to the bare library directory. Updated the Release directories section. Renamed connect.cmd to sh4si.cmd.
Version A	
	Initial release

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