Freedom Studio User Manual

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Introduction

Freedom Studio is an integrated development environment which can be used to write and debug software targeting SiFive based processors. Freedom Studio is based on the industry standard Eclipse platform and is bundled with a pre-built RISC-V GCC Toolchain, OpenOCD, and the freedom-e-sdk. The freedom-e-sdk is a complete software development kit target SiFive bare metal processors.

Product Overview

This section will describe the individual components used in a release.

Eclipse

The major versions of the Eclipse feature plugins are as follows:

- Eclipse Oxygen
- Eclipse C/C++ Development Tools
- Git Integration for Eclipse (eGit)
- Terminal View Core
- SiFive RISC-V Cross Compiler
- SiFive OpenOCD Debugging
- SiFive J-LINK Debugging
- SiFive freedom-e-sdk Project Template

Setting Up Freedom Studio

Download and Install

Freedom Studio can be downloaded from the SiFive website at the following address:

https://www.sifive.com/products/tools/

Downloads are provided for Windows, MacOS, and Linux.

Windows Installation

It is important that you choose an installation path that does not contain spaces. Freedom Studio will check the installation path when started and will warn you if it detects a path that contains any space characters.

Unzip the download to a directory on your PC by right-clicking on the zip file and selecting "Extract All". After unzipping the bundle, you can open Freedom Studio by clicking on FreedomStudio.exe.

Windows drivers are provided in the bundle for supported SiFive development boards. Please install the appropriate drivers in order to debug your device. The drivers can be found in the "FreedomStudio/SiFive/Drivers" folder.

For setting up SiFive development platforms, please consult the platform's User Guide and Windows Board Setup.

MacOS Installation

It is important that you choose an installation path that does not contain spaces. Freedom Studio will check the installation path when started and will warn you if it detects a path that contains any space characters.

Extract FreedomStudio.tar.gz to the desired folder by double clicking the bundle. Freedom Studio is not currently a signed macOS application and therefore may present an error when running. Therefore in order to run Freedom Studio on macOS it may be necessary to open Freedom Studio for the first time as described in this URL: https://support.apple.com/kb/PH25088?locale=en_US It is also possible to execute this command line to remove the extended attribute marking the .app file for quarantine:

```
$ xattr -d com.apple.quarantine FreedomStudio.app
```

Start Freedom Studio by clicking on FreedomStudio.app found in the FreedomStudio folder which was just extracted.

For setting up SiFive development platforms, please consult the platform's User Guide and macOS Board Setup.

Linux Installation

It is important that you choose an installation path that does not contain spaces. Freedom Studio will check the installation path when started and will warn you if it detects a path that contains any space characters.

Extract FreedomStudio.tar.gz to the desired folder using the following command:

```
tar -xf /path/to/FreedomStudio.tar.gz
```

For setting up SiFive development platforms, please consult the platform's User Guide and Linux OS

Board Setup.

Contents

The directory contents are as follows:

FreedomStudio

The installation root directory

FreedomStudio(.exe)(.app)

The OS specific executable to open

SiFive

SiFive files

SiFive/doc

The documentation delivered with Freedom Studio.

SiFive/Licenses

Open Source Licenses.

SiFive/Misc

Directory containing miscellaneous files such as OpenOCD config files, and Linux OpenOCD udev rules

SiFive/openocd*

Directory containing the bundled OpenOCD

SiFive/toolchain

Directory containing the RISC-V GCC toolchain

Build Tools (Windows Only)

Tools which allow eclipse CDT to function in a Windows environment such as make, echo, etc...

jre (Windows and Linux Only)

The Java Run Time Environment (JRE). On macOS the JRE is located under the FreedomStudio.app bundle.

Tools Setup

Freedom Studio will automatically detect its installation path on the first run and configure itself to use the bundled tools described in Section <Contents>>. If, for any reason, Freedom Studio was not able to detect the bundled tools, it will prompt the user to enter the tool paths directly with the dialog shown in Figure [Toolchain Selection Dialog]. If prompted, be sure to select the "bin" directory which contains the tool binaries. These paths will set the global defaults used by Freedom Studio.

The tool paths can be changed at anytime by clicking the following:

Windows and Linux - *Window – Preferences – Freedom Studio*

MacOS - *Freedom Studio – Preferences – Freedom Studio*

Global RISC-V Toolchain Paths - for SiFive toolchains, select the default toolchain *RISC-V GCC/Newlib* and use the browse button to select the toolchain directory

Global OpenOCD Paths - for SiFive OpenOCD distributions, set the OpenOCD executable to "openocd" and use the browse button to select the OpenOCD directory

The tool path preferences can be set at 3 different scopes: Global, Workspace, and Project. Global scope sets the default for the installation and is the lowest priority. Workspace scope allows you to set the toolchain preferences specific a a given Workspace, and will override the Global setting. Project scope, which can be set by right clicking a project in your workspace and selecting *Properties – Freedom Studio*, allows you to set preferences on a per-project basis. Project scope always takes priority over Global and Workspace.

This flexibility allows the user to easily work with a number of different tools installed on the same system, such as one built from source using Freedom-E-SDK, while still maintaining project portability.

The Freedom Studio Environment

Workspaces

Eclipse uses workspaces to group together a set of related projects. Eclipse workspaces allow for a lot of flexibility in how one organizes their projects. For example, it is possible to have a workspace which contains only a single project. It is also possible to have a workspace which contains multiple related projects such as a library project and an application which depends on that library.

Switching workspaces is accomplished by selecting *File – Switch Workspace*.

When starting Freedom Studio, Eclipse will prompt you to select a workspace. Freedom Studio will remember the locations of previously selected workspaces.

When choosing a workspace location do not chose a location that contains spaces in the path.

Eclipse Perspectives

Eclipse uses perspectives to group windows together which are collectively useful for a given task.

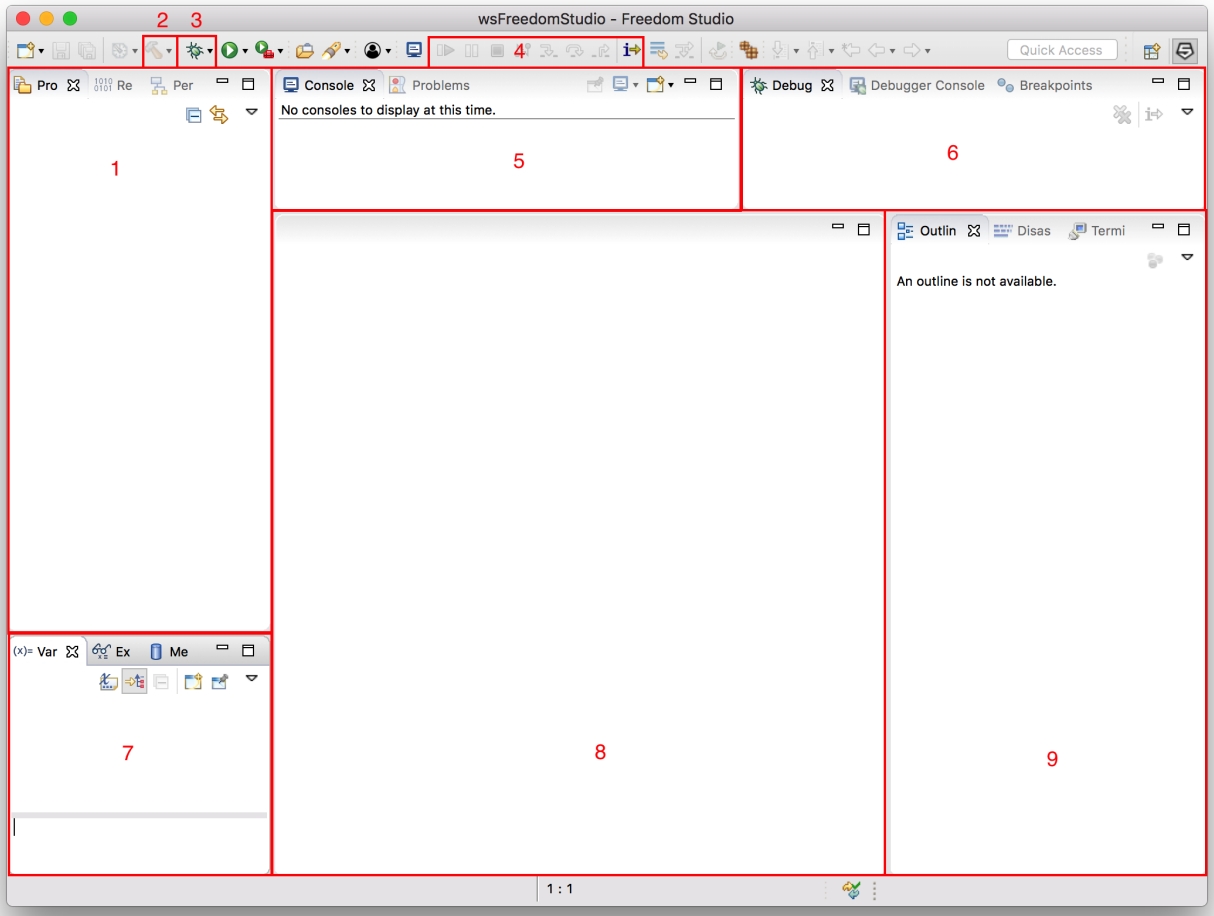
Freedom Studio ships with its own SiFive perspective which can be useful for both programming and debugging. Please see Section [SiFive Perspective] for a detailed description of the SiFive Eclipse perspective.

Freedom Studio also ships with the standard Eclipse perspectives: C/C++ , Debug, and Git. From Eclipse, you can change perspectives by clicking *Window – Perspectives – Open Perspective*.

Perspectives are user customizable and persistent to a workspace.

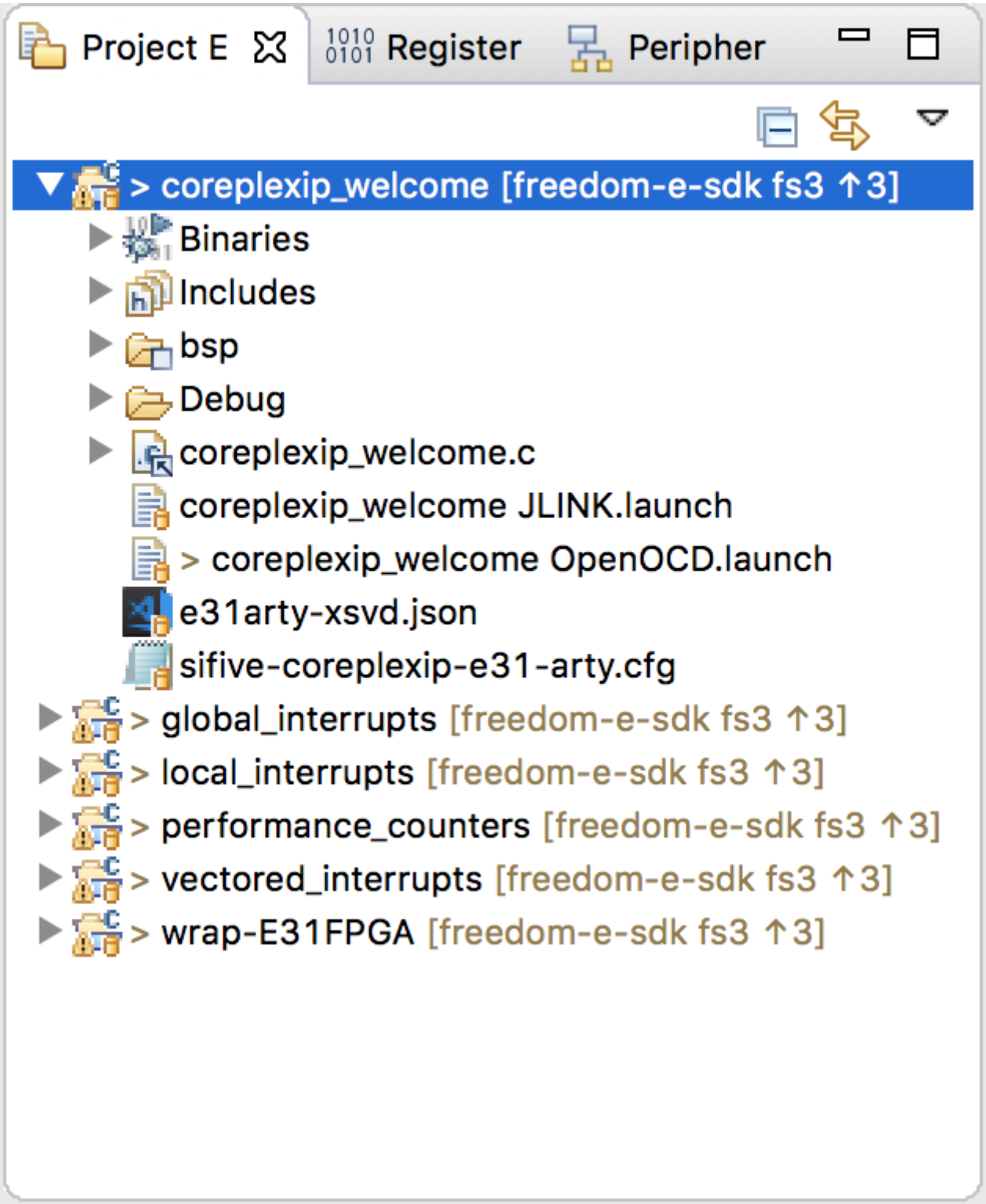
The SiFive Perspective

The SiFive Perspective



1. Project Explorer, Register, and Peripheral Views. These views are described below.
2. Build Toolbar Button. Pressing this button will build (compile) the active project.
3. Debug Toolbar Button. The down arrow next to the bug lets you pick a specific configuration.
4. Debug Control Toolbar Buttons. These buttons are used for debug run, halt, and stepping control.
5. Console. These views display useful information when building applications.
6. Breakpoint and Debug Views displays useful information when debugging applications.
7. Variable, Expression, and Memory Views. These views are described below.
8. Editor View is used to edit source code.
9. Outline, Disassembly, and Terminal Views are described below.

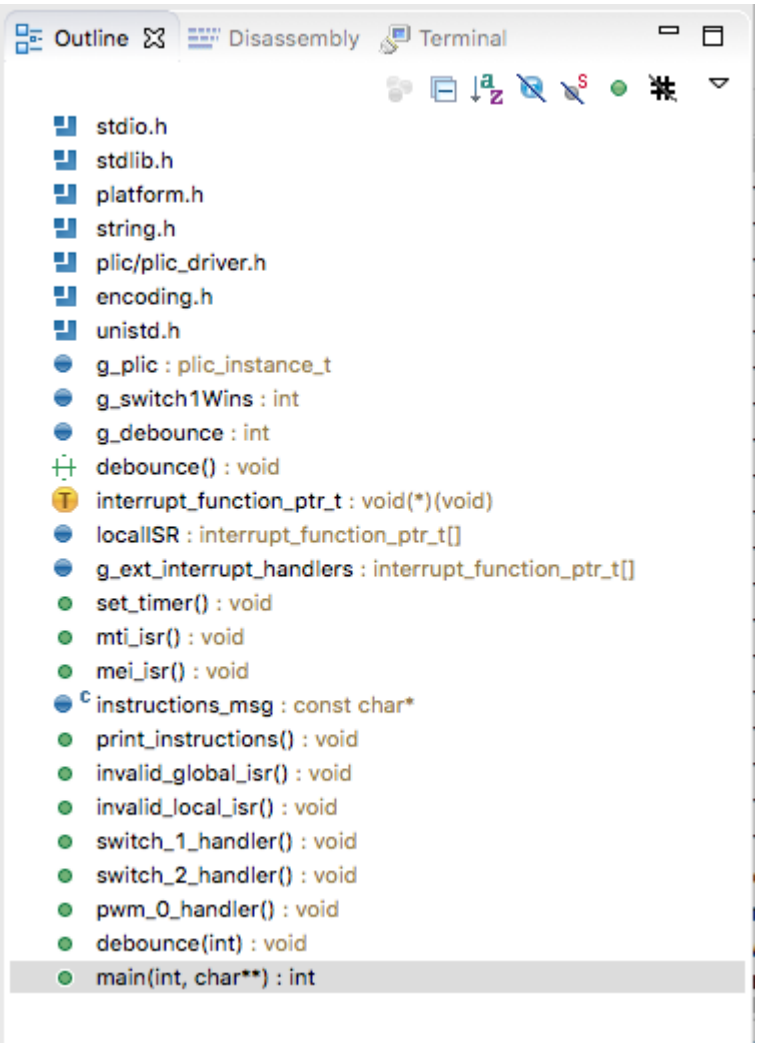
Project Explorer



The Project Explorer view displays projects in the workspace. Use this view for opening, editing, and creating new project source files. If a project contains files under revision control, Project Explorer will also display information regarding the repositories and branches.

Editor, Outline, Disassembly

The Editor and Outline views are used to write and navigate code. The Editor also provides useful contextual information for your code. Hovering the mouse over statements will reveal pop-ups which expand macros, evaluate variables and structures, provide function definitions, etc... Double-clicking a line number in the editor will set a breakpoint at that line.

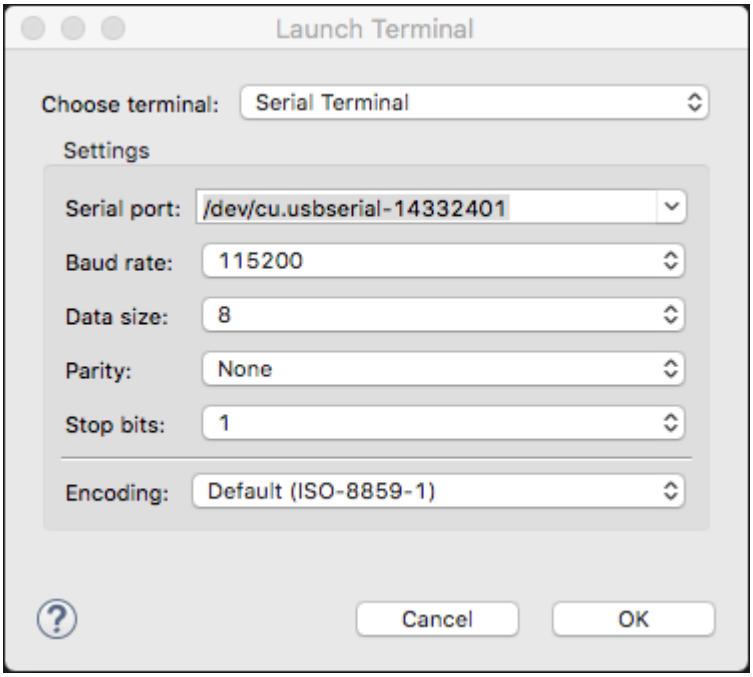


The Outline view, shown in Figure [Outline View], gives a "top-level" view of the active file in the editor including functions, types, constants, etc... Clicking on an item in the Outline view will take you to that items location in the source code.

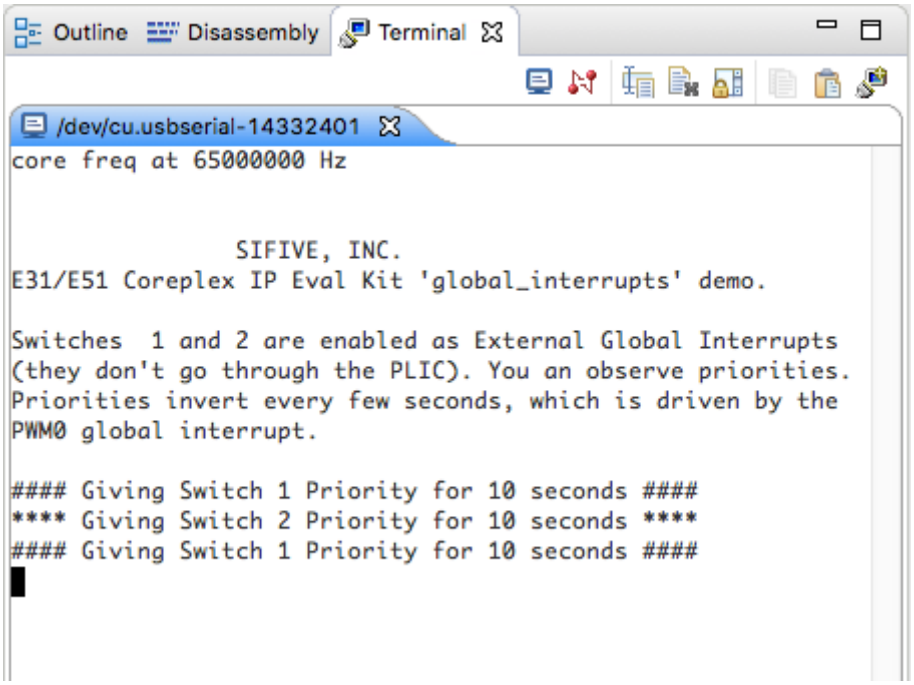
Terminal

The Terminal view, shown in Figure [Terminal View], can be used to display a local terminal, a serial terminal, or ssh into a remote machine. The serial terminal allows the user to view serial output, such as that from a SiFive development board, without leaving the development environment. On Windows platforms this view negates the need for an external serial terminal program. On MacOS and Linux platforms, it is possible to open serial port directly, or open a local terminal and run GNU Screen.

To open a serial terminal, open the Terminal view and select the "Launch Terminal" button which resembles a screen. In the **Choose Terminal** menu, select **Serial Terminal**. It is then possible to select the desired serial settings such as baud rate and encodings.



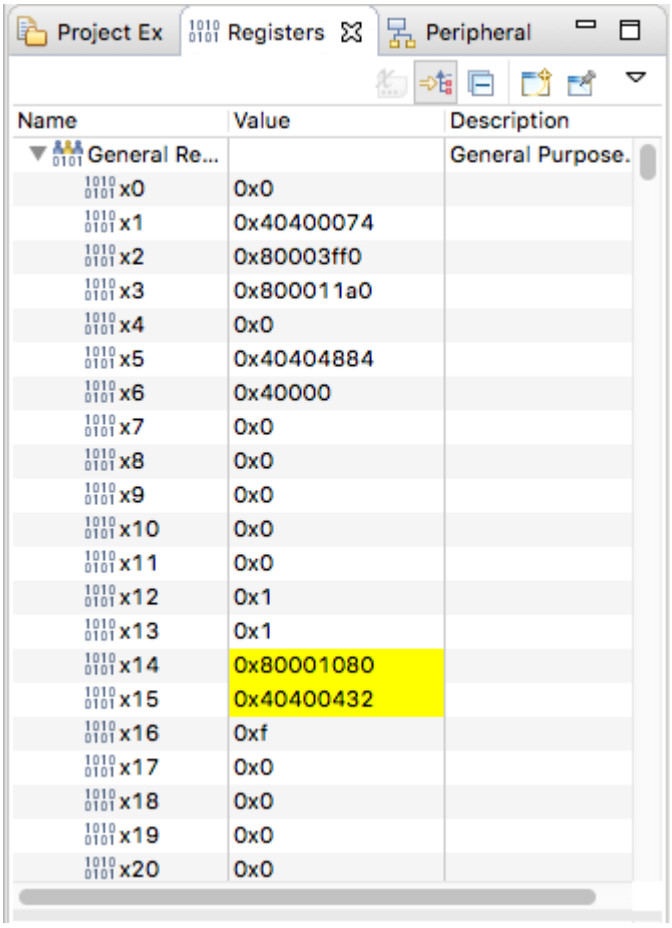
If the text in the serial terminal is displayed incorrectly, make sure that the correct baud rate is selected. SiFive example projects default to 115200 baud. Changing the encoding to UTF-8 might also help.



Breakpoints

The Breakpoints view allows for creating, enabling, and disabling of breakpoints. You can set a breakpoints properties by right-clicking on a breakpoint and selecting "Properties". From the properties menu, you can set properties such as breakpoint type (hard, soft), and ignore count.

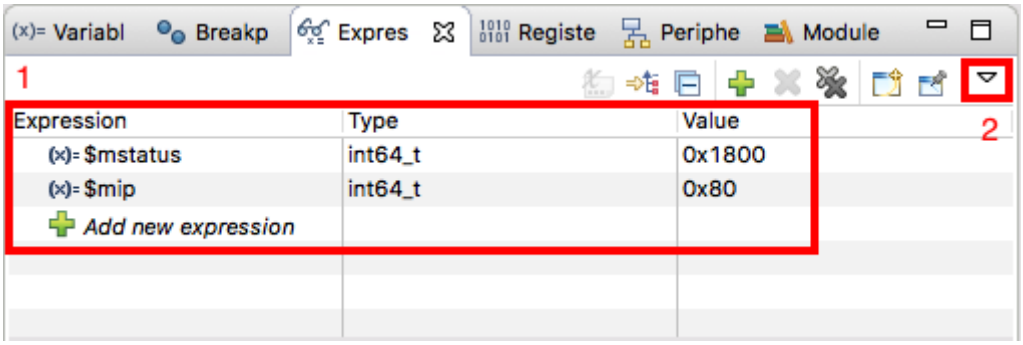
Registers



The Registers view displays the integer and floating point register files. It is possible to write to registers by double-clicking their value field. While stepping through code, the Registers view will highlight registers as they change.

Expressions

The Expression view allows you to view any variable within scope. In addition to variables, it is possible to use this view to see the current value of CSRs on your device. The Expression view, along with other eclipse views which display variables and memory, allows for changing the value format (for example to hexadecimal). The format can be changed by clicking the down arrow marked with "2" in screenshot:



Getting Started

This section walks step-by-step through creating and debugging a freedom-e-sdk project.

Start the new project wizard

From the main menu bar, select `File | New | C Project`

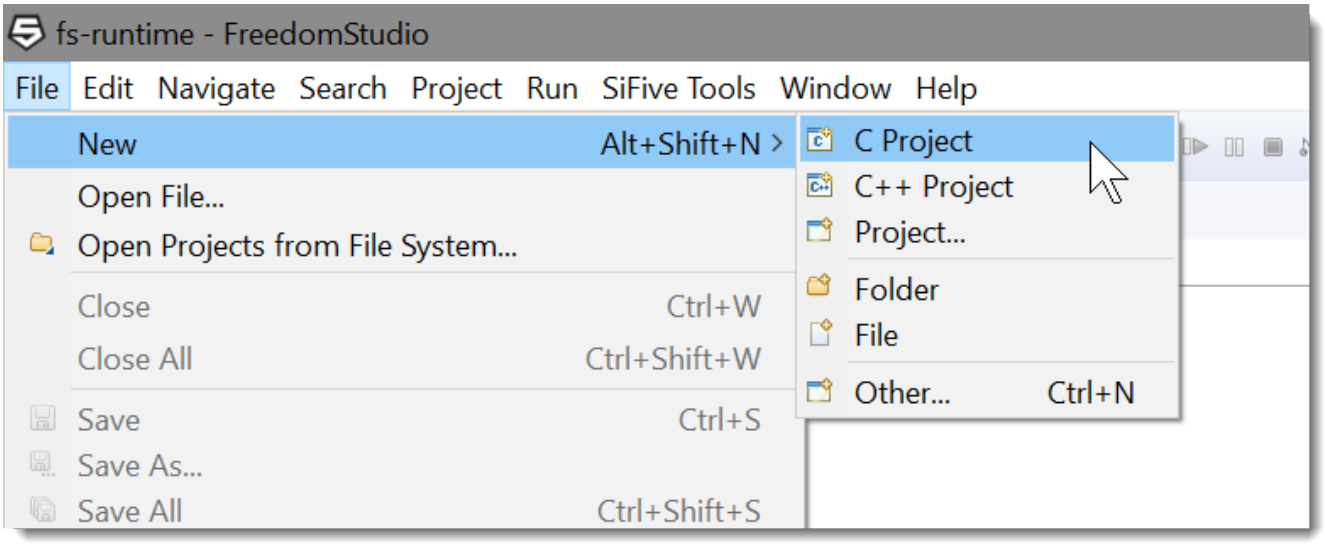


Figure 1. Start the New Project Wizard

Configuring your new project

The first page of the new project wizard is shown below.

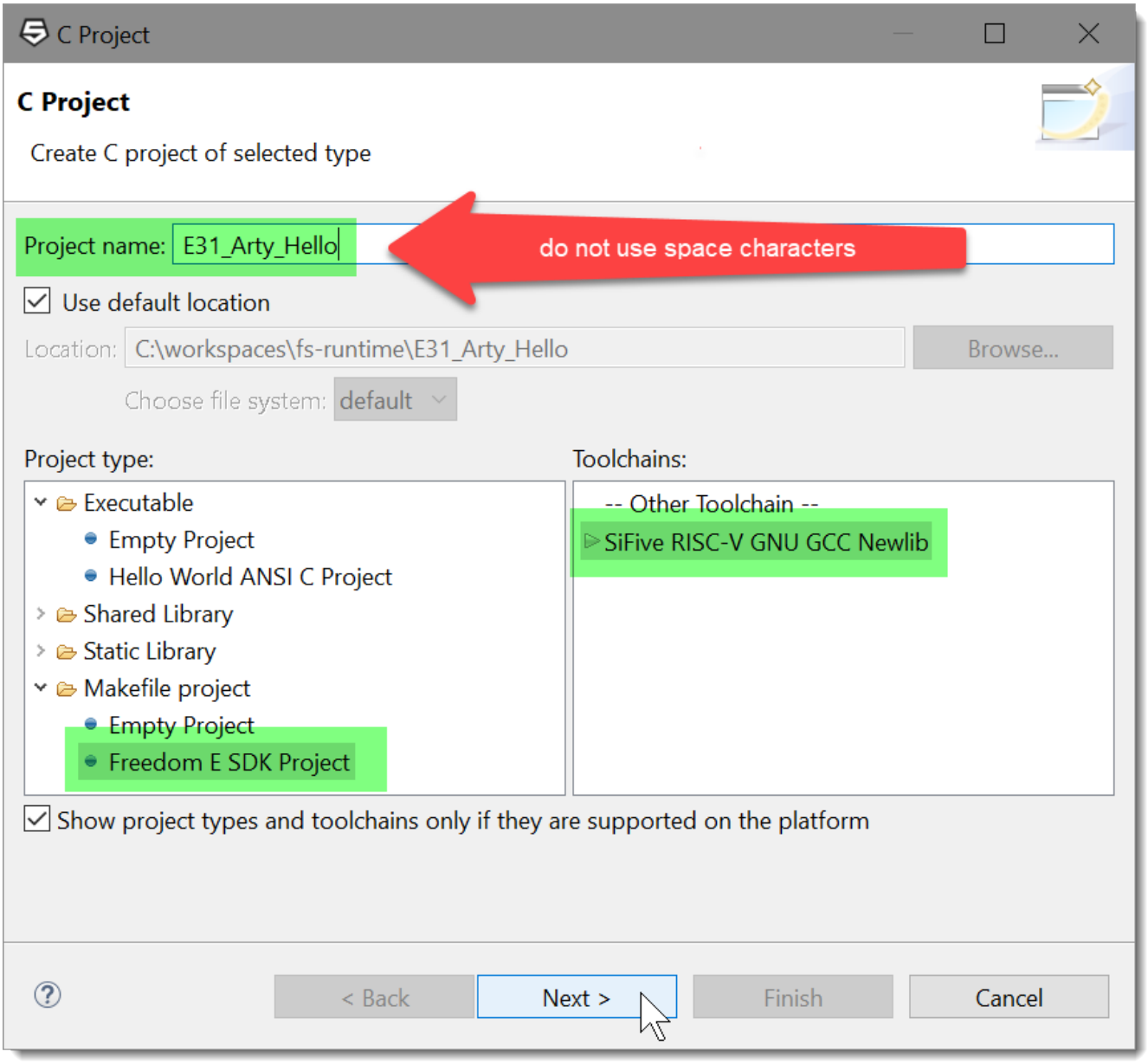


Figure 2. The New Project Wizard, Page 1

When naming your project do not use spaces in the project name.

- Give your project a name. Do not use space characters. The freedom-e-sdk Makefiles cannot handle project paths that contains spaces.
- Select the `Freedom E SDK Project` type located under the `Makefile project` node. You may need to expand the `Makefile project` node to make `Freedom E SDK Project` visible
- The `SiFive RISC-V GNU GCC Newlib` toolchain should be selected automatically. If it is not, select it.
- Click the [Next] button to go to the next wizard page.

Figure 3. The New Project Wizard, Page 2

On this page you will select your target system and an example program. You can also choose to create a debug launch configuration. For this walkthrough I'll be using a SiFive HiFive1 Rev B target and build a simple "Hello World" example program.

- Using the `Select Target` dropdown, select `sifive-hifive1-revb`
- Using the `Select Example Program` dropdown, select `hello`
- Check the `Create a ???? debug launch for this project` checkbox

The type of launch created will be either "JLink" or "openOCD". If the type indicated does not match what you are using, don't worry, you can change this on the next page.

The boxes below each dropdown display summary information about the selected target and program. This information should be helpful in selecting a target and an example program that demonstrates different features of the core and target.

You may notice that the `Finish` button is enabled, meaning you can finish this wizard right now. The settings on the following pages will take default values and your project will be create successfully. This walkthrough will continue through each page, explaining the configuration items.

Click the [Next] button to go to the next wizard page.

Freedom Studio HOWTO Guides

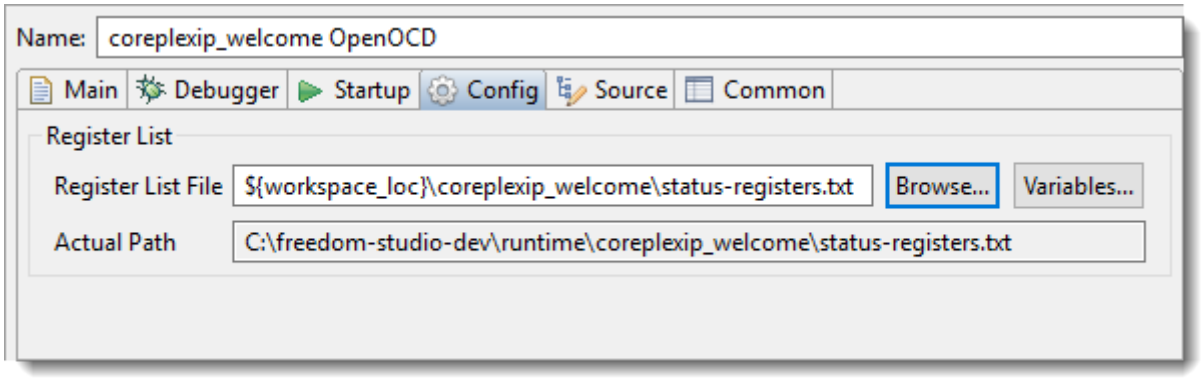
Register List Management

This document provides an overview on how to use and customize the list of registers displayed in the Freedom Studio IDE Registers View. This feature is primarily intended to give you control over what registers are displayed. You may want to use this, for example, when you do not want to see a complete list of all target registers. Or alternately, you may want to specify registers that are not included in the default list of registers.

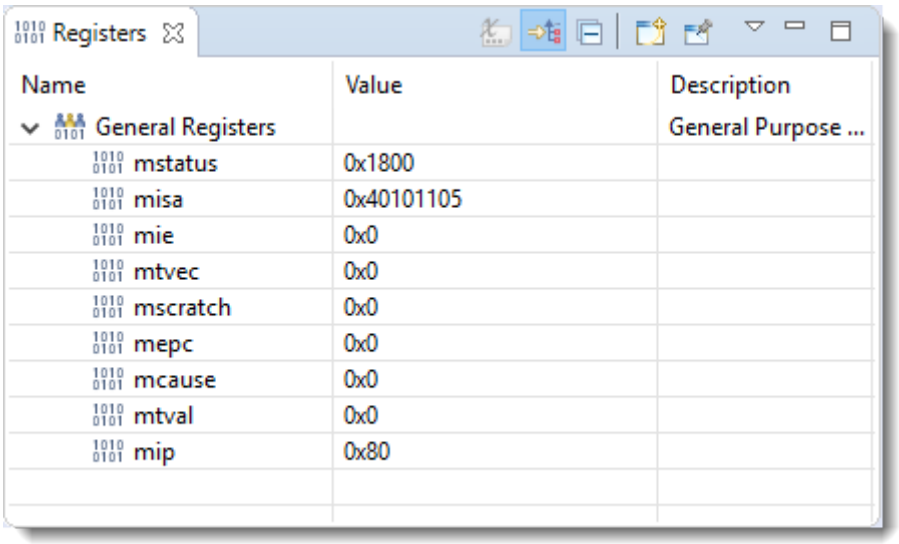
A Quick Example

Let's assume you have a register list file called 'status-registers.txt'. The content of the file looks like:

Now specify that file as a register list in the debug launch configuration:



When you launch your debug session and open the Register View you will see this list:



Creating Register List Files

The Register List File is a text file that, at it's simplest form, lists a single register name on each line. Each listed register will be displayed in the Registers View in the order specified.

Commenting the Register List File

The register list file treats any line that starts with a # (hash) character as a comment line. It is ignored by the parser. The # character can be preceded by whitespace.

Only the first word of a line is treated as a register name. Any additional words are ignored.

Specifying Register Names

Single Registers

Any register can be specified by putting the name of the register as the first word on a line.

Built-in Macros

The following macros can be used to specify multiple related registers without having to list each register individually

Table 1. Built-in Register List Macros

Macro Name	Description
general_registers	The 32 General Purpose Registers plus PC
machine_registers	The machine status registers
perfmon_registers	Performance Monitor Control and Data Registers
fpu_registers	Floating Point Registers

Include File

You can create several register list files, for example, building your lists of related registers, and then build a master register list by including these files in a composite register list file. To include another register list simply use:

```
#include <register-list-file>
```

The `#include` directive can be used multiple times in a single file.

Nested `#include` directives are supported. An `#include` file may `#include` additional files.

Where `register-list-file` is either an absolute or relative path. Relative paths are relative to the folder containing the current register list file being parsed. Keep this in mind if you are using nested `#include` directives and your register list files live in different folders.

Register Ordering

Registers are displayed in the Register View in the same order as they are specified in the Register List File.

Using Register List Files

Now that you have created one or more register list files you may want to use them with Freedom Studio. This section explains your options for specifying how to use your register list files.

Where To Specify a Register List File

A register list file can be specified in 4 place. These four locations are prioritized such that a specification in a higher priority location will override any specification in a lower priority location. The four locations are, in descending priority order (highest priority first):

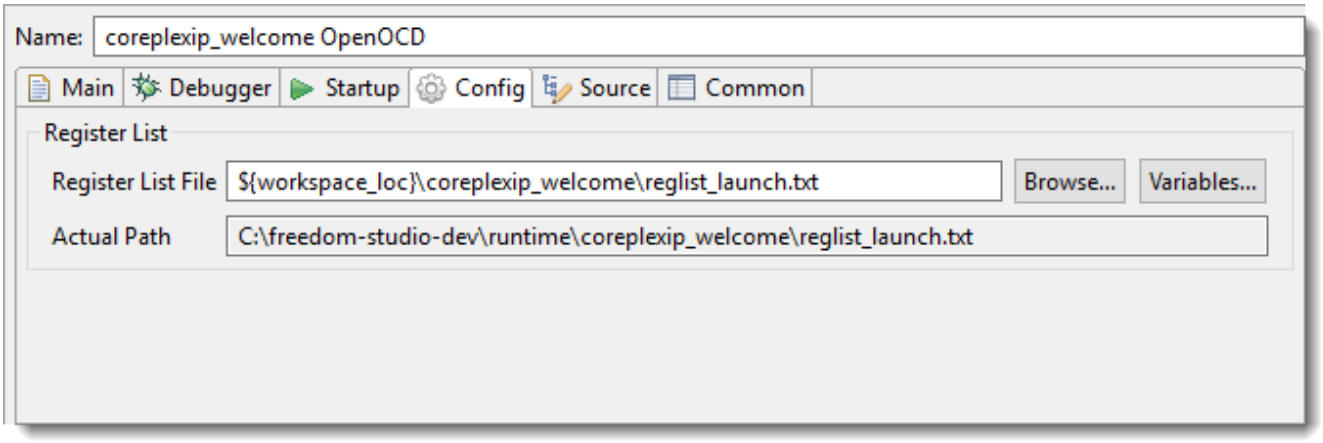
Table 2. Prioritized Register List Specification Locations

Location	Description
Debug Launch Config	Specify a register list file for each individual launch configuration
Project Property	Specify a register list file for each project
Workspace Preference	Specify a register list file for each workspace
Global Preference	Specify a global register list file, for all Freedom Studio workspaces

Debug Launch Configuration

This is the highest priority option for specifying a register list file. You will find the controls to

specify the debug launch register list file on the `Config` tab of the Debug Launch Configuration Dialog:

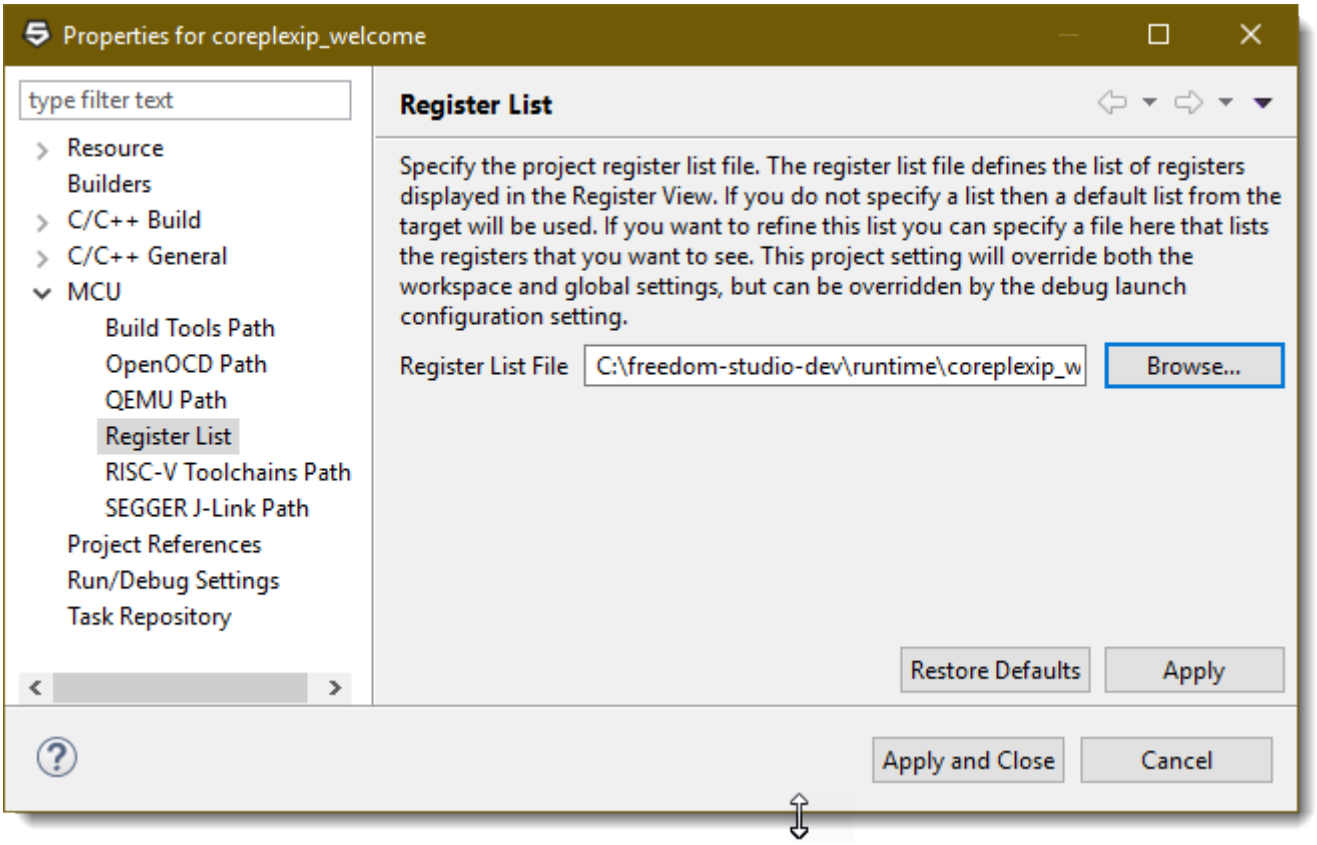


When you specify a register list file in a debug launch configuration the path displayed in the `Actual Path` box will always reflect the fully resolved path to the register list file. If you are not specifying a register list file here then the `Actual Path` may display a path to another register list file if one has been specified using a lower priority specifier.

Project Property

Specifying a register list file as a project property will cause that register list to be used with all launch configuration created for the project, overriding any global or workspace preferences. Each launch can override the project specification by using the launch configuration option to specify a register list file.

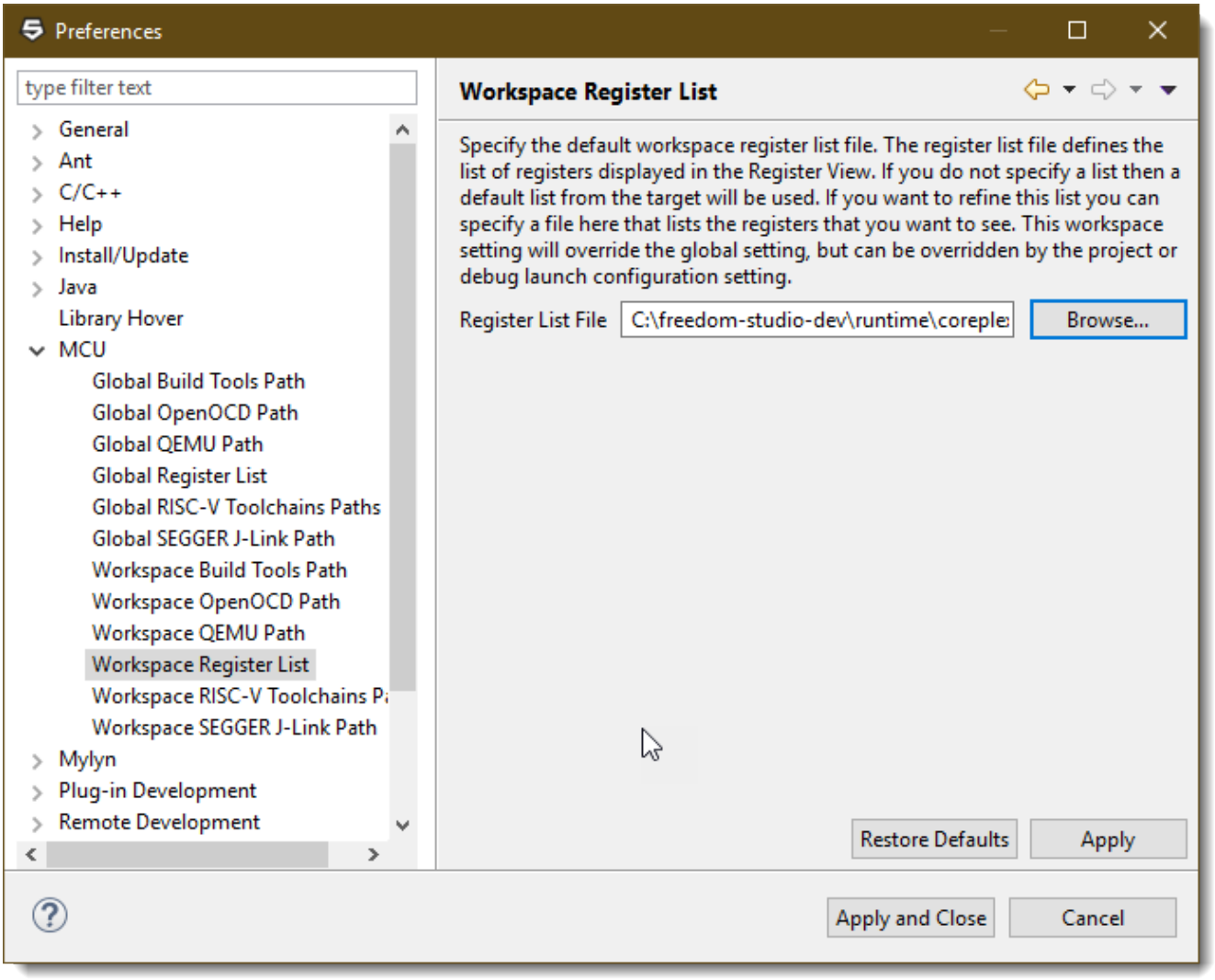
You can setup the project register list file specification by opening the Project Properties dialog and navigating to the `MCU → Register List` property page:



Workspace Preferences

Specifying a workspace register list file will cause that file to be used for all projects within the workspace unless a project overrides the setting by specifying a register list in the project properties or a debug launch configuration.

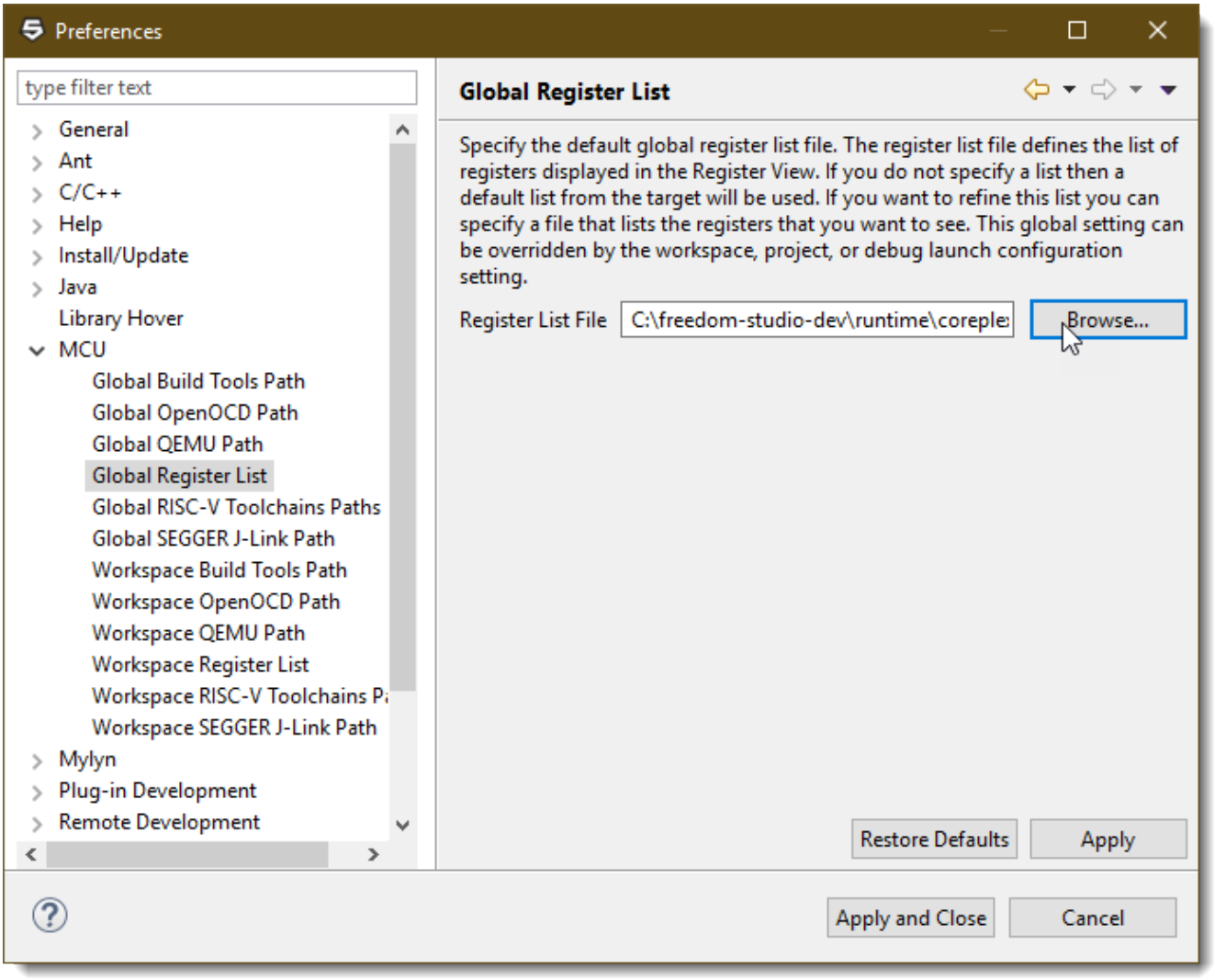
You can specify the workspace preference by opening the Freedom Studio Preference Window and navigating to the `MCU → Workspace Register List` page:



Global Preferences

Specifying a global register list file will cause that file to be used for all Freedom Studio workspaces unless a workspace, project, or debug launch overrides the setting.

You can specify the global preference by opening the Freedom Studio Preference Window and navigating to the `MCU → Global Register List` page:



Managing Hardware Breakpoint Resources

This document summarizes how to manage hardware breakpoint resources on a target system. Different cores have different numbers of hardware breakpoints. It is important for GDB to know how many hardware breakpoints exist on a target. Attempting to use more breakpoints than exist on the target will cause unpredicable debugger problems.

When GDB knows how many hardware breakpoints exist on the target, you can create as many hardware breakpoints as you need, but only the number that exist will be enabled. Freedom Studio will indicate which breakpoints cannot be enabled due to lack of resources. You can then manage the enablement of each breakpoint to ensure that the breakpoint you need is enabled (by disabling breakpoints that you do not need). This screenshot shows how Freedom Studio indicates that too many hardware breakpoints have been enabled.

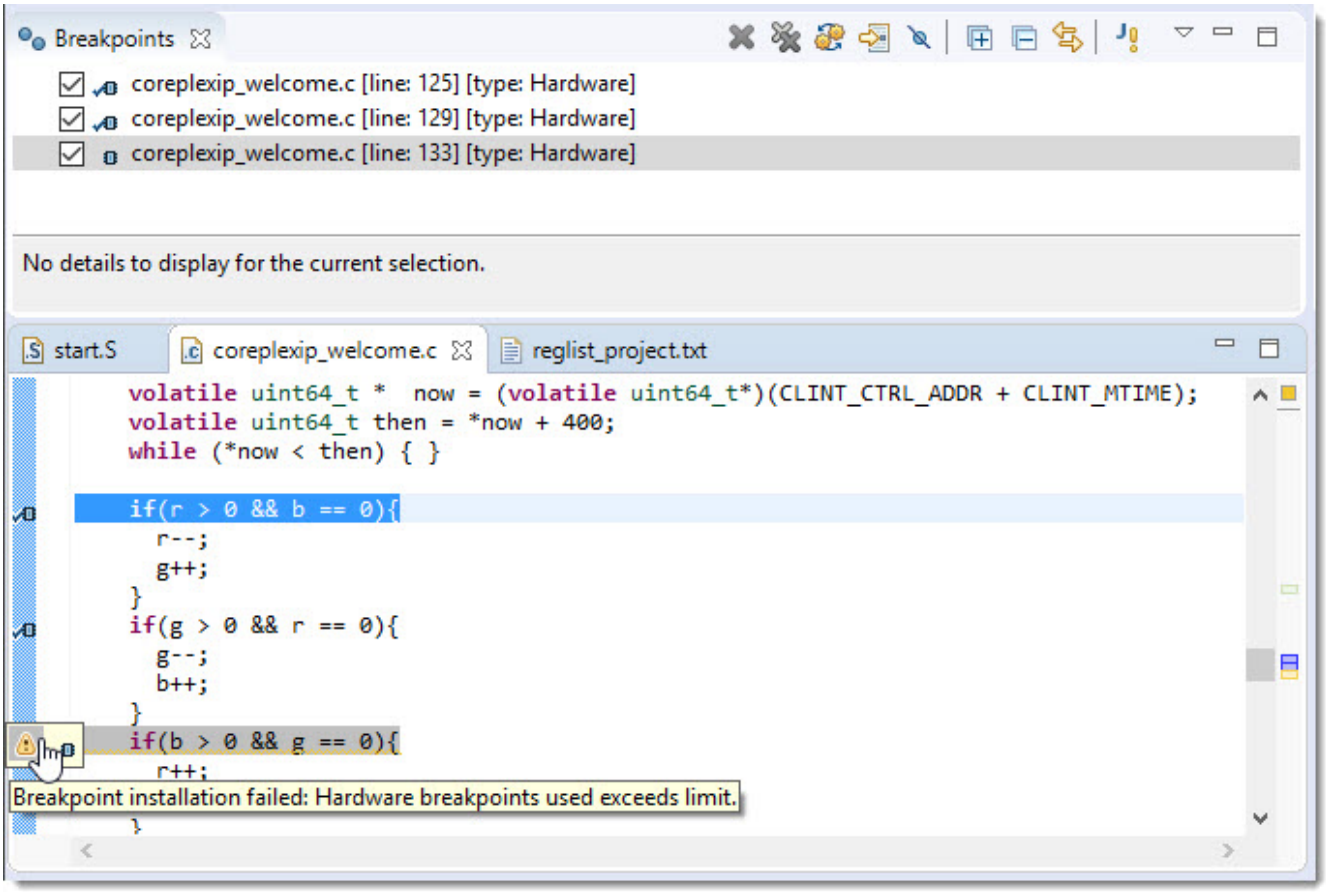


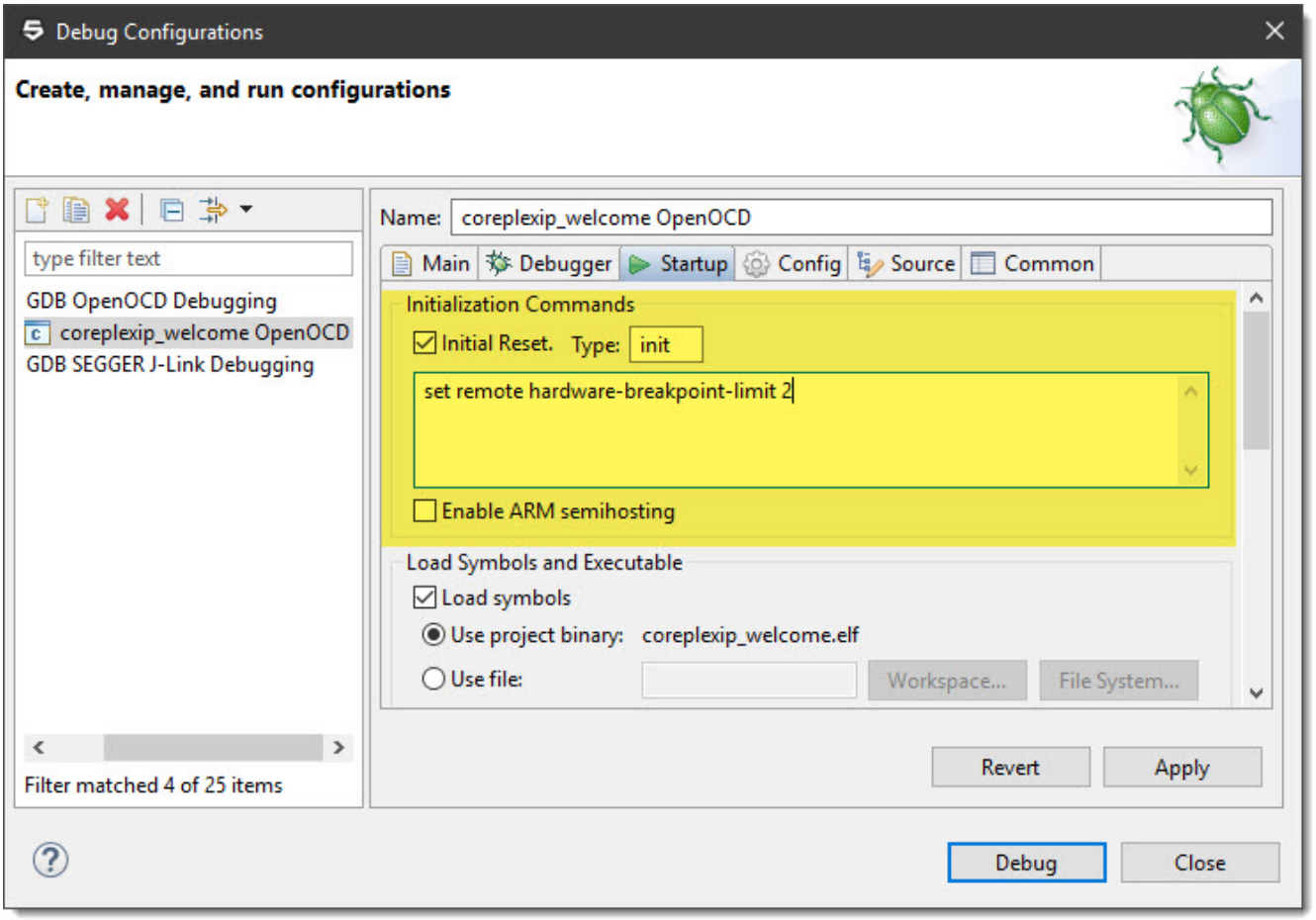
Figure 4. Too Many Hardware Breakpoints

Freedom Studio cannot automatically determine the number of hardware breakpoints present on the system. We plan to add this ability in a future release.

GDB needs to know the number of hardware breakpoints on the target. There are two ways to do this.

Option 1: Add a gdb initialization command

Add the 'set remote hardware-breakpoint-limit' command to the Initialization Commands section of a launch configuration. You must do this for every new launch configuration.



Setting this setting using Option 1 takes precedence over Option 2 (described below). If you find that your preference setting is not being applied, check to make sure that you do not have this command specified in the Initialization Commands.

Option 2: Set a preference or project property

You can set global and workspace preferences to define the number of hardware breakpoints on your target system. You can also set this in your project properties and in a launch configuration.

Finer-grain settings take priority over courser-grain settings. The priority, from highest to lowest is:

- Debug Launch Configuration
- Project Property
- Workspace Preference
- Global Preference

Each new launch configuration will use the highest priority setting that exists. If no setting exists, then Freedom Studio will use the hard-coded default of '2'.

The launch configuration dialog always describes the setting used and where the setting originates. For instance, the screenshot below shows the setting is 4 and originates from the workspace preference setting. This implies that the project property setting has not been defined (it is blank). Clicking on any of the underlined setting scopes will open the corresponding settings page where you can change the setting if desired.

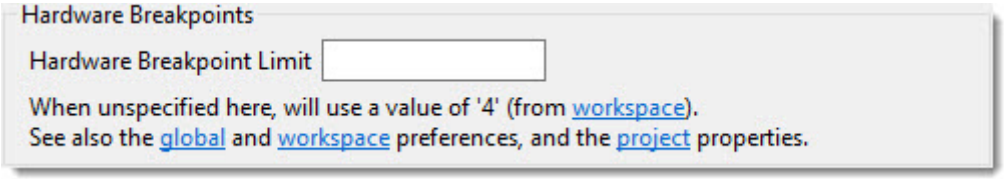


Figure 5. Setting value description

Valid settings

The following table shows the valid setting values.

Table 3. Valid Setting Values

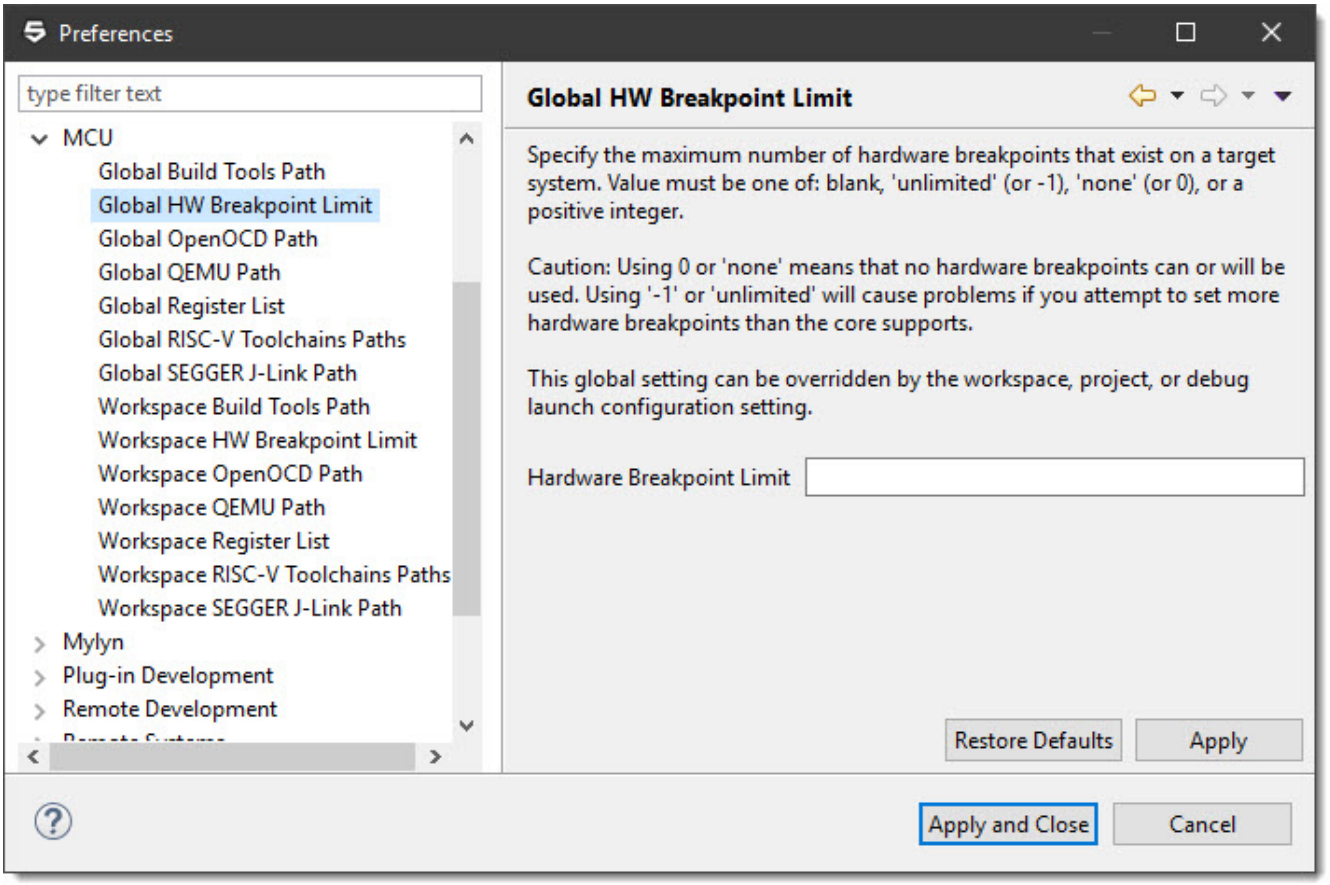
Value	Description
blank	Leave the setting blank and it will not be used.
'unlimited', or -1	Tells GDB that you have unlimited hardware breakpoints.
'none', or 0	Tells GDB that you have no hardware breakpoints.
x, a positive integer	Tells GDB that you have *x* hardware breakpoints.

GDB defaults to 'unlimited'. Freedom Studio overrides this default and uses '2'. Using 'unlimited' allows you to set more hardware breakpoints than may exist on the target. GDB will attempt to set all of them. This leads to unpredictable debugger behavior. We do not recommend using 'unlimited', but we won't stop you from doing so.

Setting the Global Preference

We recommend setting the hardware-breakpoint-limit globally when you have a single target system. This ensures that the setting applies in all workspaces, projects, and launch configurations. If you ever need to use a different target that has a different number of hardware breakpoints you can easily override the global setting using any of the higher priority settings.

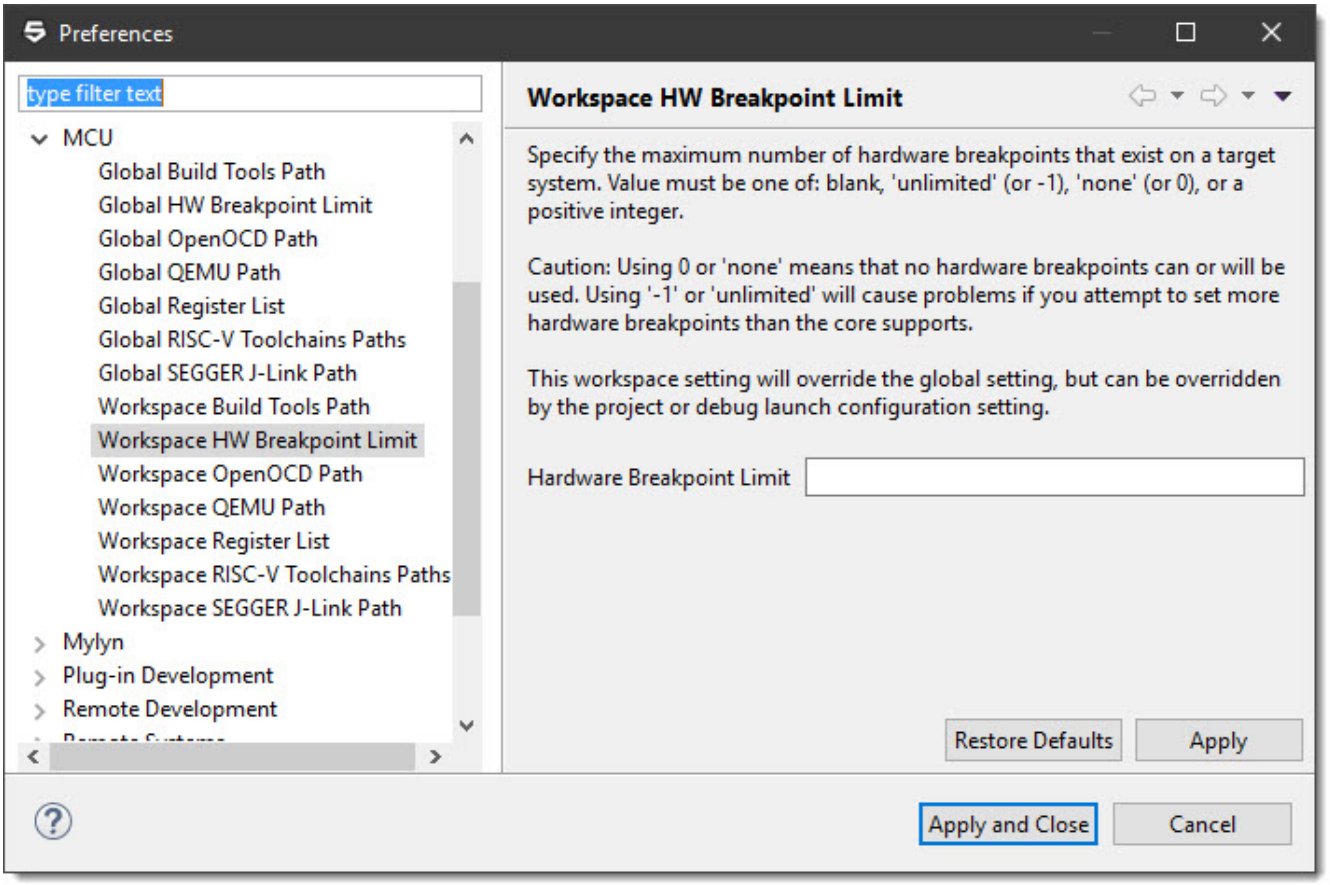
Set the global preference by opening the Preferences Dialog (`Windows -→ Preferences`) and navigating to the `MCU | Global HW Breakpoint Limit` page.



Setting the Workspace Preference

We recommend using the Workspace Preference when you have multiple target systems and want to create a workspace for each target system. This ensures the setting is correctly applied for the target used in each workspace.

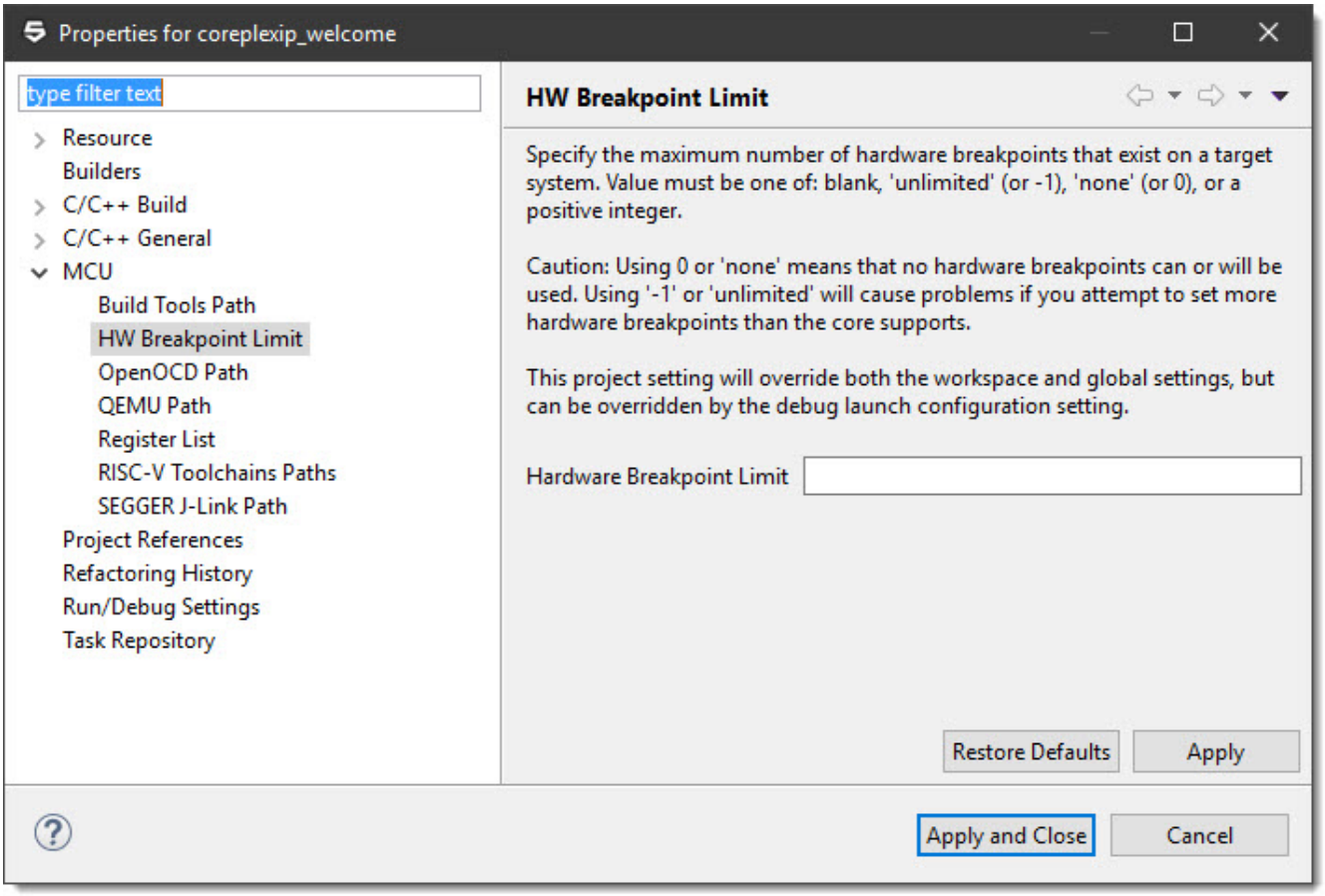
Set the workspace preference by opening the Preferences Dialog (`Windows -→ Preferences`) and navigating to the `MCU | Workspace HW Breakpoint Limit` page.



Setting the Project Property

We recommend using the Project Property setting when you have multiple target system and want to work on all of them within a single Workspace. This ensures the setting is correctly applied for the target used in each project.

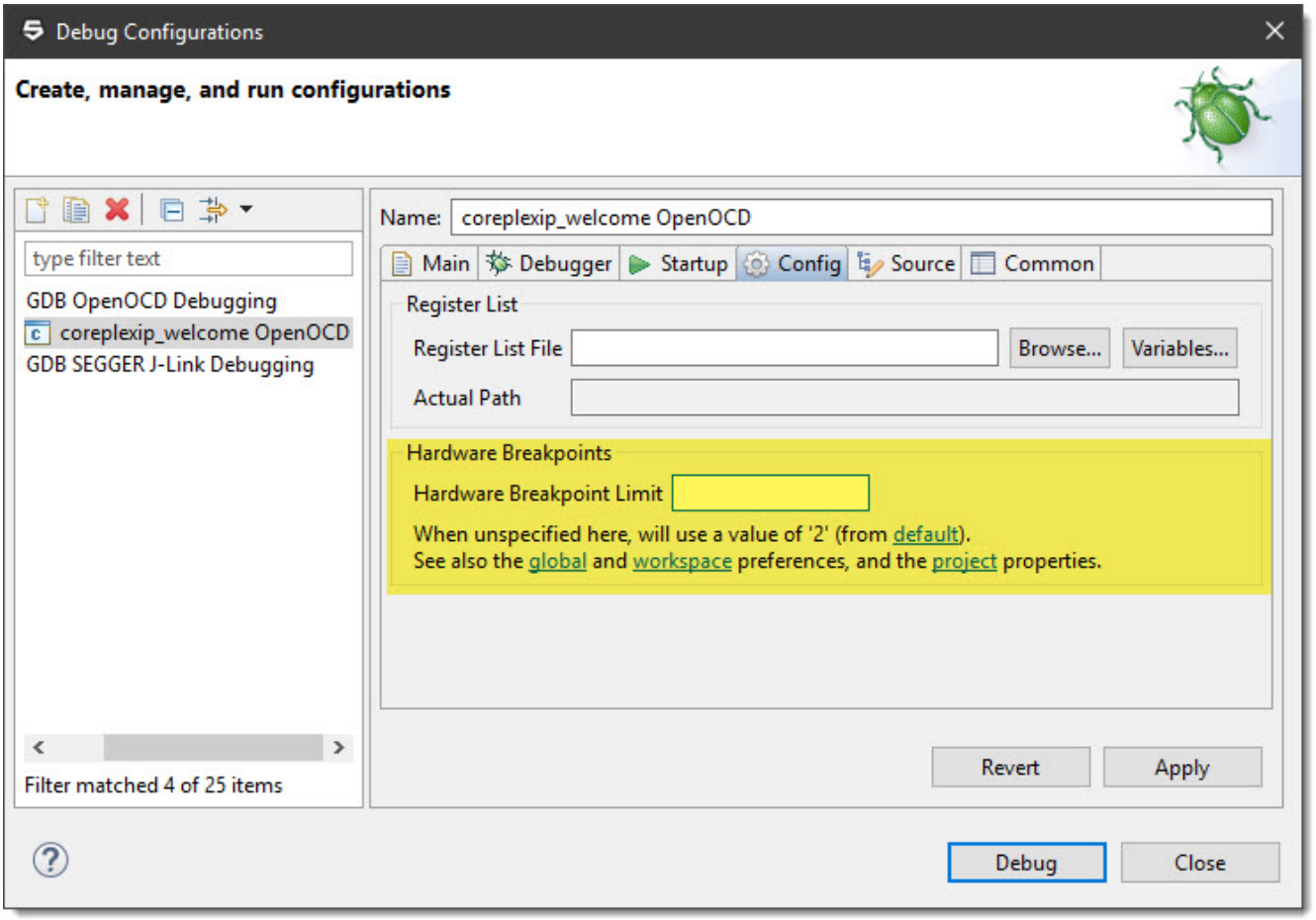
Set the project property by opening the Project Properties Dialog (`Project -→ Properties`) and navigating to the `MCU | HW Breakpoint Limit` page.



Setting the Launch Configuration Attribute

We recommend using the launch configuration attribute setting for target connections that you do not use often. This ensures the setting is not applied to oft-used targets (that are better served using a more broadly applied setting from the project, workspace, or global settings).

Set the launch configuration attribute by opening the launch configuration dialog, navigating to the 'Config' tab, where the breakpoint count can be set for this single launch config.



Conditional Optimization

This section describes how to apply compiler optimization conditionally within a source file.

Debugging optimized code can be complicated because the optimizer will change the order of the code and optimize out variables. When single-stepping through the code the source line indication can jump around erratically. You will not be able to examine variable values that have been optimized away.

The normal solution is to turn off optimizations for the entire project when you need to debug something. Sometimes this is not desirable (or even possible). In these cases you can turn off optimization for just the code that needs to be debugged using compile-time `#pragma` statements.

The comments in the following source example explain how, when, and when not do use the `#pragma` statements.

Example source code

```
// See LICENSE for license details.

#include <stdint.h>
#include <stdbool.h>
#include <stdatomic.h>
#include "encoding.h"
```

```
#include <platform.h>

#ifndef _SIFIVE_COREPLEXIP_ARTY_H
#error 'coreplexip_welcome' demo only supported for Coreplex IP Eval Kits
#endif

void pwm(uint16_t r, uint16_t g, uint16_t b);
uint16_t option0(uint16_t p1, uint16_t p2);
uint16_t option1(uint16_t p1, uint16_t p2);
uint16_t option2(uint16_t p1, uint16_t p2);

static const char sifive_msg[] = "\n\r\
\n\r\
                SIFIVE, INC.\n\r\
\n\r\
         555555555555555555555555\n\r\
        5555                   5555\n\r\
       5555                     5555\n\r\
      5555                       5555\n\r\
     5555       55555555555555555555\n\r\
    5555       555555555555555555555\n\r\
   5555                             5555\n\r\
  5555                               5555\n\r\
 5555                                 5555\n\r\
555555555555555555555555555          55555\n\r\
 55555           555555555           55555\n\r\
   55555           55555           55555\n\r\
     55555           5           55555\n\r\
       55555                   55555\n\r\
         55555               55555\n\r\
           55555           55555\n\r\
             55555       55555\n\r\
               55555   55555\n\r\
                 555555555\n\r\
                   55555\n\r\
                     5\n\r\
\n\r\
";

#if __riscv_xlen == 32
  static const char welcome_msg[] = "\n\r\
\n\r\
Welcome to the E31 Coreplex IP FPGA Evaluation Kit!\n\r\
\n\r";
#else
static const char welcome_msg[] = "\n\r\
\n\r\
Welcome to the E51 Coreplex IP FPGA Evaluation Kit!\n\r\
\n\r";
#endif
```

```
static void _putc(char c) {
  while ((int32_t) UART0_REG(UART_REG_TXFIFO) < 0);
  UART0_REG(UART_REG_TXFIFO) = c;
}

int _getc(char * c){
  int32_t val = (int32_t) UART0_REG(UART_REG_RXFIFO);
  if (val > 0) {
    *c =  val & 0xFF;
    return 1;
  }
  return 0;
}

static void _puts(const char * s) {
  while (*s != '\0'){
    _putc(*s++);
  }
}

/*
 * Enable maximum optimization for the main() function.  The pragma directive for
 * optimization act on a function scope. You cannot place these pragmas around code
 * inside of a function (it will generate a compiler error).
 */
#pragma GCC push_options
#pragma GCC optimize ("3")
int main (void){

  // 115200 Baud Rate at (65 / 2) MHz
  UART0_REG(UART_REG_DIV) = 282;
  UART0_REG(UART_REG_TXCTRL) = UART_TXEN;
  UART0_REG(UART_REG_RXCTRL) = UART_RXEN;

  // Wait a bit because we were changing the GPIOs
  volatile int i=0;
  while(i < 10000){i++;}

  _puts(sifive_msg);

  _puts(welcome_msg);

/*
 * These pragma, if uncommented, will generate compiler errors because this
 * only works when used outside of functions.  Optimization is performed
 * on function blocks, not on individual code lines.
 */
//#pragma GCC push_options
//#pragma GCC optimize ("0")
  uint16_t r=0x3F;
  uint16_t g=0;
```

```
  uint16_t b=0;
//#pragma GCC push_options

  PWM0_REG(PWM_CFG)   = 0;
  PWM0_REG(PWM_CFG)   = (PWM_CFG_ENALWAYS) | (PWM_CFG_ZEROCMP) | (PWM_CFG_DEGLITCH);
  PWM0_REG(PWM_COUNT) = 0;

  // The LEDs are intentionally left somewhat dim.
  PWM0_REG(PWM_CMP0)  = 0xFE;

  while(1){
    volatile uint64_t *  now = (volatile uint64_t*)(CLINT_CTRL_ADDR + CLINT_MTIME);
    volatile uint64_t then = *now + 400;
    while (*now < then) { }

    if(r > 0 && b == 0){
      r--;
      g++;
    }
    if(g > 0 && r == 0){
      g--;
      b++;
    }
    if(b > 0 && g == 0){
      r++;
      b--;
    }

    pwm(r,g,b);

    g = option0(r, b);
    b = option1(r, g);
    r = option2(g, b);

  }// While (1)
}
#pragma GCC pop_options

/*
 * This function uses the project setting for optimization
 */
void pwm(uint16_t r, uint16_t g, uint16_t b)
{
    PWM0_REG(PWM_CMP1)  = 0xFF - (r >> 2);
    PWM0_REG(PWM_CMP2)  = 0xFF - (g >> 2);
    PWM0_REG(PWM_CMP3)  = 0xFF - (b >> 2);
}

/*
 * Enable maximum optimization.  The 'result' variable will be optimized out.
 */
```

```
#pragma GCC push_options
#pragma GCC optimize ("3")
uint16_t option0(uint16_t p1, uint16_t p2) {
    int result = p1 * p2;
    return result;
}
#pragma GCC pop_options

/*
 * Turn off all optimization. The 'result' variable is not optimized out.
 */
#pragma GCC push_options
#pragma GCC optimize ("0")
uint16_t option1(uint16_t p1, uint16_t p2) {
    int result = p1 * p2;
    return result;
}
#pragma GCC pop_options

/*
 * Enable maximum optimization.  The 'result' variable would normally be optimized
out.
 */
#pragma GCC push_options
#pragma GCC optimize ("3")
uint16_t option2(uint16_t p1, uint16_t p2) {
    /*
     * Use 'volatile' keyword to ensure variable does not get optimized out.
     */
    volatile int result = p1 * p2;
    return result;
}
#pragma GCC pop_options
```

Known Issues

Freedom Studio is still considered Beta software and as such there are a number of known, but minor, issues which are described below.

If you come across other issues not reported here, please let us know on our forum: https://forums.sifive.com/.

When the debugger first connects I receive message saying "No source available for address"

This occurs when instructing the debugger to halt immediately after connecting to the target. It is

safe to ignore this message. Stepping/Running the target will work as expected from this point.

Upon starting a debug connection, the Console prints out a lot of text regarding CSRs in red font

While red font can be scary, it is generally benign debugging output. This issue will be addressed in a future release.

Trouble Shooting

USB Permission Issues

By default, some Linux distributions do not give users permissions to access USB devices. The HiFive1 and FPGA getting started guides describe the process to grant your user the correct permissions. For your convenience the *99-openocd.rules* file is included with in the *FreedomStudio/SiFive/Misc* directory.

Mac OS FTDI Driver Issues

There is an issue with Apple's FTDI driver which is used by OpenOCD. This can be fixed from a console using the procedure below:

- Open *Applications/Utilities/Terminal*
- Paste in the following command:
  `sudo kextunload -p -b com.apple.driver.AppleUSBFTDI`
- Paste in the following command:
  `sudo kextutil -b com.apple.driver.AppleUSBFTDI -p AppleUSBEFTDI-6010-1`

After logging out and logging back into your Mac, it may be necessary to issue the commands above again. It is also possible to add the above commands to your user's *.17ex/.bash_profile*. By doing so, the above commands will be issued every time your user logs in.

Appendix A: Target Board Setup

Windows Board Setup

This section will describe how to connect SiFive development boards to your Windows computer.

By default, Windows has the standard FTDI driver installed while OpenOCD expects to communicate over USB using libusb. In order to allow OpenOCD to communicate with the SiFive development boards, it is necessary to instruct Windows to load the libusb driver.

In the Windows bundle there are drivers included to do this. Install the drivers by navigating to the *FreedomStudio/SiFive/Misc* folder and double-clicking the appropriate driver for your board.

Note: This is a permanent change and the drivers must be uninstalled in order return to the original functionality. This can be done through Windows Add/Remove programs.

macOS Board Setup

By default, macOS has the standard FTDI driver installed while OpenOCD expects to communicate over USB using libusb. In order to allow OpenOCD to communicate with the SiFive development boards, it is necessary to unload the FTDI driver from macOS.

- Open *Applications/Utilities/Terminal*
- Paste in the following command:
  `sudo kextunload -p -b com.apple.driver.AppleUSBFTDI`
- Paste in the following command:
  `sudo kextutil -b com.apple.driver.AppleUSBFTDI -p AppleUSBEFTDI-6010-1`

Note: This is not a permanent solution and after logging out of you computer it is necessary to issue the above commands above.

To avoid having to issue these commands on every log-in, it is possible to add the above commands to your user's *.17ex/.bash_profile*. By doing so, the above commands will be issued automatically every time your user logs in.

Linux OS Board Setup

By default, most Linux distributions do not give users permissions to access USB devices. One either needs root access or to be given the appropriate permissions.

Below are steps you can follow to access your development kit without sudo permissions:

1. With your board's debug interface connected, make sure your device shows up with the lsusb command:

   ```
   lsusb
   ...
   Bus XXX Device XXX: ID 0403:6010 Future Technology Devices International, Ltd FT2232C Dual USB-UART/FIFO IC
   ```

2. Set the udev rules to allow the device to be accessed by the plugdev group:

   For your convenience the *99-openocd.rules* file is included with in the *FreedomStudio/SiFive/Misc* directory.

   ```
   sudo cp 99-openocd.rules /etc/udev/rules.d/
   ```

3. See if your board shows up as a serial device belonging to the plugdev group:

```
ls /dev/ttyUSB*
/dev/ttyUSB0 /dev/ttyUSB1
```

(If you have other serial devices or multiple boards attached, you may have more devices listed). For serial communication with the UART, you will always want to select the higher number of the pair, in this example /dev/ttyUSB1.

```
ls -l /dev/ttyUSB1
crw-rw-r– 1 root plugdev 188, 1 Nov 28 12:53 /dev/ttyUSB1
```

4. Add yourself to the plugdev group. You can use the whoami command to determine your user name.

```
whoami your_user_name > sudo usermod -a -G plugdev your_user_name
```

5. Log out and log back in, then check that you're now a member of the plugdev group:

```
groups
… plugdev …
```

If you are not part of the plugdev group, perform a full reset.

Now you should be able to access the serial (UART) and debug interface without sudo permissions.

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Appendix C: Software Licenses

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This be the placeholder!  Aarg!
```

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means either the Program or any derivative work under copyright law:
that is to say, a work containing the Program or a portion of it,
either verbatim or with modifications and/or translated into another
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Activities other than copying, distribution and modification are not
covered by this License; they are outside its scope.  The act of
running the Program is not restricted, and the output from the Program
is covered only if its contents constitute a work based on the
Program (independent of having been made by running the Program).
Whether that is true depends on what the Program does.

  1. You may copy and distribute verbatim copies of the Program's
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conspicuously and appropriately publish on each copy an appropriate
copyright notice and disclaimer of warranty; keep intact all the
notices that refer to this License and to the absence of any warranty;
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along with the Program.

You may charge a fee for the physical act of transferring a copy, and
you may at your option offer warranty protection in exchange for a fee.

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of it, thus forming a work based on the Program, and copy and
distribute such modifications or work under the terms of Section 1
above, provided that you also meet all of these conditions:

    a) You must cause the modified files to carry prominent notices
    stating that you changed the files and the date of any change.

    b) You must cause any work that you distribute or publish, that in
    whole or in part contains or is derived from the Program or any
    part thereof, to be licensed as a whole at no charge to all third
    parties under the terms of this License.

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    when run, you must cause it, when started running for such
    interactive use in the most ordinary way, to print or display an
    announcement including an appropriate copyright notice and a
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    does not normally print such an announcement, your work based on
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sections when you distribute them as separate works.  But when you
distribute the same sections as part of a whole which is a work based
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In addition, mere aggregation of another work not based on the Program
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    b) Accompany it with a written offer, valid for at least three
    years, to give any third party, for a charge no more than your
    cost of physically performing source distribution, a complete
    machine-readable copy of the corresponding source code, to be
    distributed under the terms of Sections 1 and 2 above on a medium
    customarily used for software interchange; or,

    c) Accompany it with the information you received as to the offer
    to distribute corresponding source code.  (This alternative is
    allowed only for noncommercial distribution and only if you
    received the program in object code or executable form with such
    an offer, in accord with Subsection b above.)

The source code for a work means the preferred form of the work for
making modifications to it.  For an executable work, complete source
code means all the source code for all modules it contains, plus any
associated interface definition files, plus the scripts used to
control compilation and installation of the executable.  However, as a
special exception, the source code distributed need not include
anything that is normally distributed (in either source or binary
form) with the major components (compiler, kernel, and so on) of the
operating system on which the executable runs, unless that component
itself accompanies the executable.

If distribution of executable or object code is made by offering
access to copy from a designated place, then offering equivalent
access to copy the source code from the same place counts as
distribution of the source code, even though third parties are not
compelled to copy the source along with the object code.
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  Ty Coon, President of Vice

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or can get the source code.  And you must show them these terms so they
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  Developers that use the GNU GPL protect your rights with two steps:
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  Some devices are designed to deny users access to install or run
modified versions of the software inside them, although the manufacturer
can do so.  This is fundamentally incompatible with the aim of
protecting users' freedom to change the software.  The systematic
pattern of such abuse occurs in the area of products for individuals to
use, which is precisely where it is most unacceptable.  Therefore, we
have designed this version of the GPL to prohibit the practice for those
products.  If such problems arise substantially in other domains, we
stand ready to extend this provision to those domains in future versions
of the GPL, as needed to protect the freedom of users.

  Finally, every program is threatened constantly by software patents.
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make it effectively proprietary.  To prevent this, the GPL assures that
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  The precise terms and conditions for copying, distribution and
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  0. Definitions.

  "This License" refers to version 3 of the GNU General Public License.

  "Copyright" also means copyright-like laws that apply to other kinds of
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  "The Program" refers to any copyrightable work licensed under this
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"recipients" may be individuals or organizations.

  To "modify" a work means to copy from or adapt all or part of the work
in a fashion requiring copyright permission, other than the making of an
exact copy.  The resulting work is called a "modified version" of the
earlier work or a work "based on" the earlier work.

  A "covered work" means either the unmodified Program or a work based
on the Program.

  To "propagate" a work means to do anything with it that, without
permission, would make you directly or secondarily liable for
infringement under applicable copyright law, except executing it on a
computer or modifying a private copy.  Propagation includes copying,
distribution (with or without modification), making available to the
public, and in some countries other activities as well.

  To "convey" a work means any kind of propagation that enables other
parties to make or receive copies.  Mere interaction with a user through
a computer network, with no transfer of a copy, is not conveying.

  An interactive user interface displays "Appropriate Legal Notices"
to the extent that it includes a convenient and prominently visible
feature that (1) displays an appropriate copyright notice, and (2)
tells the user that there is no warranty for the work (except to the
extent that warranties are provided), that licensees may convey the
work under this License, and how to view a copy of this License.  If
the interface presents a list of user commands or options, such as a
menu, a prominent item in the list meets this criterion.

  1. Source Code.

  The "source code" for a work means the preferred form of the work
for making modifications to it.  "Object code" means any non-source
form of a work.

  A "Standard Interface" means an interface that either is an official
standard defined by a recognized standards body, or, in the case of
interfaces specified for a particular programming language, one that
is widely used among developers working in that language.

  The "System Libraries" of an executable work include anything, other
than the work as a whole, that (a) is included in the normal form of
packaging a Major Component, but which is not part of that Major
Component, and (b) serves only to enable use of the work with that
Major Component, or to implement a Standard Interface for which an
implementation is available to the public in source code form.  A
"Major Component", in this context, means a major essential component
(kernel, window system, and so on) of the specific operating system
(if any) on which the executable work runs, or a compiler used to
produce the work, or an object code interpreter used to run it.
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  The "Corresponding Source" for a work in object code form means all
the source code needed to generate, install, and (for an executable
work) run the object code and to modify the work, including scripts to
control those activities.  However, it does not include the work's
System Libraries, or general-purpose tools or generally available free
programs which are used unmodified in performing those activities but
which are not part of the work.  For example, Corresponding Source
includes interface definition files associated with source files for
the work, and the source code for shared libraries and dynamically
linked subprograms that the work is specifically designed to require,
such as by intimate data communication or control flow between those
subprograms and other parts of the work.

  The Corresponding Source need not include anything that users
can regenerate automatically from other parts of the Corresponding
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  The Corresponding Source for a work in source code form is that
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  4. Conveying Verbatim Copies.

  You may convey verbatim copies of the Program's source code as you
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keep intact all notices of the absence of any warranty; and give all
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  You may charge any price or no price for each copy that you convey,
and you may offer support or warranty protection for a fee.

  5. Conveying Modified Source Versions.

  You may convey a work based on the Program, or the modifications to
produce it from the Program, in the form of source code under the
terms of section 4, provided that you also meet all of these conditions:

    a) The work must carry prominent notices stating that you modified
    it, and giving a relevant date.

    b) The work must carry prominent notices stating that it is
    released under this License and any conditions added under section
    7.  This requirement modifies the requirement in section 4 to
    "keep intact all notices".

    c) You must license the entire work, as a whole, under this
    License to anyone who comes into possession of a copy.  This
    License will therefore apply, along with any applicable section 7
    additional terms, to the whole of the work, and all its parts,
    regardless of how they are packaged.  This License gives no
    permission to license the work in any other way, but it does not
    invalidate such permission if you have separately received it.

    d) If the work has interactive user interfaces, each must display
    Appropriate Legal Notices; however, if the Program has interactive
    interfaces that do not display Appropriate Legal Notices, your
    work need not make them do so.
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  A compilation of a covered work with other separate and independent
works, which are not by their nature extensions of the covered work,
and which are not combined with it such as to form a larger program,
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"aggregate" if the compilation and its resulting copyright are not
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parts of the aggregate.

  6. Conveying Non-Source Forms.

  You may convey a covered work in object code form under the terms
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machine-readable Corresponding Source under the terms of this License,
in one of these ways:

    a) Convey the object code in, or embodied in, a physical product
    (including a physical distribution medium), accompanied by the
    Corresponding Source fixed on a durable physical medium
    customarily used for software interchange.

    b) Convey the object code in, or embodied in, a physical product
    (including a physical distribution medium), accompanied by a
    written offer, valid for at least three years and valid for as
    long as you offer spare parts or customer support for that product
    model, to give anyone who possesses the object code either (1) a
    copy of the Corresponding Source for all the software in the
    product that is covered by this License, on a durable physical
    medium customarily used for software interchange, for a price no
    more than your reasonable cost of physically performing this
    conveying of source, or (2) access to copy the
    Corresponding Source from a network server at no charge.

    c) Convey individual copies of the object code with a copy of the
    written offer to provide the Corresponding Source.  This
    alternative is allowed only occasionally and noncommercially, and
    only if you received the object code with such an offer, in accord
    with subsection 6b.

    d) Convey the object code by offering access from a designated
    place (gratis or for a charge), and offer equivalent access to the
    Corresponding Source in the same way through the same place at no
    further charge.  You need not require recipients to copy the
    Corresponding Source along with the object code.  If the place to
    copy the object code is a network server, the Corresponding Source
    may be on a different server (operated by you or a third party)
    that supports equivalent copying facilities, provided you maintain
    clear directions next to the object code saying where to find the
    Corresponding Source.  Regardless of what server hosts the
    Corresponding Source, you remain obligated to ensure that it is
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    available for as long as needed to satisfy these requirements.

    e) Convey the object code using peer-to-peer transmission, provided
    you inform other peers where the object code and Corresponding
    Source of the work are being offered to the general public at no
    charge under subsection 6d.

  A separable portion of the object code, whose source code is excluded
from the Corresponding Source as a System Library, need not be
included in conveying the object code work.

  A "User Product" is either (1) a "consumer product", which means any
tangible personal property which is normally used for personal, family,
or household purposes, or (2) anything designed or sold for incorporation
into a dwelling.  In determining whether a product is a consumer product,
doubtful cases shall be resolved in favor of coverage.  For a particular
product received by a particular user, "normally used" refers to a
typical or common use of that class of product, regardless of the status
of the particular user or of the way in which the particular user
actually uses, or expects or is expected to use, the product.  A product
is a consumer product regardless of whether the product has substantial
commercial, industrial or non-consumer uses, unless such uses represent
the only significant mode of use of the product.

  "Installation Information" for a User Product means any methods,
procedures, authorization keys, or other information required to install
and execute modified versions of a covered work in that User Product from
a modified version of its Corresponding Source.  The information must
suffice to ensure that the continued functioning of the modified object
code is in no case prevented or interfered with solely because
modification has been made.

  If you convey an object code work under this section in, or with, or
specifically for use in, a User Product, and the conveying occurs as
part of a transaction in which the right of possession and use of the
User Product is transferred to the recipient in perpetuity or for a
fixed term (regardless of how the transaction is characterized), the
Corresponding Source conveyed under this section must be accompanied
by the Installation Information.  But this requirement does not apply
if neither you nor any third party retains the ability to install
modified object code on the User Product (for example, the work has
been installed in ROM).

  The requirement to provide Installation Information does not include a
requirement to continue to provide support service, warranty, or updates
for a work that has been modified or installed by the recipient, or for
the User Product in which it has been modified or installed.  Access to a
network may be denied when the modification itself materially and
adversely affects the operation of the network or violates the rules and
protocols for communication across the network.
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  Corresponding Source conveyed, and Installation Information provided,
in accord with this section must be in a format that is publicly
documented (and with an implementation available to the public in
source code form), and must require no special password or key for
unpacking, reading or copying.

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