Freedom Studio User Manual

2019-05-0

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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 targeting 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 QEMU 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/boards/#software

Downloads are provided for Windows, MacOS, and Linux.

Windows Installation

Important

Rule #1
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.

Rule #2
You must enable Windows Long Path support. You must do this before extracting the product archive. The Freedom Studio installation folder contains paths that are deep enough to exceed the "legacy" MAX_PATH (=260) character limit imposed by Windows. This limit is still enabled by default, but Windows 10 (starting with version 1607) allows for disabling this limit by installing a specific register key/value using the Windows regedit tool:

HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control\FileSystem
LongPathsEnabled REG_DWORD = 0x1

To simplify this process you can download the following registry file and double-click it to install this key automatically:

https://static.dev.sifive.com/dev-tools/FreedomStudio/misc/EnableLongPaths.reg

If you still have problems extracting the archive after enabling Long Path Support contact support@sifive.com

More information on this topic can be found here:

https://docs.microsoft.com/en-us/windows/desktop/fileio/naming-a-file#paths

Now that we have those important notes are out of the way…

You can install multiple versions of Freedom Studio on your system, and use all of them.

We recommend that you keep the installation path as short as possible. We suggest creating a folder at the root of your installation drive called "FreedomStudio" (no spaces).

Then inside that folder you can install multiple versions of Freedom Studio into subfolders. Like:

```
c:\FreedomStudio
  |
  +- FreedomStudio-2019.03
  +- FreedomStudio-2019.05
```

The product zip archive extracts to a long folder name (for instance `FreedomStudio-4.7.2.2019-03-4-win32.win32.x86_64`). We recommend that you shorten the folder name using a naming scheme similar (or identical) to the one shown above.

We recommend using a tool like 7-Zip to handle large zip archives on Windows. Unzip the downloaded zip archive 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 double-clicking on FreedomStudio.exe in the installation directory.

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

MacOS Installation

Important

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

Important

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 -xzf /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 ???. 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.

Important

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.

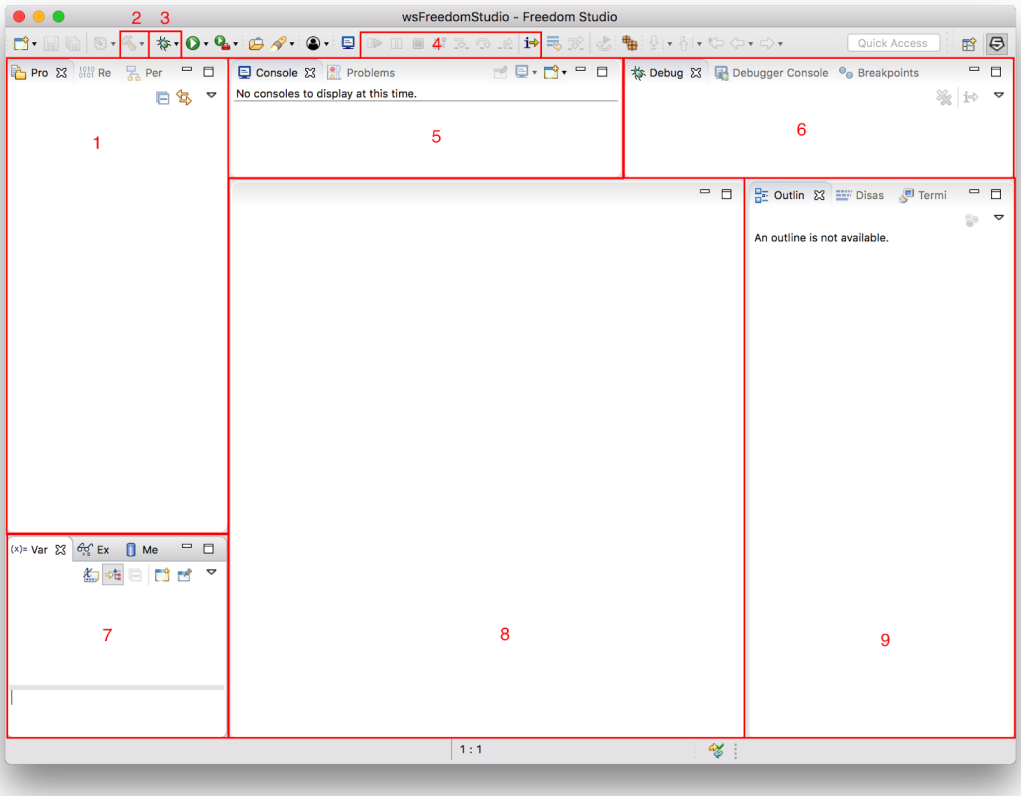
Freedom Studio ships with its own SiFive perspective which can be useful for both programming and debugging. Please see Section ??? for a detailed description of the SiFive Eclipse perspective.

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

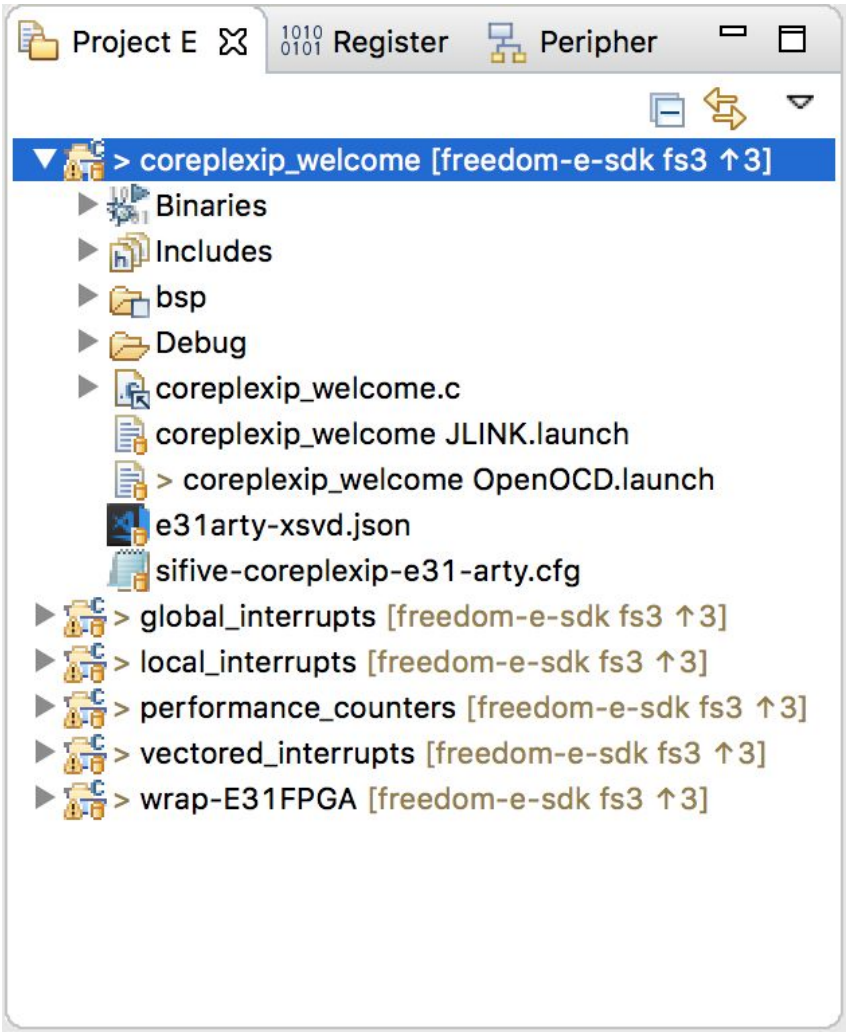
The SiFive Perspective.



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.

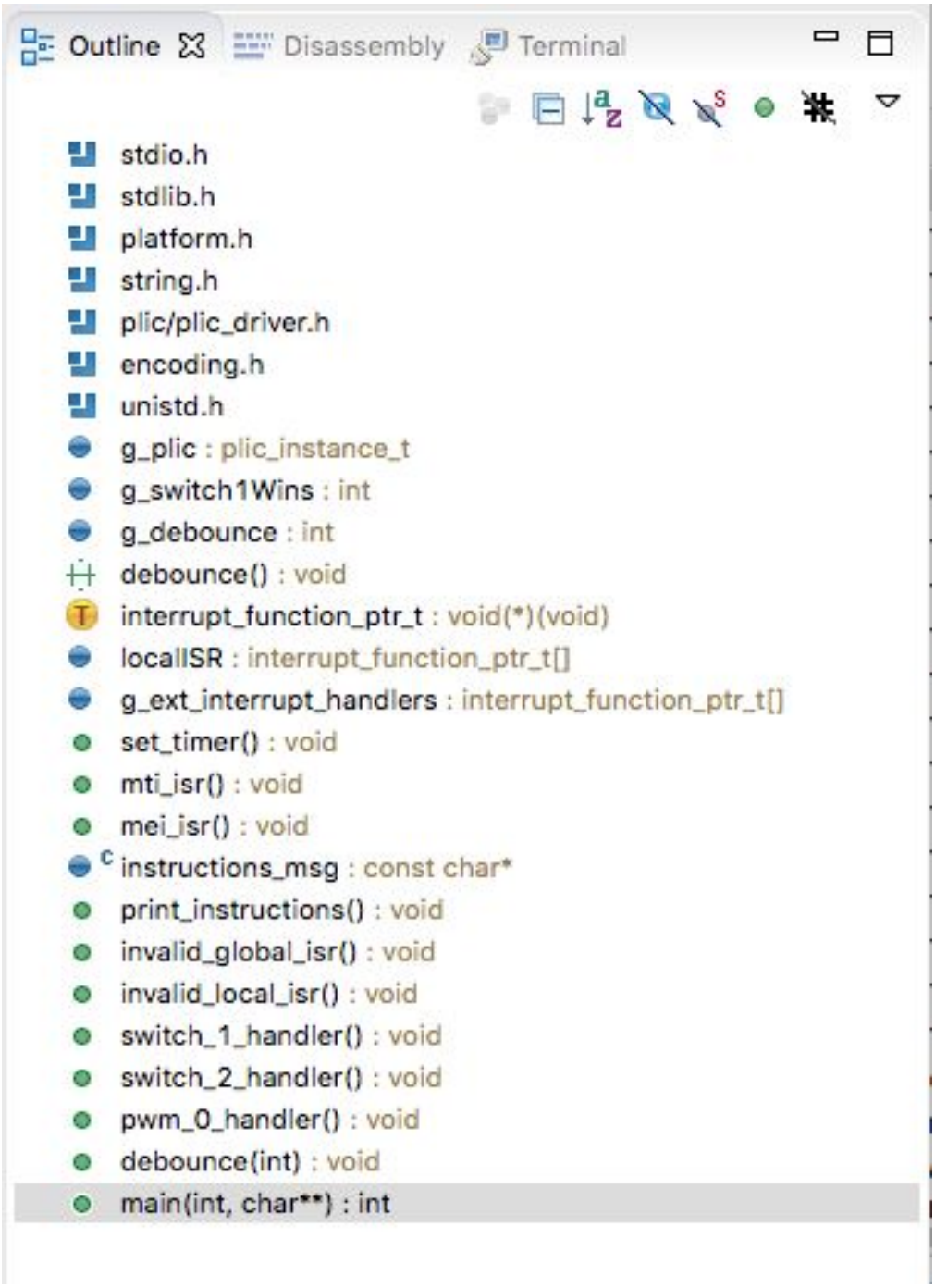
Project Explorer



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.

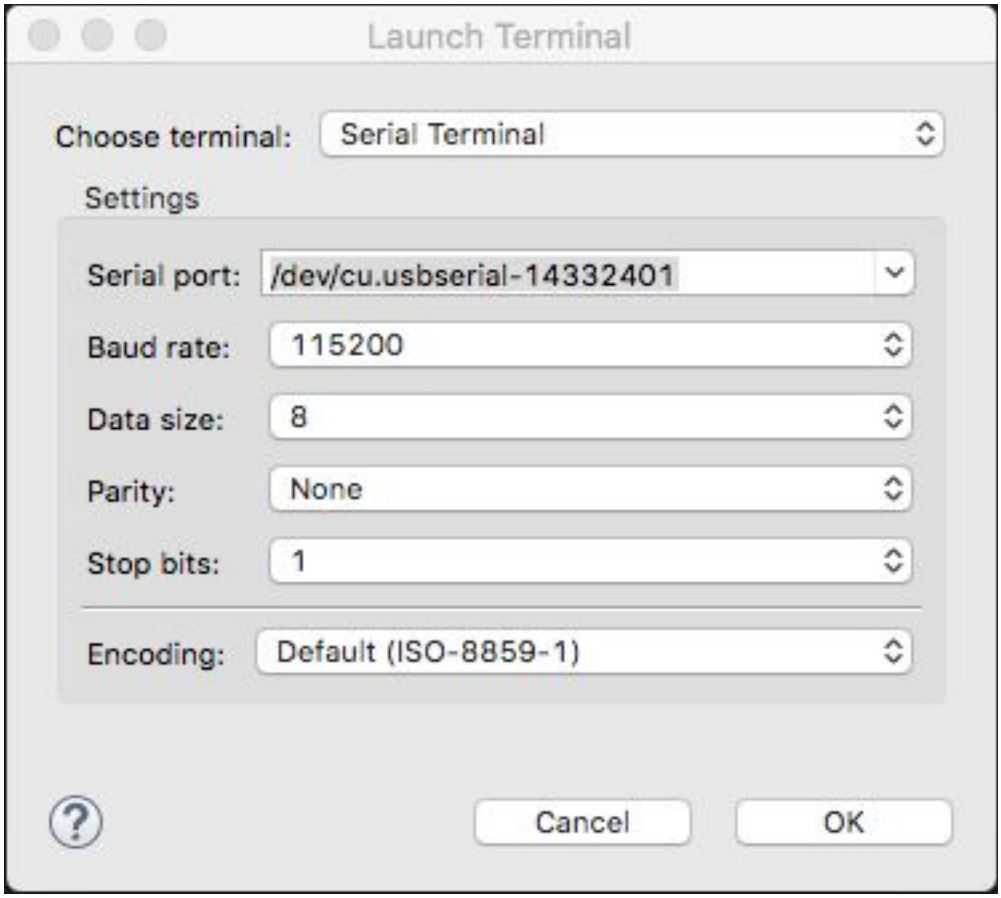


The Outline view, shown in Figure ???, gives a "top-level" view of the active file in the editor including functions, types, constants, etc… Clicking on an item in the Outline view will take you to that items location in the source code.

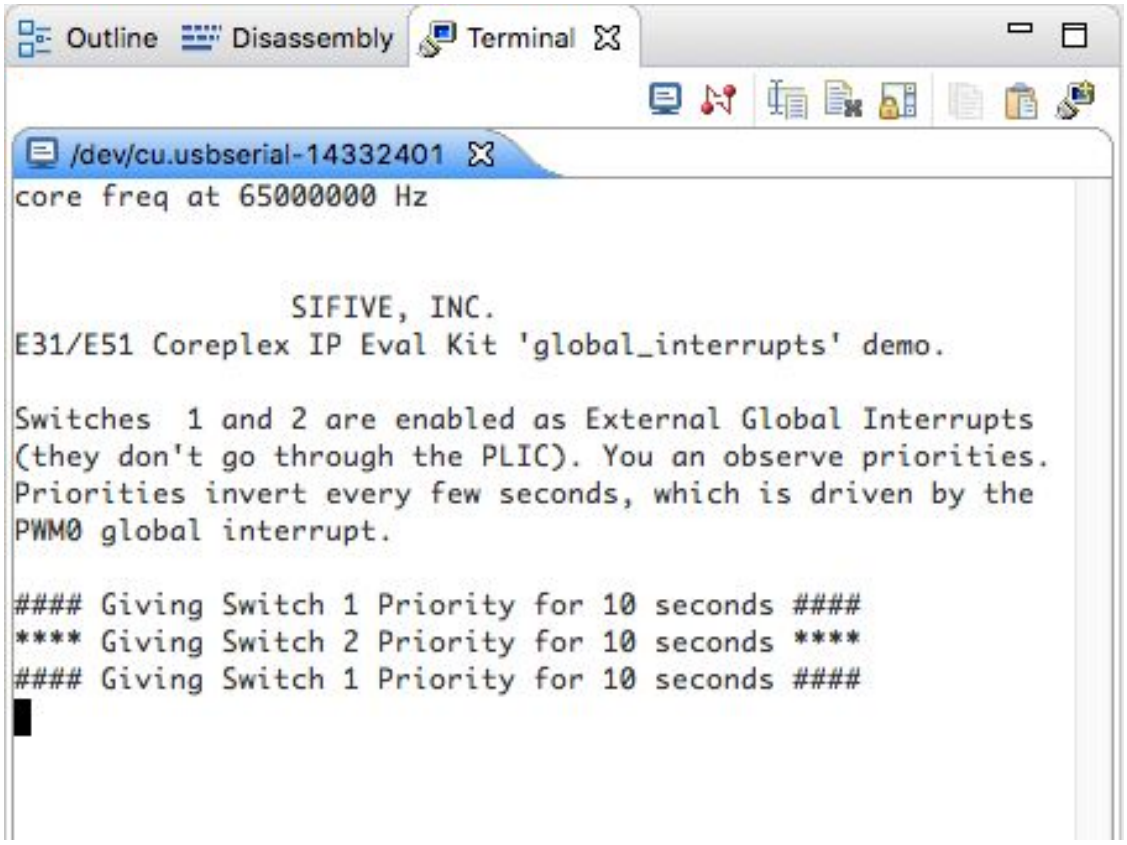
Terminal

The Terminal view, shown in Figure ???, 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.



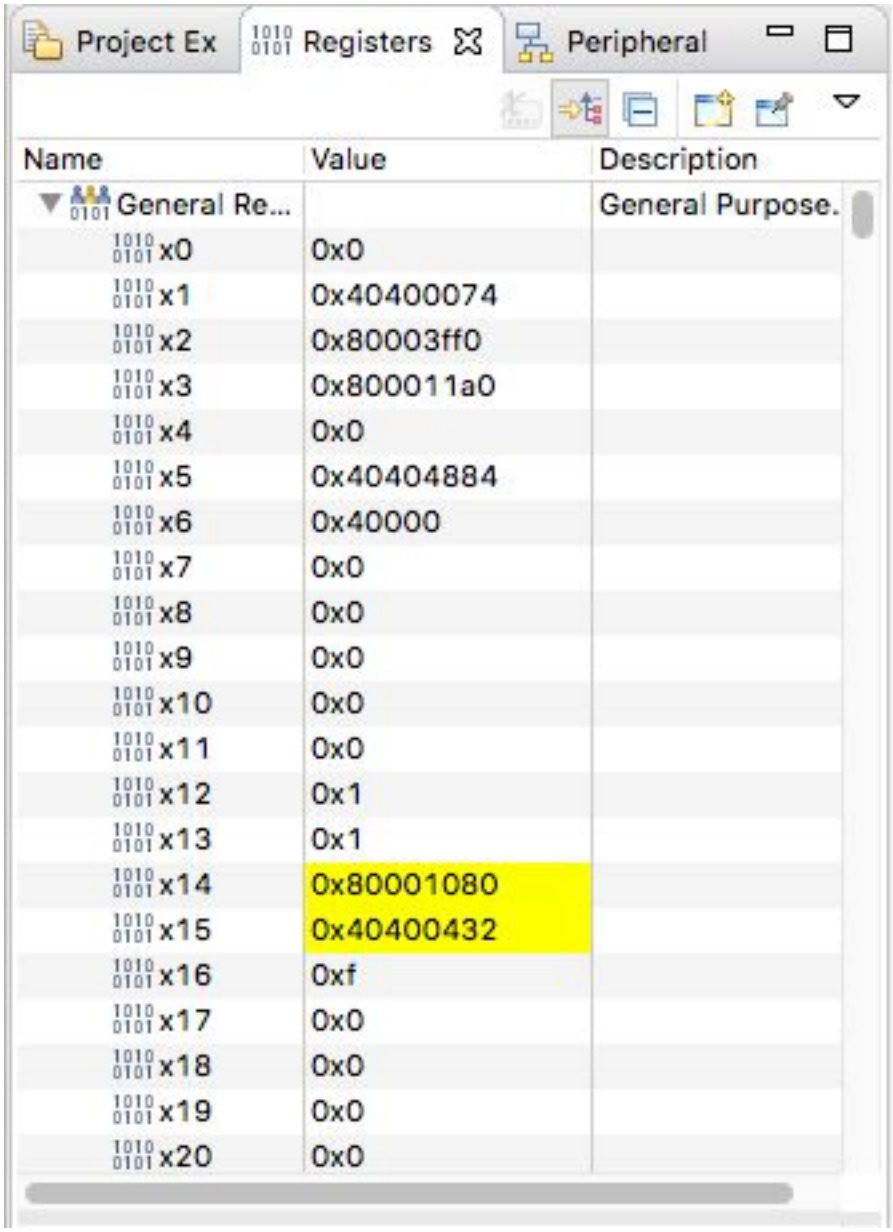
If the text in the serial terminal is displayed incorrectly, make sure that the correct baud rate is selected. SiFive example projects default to 115200 baud. Changing the encoding to UTF-8 might also help.



Breakpoints

The Breakpoints view allows for creating, enabling, and disabling of breakpoints. You can set a breakpoint's 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

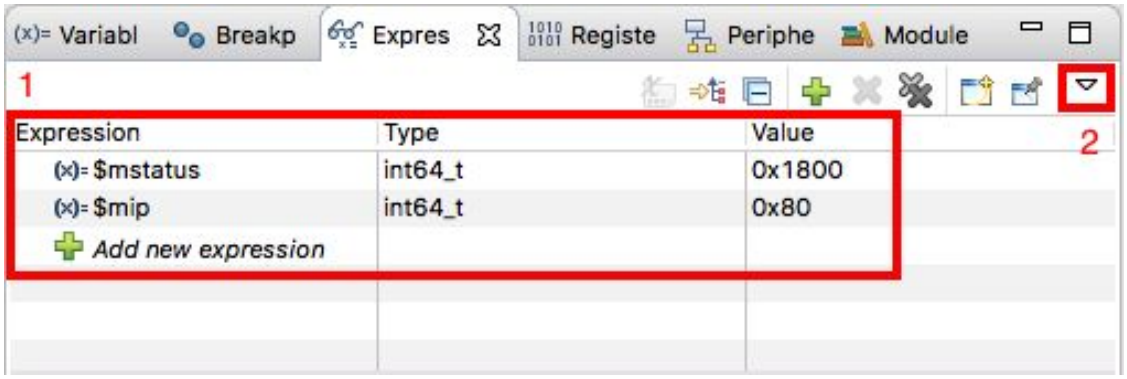


The Registers view displays the integer and floating point register files. It is possible to write to registers by double-clicking their value field. While stepping through code, the Registers view will highlight registers as they change.

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:



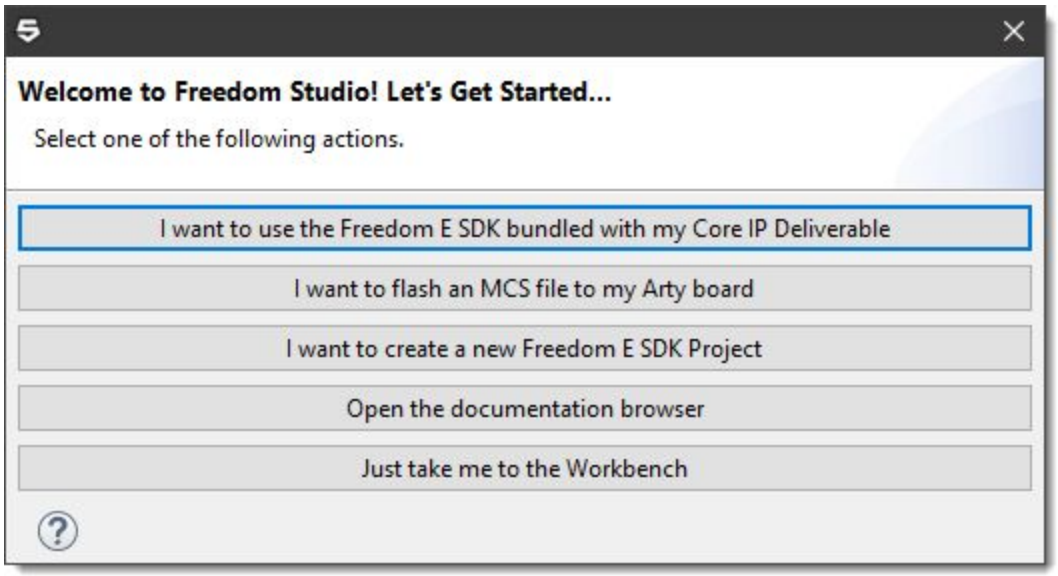
Getting Started

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

Starting with version 19.05, Freedom Studio includes a brand new dedicated Freedom E SDK project wizard.

The First Run Dialog

When you start Freedom Studio with a new workspace you will be presented with the First Run Dialog. This dialog is simply an easy way to get started with common first time tasks.



- **I want to use the Freedom e SDK bundled with my Core IP Deliverable**
  Choose this option if you have a core IP deliverable that you'd like to start working with. With this option you will tell Freedom Studio where the core IP deliverable

freedom-e-sdk folder is. Freedom Studio will then use this bundled SDK when creating new projects.

- **I want to flash an MCS file to my Arty board**
  Choose this option if you want to get started by flashing an MCS file to your Arty board. You will also have the choice to jump right into creating a project at the end of the flashing process.

- **I want to create a new Freedom E SDK project**
  If you have a HiFive series board or an Arty FPGA board already flashed with core IP and want to jump straight to creating a project, select this option.

- **Open the documentation browser**
  Choose this option to open the documentation browser. From here you can dig into all the documentation bundled with Freedom Studio.

- **Just take me to the workbench**
  If you don't want to start with any of the options listed above, choose this option and you'll be taken to your new clean workspace.

Flashing Your Arty FPGA Board

Before you continue

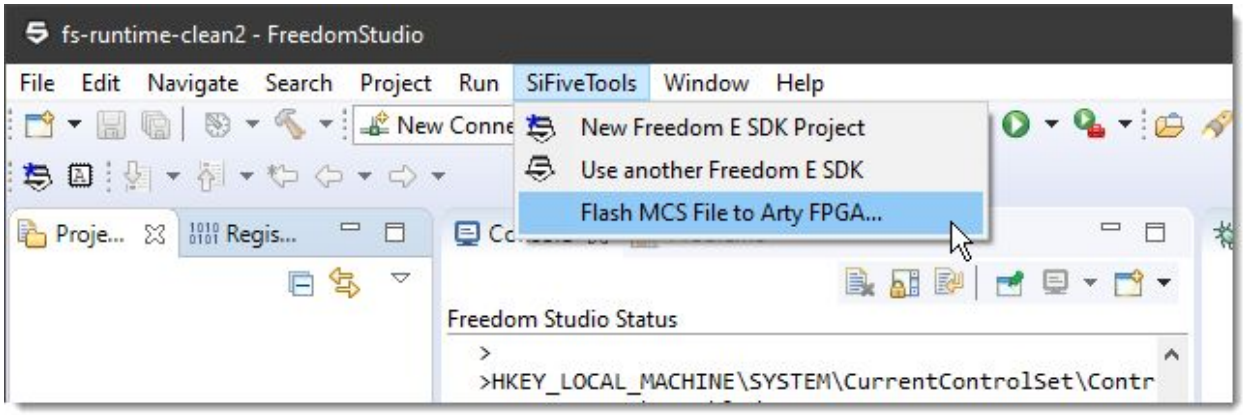
Before continuing with this section please review the Target Board Setup instructions to ensure that everything is properly configured and all host dependencies have been installed.

Flashing the Arty requires both the Olimex probe and the Arty board USB connector be connected to the host PC. Both USB connection are used during the process. Do not simply connect the Arty USB to a power supply when flashing.

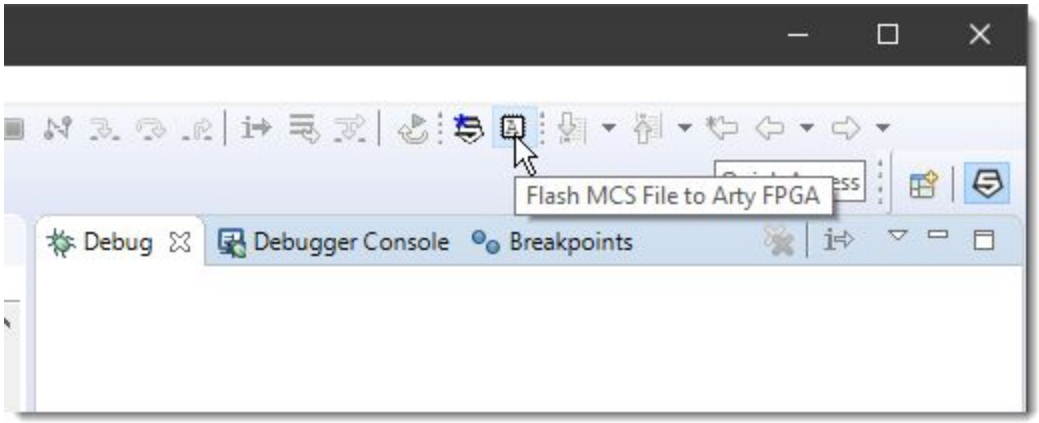
Flashing an Arty Board using a JLink connection is not supported at this time.

Flash the Arty Board

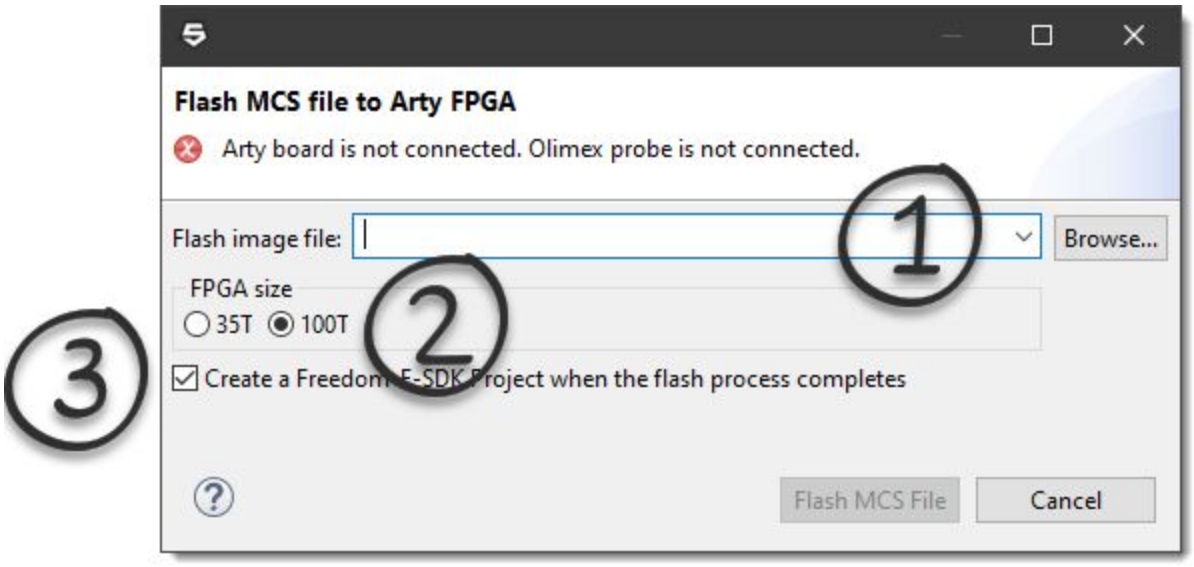
First open the Arty Flash Dialog. This dialog can be opened from the main menu by selecting SiFiveTools → Flash MCS File to Arty FPGA…



or by clicking the Arty Flash icon on the main toolbar:



Selecting either of these will open the Arty Flash Dialog. This dialog will look a little different on each host platform:



1. First select the MCS file you want to flash. MCS files are available in Core IP deliverables; in downloaded evaluation packages, or directly from Sifive, or may be created in your flow.
2. Important: Make sure you select the correct FPGA configuration for your MCS file and Arty board. Freedom Studio will attempt to select the correct setting, but if it cannot be determined heuristically,, no default selection is made and you will have to choose. Choose wisely.
3. Check this box if you want to open the New Freedom E SDK Project Wizard when the flashing process is completed.

Once you've made your selections, click the **Flash MCS File** button to start the flashing process. See the notes below regarding Windows hosts.

The flash process can take several minutes to complete. When it is complete Freedom Studio will prompt you to press the PROG button on the Arty board. You must do this in order to load and use the newly flashed MCS file.

Windows Only

On Windows host platforms Freedom Studio can monitor the connection status of the Olimex probe and the Arty Digilent connection. The Arty Flasher will report the status (as shown above) and the **Flash MCS File** button will not be enabled unless both are detected as connected.

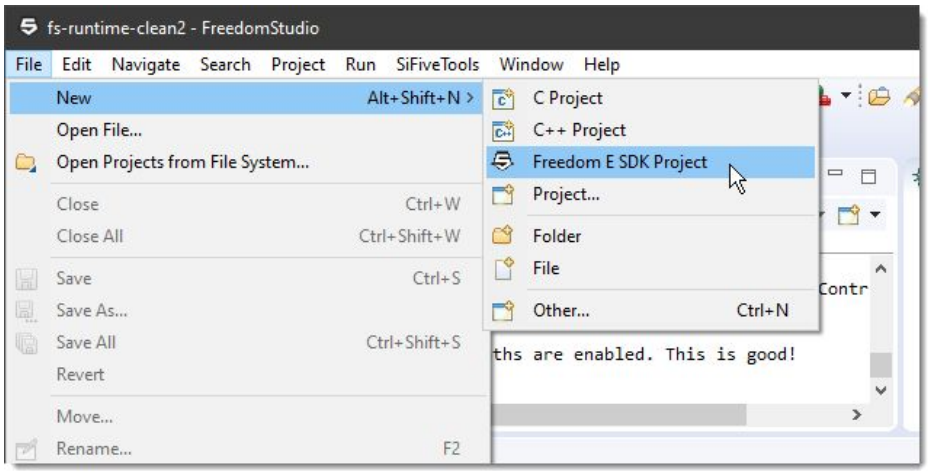
Freedom Studio also monitors the driver status for both devices and will install required drivers as parts of the flashing process. You may have to authorize the driver installation if

Windows displays a UAC prompt. Flashing will not succeed unless you authorize the driver installation.

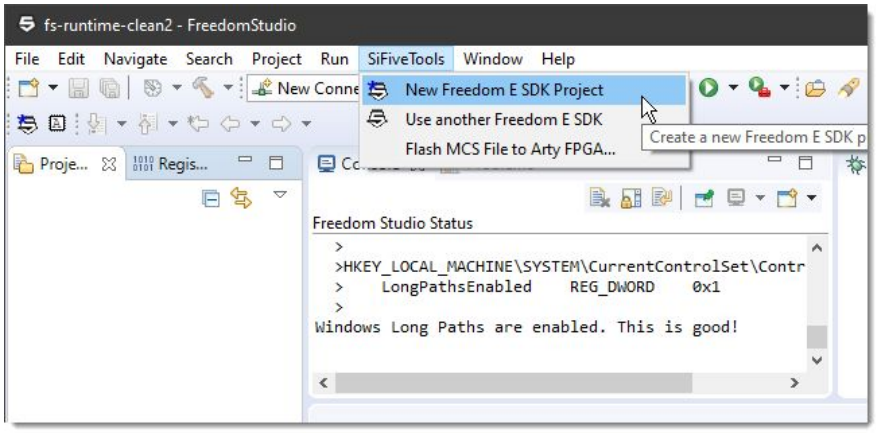
Create a Freedom E SDK Project

Creating a new Freedom E SDK Project is very simple. There are multiple ways to start:

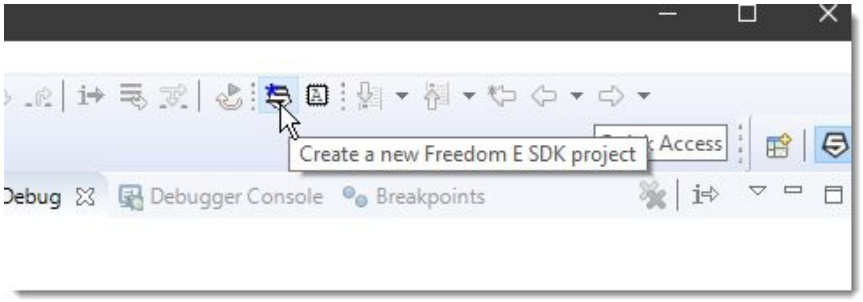
- From the main menu, select **File → New → Freedom E SDK Project**, as shown below:



- From the SiFiveTools menu, select **New Freedom E SDK Project**, as shown:



- On the main application toolbar, click the “New Freedom E SDK Project” icon, as shown:



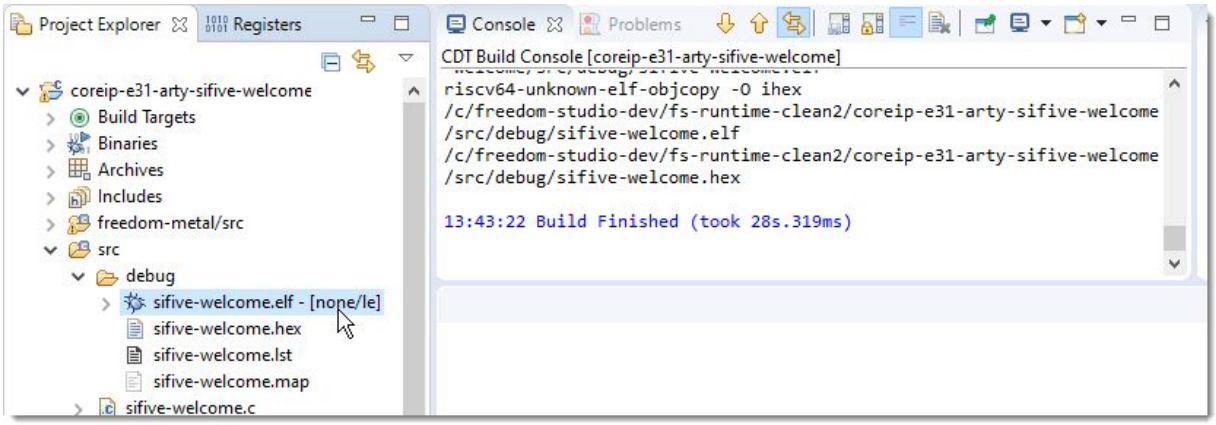
Selecting any of these will open the Freedom E SDK New Project Wizard. The first page of this wizard is shown below:

1. When you first open the wizard the target selection box might be empty. You need to select a target from the options in the drop-down. You should select the target that matches your core and target platform of choice. For instance if you have an Arty Board and are using an E31 core you will want to choose "coreip-e31-arty".
2. Select an example program. Several examples are provided and each one demonstrates different features sets of the core.
3. The project name is automatically generated based on your target and example selections. If you do not like the generated name you can change it on the next wizard page.
4. Finally, you can choose to automatically create a debug launch configuration for your new project. Select the type of launch as determined by your debugger probe.

Choose “OpenOCD” if you are using an Olimex probe, and “JLink” if you are using a JLink probe or a target with a built-in JLink OB device, and “QEMU” if you are using one of the QEMU targets. Selecting certain targets will automatically select the best option for that target.

That’s really all there is to creating a new Freedom E SDK project. If you are satisfied with your choices, go ahead and click the **Finish** button. If you would like to change the project name, click the **Next** button and give your project a new name on the following page.

When you click the **Finish** button, Freedom Studio will create your new project and build it. When the build is complete Freedom Studio will reveal the built ELF file in the project explorer, as shown:



If you chose to create a debug launch configuration when creating your project the Debug Launch Configuration Dialog will automatically open after the ELF file is revealed.

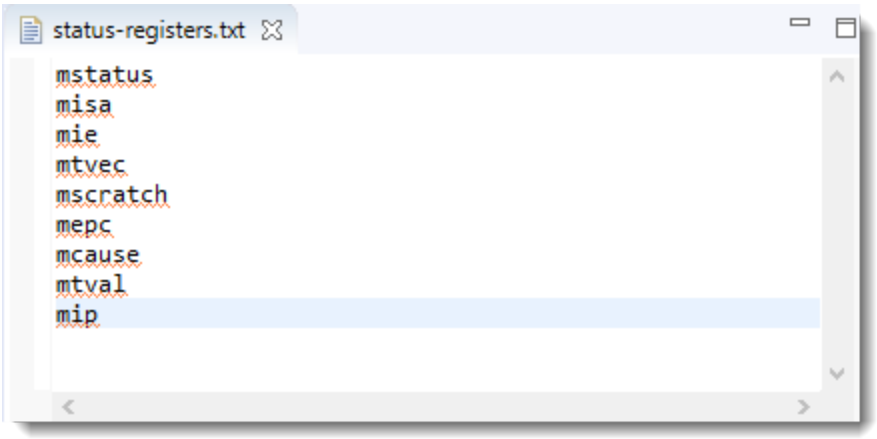
Freedom Studio HOWTO Guides

Register List Management

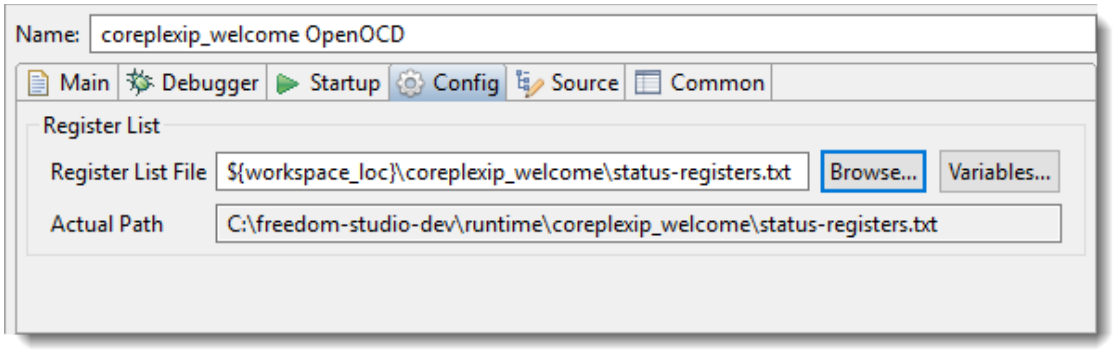
This document provides an overview on how to use and customize the list of registers displayed in the Freedom Studio IDE Registers View. This feature is primarily intended to give you control over what registers are displayed. You may want to use this, for example, when you do not want to see a complete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

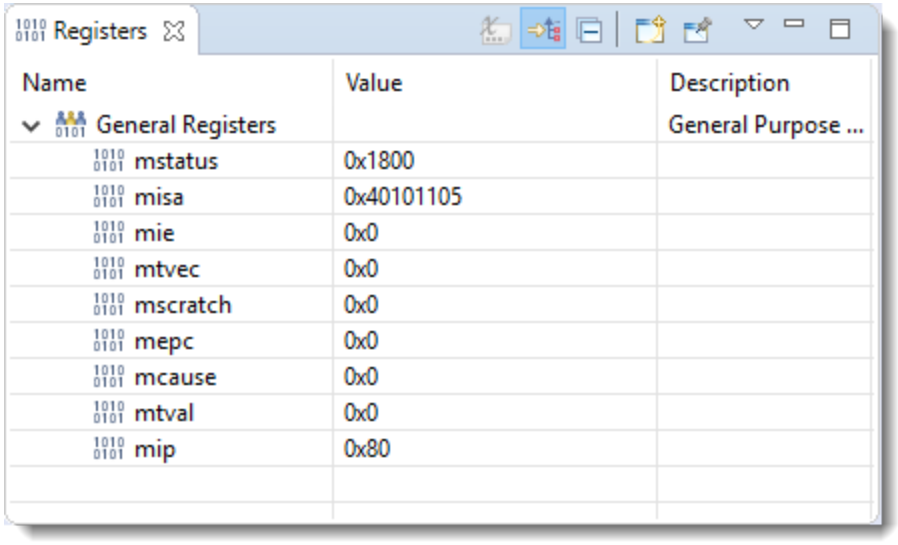
Let’s assume you have a register list file called 'status-registers.txt'. The content of the file looks like:



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

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

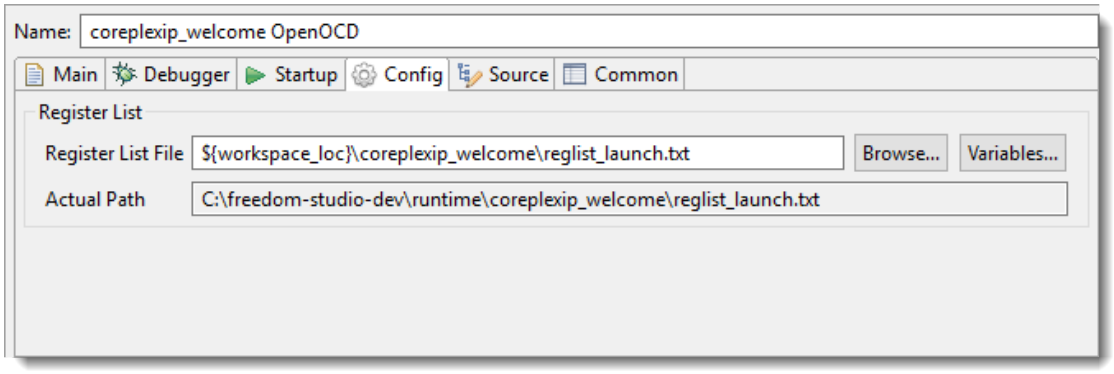
A register list file can be specified in 4 place. These four locations are prioritized such that a specification in a higher priority location will override any specification in a lower priority location. The four locations are, in descending priority order (highest priority first):

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:

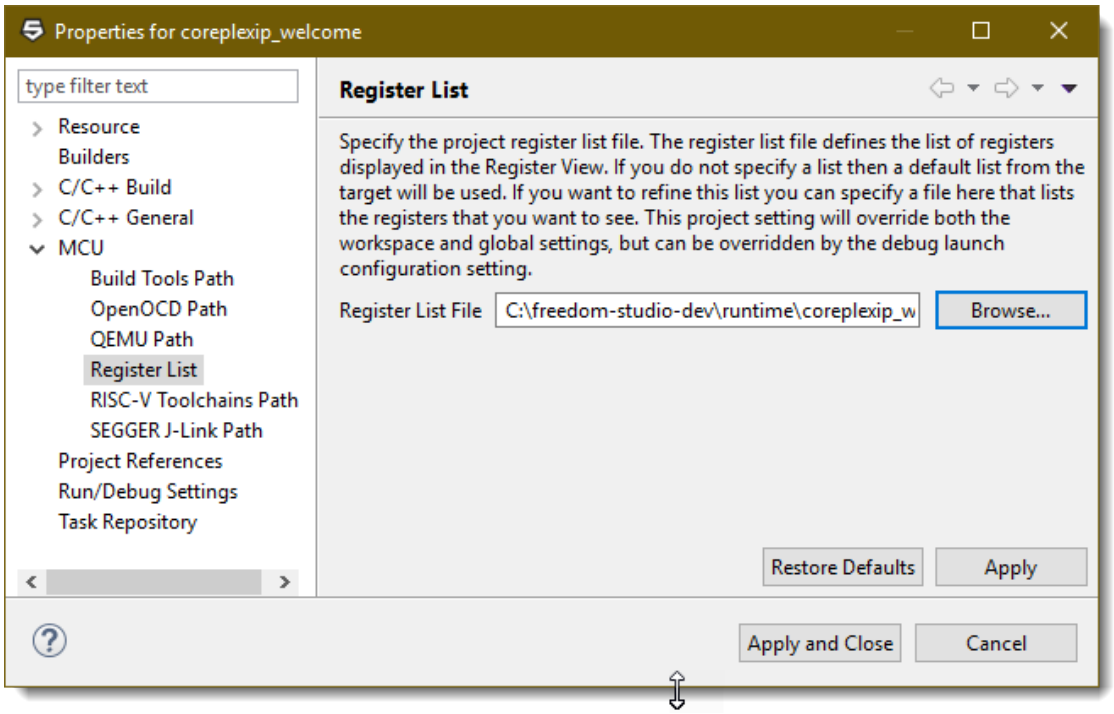


When you specify a register list file in a debug launch configuration the path displayed in the `Actual Path` box will always reflect the fully resolved path to the register list file. If you are not specifying a register list file here then the `Actual Path` may display a path to another register list 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.

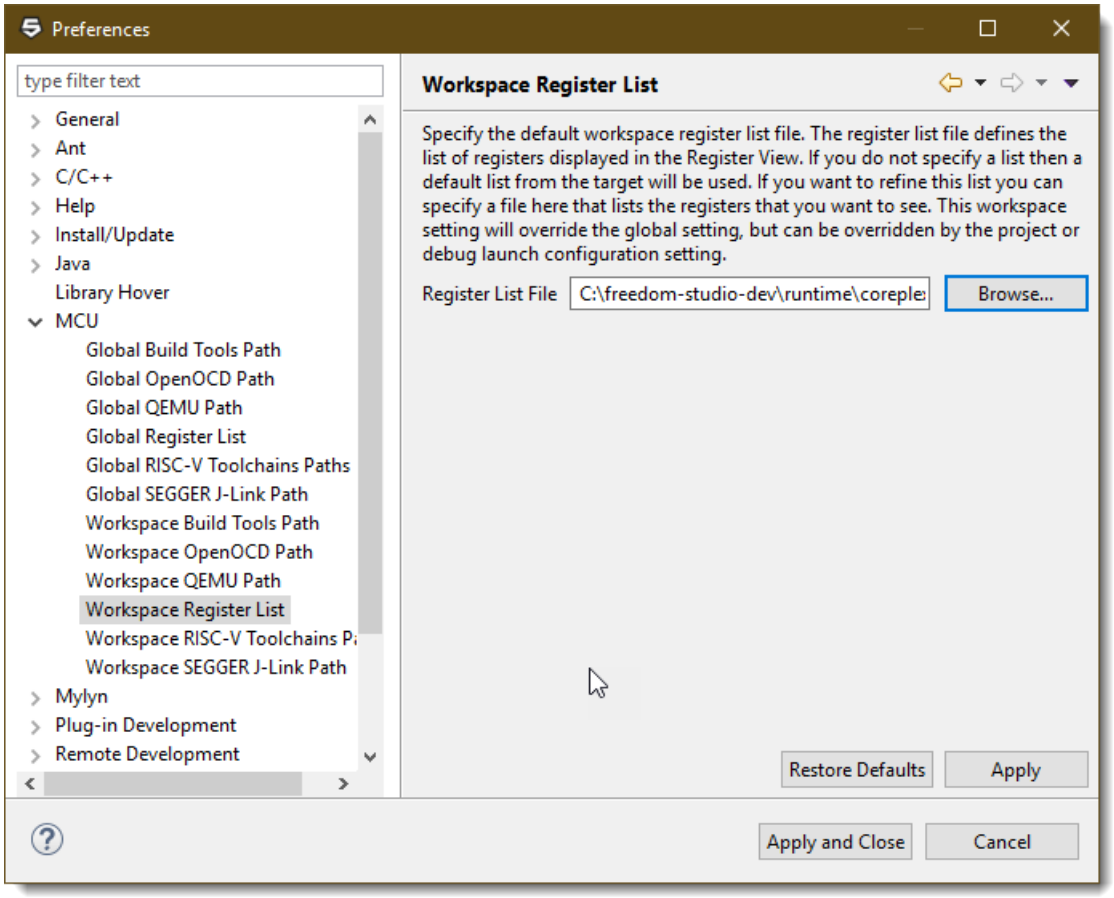
You can setup the project register list file specification by opening the Project Properties dialog and navigating to the `MCU → Register List` property page:



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.

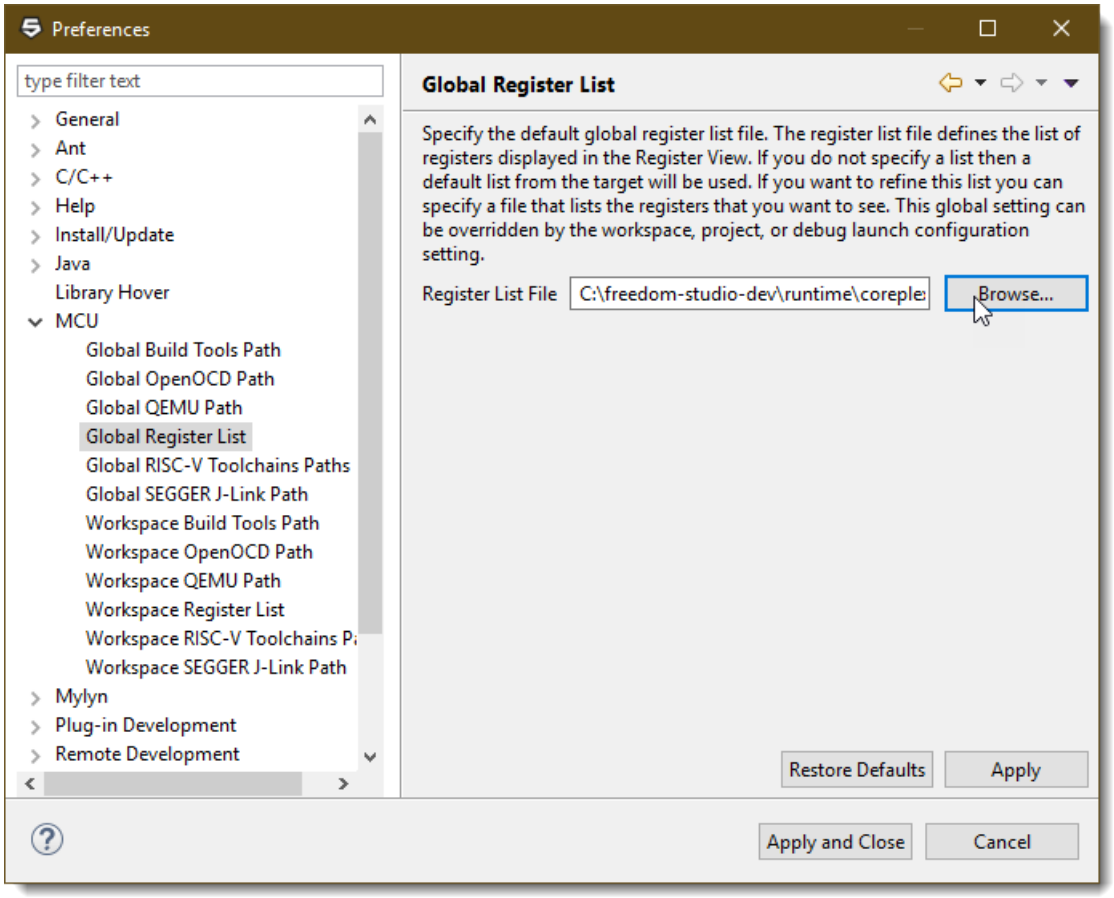
You can specify the workspace preference by opening the Freedom Studio Preference Window and navigating to the `MCU → Workspace Register List` page:



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.

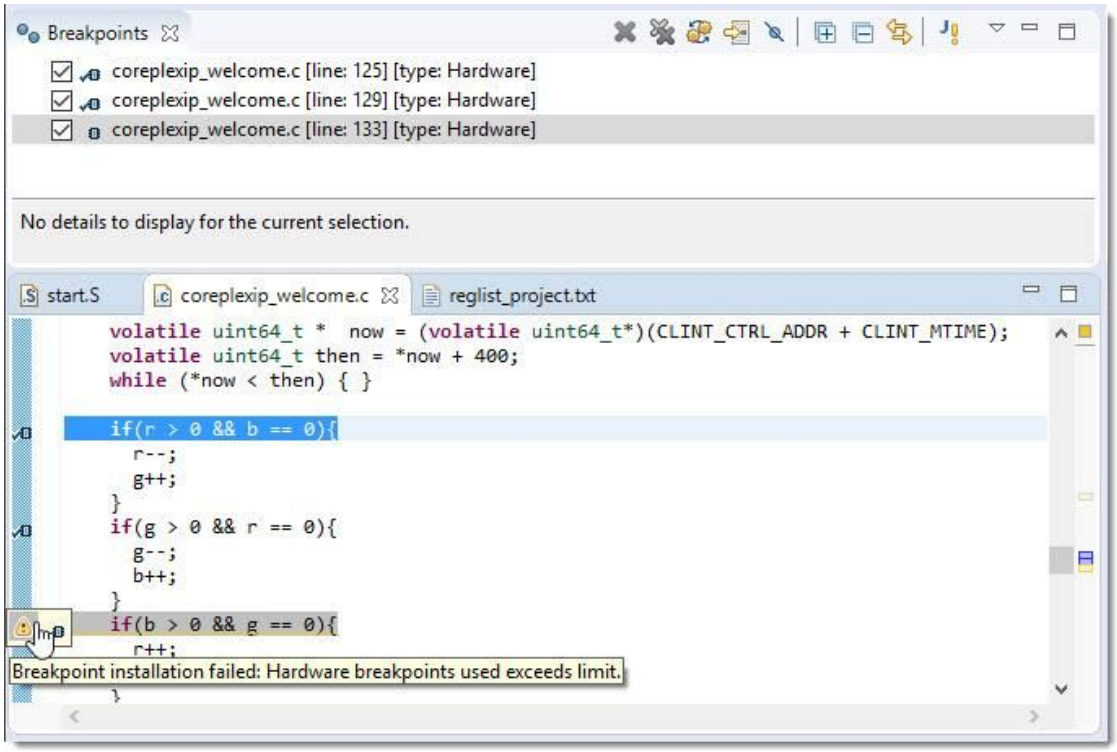
You can specify the global preference by opening the Freedom Studio Preference Window and navigating to the `MCU → Global Register List` page:



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.



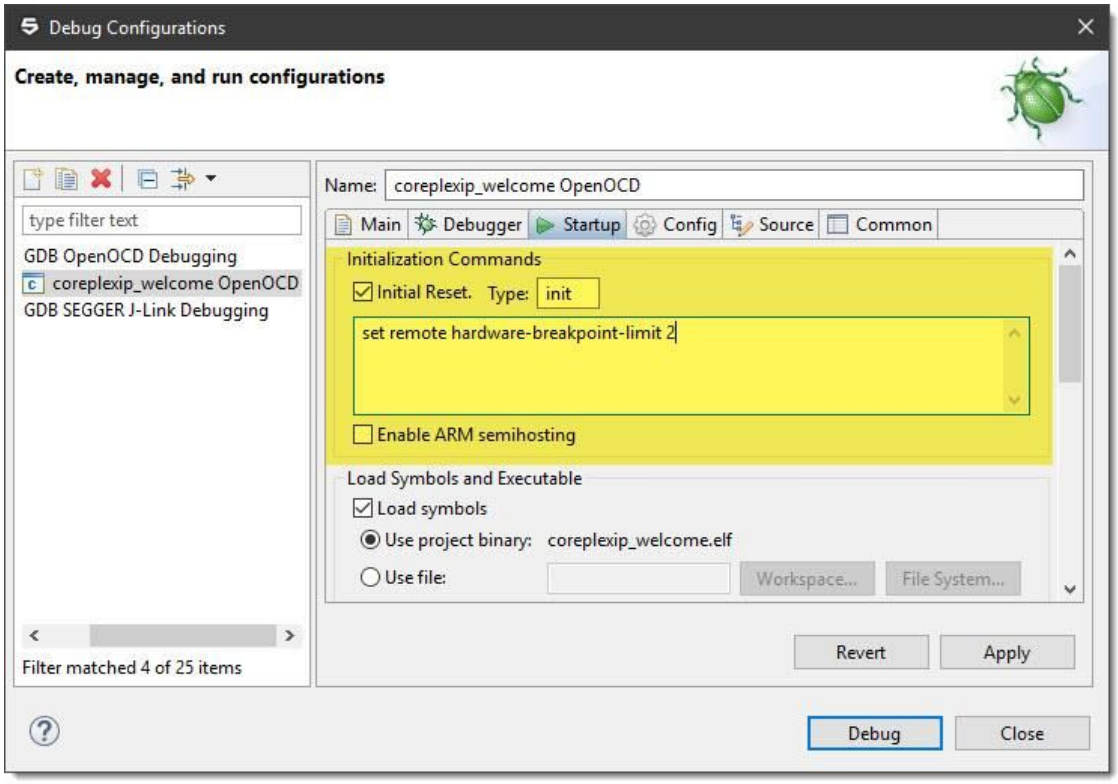
Too Many Hardware Breakpoints

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.



Note

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

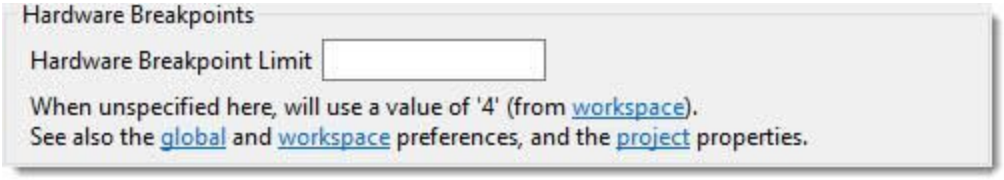
You can set global and workspace preferences to define the number of hardware breakpoints on your target system. You can also set this in your project properties and in a launch configuration.

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.



Setting value description

Valid settings

The following table shows the valid setting values.

Valid Setting Values

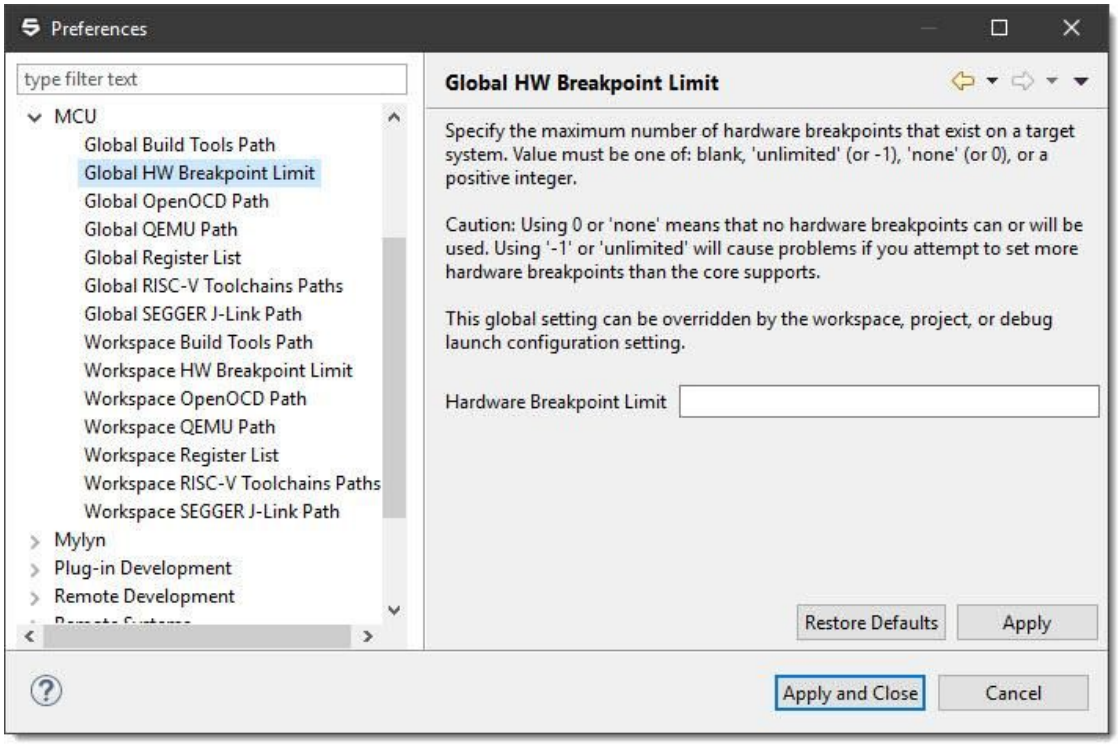
Value	Description
blank	Leave the setting blank and it will not be used.
'unlimited', or -1	Tells GDB that you have unlimited hardware breakpoints.
'none', or 0	Tells GDB that you have no hardware breakpoints.
x, a positive integer	Tells GDB that you have *x* hardware breakpoints.

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.

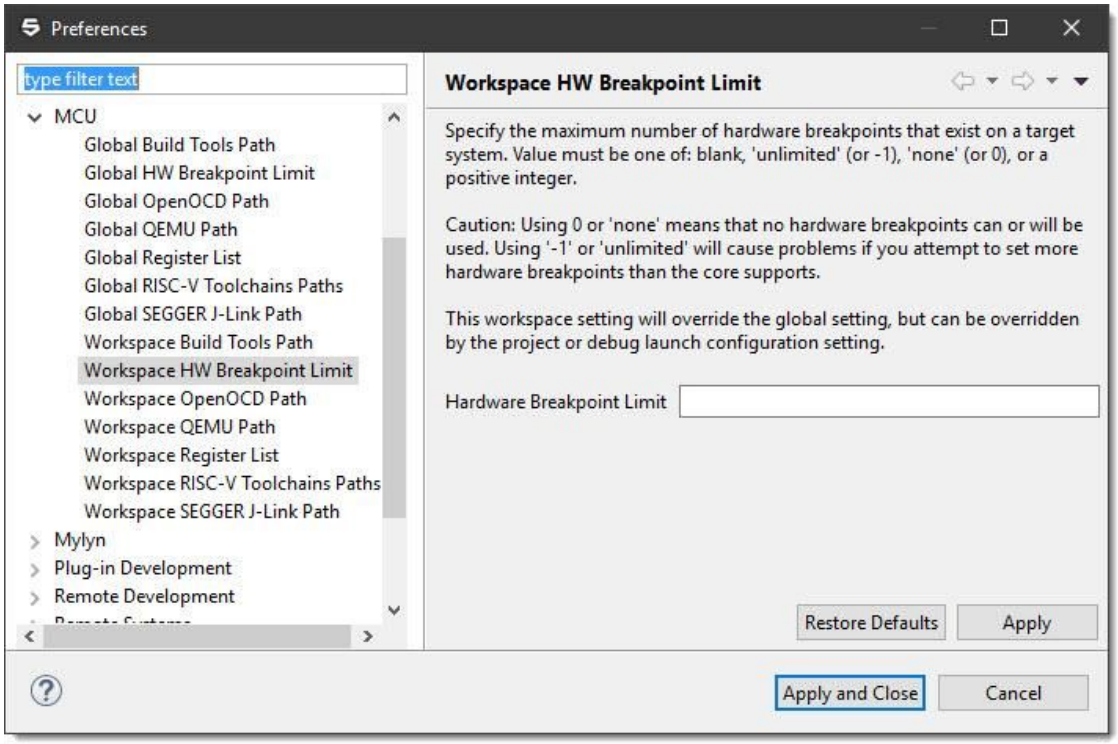
Set the global preference by opening the Preferences Dialog (`Windows -→ Preferences`) and navigating to the `MCU | Global HW Breakpoint Limit` page.



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.

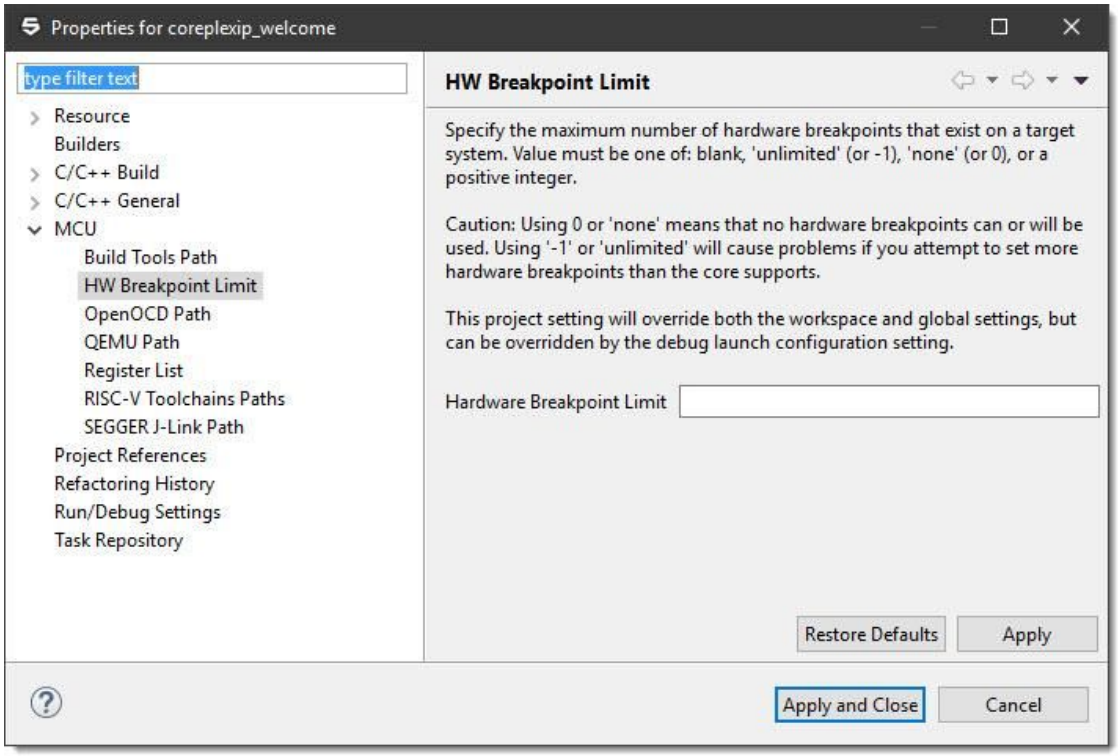
Set the workspace preference by opening the Preferences Dialog (`Windows -→ Preferences`) and navigating to the `MCU | Workspace HW Breakpoint Limit` page.



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.

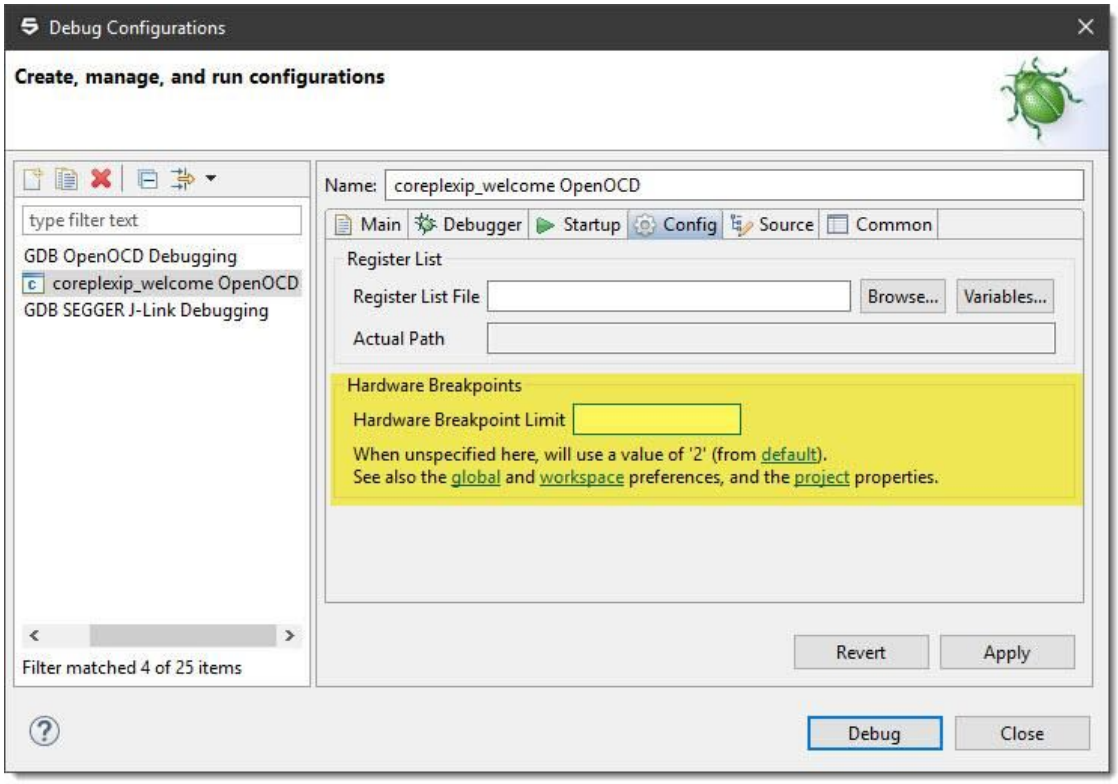
Set the project property by opening the Project Properties Dialog (`Project -→ Properties`) and navigating to the `MCU | HW Breakpoint Limit` page.



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\
         55555555555555555555555\n\r\
        5555                   5555\n\r\
       5555                     5555\n\r\
      5555                       5555\n\r\
     5555       555555555555555555555\n\r\
    5555       5555555555555555555555\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 in red colored font

While red font can be scary, it is generally benign debugging output. This happens because OpenOCD output status message through stderr and Freedom Studio renders stderr in red. You can change this color in the Freedom Studio Preference, but be aware that this will affect all consoles that accept and display stderr text.

Trouble Shooting

Linux 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.

Correcting Terminal Output

When using the Terminal View in Freedom Studio you may see terminal output from a target UART that does not properly handle “carriage returns”. You may see output that looks like :

To resolve this, open a command window and issue the following command:

```
stty -F <tty-device-name> onlcr inlcr
```

You can do this while connected to the terminal in Freedom Studio. You should see immediate results. You may need to adjust other stty settings depending on your environment.

Target Board Setup

Windows Board Setup

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

Digilent (on Arty boards) and Olimex devices require specific device drivers to function properly with Freedom Studio. Starting with Freedom Studio 2019.05 these device drivers are automatically installed when needed. There is no need to manually install any device drivers. When a driver is installed you may be prompted by Windows UAC to authorize the installation of the driver.

The device driver for the Digilent USB connection is only installed when you use the Arty Flashing utility within Freedom Studio. If you intended to use Vivado to update your FPGA images then we suggest you use Vivado only to update your FPGA. Vivado and Freedom Studio use two different device drivers for updating the FPGA image.

If you have used Freedom Studio to update or install and FPGA image and then decide to use Vivado, you will need to manually uninstall the device driver installed by Freedom Studio (via the Device Manager) before Vivado will recognize the target again.

Windows JLink USB Driver

Note

If you have installed JLink software independently of Freedom Studio then the USB driver is already installed.

If you are using a HiFive1-revB board (which has a JLink interface built-in), or if you intend to use a JLink Probe you need to ensure that the JLink USB device driver is installed.

Freedom Studio, at this time, does not install this driver automatically. The driver installation file is located at:

```
<install-folder>/SiFive/jlink/jlink<version-info>/USBDriver/x64/dpinst_x64.exe
```

Run the installer and accept the default choices.

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.

The procedure to unload the driver is available through the *SiFiveTools -> Setup OpenOCD FTDI Access* menu entry or by typing it manually at the command prompt:

- 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.

To switch back to standard Apple FTDI Access the *SiFiveTools -> Restore Apple FTDI Access* menu entry can be used or again it can be typed manually at the command prompt:

- 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`

Linux OS Board Setup

Required Libraries

For Arty board and Olimex support The following libraries need to be installed on the host system:

- libftdi1
- libusb

These can be installed on Ubuntu with the following command:

```
>sudo apt-get install libftdi1-2 libusb-0.1-4 libusb-1.0
```

And on CentOS 7 with the following command:

```
>sudo yum install libftdi libusb
```

And on Fedora 29 with the following command:

```
>sudo yum install libftdi-1.3-12.fc29.x86_64 libusb-1:0.1.5-13.fc29.x86_64
```

Let's Check Our Dependencies

The two programs that require these libraries are `OpenOCD` and `xc3sprog`. You can check that all dependencies are satifsied using the `ldd` utility.

For instance, on Ubuntu:

```
$ cd ~/FreedomStudio/SiFive/xc3sprog/xc3sprog-0.1.2-2019.04.1
$ ldd xc3sprog
    linux-vdso.so.1 =>  (0x00007ffed35f8000)
    libftdi1.so.2 => not found
    libusb-0.1.so.4 => not found
    libstdc++.so.6 => /usr/lib/x86_64-linux-gnu/libstdc++.so.6
(0x00007f395565f000)
    libgcc_s.so.1 => /lib/x86_64-linux-gnu/libgcc_s.so.1 (0x00007f3955447000)
    libc.so.6 => /lib/x86_64-linux-gnu/libc.so.6 (0x00007f395507d000)
    libm.so.6 => /lib/x86_64-linux-gnu/libm.so.6 (0x00007f3954d74000)
    /lib64/ld-linux-x86-64.so.2 (0x00007f3955a42000)
$ cd
~/FreedomStudio/SiFive/riscv-openocd/riscv-openocd-0.10.0-2019.05.0-RC1/bin
$ ldd openocd
    linux-vdso.so.1 =>  (0x00007ffe3cadd000)
    libusb-1.0.so.0 => /lib/x86_64-linux-gnu/libusb-1.0.so.0
(0x00007fe58b0b1000)
    libm.so.6 => /lib/x86_64-linux-gnu/libm.so.6 (0x00007fe58ada8000)
    librt.so.1 => /lib/x86_64-linux-gnu/librt.so.1 (0x00007fe58aba0000)
    libdl.so.2 => /lib/x86_64-linux-gnu/libdl.so.2 (0x00007fe58a99c000)
    libpthread.so.0 => /lib/x86_64-linux-gnu/libpthread.so.0
```

```
(0x00007fe58a77f000)
    libc.so.6 => /lib/x86_64-linux-gnu/libc.so.6 (0x00007fe58a3b5000)
    libudev.so.1 => /lib/x86_64-linux-gnu/libudev.so.1 (0x00007fe58b4b2000)
    /lib64/ld-linux-x86-64.so.2 (0x00007fe58b2c9000)
```

While OpenOCD looks good, we can see the we need to install libusb (version 0.1) and libftdi in order to satisfy dependencies for xc3sprog, so let's do that:

```
$ sudo apt-get install libftdi1-2 libusb-0.1-4
  <not showing all the ouput here>
$ cd ~/FreedomStudio/SiFive/xc3sprog/xc3sprog-0.1.2-2019.04.1
$ ldd xc3sprog
    linux-vdso.so.1 =>  (0x00007ffc051b5000)
    libftdi1.so.2 => /usr/lib/x86_64-linux-gnu/libftdi1.so.2
(0x00007fbded75d000)
    libusb-0.1.so.4 => /lib/x86_64-linux-gnu/libusb-0.1.so.4
(0x00007fbded554000)
    libstdc++.so.6 => /usr/lib/x86_64-linux-gnu/libstdc++.so.6
(0x00007fbded171000)
    libgcc_s.so.1 => /lib/x86_64-linux-gnu/libgcc_s.so.1 (0x00007fbdecf59000)
    libc.so.6 => /lib/x86_64-linux-gnu/libc.so.6 (0x00007fbdecb8f000)
    libusb-1.0.so.0 => /lib/x86_64-linux-gnu/libusb-1.0.so.0
(0x00007fbdec977000)
    libm.so.6 => /lib/x86_64-linux-gnu/libm.so.6 (0x00007fbdec66e000)
    /lib64/ld-linux-x86-64.so.2 (0x00007fbded96b000)
    libudev.so.1 => /lib/x86_64-linux-gnu/libudev.so.1 (0x00007fbdedb54000)
    libpthread.so.0 => /lib/x86_64-linux-gnu/libpthread.so.0
(0x00007fbdec451000)
    librt.so.1 => /lib/x86_64-linux-gnu/librt.so.1 (0x00007fbdec249000)
```

That looks good! Now both openocd and xc3sprog are ready to go.

Enable Access to USB Devices

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 (although sudo permissions are required for the initial setup):

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

```
+

$ lsusb
  .
  .
  .
```

With your devices connected, check the output of the `lsusb` command to see that your devices are visible to the system. Use the table below to determine which entry you should see for your devices.

lsusb identifiers

Device	USB Identifier
Arty USB	Bus XXX Device XXX: ID 0403:6010 Future Technology Devices International, Ltd FT2232C Dual USB-UART/FIFO IC
HiFive2	Bus 001 Device 019: ID 0403:6011 Future Technology Devices International, Ltd FT4232H Quad HS USB-UART/FIFO IC
Olimex	Bus XXX Device XXX: ID 15ba:002a Olimex Ltd. ARM-USB-TINY-H JTAG interface.
HiFive1 RevB	Bus XXX Device XXX: ID 1366:1051 SEGGER
JLink Probe	Bus XXX Device XXX: ID 1366:0101 SEGGER J-Link PLUS

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

Note

For your convenience a *99-freedomstudio.rules* file is included with Freedom Studio in the *FreedomStudio/SiFive/Misc* directory. You can install this file with this command:

```
$ sudo cp 99-freedomstudio.rules /etc/udev/rules.d/
```

The 99-freedomstudio.rules files installs rules that recognize the following USB devices and adds them to the plugdev group:

- Olimex ARM_USB_TINY_H
- HiFive2
- Arty Digilent USB

Step 3: See if your board shows up as a serial device belonging to the plugdev group. For instance with the Arty Board USB connector connected and an Olimex probe connected you should see something like

```
$ ls -l /dev/ttyUSB*
.
.
crw-rw-r-- 1 root plugdev 188, 0 Jun  7 11:01 /dev/ttyUSB0
crw-rw-r-- 1 root plugdev 188, 1 Jun  7 11:01 /dev/ttyUSB1
crw-rw-r-- 1 root plugdev 188, 2 Jun  7 11:07 /dev/ttyUSB2
```

.
.

But how do you know which serial port belongs to which device? You cannot tell from the output above. In fact, there is no simple way to do it, so we have provided a handy shell script called *listusb.sh* located in the *FreedomStudio/SiFive/Misc* directory.

Running that script yields much enlightenment:

```
$ ./listusb.sh
/dev/ttyUSB1 - Digilent_Digilent_USB_Device_210319A92CC9
/dev/ttyUSB0 - Digilent_Digilent_USB_Device_210319A92CC9
/dev/ttyUSB2 - 15ba_Olimex_OpenOCD_JTAG_ARM-USB-TINY-H_OL150D61
```

Note

If you have other serial devices or multiple boards attached, you may have more devices listed.

The ID (ttyUSB *X*) is assigned dynamically and is dependent on the order in which you connect your devices. Their assignment will change if you disconnect and reconnect in a different order. (But as long as you do not disconnect a device, its assigned ID will not change.)

Note

If your device present more than a single UART you will always want to select the higher number of the pair. In the example above you would want to use /dev/ttyUSB1

Note

The tty/USB device provided by the Olimex probe cannot be used as a UART. You can ignore this device.

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

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

1. 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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```
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```

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