

# 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 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 2019.06
- Java 11 JRE with OpenJ9 (<https://www.eclipse.org/openj9/>)
- 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 should enable Windows Long Path support. You should do this before extracting the product archive. The Freedom Studio installation folder may contain 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](mailto: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>

#### Important Note

Starting with Freedom Studio 2019.08 the windows package contains much shorter paths (around 199 character). This means the native Windows extraction tools should work fine as long as the total length of the installation root path is less than about 60 characters. If it is longer, then you should use a tool like 7-zip to extract the package.

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 about 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 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](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.

### **Important**

Starting with FreedomStudio 2019.08, The Freedom Studio IDE will no longer run on CentOS6 because the upgraded Eclipse platform (2019.06) only supports GTK3, and GTK3 is not available on CentOS6.

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 a dialog box.. 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 choose 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.

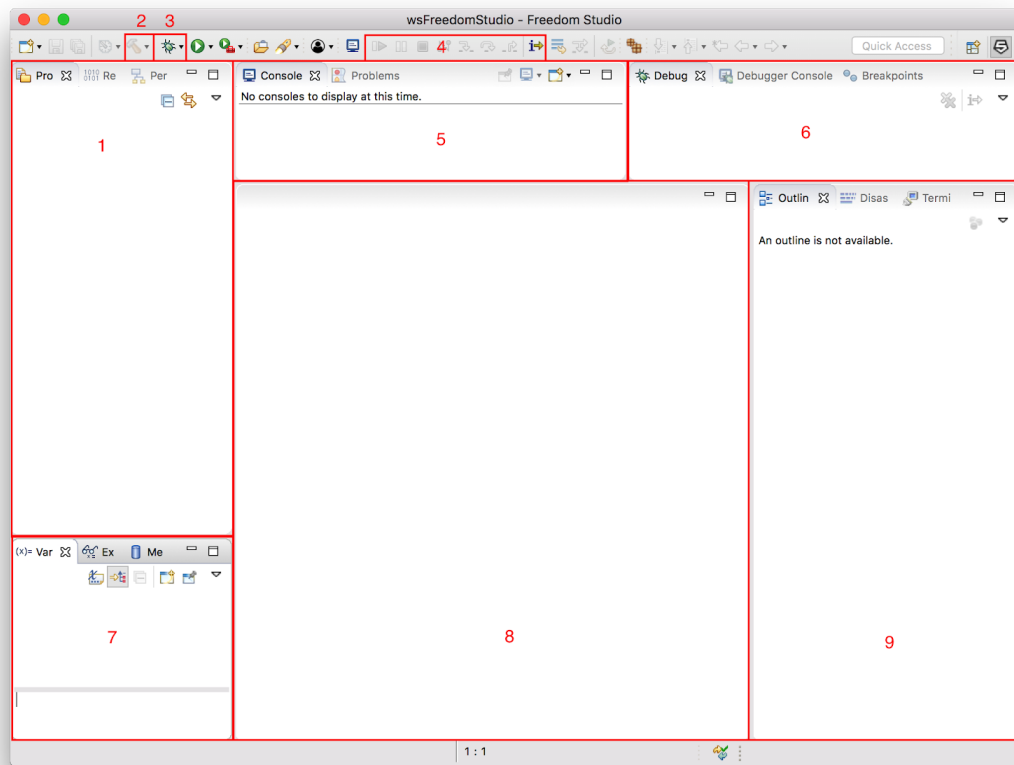
Freedom Studio ships with its own SiFive perspective which can be useful for both programming and debugging. Please see Section [The SiFive Perspective](#) for a detailed description of the SiFive Eclipse perspective.

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.

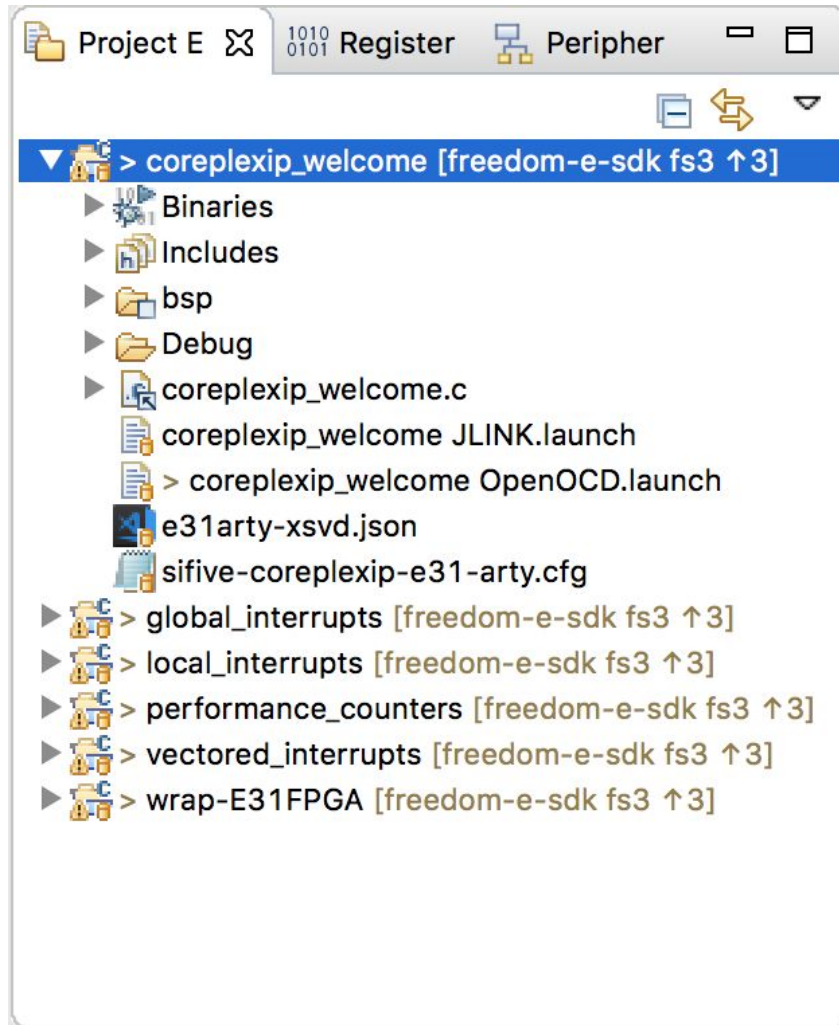
## The SiFive Perspective

**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.



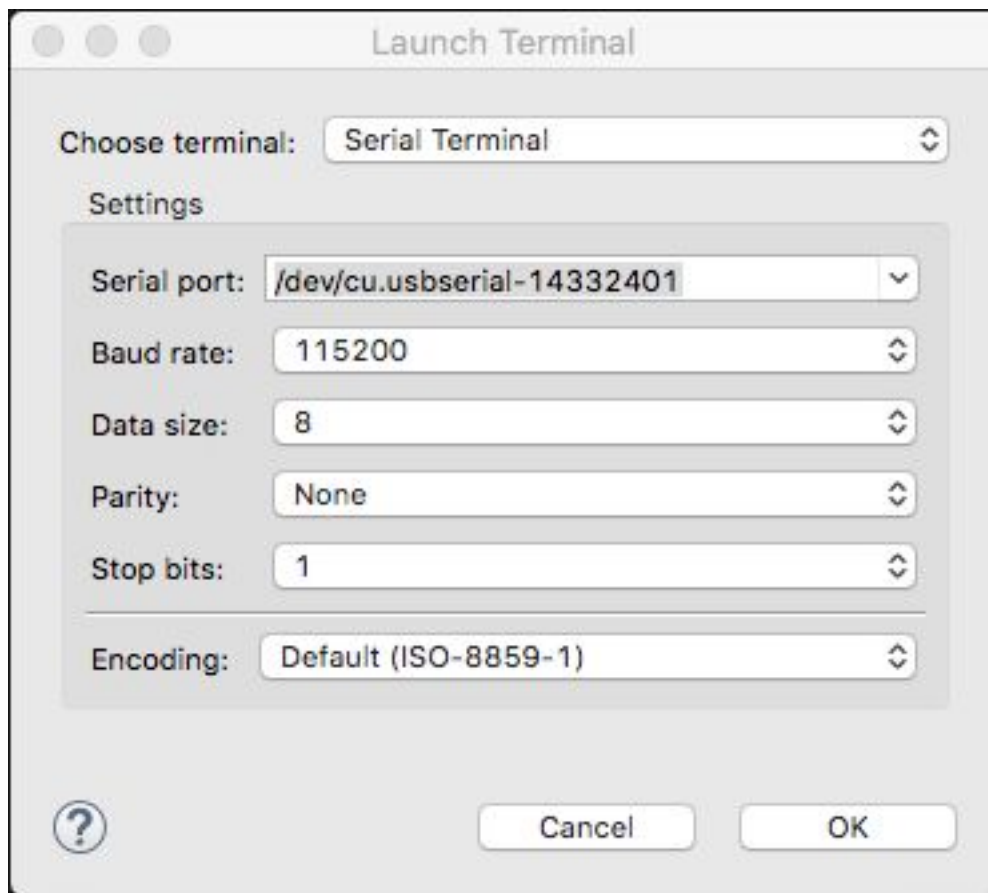
The Outline view, shown in above, gives a "top-level" view of the active file in the editor including functions, types, constants, etc... Clicking on an item in the Outline view will take you to that item's location in the source code.

## Terminal

The Terminal view, shown below, 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,

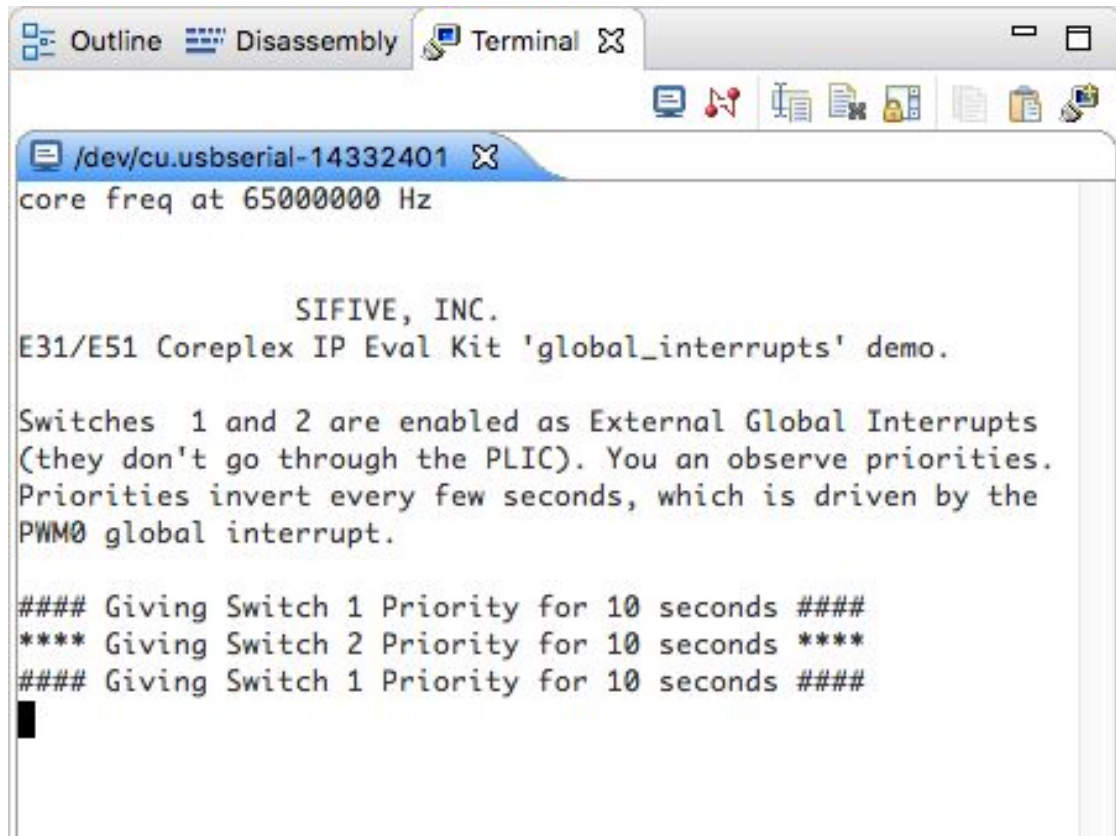
such as that from a SiFive development board, without leaving the development environment. On Windows platforms this view negates the need for an external serial terminal program. On MacOS and Linux platforms, it is possible to open serial port directly, or open a local terminal and run [GNU Screen](#).

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.





The screenshot shows a terminal window within an IDE. The IDE's top bar includes tabs for 'Outline', 'Disassembly', and 'Terminal'. The terminal window has a title bar that reads '/dev/cu.usbserial-14332401'. The output text in the terminal is as follows:

```
core freq at 65000000 Hz

                SIFIVE, INC.
E31/E51 Coreplex IP Eval Kit 'global_interrupts' demo.

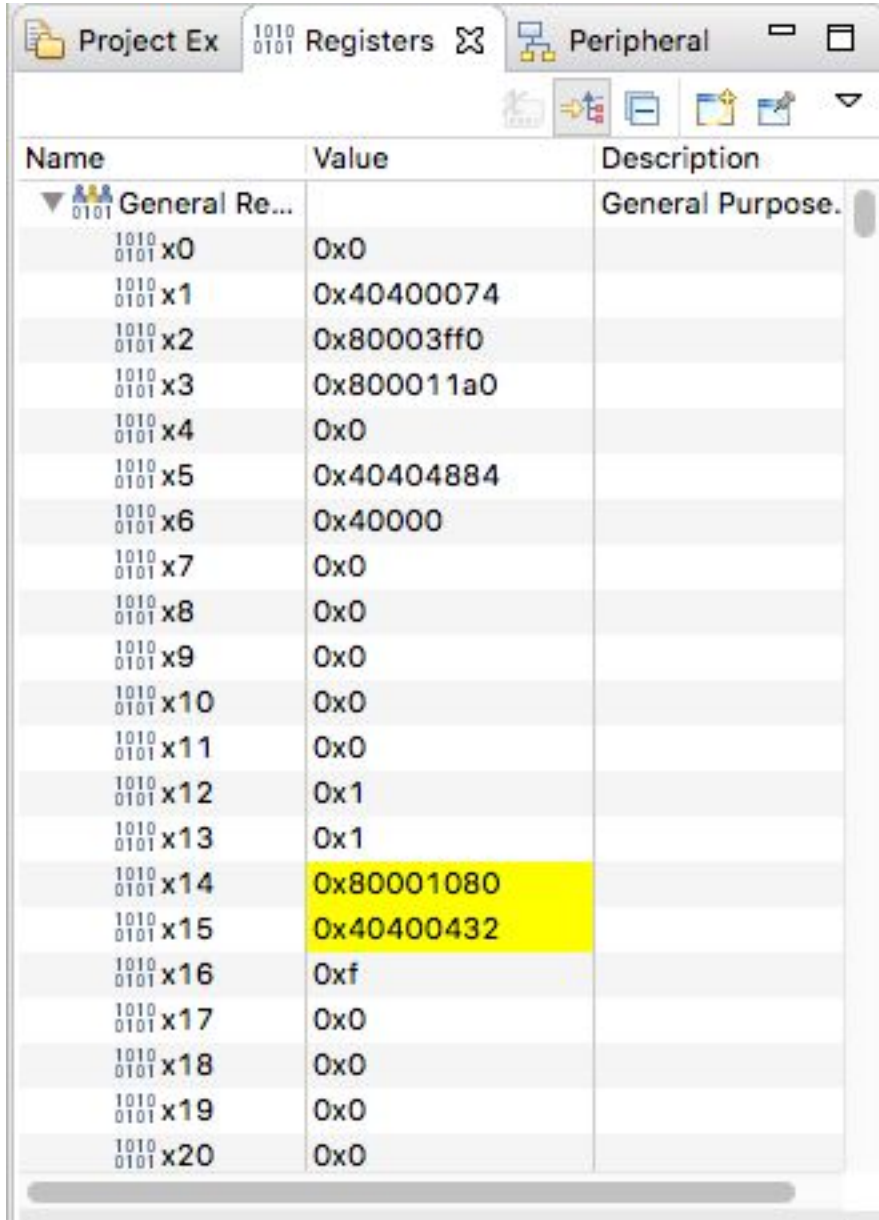
Switches 1 and 2 are enabled as External Global Interrupts
(they don't go through the PLIC). You can observe priorities.
Priorities invert every few seconds, which is driven by the
PWM0 global interrupt.

#### Giving Switch 1 Priority for 10 seconds ####
**** Giving Switch 2 Priority for 10 seconds ****
#### Giving Switch 1 Priority for 10 seconds ####
█
```

## 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



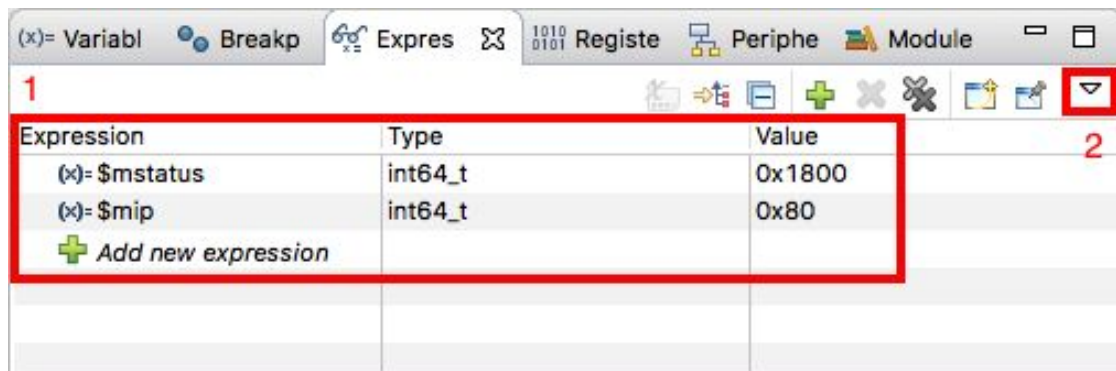
Name	Value	Description
General Re...		General Purpose.
x0	0x0	
x1	0x40400074	
x2	0x80003ff0	
x3	0x800011a0	
x4	0x0	
x5	0x40404884	
x6	0x40000	
x7	0x0	
x8	0x0	
x9	0x0	
x10	0x0	
x11	0x0	
x12	0x1	
x13	0x1	
x14	0x80001080	
x15	0x40400432	
x16	0xf	
x17	0x0	
x18	0x0	
x19	0x0	
x20	0x0	

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:



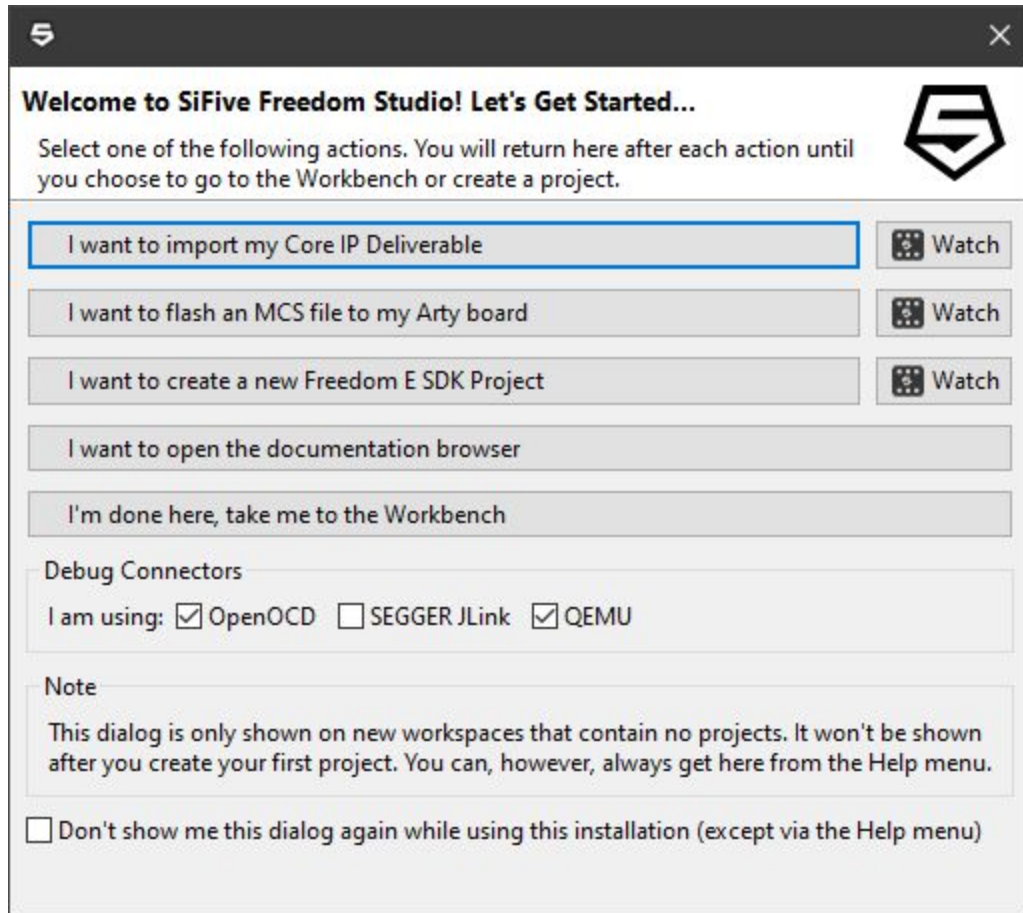
## Getting Started

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

Starting with version Freedom Studio 2019.05, 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.



### Quick Actions

Some quick action buttons have a “Watch Video” button next to them. Pressing this button will open a how-to video link in your browser.

- **I want to import 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 select an IP Deliverable package (usually a tar.gz file) and Freedom Studio will create a new IP project from the package. The wizard will optionally offer to program an included MCS file or BIT file, and create a new software project from the freedom-e-sdk embedded in the package.
- **I want to load an FPGA image to my Arty board**  
Choose this option if you want to get started by programming an MCS or BIT file to your Arty board. You will also have the choice to jump right into creating a project

at the end of the programming process.

- **I want to create a new Freedom E SDK project**

If you have a HiFive series board or an Arty FPGA board already programmed with core IP and want to jump straight to creating a project, select this option.

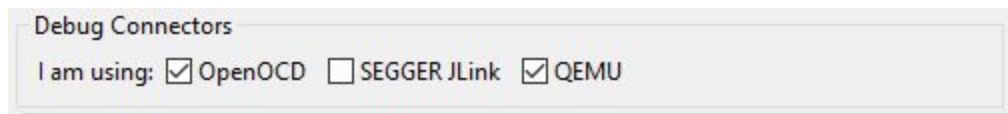
- **Open the documentation browser**

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.

## Debug Connectors



The Debug Connectors section of the Getting Started dialog lets you specify which debug connectors you want to use. Check those you want to use, and uncheck those that you will not be using. Uncheck items will no longer show up in the IDE and will help reduce the amount of UI clutter.

You can change these settings at any time using this dialog (from the Help menu) or from the Debug Connector Preference Page.

## Programming 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.

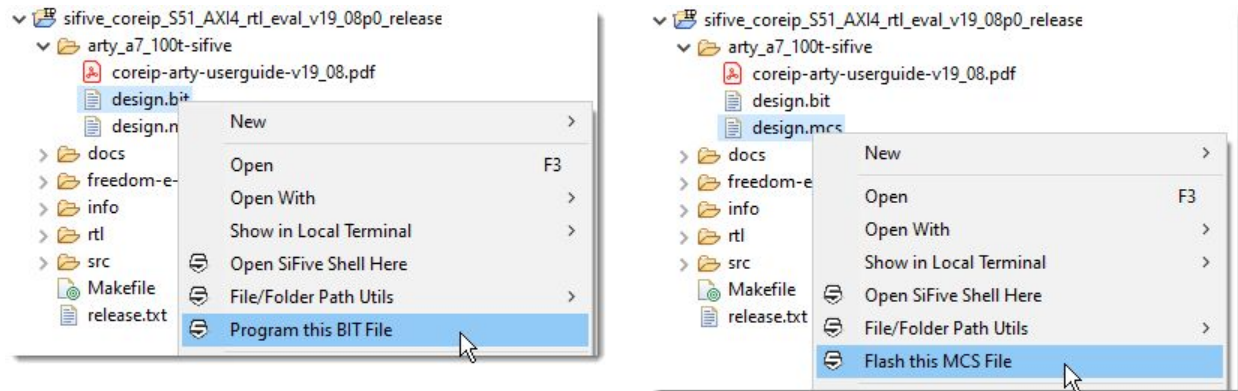
Flashing an MCS file on the Arty requires both the Olimex probe and the Arty board USB connector be connected to the host PC. Both USB connections are used during the process. Do not simply connect the Arty USB to a power supply when flashing.

Programming a BIT file to the Arty requires only the Arty board USB connection be connected to your PC. The Olimex probe is not used in the programming process, however, having the Olimex connected will ensure that the correct device drivers for debugging with the Olimex are installed.

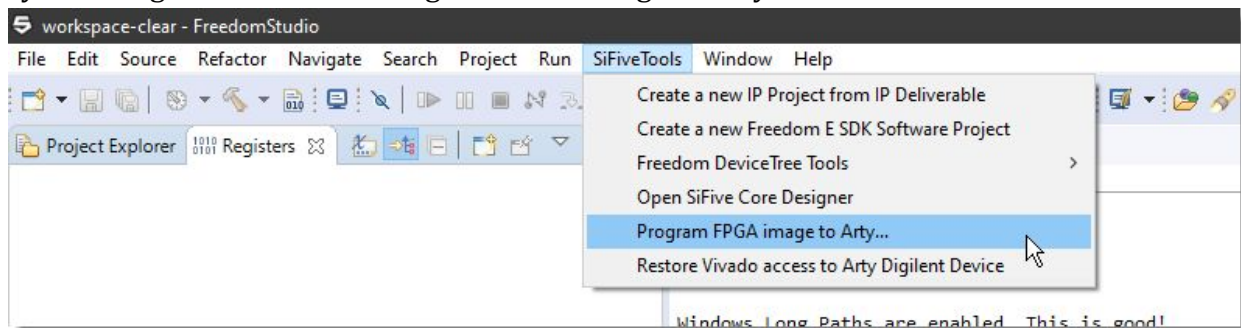
Programming an Arty Board using a JLink connection is not supported at this time.

## Programming the Arty Board

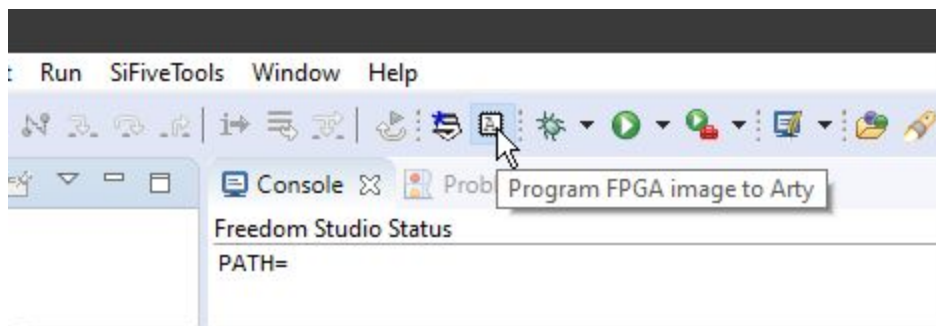
The easiest way to program an MCS or BIT file onto the Arty board FPGA is to right-click on the file in the project explorer:



If the FPGA image file is not in a workspace project, you can open the from the main menu by selecting SiFiveTools → Program FPGA image to Arty...

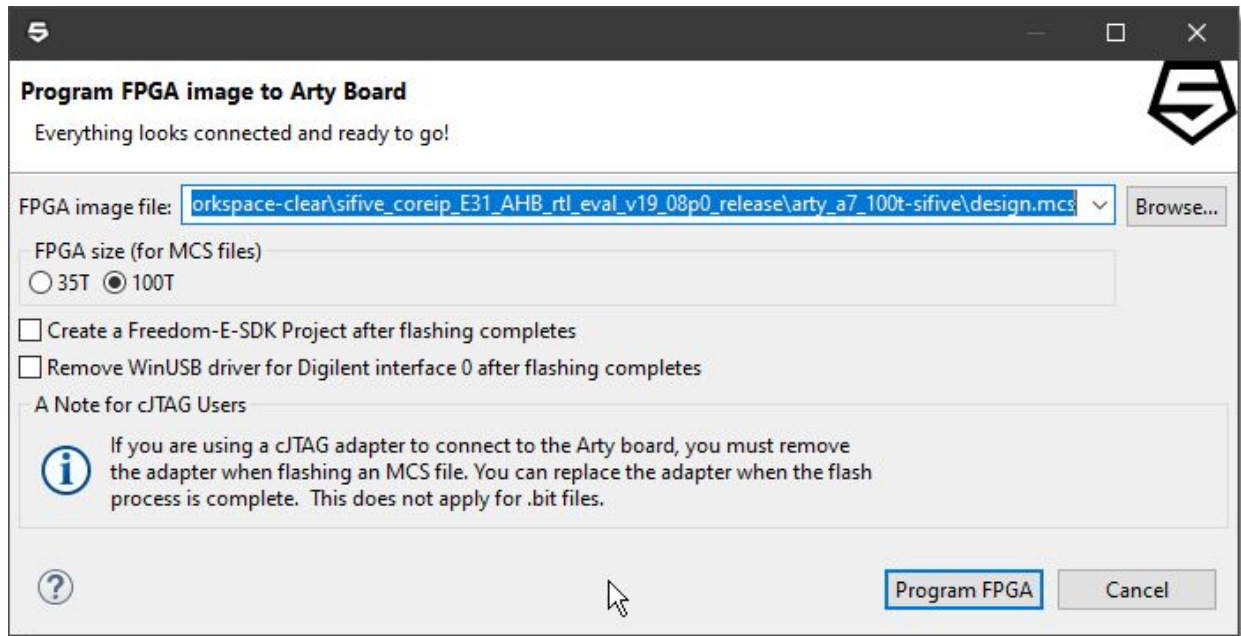


or by clicking the Arty Programming icon on the main toolbar:



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





1. First select the MCS or BIT file you want to program. These files are available in Core IP deliverables; in downloaded evaluation packages, or directly from Sifive, or may be created in your flow. Use the Browse button to locate and select the desired image file.
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. [This setting is not applicable for BIT files and the controls will be disabled when you select a BIT file to program]
3. Create a Freedom-E-SDK Project: Check this box if you want to open the New Freedom E SDK Project Wizard when the programming process is completed.
4. If you intend to use Vivado to program your FPGA bitstream you can have Freedom Studio uninstall the device driver used by Freedom Studio. This will allow Vivado to connect to the target. If you do not plan to use Vivado to program images, then leave this box unchecked as it will speed up future programming operations within Freedom Studio.

Once you've made your selections, click the **[Program FPGA]** button to start the programming process. See the notes below regarding Windows hosts.

Flashing an MCS file 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.

Programming a BIT file is much faster (just a few seconds). Programmed BIT file are ephemeral. Power-cycling the board, or pressing the PROG button will "erase" the programmed BIT 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 Programmer will report the status (as shown above) and the **[Program FPGA]** button will not be enabled unless all required devices are detected as connected.

Freedom Studio also monitors the driver status for both devices and will install required drivers as parts of the programming process. You may have to authorize the driver installation if Windows displays a UAC prompt. Programming will not succeed unless you authorize the driver installation.

## Advanced Quick Programming

If you hold a <SHIFT> key down when you right-click on an image file and select the menu entry to program the file, the Arty Programming Dialog will not be opened and the selected image file will be immediate programmed to the Arty board.

It is important that you know that everything is setup and working properly to ensure a successful programming operation. If you are unsure, don't use the <SHIFT> key shortcut.

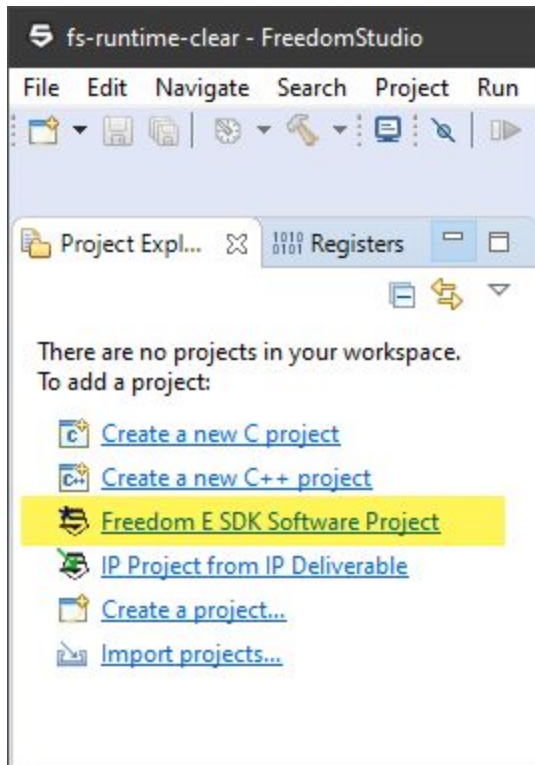
This shortcut works with Arty 100T MCS images, and both 35T and 100T BIT files. If you need to program a 35T MCS file you need to use the dialog to select the 35T option.

## Create a Freedom E SDK Software Project

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

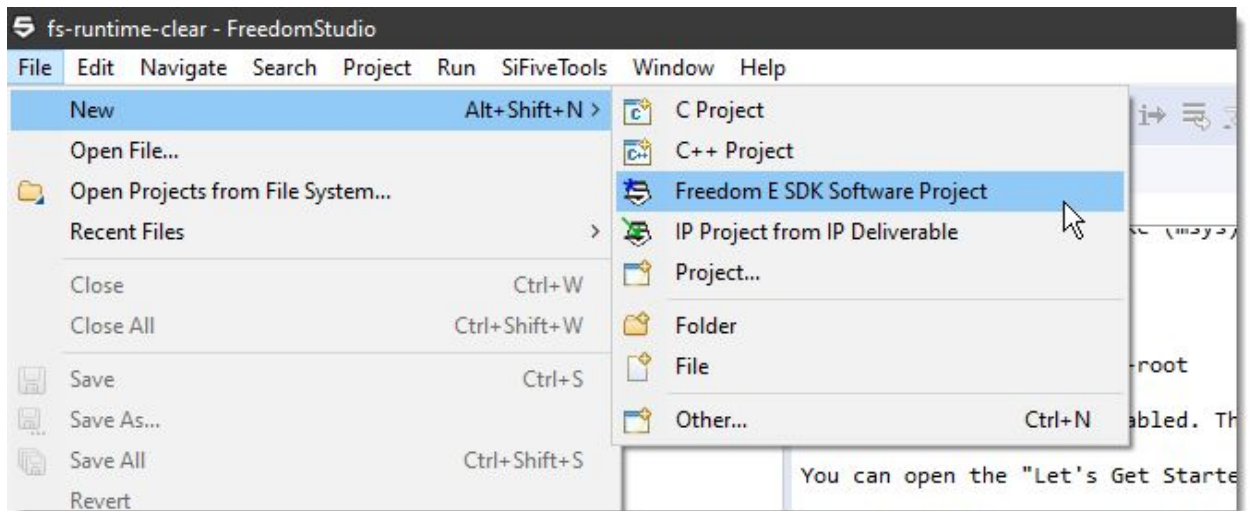
- If you have just created a new workspace with no existing projects, the Project Explorer view will have a quick start menu, similar to this:



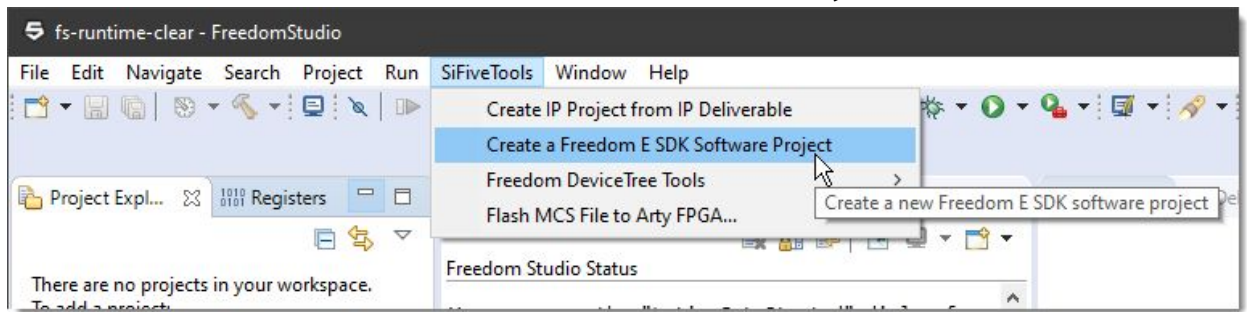


Select "Freedom E SDK Software Project", to open the wizard.

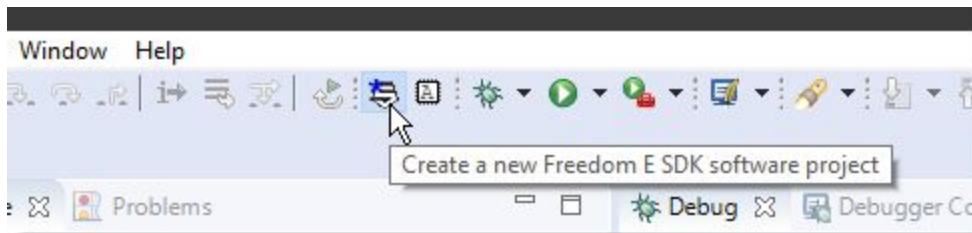
- From the main menu, select **File** → **New** → **Freedom E SDK Software Project**, as shown below:



- 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. New in Freedom Studio 2019.08 is the ability to work with multiple SDK instances. You can select from any SDK instance on your host computer and create software

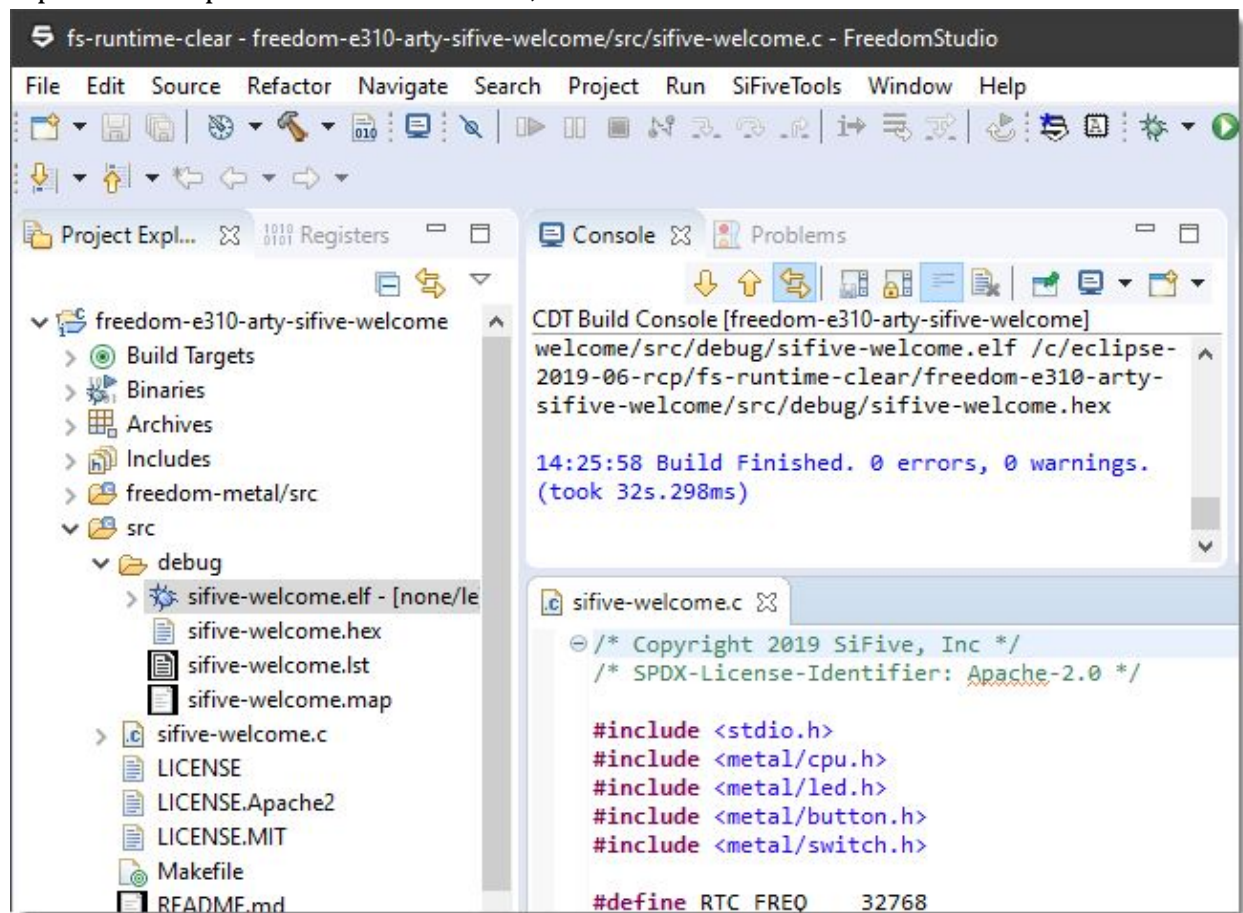
projects from the selected SDK. The drop-down box is automatically populated with any SDK instances found in your workspace projects. Using the '+' button you can also select an SDK instance that is not contained in your workspace.

2. 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.
3. Select an example program. Several examples are provided and each one demonstrates different features sets of the core.
4. 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.
5. 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 next 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 and open the main source file, 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 built.

## IP Projects

Freedom Studio 2019.08 introduces a new project type called "IP Projects". IP Projects are created by importing an IP Deliverable package. Once imported, you can use Freedom Studio to perform actions on the IP package assets.

### Creating a new IP Project

There are two ways to create an IP Project:

1. Import an IP Deliverable package. This can be a tar.gz file or an unpacked folder on your host system. You will use the "IP Project from IP Deliverable" wizard to import your package.
2. Any clone of the open sourced freedom-e-sdk can be easily converted to an IP project to enable all the Freedom Studio integrations.



## IP Project from IP Deliverable Wizard

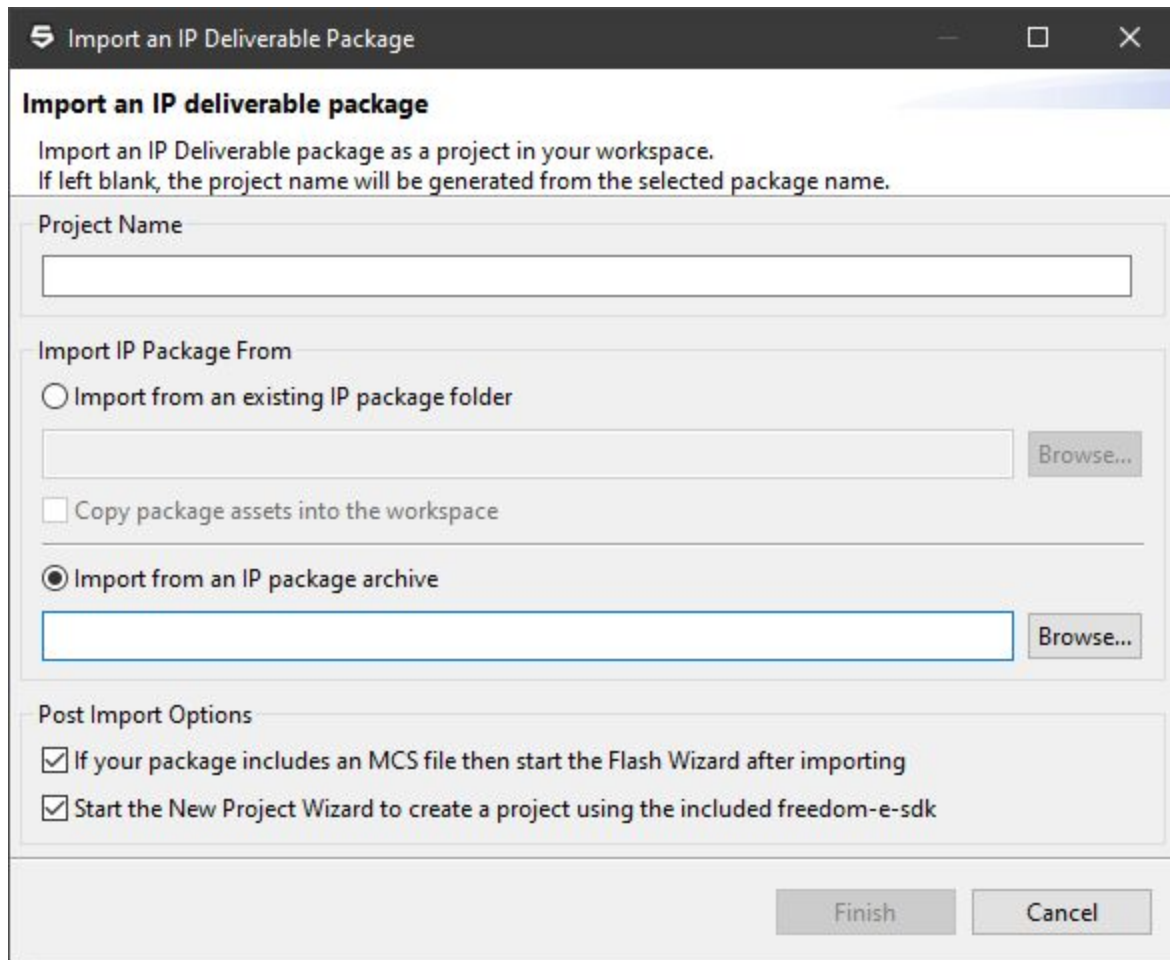
This wizard is accessible from all the usual spots in Freedom Studio:

- The “Let’s Get Started” Dialog (via the Help menu)
- The SiFiveTools menu
- Main Menu -> File -> New -> IP Project from IP Deliverable
- Project Explorer Context Menu
- New Workspace Project Explorer Menu

Before creating a new IP Project you should have an IP Deliverable tarball. If you do not, go to the SiFive Core Designer website and create an awesome SiFive RISC-V core based SOC. When you receive your IP deliverable pack, return here to continue.

### Open the Wizard

Open the “IP Project from IP Deliverable” wizard using any of the commands listed above. This wizard has only a single page:



The screenshot shows a dialog box titled "Import an IP Deliverable Package". The main heading is "Import an IP deliverable package". Below this, it says "Import an IP Deliverable package as a project in your workspace. If left blank, the project name will be generated from the selected package name." The dialog is divided into several sections:

- Project Name:** A text input field.
- Import IP Package From:**
  - ☐ Import from an existing IP package folder: Includes a text input field and a "Browse..." button.
  - ☐ Copy package assets into the workspace
  - ☒ Import from an IP package archive: Includes a text input field and a "Browse..." button.
- Post Import Options:**
  - ☒ If your package includes an MCS file then start the Flash Wizard after importing
  - ☒ Start the New Project Wizard to create a project using the included freedom-e-sdk

At the bottom right, there are "Finish" and "Cancel" buttons.

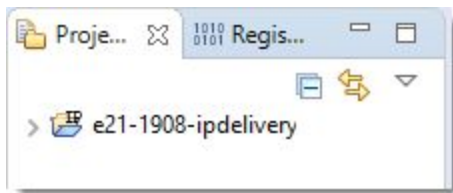
The most common scenario is to create the new project by pointing to the IP tarball, so that is the default option when the wizard is opened. You can also import from an existing folder (perhaps you unpacked the tarball outside of Freedom Studio already). When importing from a folder you have the option of linking to the folder content, or copying the content into the workspace.

A project name will be generated automatically from the name of the IP tarball. You can accept this name, or enter a name manually.

At the bottom of the page are two options:

1. Option 1 tells Freedom Studio to open the Arty Programmer Dialog to program the MCS or BIT file included in the IP package. The dialog will default to the MCS file (if one is found), but you can choose the BIT file (if one exists) from the dropdown selector.
2. Option 2 tells Freedom Studio to start the Freedom E SDK Software Project wizard when the import is complete.

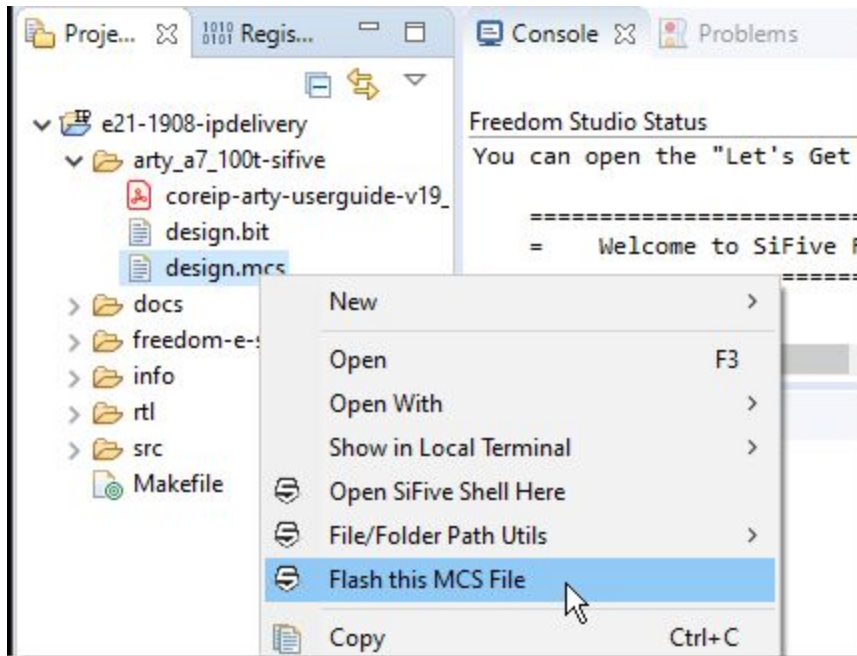
If you have an IP tarball, go ahead and select it using the “Browse...” button and create a new IP Project. IP Projects are denoted in the Project Explorer with a small “IP” icon in the upper-right corner of the project icon.



## Working with the IP Project

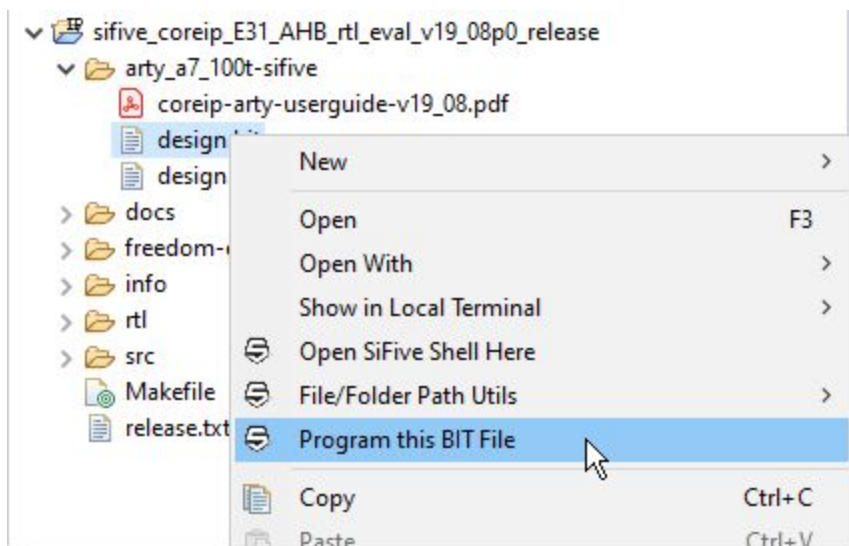
Now that you have a new IP Project, let's do stuff with it. You can:

- **Flash the included MCS file:** Right-click on the MCS file in the project and selecting "Flash this MCS File"



This will open the Arty Programmer Dialog with the selected MCS file ready to go.

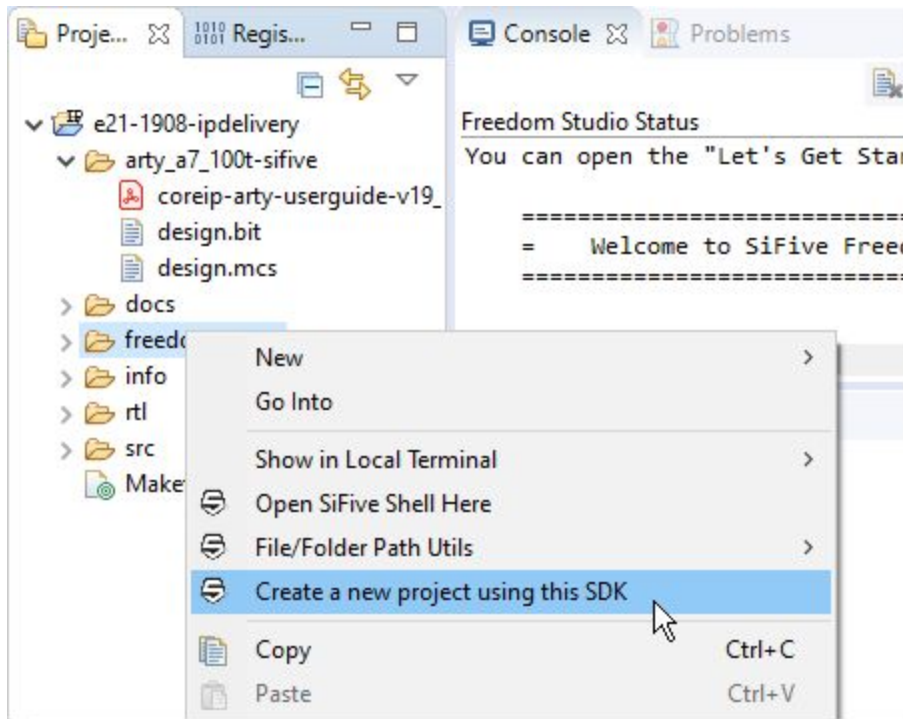
- **Program the included BIT file:** Right-click on the BIT file in the project and selecting "Program this BIT File"



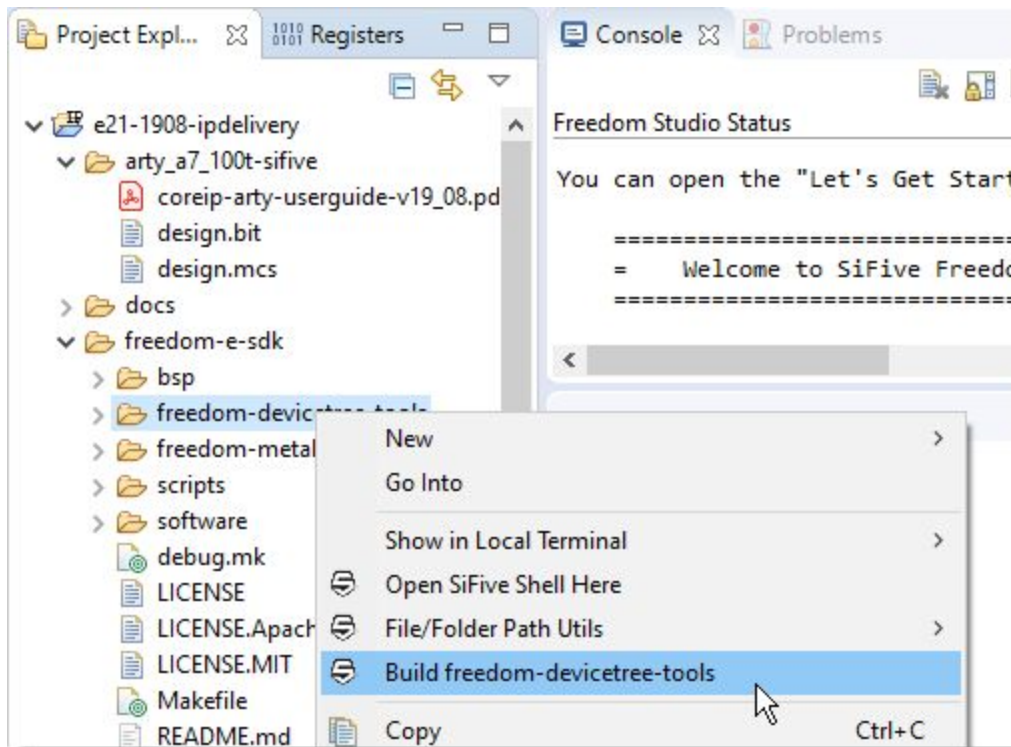


This will open the Arty Programmer Dialog with the selected BIT file ready to go

- **Create a new Freedom E SDK Software Project:** Right-click on the freedom-e-sdk folder and select “Create a new project using this SDK”

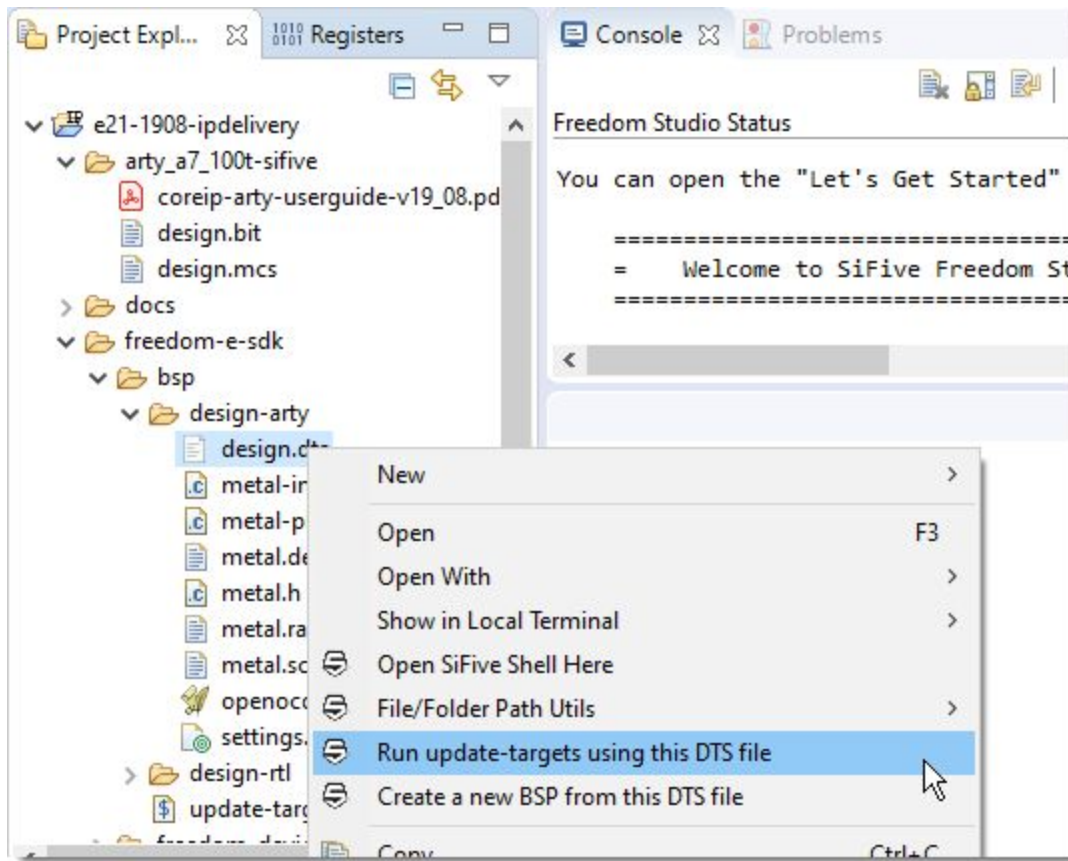


- **Build the freedom-devicetree-tools:** right-click on the “freedom-devicetree-tools” folder (found under the freedom-e-sdk folder) and select “Build freedom-devicetree-tools”



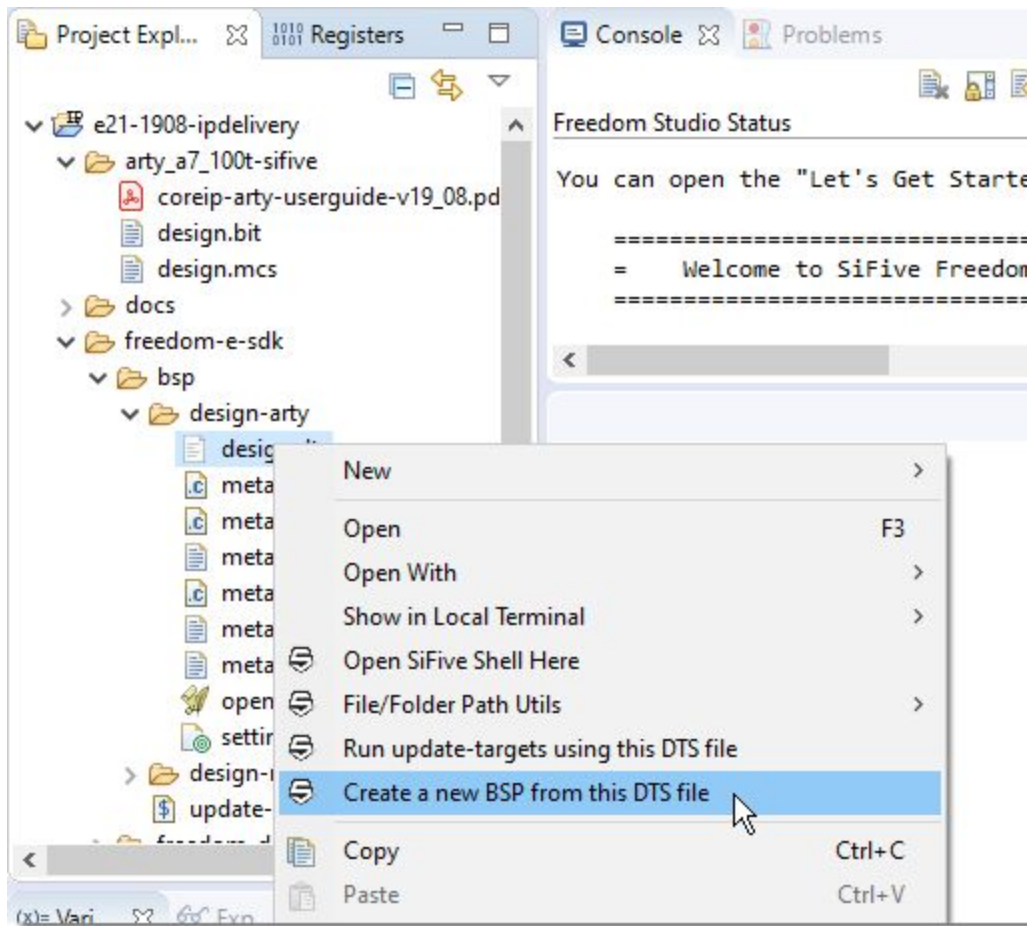
Building these tools requires that several native packages be installed on the host system. On Windows and Mac Freedom Studio will offer to install these packages if they are not detected (they are not included with the Freedom Studio installation). On Linux, manual installation of these packages is required. See the [freedom-devicetree-tools github project](#) for details on which packages are required.

- **Rebuild your BSP:** If you have edited your BSP DTS file, right-click on the DTS file and select “Run update-targets using this DTS file”

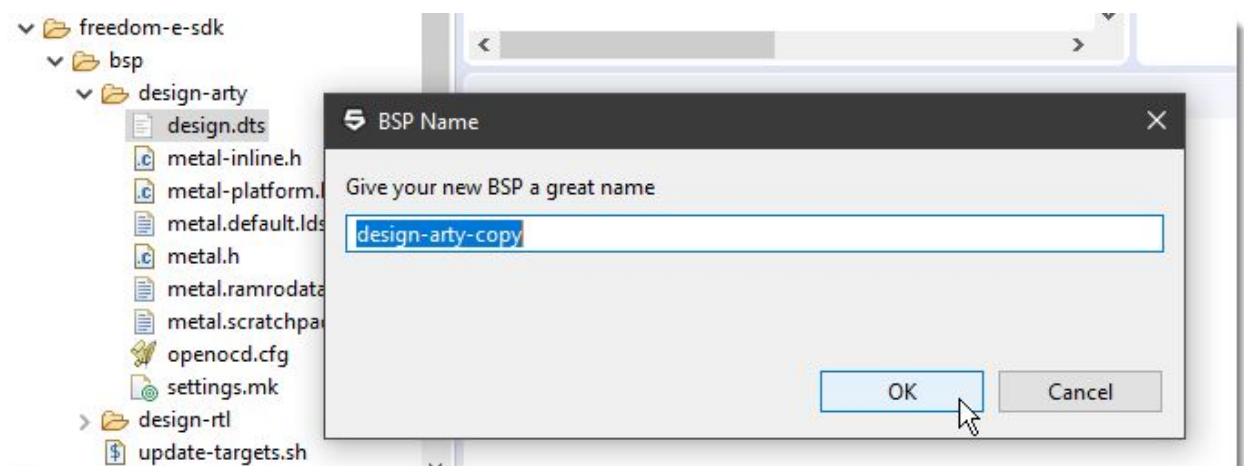


This command requires that the freedom-devicetree-tools are compiled. If they are not, Freedom Studio will ask if you'd like to compile them first, then continue updating the BSP.

- **Create a new BSP from an existing BSP:** Right-click on a DTS file in a BSP folder and select “Create a new BSP from this DTS file”



You will be prompted to give your new BSP a name.



The BSP type (Arty or RTL) will be determined by the existing settings.mk file. If for

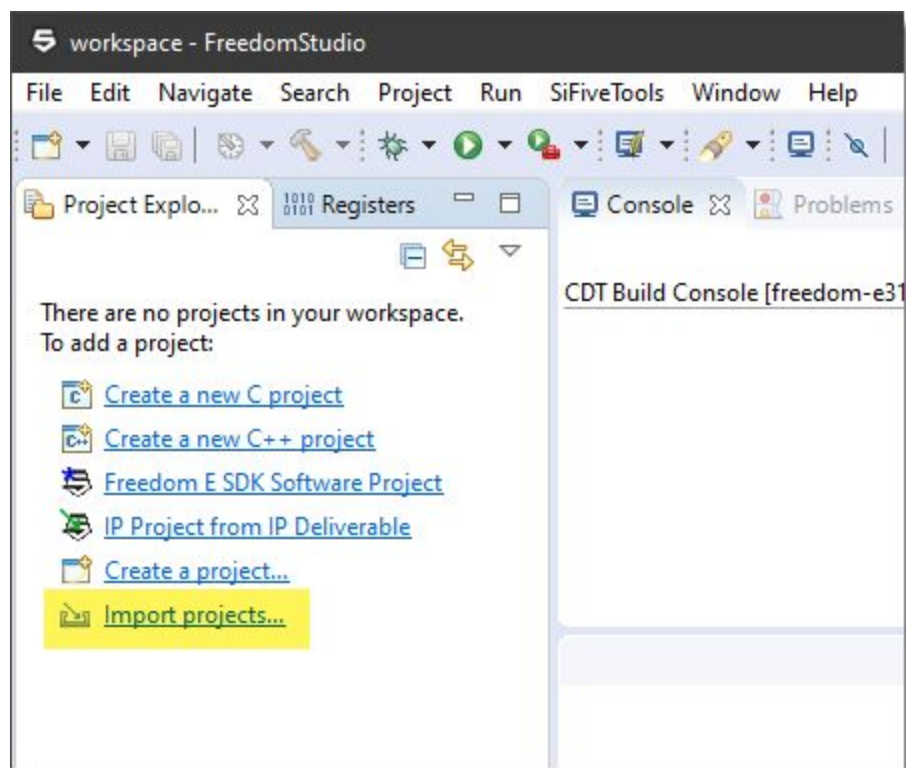
some reason the settings.mk is not present or does not specify the type, Freedom Studio will prompt you for the type of BSP to create.

When you click OK Freedom Studio will create a new BSP folder (a sibling to the existing folder) and automatically run update-targets on the new BSP to generate the BSP support files.

## Migrating Freedom Studio 2019.05 to Freedom Studio 2019.08

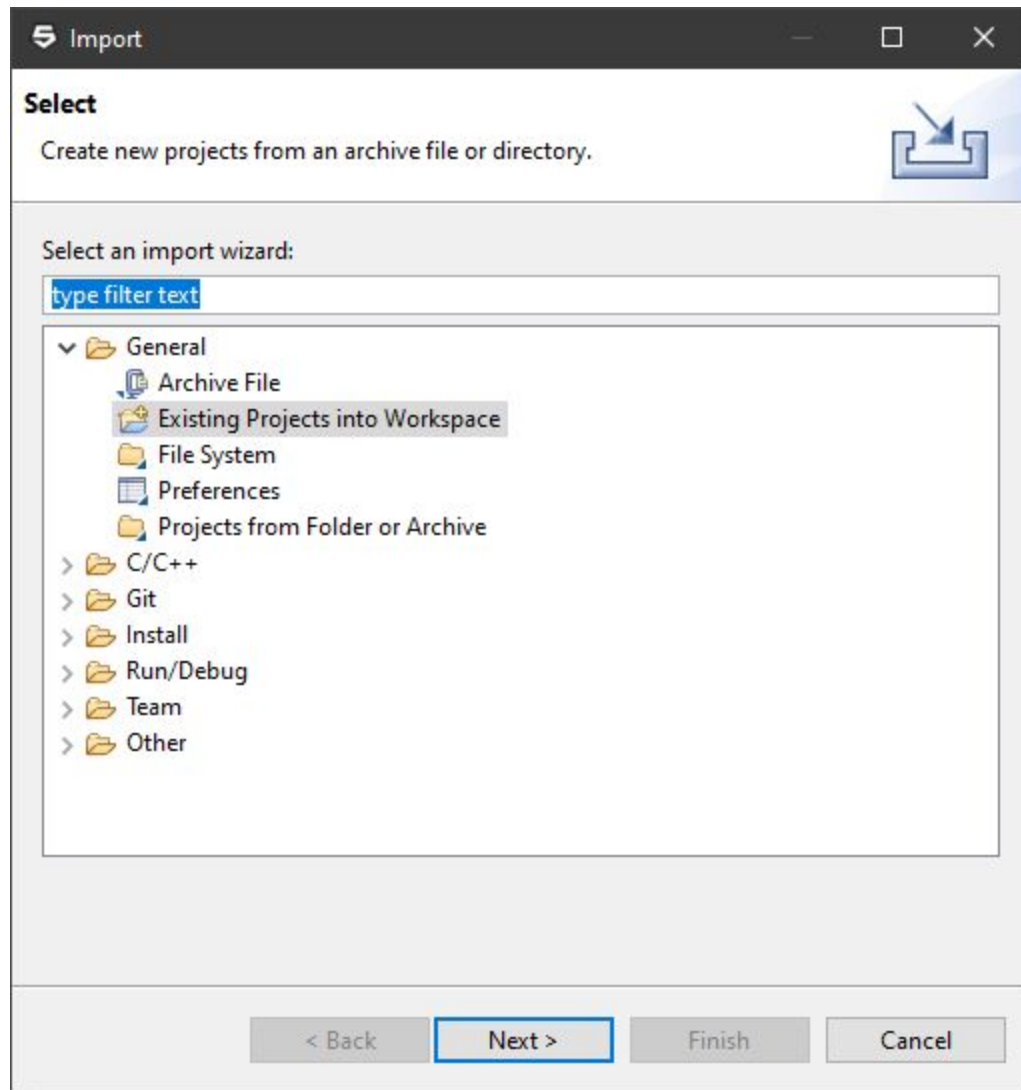
### Migrating Projects

We have updated the version of Eclipse from Oxygen (2017.06) to 2019.06 (a 2 year leap). Workspaces from Freedom Studio 2019.05 will be upgraded when opened in Freedom Studio 2019.08. This will render the workspace no longer compatible with Freedom Studio 2019.05. A safer migration is to create a new workspace for Freedom Studio 2019.08 and then import the projects from your Freedom Studio 2019.05 workspace using the Import Wizard called "Existing Projects into Workspace" accessed via the Import dialog. If you have a new empty workspace open, then you can open this Dialog from the empty Project Explorer by selecting "Import projects..."



If you already have one or more projects in your workspace then open the Import dialog from the main menu: File → Import.

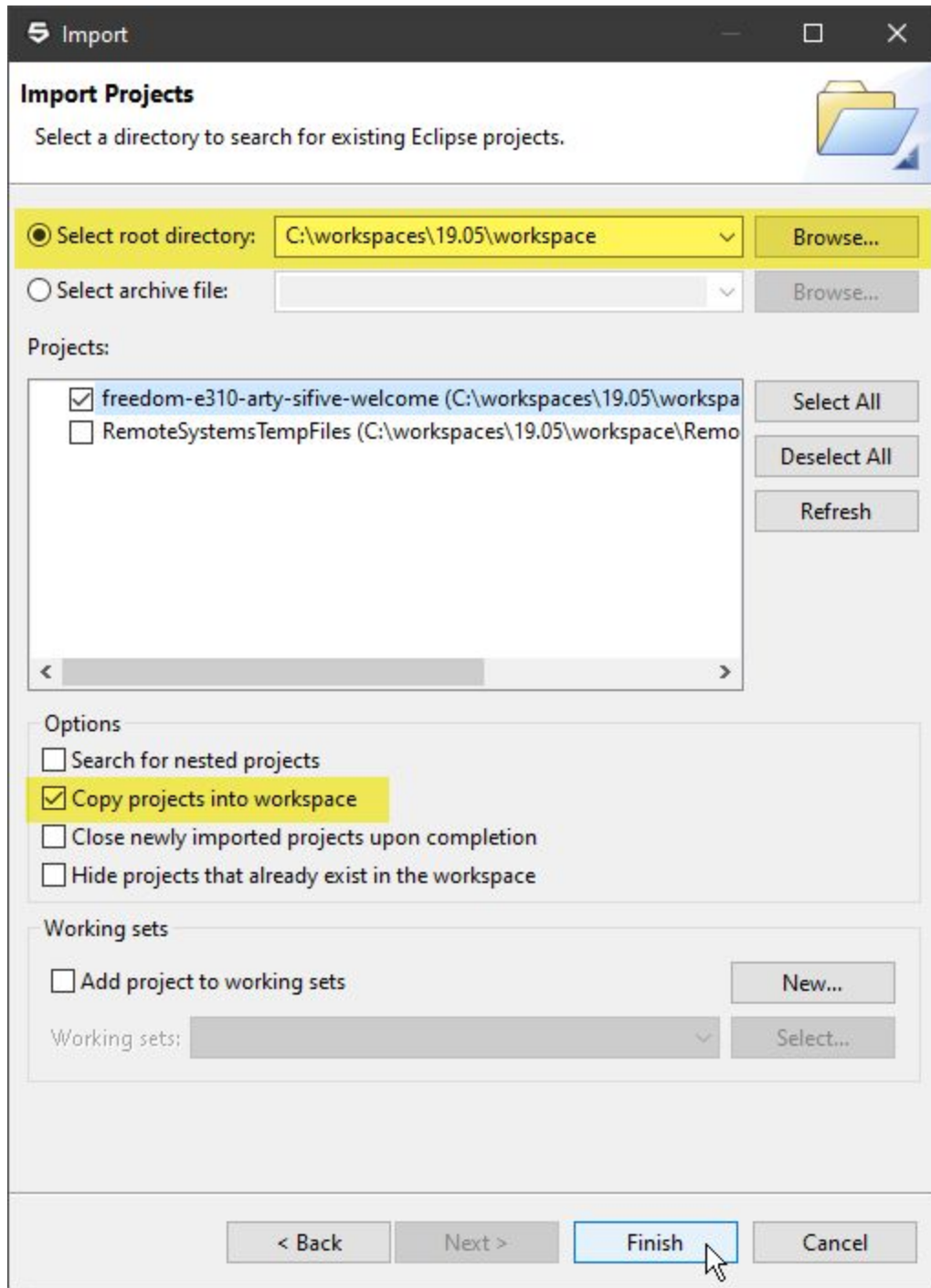
Once opened, expand the “General” category, and select “Existing Projects into Workspace”.



Click [Next>], then [Browse...] to select the Freedom Studio 2019.05 workspace directory. The Import wizard will show a list of all projects in the workspace. Check the ones you want to import. (If present, you should uncheck the project called “RemoteSystemTempFiles”)

Be sure to check "Copy projects into workspace" so that your original Freedom Studio 2019.05 projects do not get updated.





Once you've checked that all imported projects are functioning correctly you may then decide to delete the Freedom Studio 2019.05 workspace and projects.

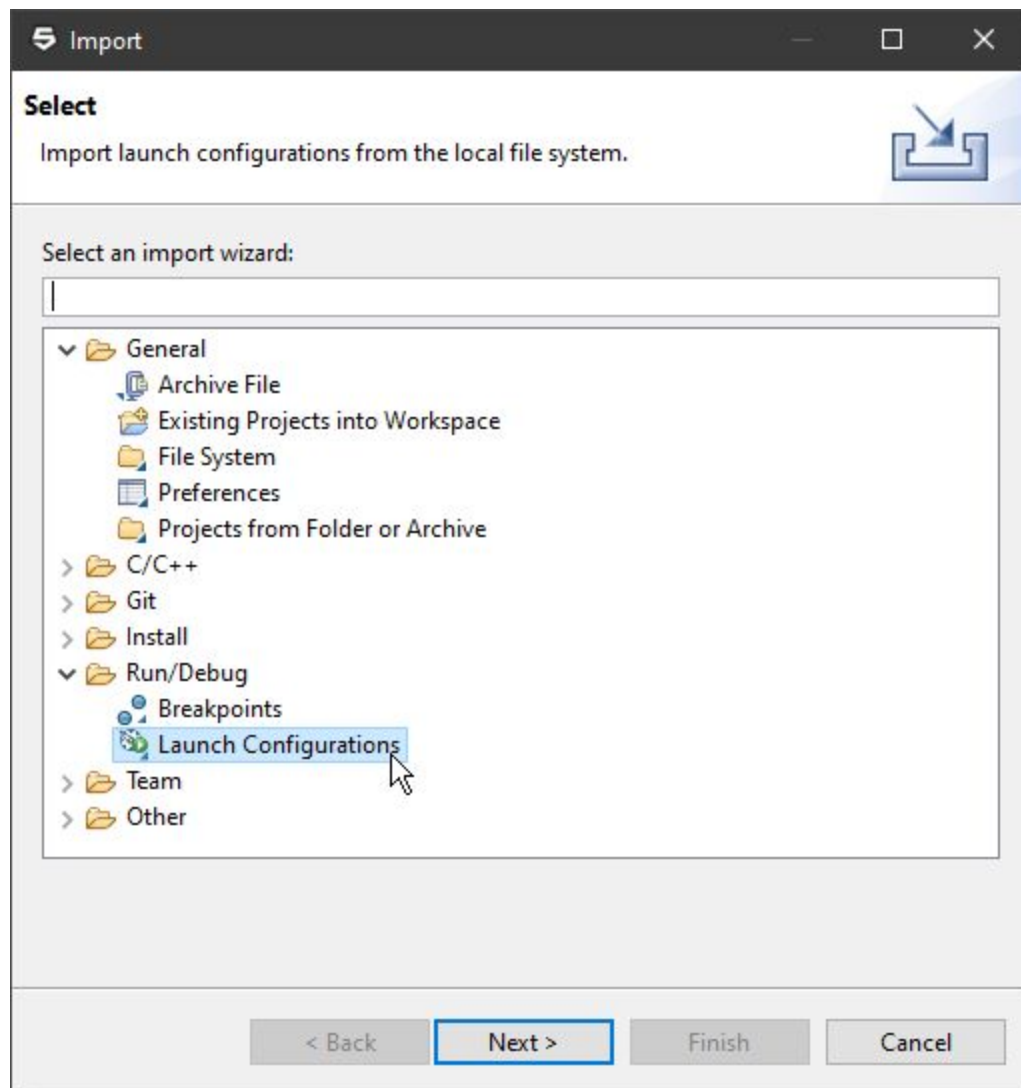


## Migrating Debug Launch Configurations

### Importing Debug Launch Configurations

If your debug launch configurations are “shared” configuration stored in your project directory then they will be imported when you import your projects as described in the previous section.

If your debug launch configurations are “local” then they will not be imported when you import your projects. You will have to use the “Launch Configurations” import wizard. Open the Import dialog (File → Import), select the “Run/Debug” category, select the “Launch Configurations” wizard, then click [Next>] to open the wizard.



Now use the [Browse...] button to select the following location within your Freedom Studio 2019.05 workspace directory:

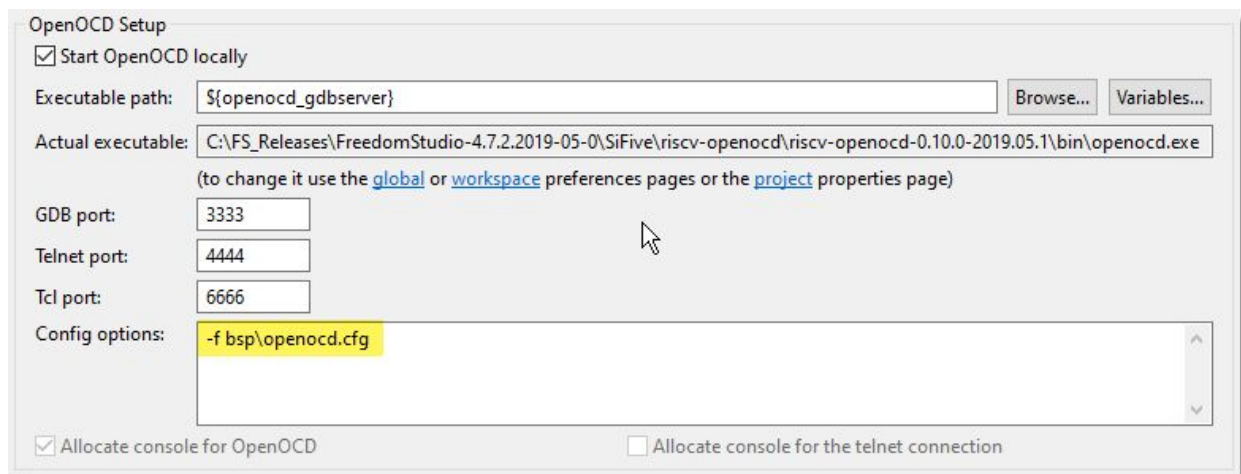
```
<2019.05-workspace-dir>/ .metadata/.plugins/org.eclipse.debug.core/.launches
```

The dialog will show the .launches directory in the left hand pane. Check the checkbox. The dialog will now list all “local” debug launch in the right pane. Check those that you want to import. Then click [Finish]

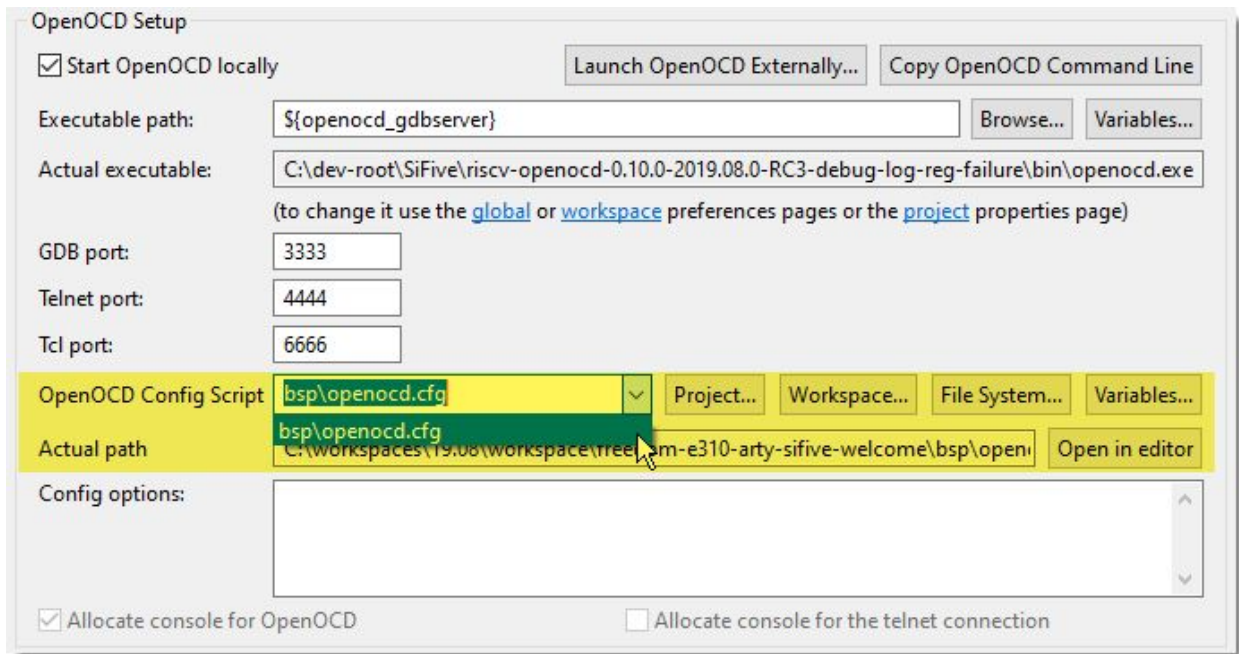
## Updating Debug Launch Configurations

Debug launch configurations from Freedom Studio 2019.05 are compatible with Freedom Studio 2019.08 (this may not always be true in future versions of Freedom Studio).

The only significant change for Freedom Studio 2019.08 is that now you can more easily specify the openocd configuration script. In Freedom Studio 2019.05 you had to specify the script in the “Config options” text box using the “-f <path>” construct. Like this:



This method still works with Freedom Studio 2019.08. You do not have to do anything. But Freedom Studio 2019.08 has a better method to select and manage openocd configuration scripts. If you want to use the new method, simply delete the “-f <script>” construct and use the new script selector UI to specify the script. The OpenOCD Config Script dropdown box will auto-populate with scripts found in the current project, just select the correct (or only) one. Like this:



You'll notice it is also easy to select a script from anyplace else on your host system if you need to.

## What's New

### What's New in Freedom Studio 2019.08.2

#### Arty Programming Improvements

[Windows] The Digilent Device, Interface 0 WinUSB driver can now be uninstalled from Freedom Studio. This is required in order to give Vivado access to the device. In previous releases the driver needed to be uninstalled manually using the Device Manager. Removal of the driver can be done by:

1. SiFiveTools Menu → Restore Vivado Access to Arty Digilent Device
2. A checkbox on the Arty Programming Dialog, that, when checked, will remove the driver after programming process completes.

When device drivers are installed as part of the Arty programming process, Freedom Studio now waits for the driver installation to complete. The user no longer needs to dismiss the message prompt that asks to wait until the driver installation process is complete.

The Arty Programming Progress Dialog now reports more information during the driver installation and programming process.

The Arty Programming Dialog now includes a message reminding users that when flashing an MCS file the user need to remove the cJTAG adapter first. This is not required when programming a BIT file.

The Arty Programming Dialog now supports programming .bit bitstream files.

#### Knowledge Base Buttons

Freedom Studio now has Knowledge Base buttons in various places. Pressing these buttons will open the SiFive Customer Knowledge Base in your browser with related topics automatically listed. These buttons can be disabled and hidden on the Freedom Studio/Assistive Feature preference page.

#### Video Buttons

Freedom Studio now included Watch Video buttons in various places. Pressing these buttons will open related how-to videos in your browser. These buttons can be disabled and hidden on the Freedom Studio/Assistive Feature preference page.

#### Remove Temporary Breakpoints

At the start of a debug launch any existing temporary breakpoints are removed. This prevents temporary breakpoints from a previous launch or different project from accidentally interfering with a debug launch.

## Variable View Shortcut

The Variables View has been added to the SiFive perspective shortcut menu.

## Ability to Hide Unused Target Connectors

Freedom Studio allows you to hide unused target connectors. For instance, if you do not have JLink probes, you can now hide all JLink features within Freedom Studio and reduce the amount of clutter in the UI. Connector visibility is configured in the Freedom Studio → Debug Connectors Preference Page.

## No more “Local C/C++ Application” Launches

In previous releases, if the “bug” icon was pressed and there was no launch history, Freedom Studio would default to creating a “Local C/C++ Application” launch that would not work. Starting now, Freedom Studio will do one of three things when the bug icon is pressed.

1. If there is a launch history, the last successful launch will be re-launched.
2. If multiple target connectors are enabled, a dialog will be presented asking you to select the type of launch to use. After selecting the launch type, either an existing launch config of that type will be used, or if one does not exist, a new one will be created.
3. If only a single target connector is enabled, it will be used automatically. Either an existing launch config will be used, or if one does not exist, a new one will be created.

## What’s New in Freedom Studio 2019.08.1

### Updated Eclipse Platform and OpenJ9

Freedom Studio has been updated to the latest [Eclipse 2019.06](#) release and Oracle Java has been replaced by [Eclipse OpenJ9](#).

### Create IP Projects from IP Deliverable Packages

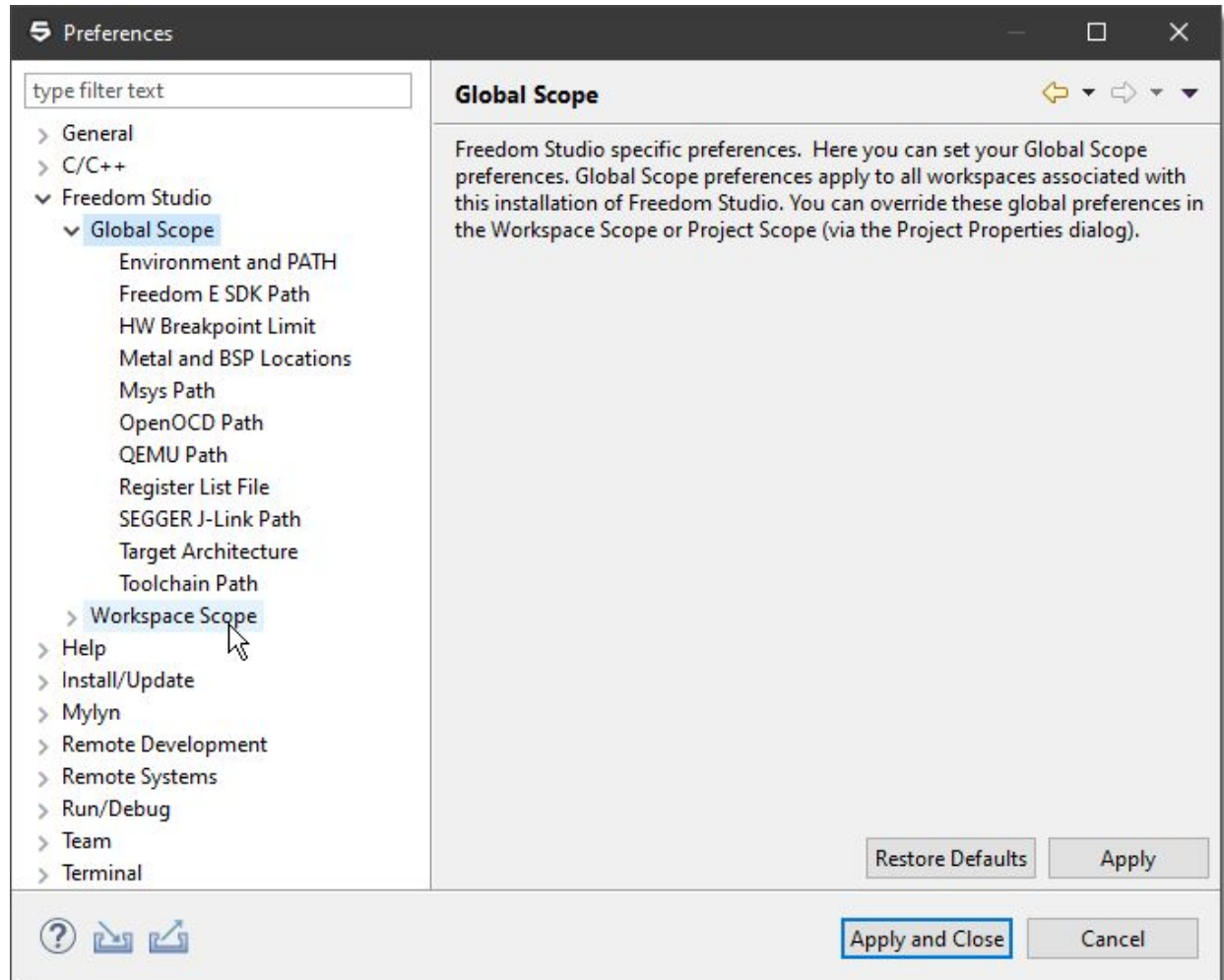
IP Deliverable packages can now be imported into Freedom Studio as “IP Projects”. An IP Project is not a normal software project, but a higher level container project to hold all the assets from an IP Deliverable. Once a package has been imported Freedom Studio makes it simple to program FPGA image files, modify, create, and rebuild BSPs, and create multiple software projects using the same BSP and Metal library.

### Work Easily with Multiple SDKs

This release of Freedom Studio makes it much easier to work with multiple instances of Freedom E SDKs on your host system. You no longer need to constantly go to the Preferences page and point to the instance you want to work with. The Freedom E SDK Software Project wizard and IP Projects make working with any instance of the SDK simple.

## Cleaner Preference UI

The Freedom Studio 2019.08 preference pages have been divided into Global and Workspace categories:



## Windows MSYS Environment

The Windows MSYS environment has been greatly expanded to include many new tools and the ability to install additional MSYS packages using the 'pacman' tool. This expands the ability to write sophisticated Makefiles that can be used on all three host platforms.

This enhancement is why the Windows package has grown much larger.

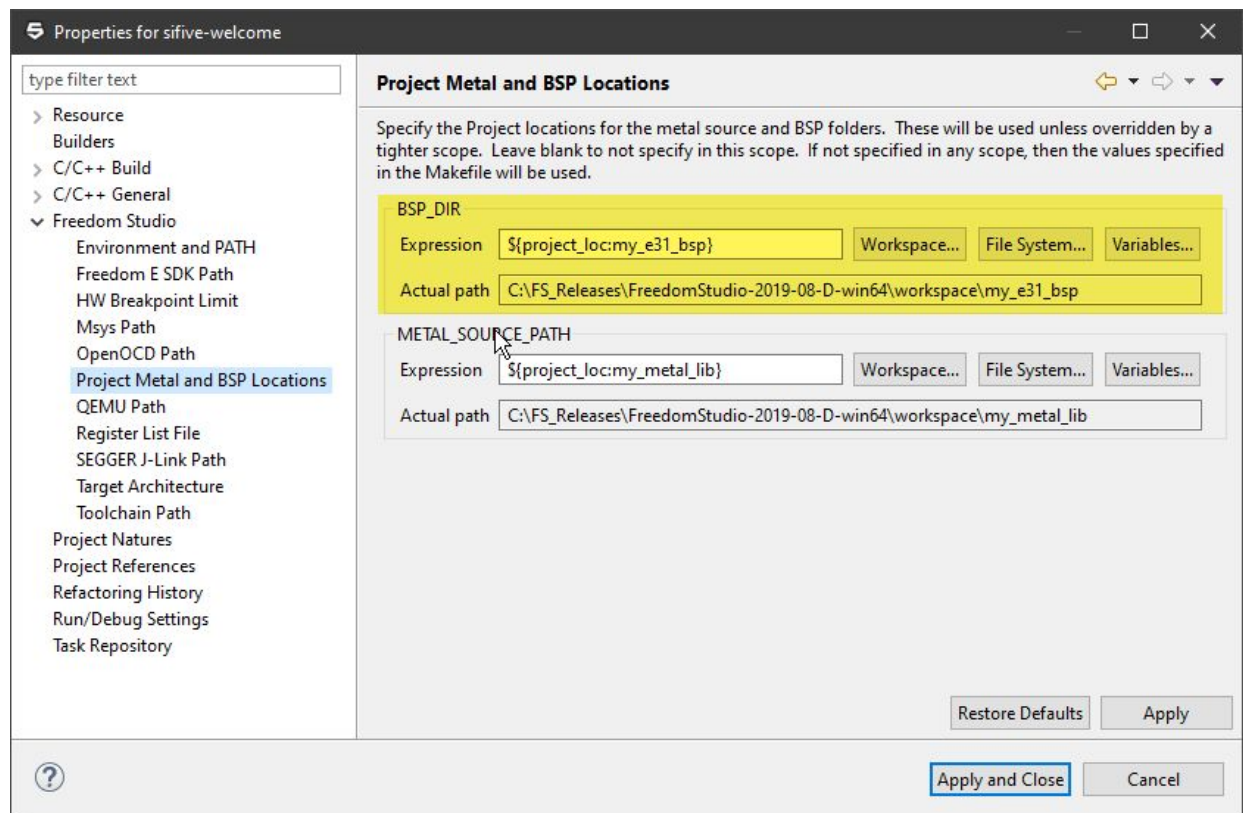
You can also point Freedom Studio to a different MSYS environment (that you have installed and are responsible for managing) via the Global Preferences, Workspace Preferences, or Project Properties.

## Share BSP with Multiple Projects

Prior to Freedom Studio 2019.08 each freedom-e-sdk based project had to have its own copy of the BSP. Changes in one copy had to be manually propagated to other copies.

You can now share a BSP with multiple projects. The BSP can be located in your workspace (as a separate project, or as part of a software project), or anywhere on the host file system. You can specify a BSP location via the Global Preferences, Workspace Preferences, or Project Properties.

For example, the Project Properties dialog shown here specifies that the BSP for this project should be pulled from the “my\_e31\_bsp” project in the Workspace.



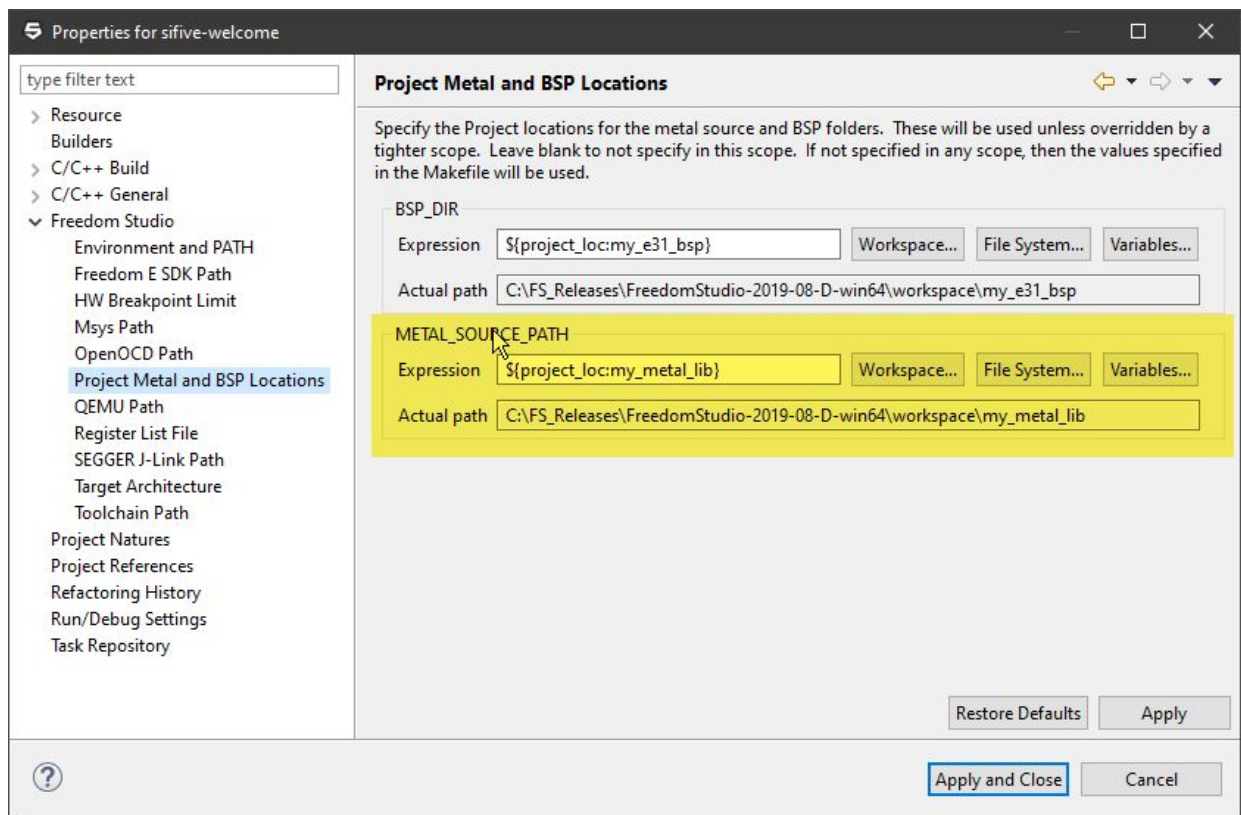


## Share Metal Library with Multiple Projects

Prior to Freedom Studio 2019.08 each freedom-e-sdk based project had to have its own copy of the metal library. Changes in one copy had to be manually propagated to other copies.

You can now share a metal library with multiple projects. The metal library can be located in your workspace (as a separate project, or as part of a software project), or anywhere on the host file system. You can specify a metal library location via the Global Preferences, Workspace Preferences, or Project Properties.

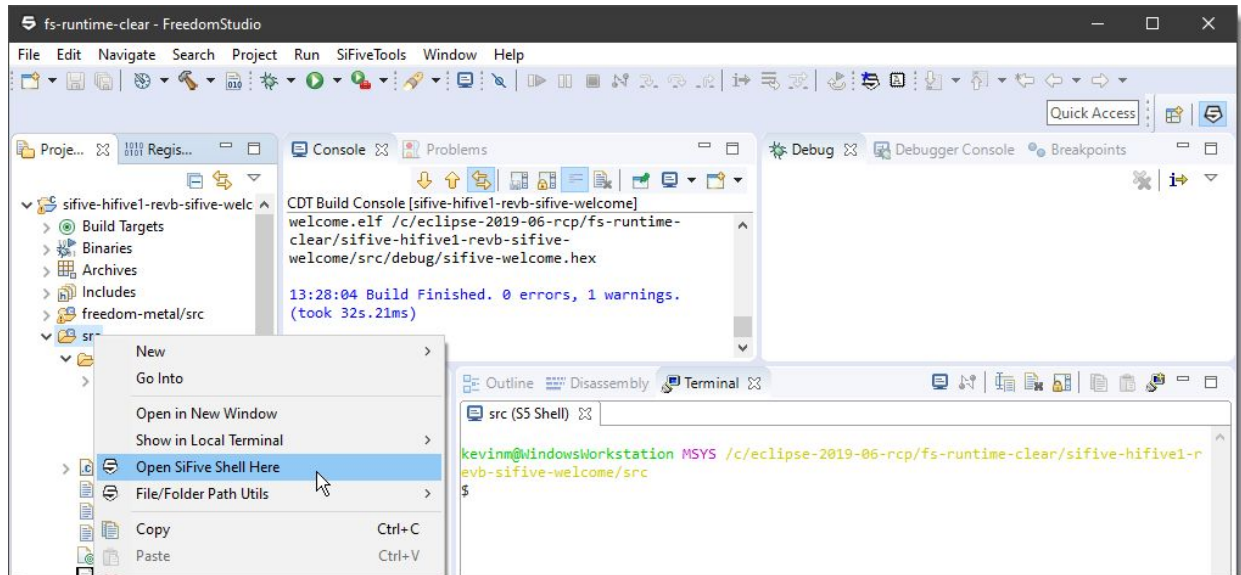
For example, the Project Properties dialog shown here specifies that the metal library for this project should be pulled from the “my\_metal\_lib” project in the Workspace.





## The SiFive Shell

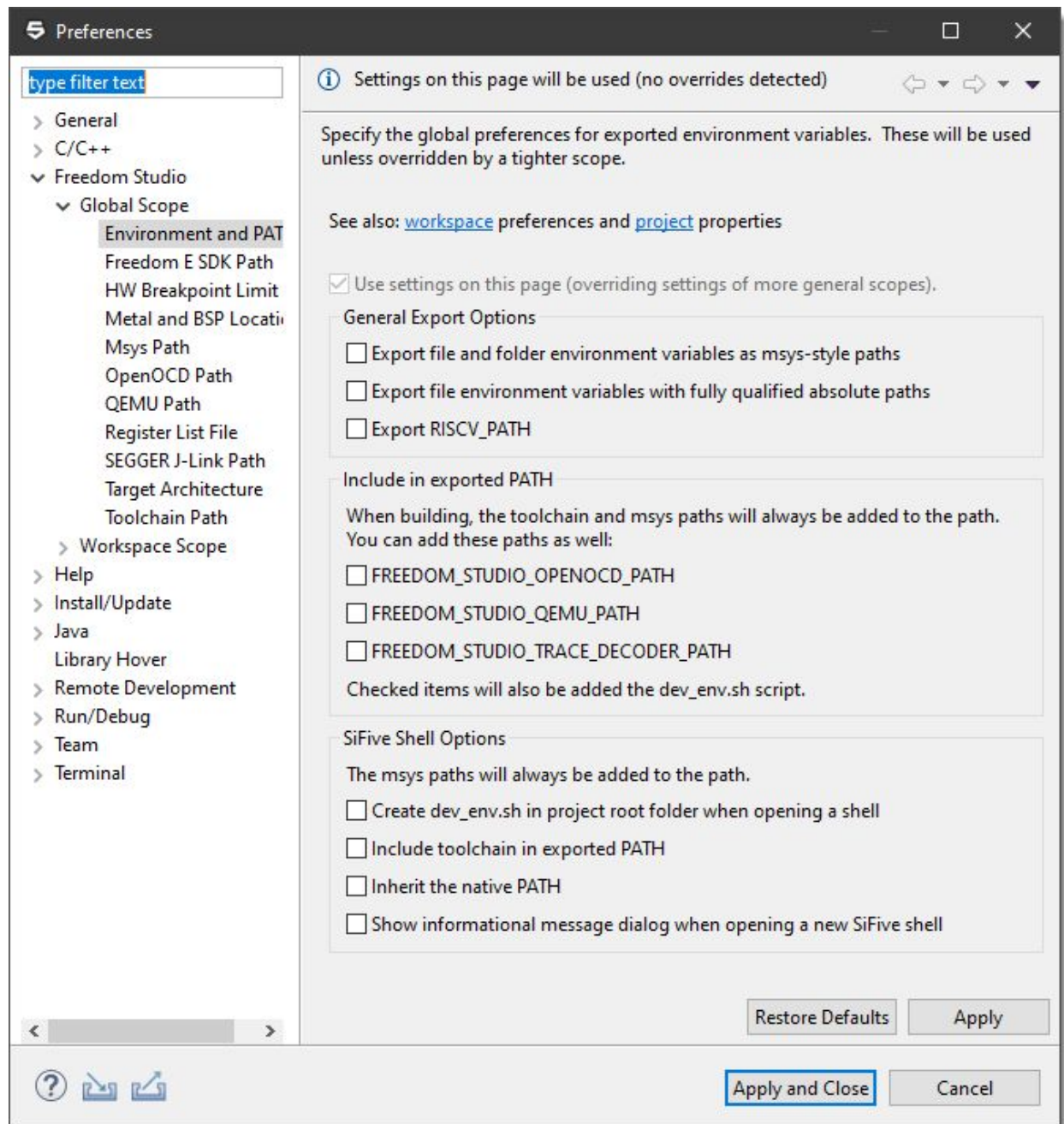
You can now open a shell in the Terminal View at any location in a project by right-clicking on the location in the Project Explorer and selecting “Open SiFive Shell Here”



By default Freedom Studio will use bash for the shell on Windows and the SHELL variable on Linux and MacOS. If you need to use a different shell you can set the environment variable `SIFIVE_SHELL=<path-to-shell-of-choice>`. On Windows, you'll want to ensure that your chosen shell is installed in the MSYS environment.

## Environment and PATH Exports

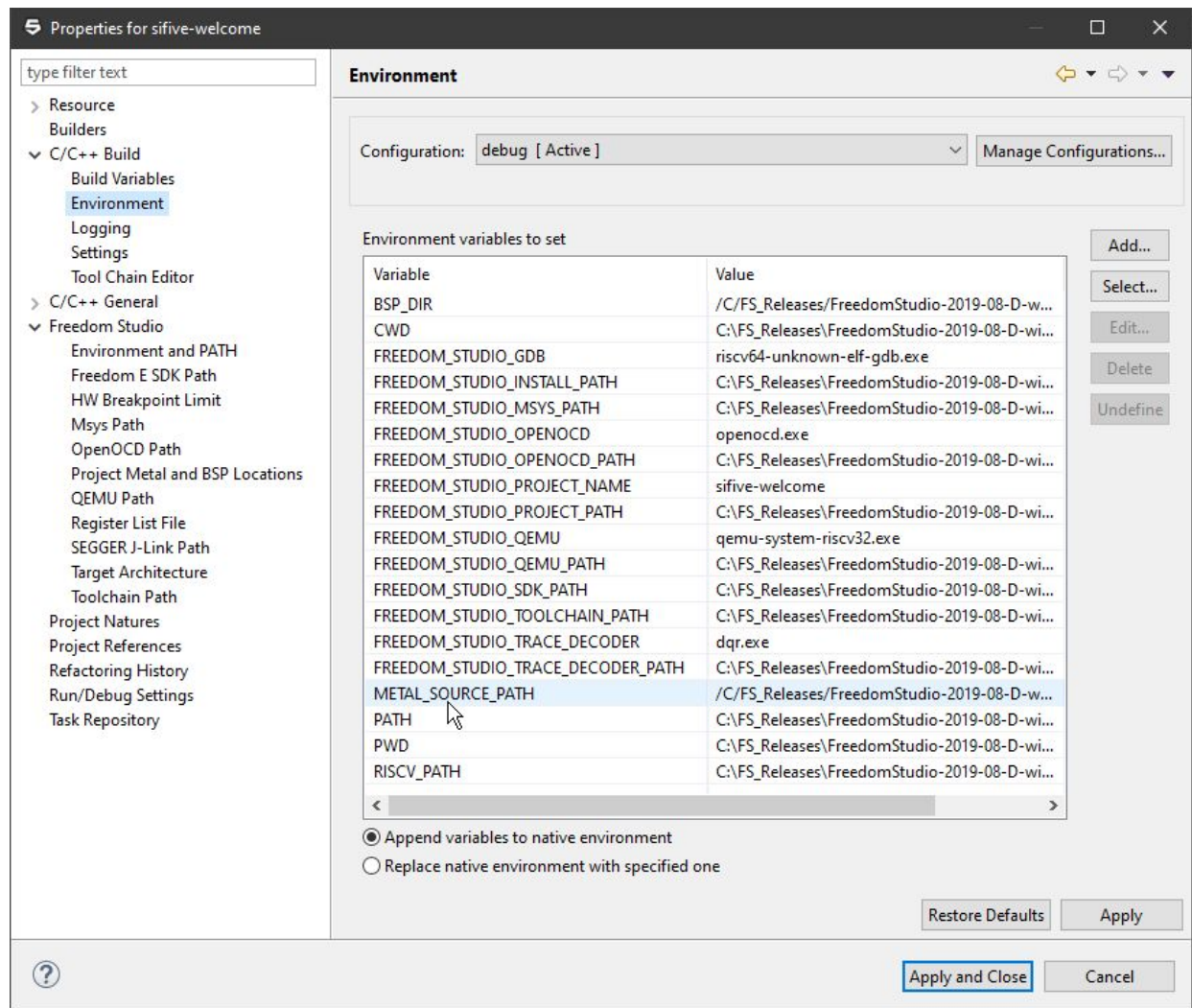
When you build a freedom-e-sdk based project several environment variables can be exported and the PATH can be changed to include various tool locations. This is controlled in the new “Environment and PATH” node of the Global Preferences, Workspace Preferences, or Project Properties.



#### Notes:

- **Export RISC\_V\_PATH**  
If checked, RISC\_V\_PATH is exported in to the build environment and into the dev\_env.sh script.
- **Create dev\_env.sh in project root folder when opening a shell**  
This option, when enabled, will create a shell script file called dev\_env.sh in the project root folder when you open a SiFive Shell. This script defines several environment variables and adds additional entries (if enabled) to the PATH. You can also create this file using the Project Explorer context menu on a Project node.
- **Include toolchain in exported PATH**  
If checked, the project toolchain will be added to the PATH in dev\_env.sh
- **Inherit native PATH**  
[Windows Only] If checked, the native PATH will be added to the MSYS PATH
- **Show informational message dialog when opening a new SiFive Shell**  
[Global Preferences Only] If checked, Freedom Studio will display an informational dialog box when opening a new shell. This information summarizes the state of the dev\_env.sh feature.

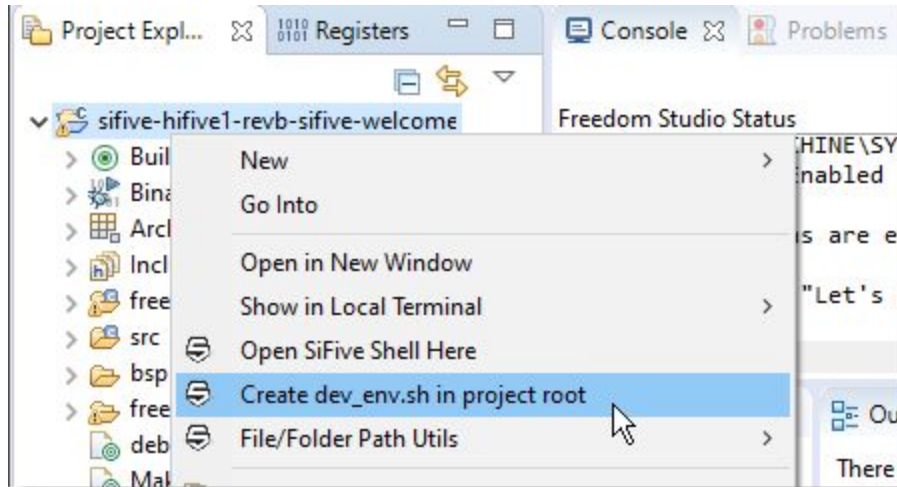
A complete list of exported environment variables can be viewed on the “C/C++ Build/Environment” project property node. For example:



All of these variables are available to use in your Makefiles and scripts. But be aware that these are exported only when building from within Freedom Studio. If you want to maintain CLI builds then be sure to update your makefiles to specify appropriate defaults for any used variables, or to source the optionally generated dev\_env.sh file.

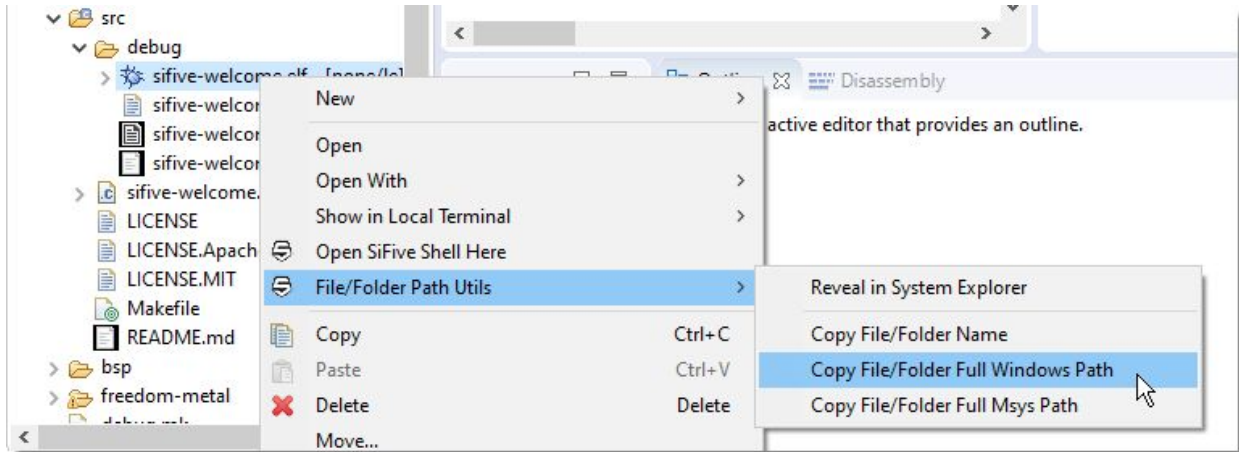
## Create dev\_env.sh for Project

The context menu for a project node in the Project Explorer has a new menu entry called “Create dev\_env.sh in project root”. Selecting this menu item will create a new dev\_env.sh script file in the project root. An existing dev\_env.sh file will be replaced without warning. Do not hand edit this script file. Your changes will be lost.



## File/Folder Path Utils

The context menu for project files and folders in the Project Explorer has a new sub-menu called “File/Folder Path Utils”. This submenu has some simple, but very useful items.



- **Reveal in System Explorer**  
Selecting this menu item will open the default file explorer application on your host system and take you to the folder containing the selected resource.
- **Copy File/Folder Name**  
Selecting this menu item will copy the file or folder name to the clipboard.
- **Copy File/Folder Full Windows Path**  
[Windows only] Copies the full absolute path of the selected resource to the system clipboard using Windows compatible paths.
- **Copy File/Folder Full Msys Path**  
[Windows only] Copies the full absolute path of the selected resource to the system clipboard using Msys compatible paths.
- **Copy File/Folder Full Path**  
[Linux/MacOS] Copies the full absolute path of the selected resource to the system clipboard.

## Shorter Package Paths

This change primarily affects Windows users, but is also reflected in Linux and Mac packages. The Freedom Studio distribution archives are built to contain shorter paths. All paths are less than the Windows MAX\_PATH limit of 268 characters (the longest is around 199 characters). This means that the native Windows extraction tool can successfully extract the Freedom Studio archive as long as the sum of the path length to the installation location and the deepest path in the archive is less than MAX\_PATH.

If you want to install to a location that may exceed MAX\_PATH then you must use a third-party extraction tool (like 7-Zip) to extract the archive.



## Benchmark Examples Default to Release Configuration

When creating a new freedom-e-sdk project with 'coremark' or 'dhrystone' the project will default to the "release" configuration. All other example programs will default to the 'debug' configuration.

Defaulting to the 'release' configuration for benchmarks helps to ensure that: (1) accurate benchmark results are reported by default (the user does not have to remember to switch to the 'release' configuration); (2) benchmarks will build successfully and fit into the available memory.

## Selecting File Resources

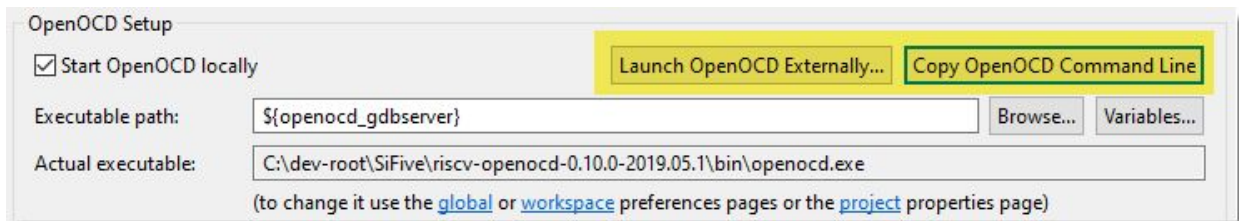
Selecting file resources in debug launch configurations is easier. You can now select from Project, Workspace, or File System scopes, and use Eclipse variables to build expressions.



There is a new "Open in Editor" button that will open the selected resource in a Freedom Studio editor window.

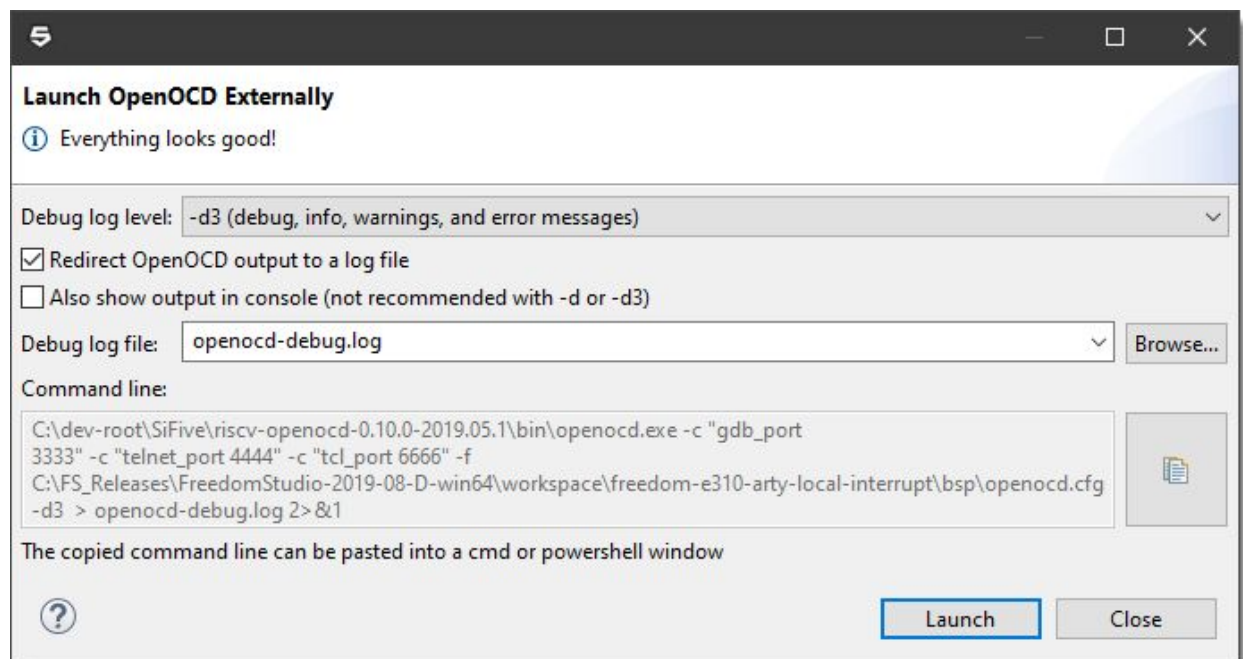
## Launch OpenOCD Externally

Sometimes you need to launch OpenOCD as an external process. This is most useful when you need to capture an OpenOCD debug log to a file. Freedom Studio now has helper features to make this process simpler. The OpenOCD launch configuration dialog gains two new buttons that make it very easy to launch OpenOCD as an external process (i.e. a process not managed by Freedom Studio).



The “Copy OpenOCD Command Line” button copies the exact command line that Freedom Studio will use when launching to the system clipboard. You can paste (and edit, if desired) this command line in a shell (cmd prompt or powershell in Windows, or a terminal shell in Linux and MacOS).

The “Launch OpenOCD Externally...” button opens a new dialog box where you can configure the OpenOCD process with a custom debug level and optionally redirect the output to a file.



The “Debug log level” combo box lets you select a custom log level for the session. When preparing a debug log to send to support@sifive please use “-d3”.



If the “Redirect OpenOCD output to a log file” checkbox is not checked OpenOCD log output only goes to the console. Checking this box will output the log to the specified file.

If you check the “Also show output in the console” checkbox then the out will go to both the console and the log file. It is recommended that you not check this box when using the “-d3” log level.

The “Debug log file” specifies where to create the log file. If a relative path is specified, then the path is relative to the project directory.

You can use the “Copy” button (to the right of the command line box) to copy the command line to the clipboard.

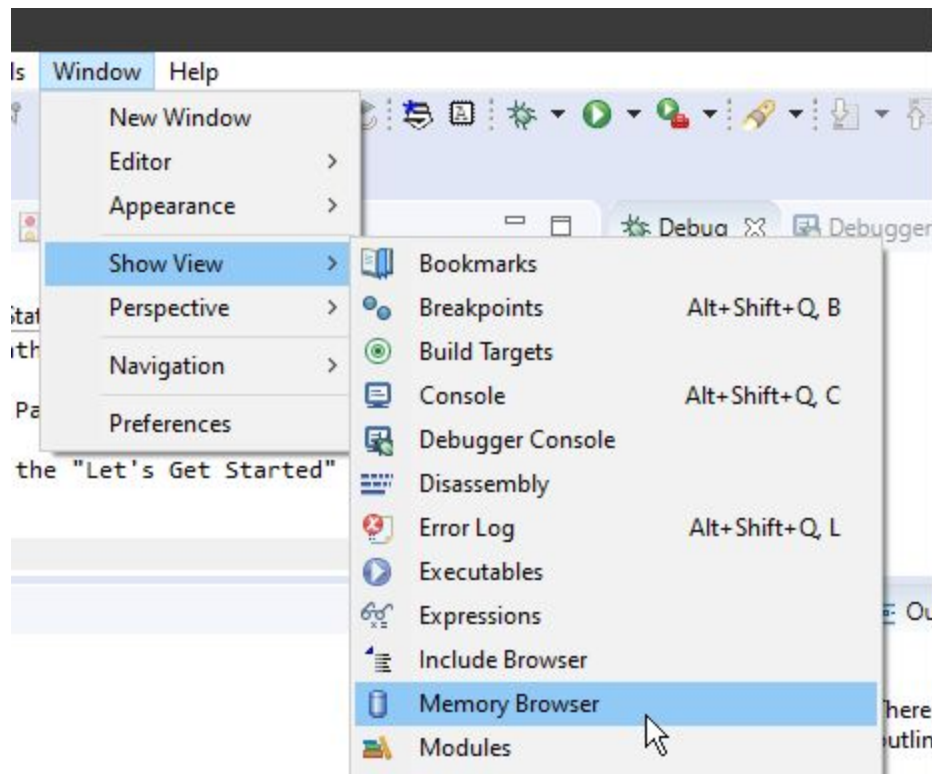
When launched as an external (unmanaged) process it is your responsibility to terminate the OpenOCD process when it is no longer needed. Note that you do not have to terminate the OpenOCD process and restart it between successive debug launches. Freedom Studio will happily use the running process multiple times.

Windows Only: When the “Launch” button is pressed, a new Command Window is opened and the OpenOCD process is started and the “Start OpenOCD locally” checkbox is automatically unchecked. [Linux and MacOS do not show the “Launch” button, but the command line can still be copied and pasted into a terminal shell. Be sure to uncheck the “Start OpenOCD locally” checkbox.]

## Use Memory Browser (instead of Memory View)

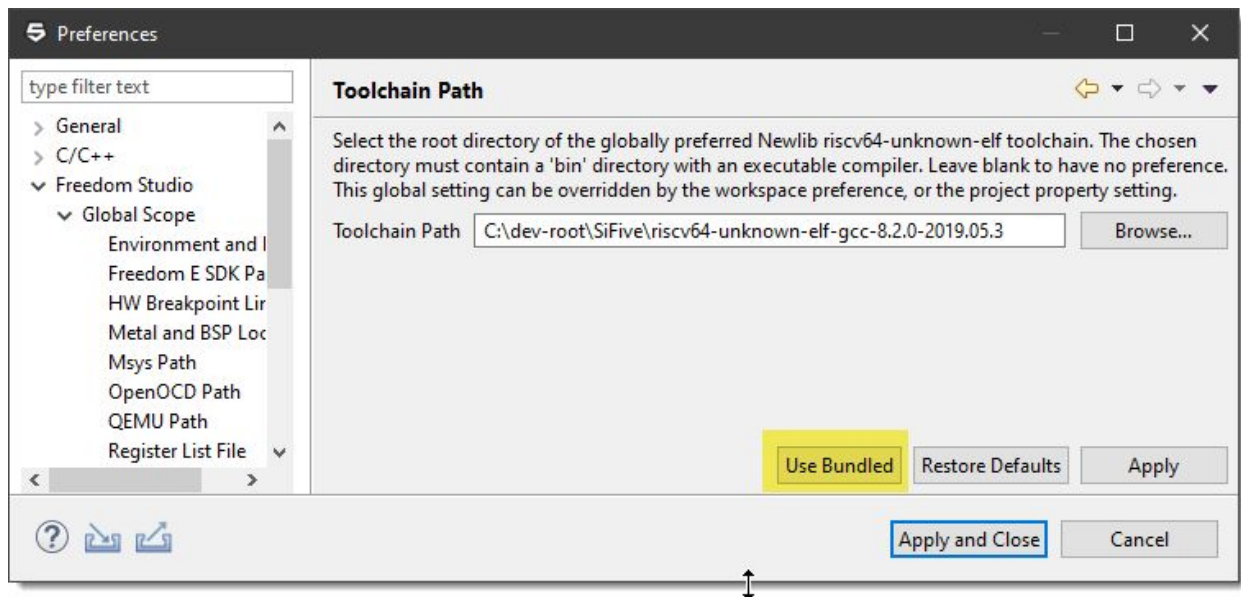
The SiFive Perspective now uses the Memory Browser by default for examining target memory. There are known problems with the Memory View that can cause Eclipse (and thus Freedom Studio) to hang. We do not recommend using the Memory View any longer.

If the Memory Browser is not open, you can open it via the Main Menu | Window | Show View menu:



## Use Bundled Packages

Many of the Freedom Studio preference pages now have a “Use Bundled” button that simplifies reverting to the bundled package after having selected an unbundled instance of the package.



### Traditional New Project Wizard Works Again

The traditional new project wizard path to creating freedom-e-sdk project shipped in a broken state in Freedom Studio 2019.05. It has been repaired and can be used to create new projects again (although there are much easier ways to do this).

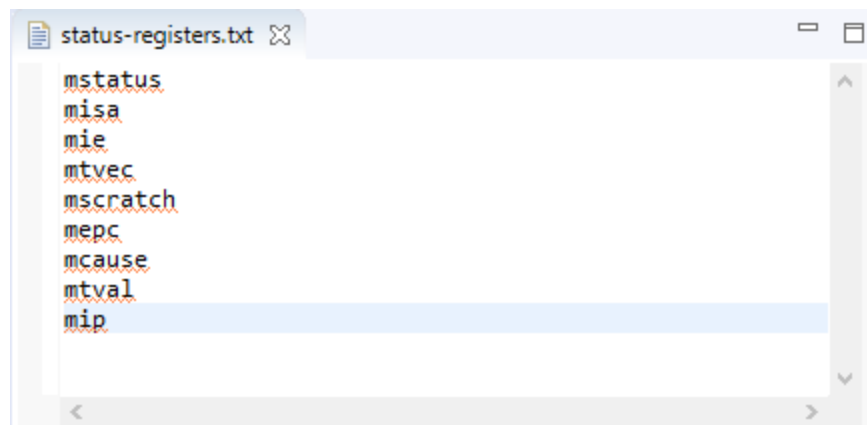
## Freedom Studio HOWTO Guides

### 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:

Name	Value	Description
General Registers		General Purpose ...
mstatus	0x1800	
misa	0x40101105	
mie	0x0	
mtvec	0x0	
mscratch	0x0	
mepc	0x0	
mcause	0x0	
mtval	0x0	
mip	0x80	

## Creating Register List Files

The Register List File is a text file that, at its 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

### *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*

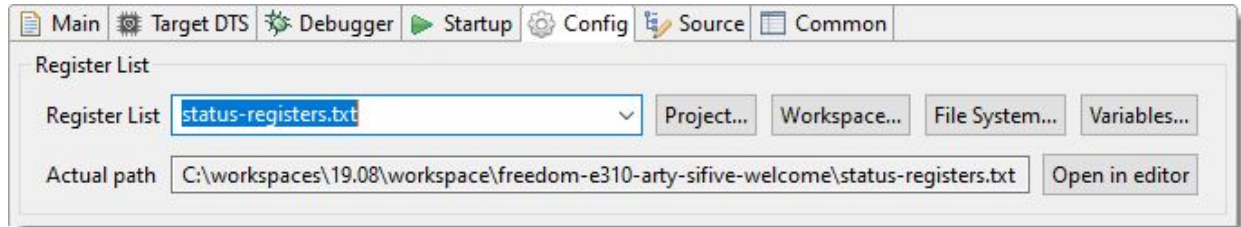
A register list file can be specified in 4 places. These four locations are prioritized such that a specification in a higher priority location will override any specification in a lower priority location. The four locations are, in descending priority order (highest priority first):

#### *Prioritized Register List Specification Locations*

<b>Location</b>	<b>Description</b>
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:

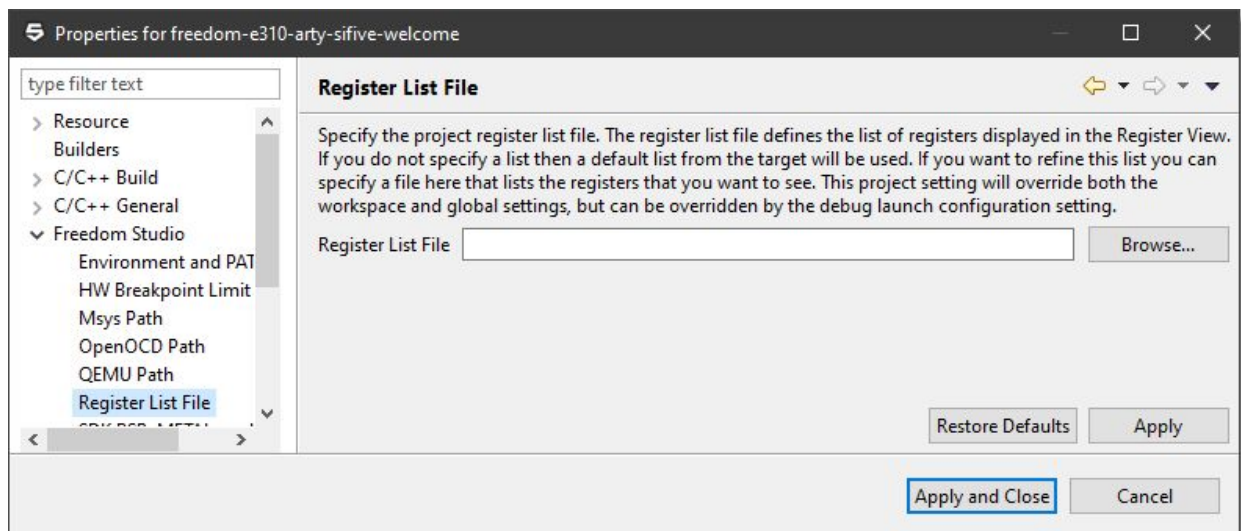


When you specify a register list file in a debug launch configuration the path displayed in the Actual Path box will always reflect the fully resolved path to the register list file. If you are not specifying a register list file here then the Actual Path may display a path to another register list file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

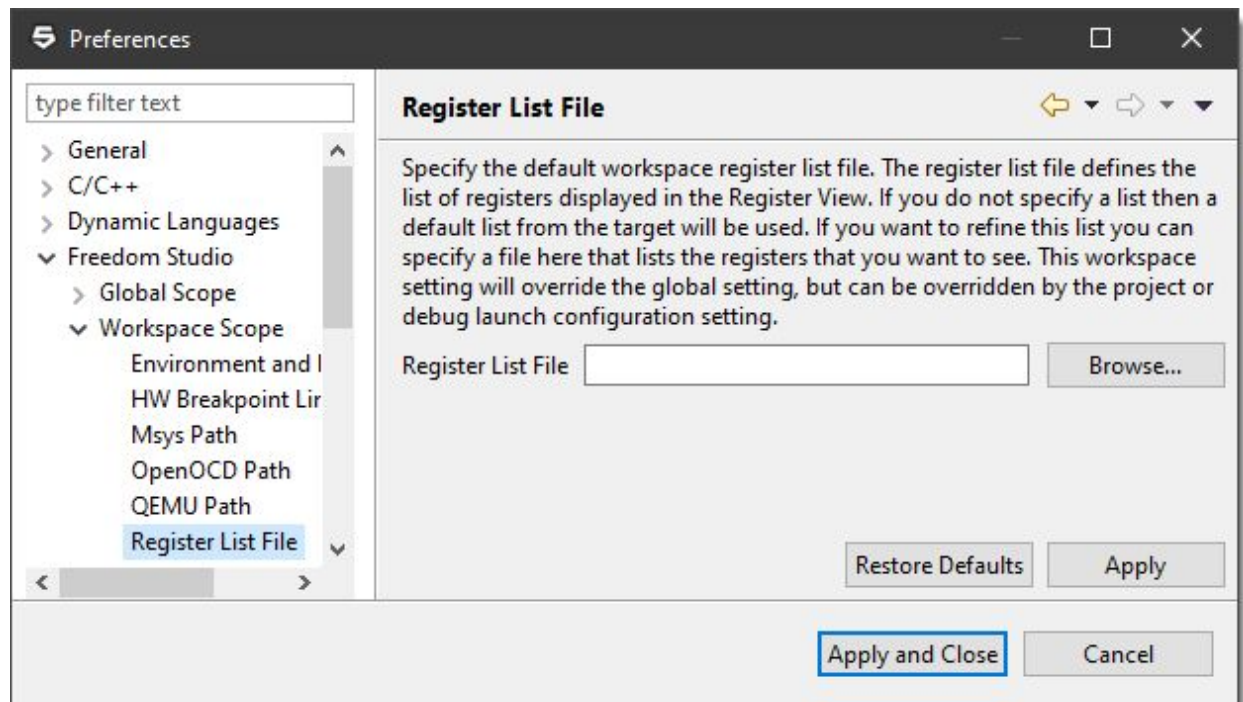
You can setup the project register list file specification by opening the Project Properties dialog and navigating to the MCU → Register List property page:



## 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:

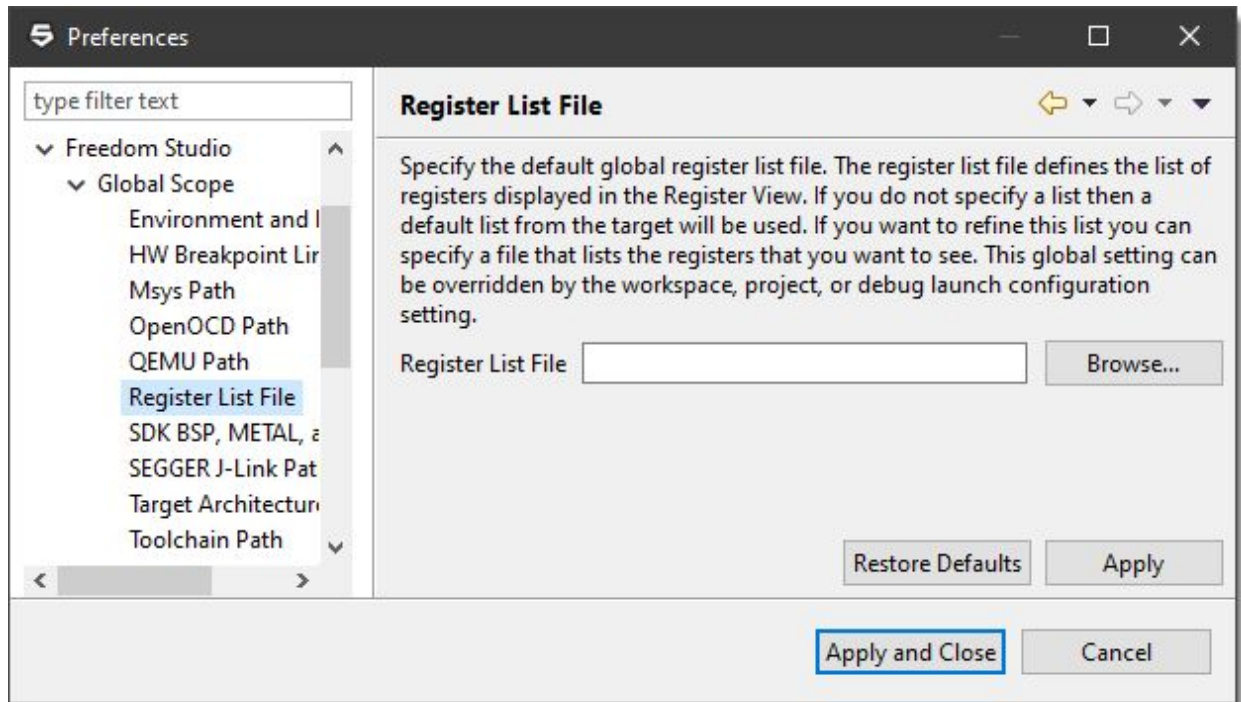


## Global Preferences

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:

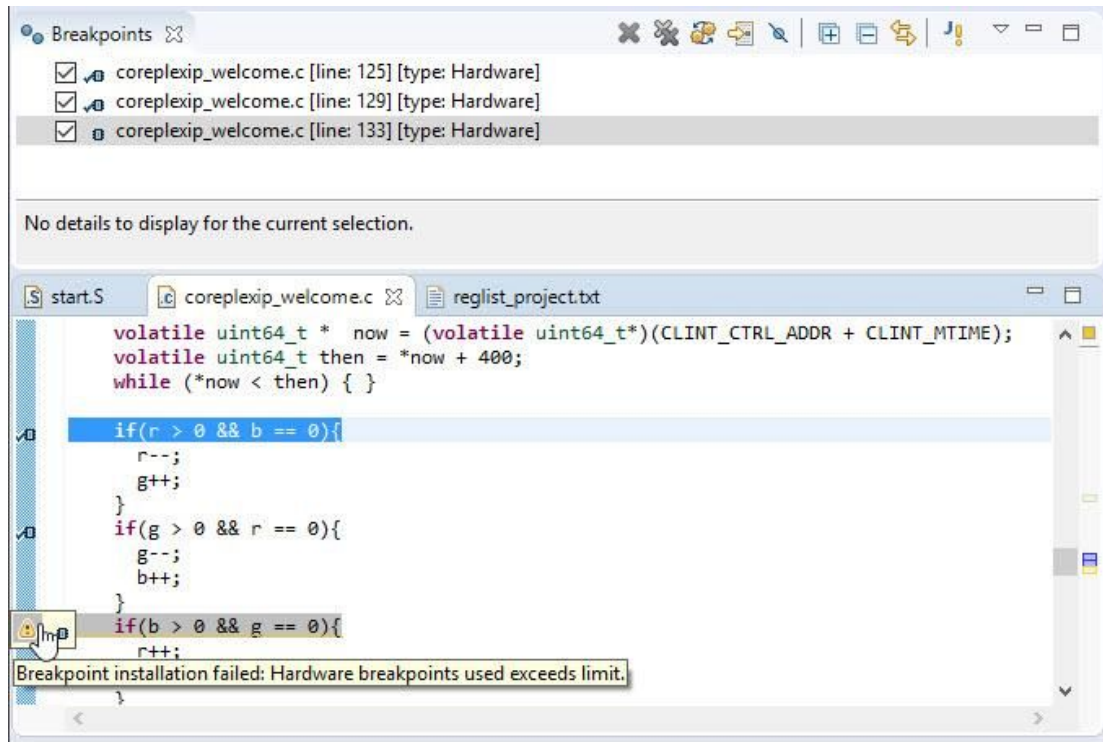




## Managing Hardware Breakpoint Resources

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 unpredictable 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.



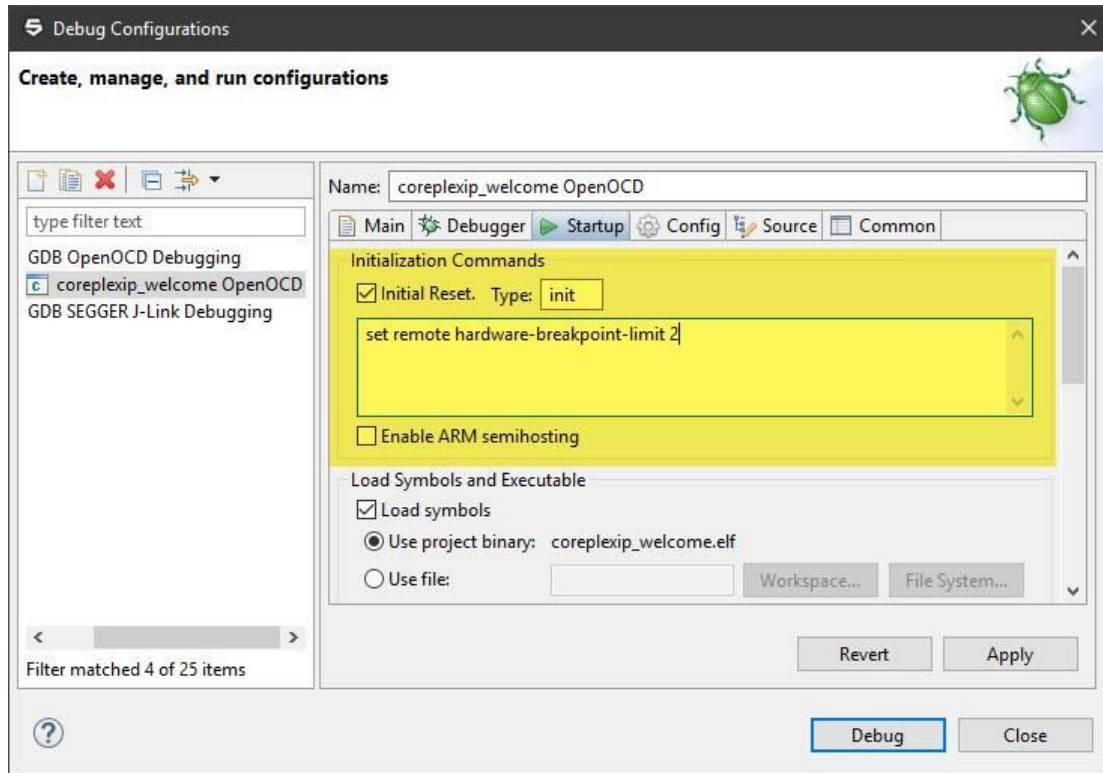
### *Too Many Hardware Breakpoints*

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

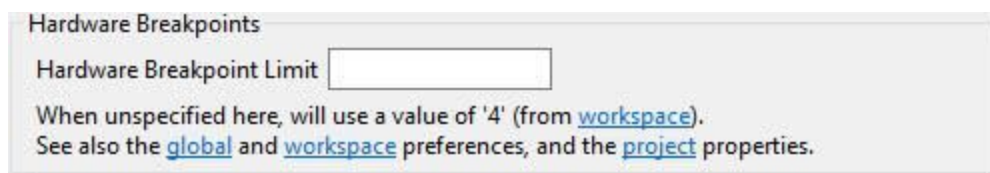
You can set global and workspace preferences to define the number of hardware breakpoints on your target system. You can also set this in your project properties and in a launch configuration.

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*

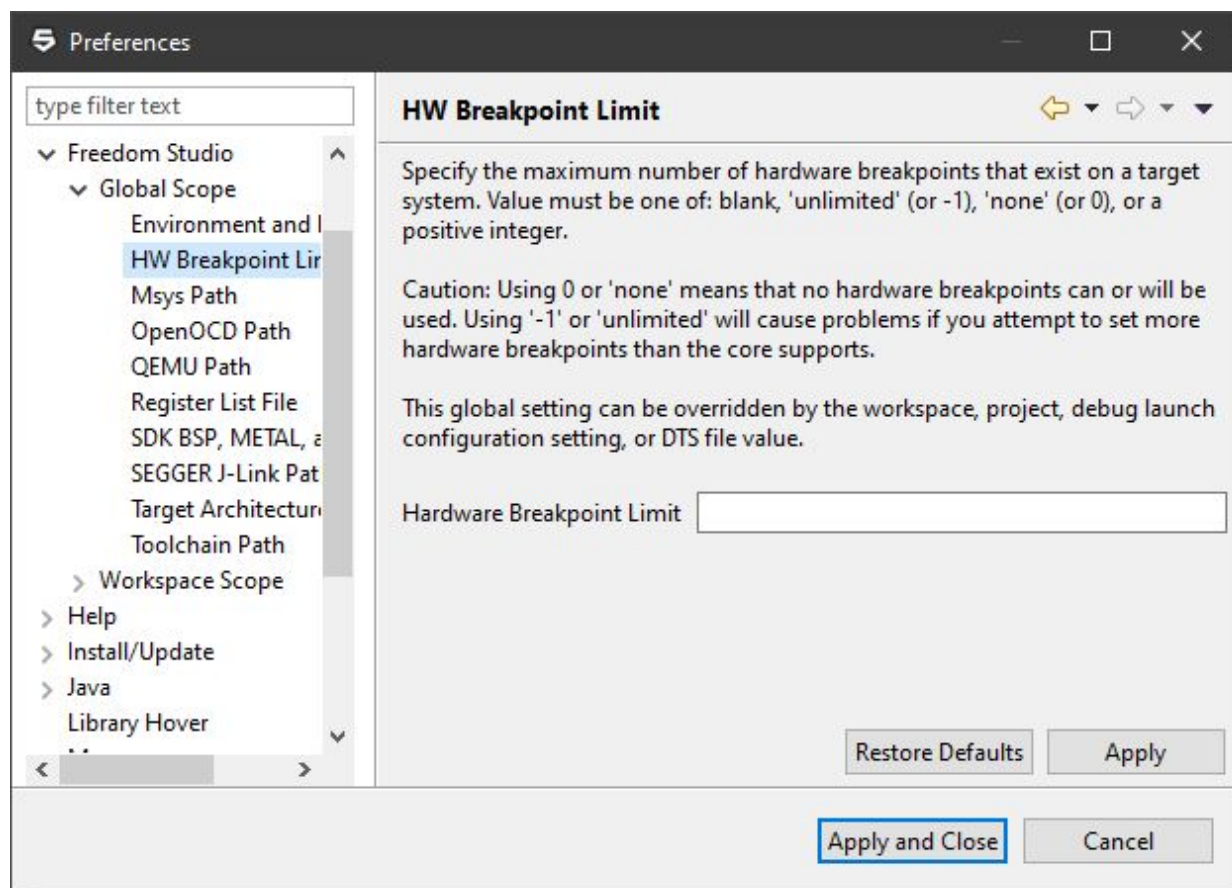
Value	Description
blank	Leave the setting blank and it will not be used.
'unlimited', or -1	Tells GDB that you have unlimited hardware breakpoints.
'none', or 0	Tells GDB that you have no hardware breakpoints.
x, a positive integer	Tells GDB that you have x hardware breakpoints.

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.

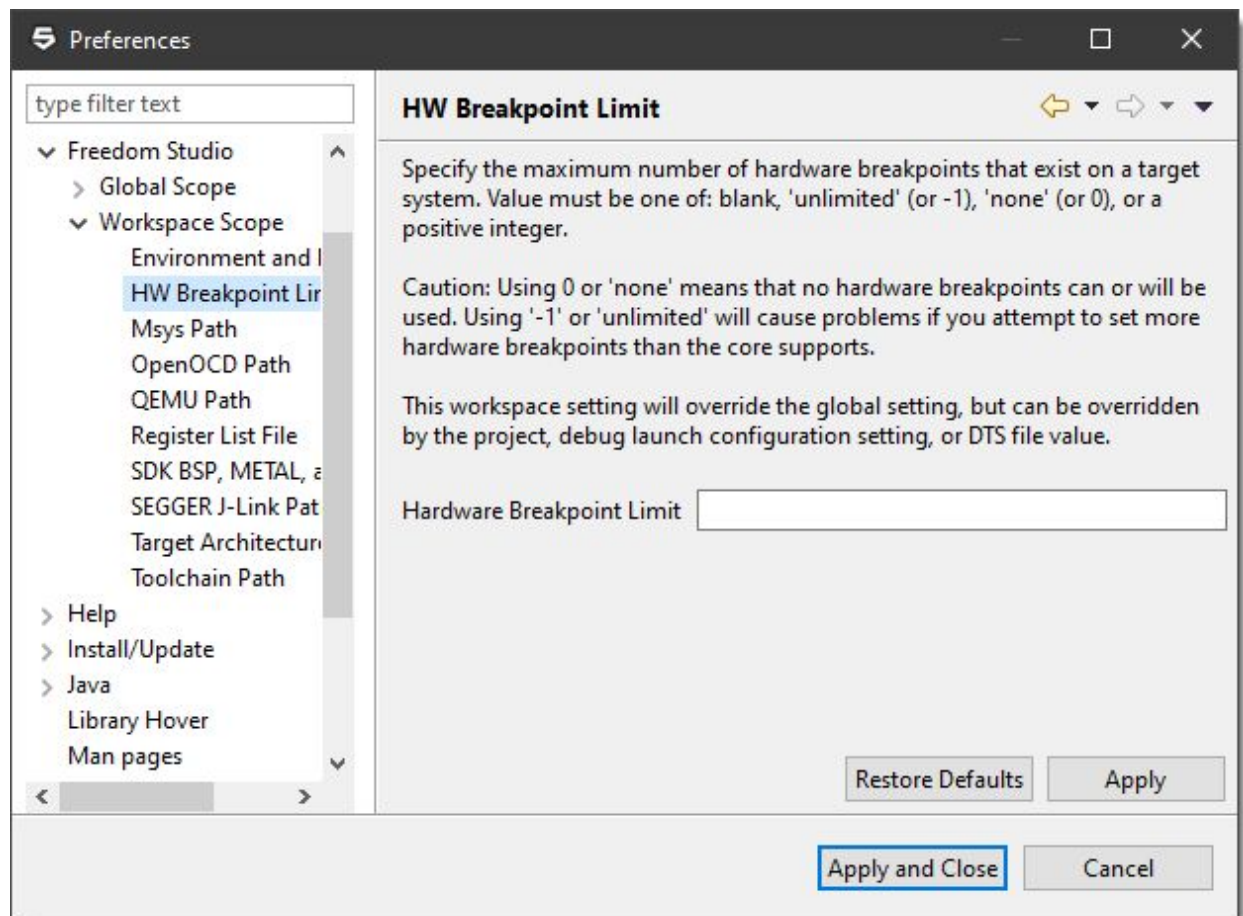
Set the global preference by opening the Preferences Dialog (Windows → Preferences) and navigating to the MCU | Global HW Breakpoint Limit page.



## 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.

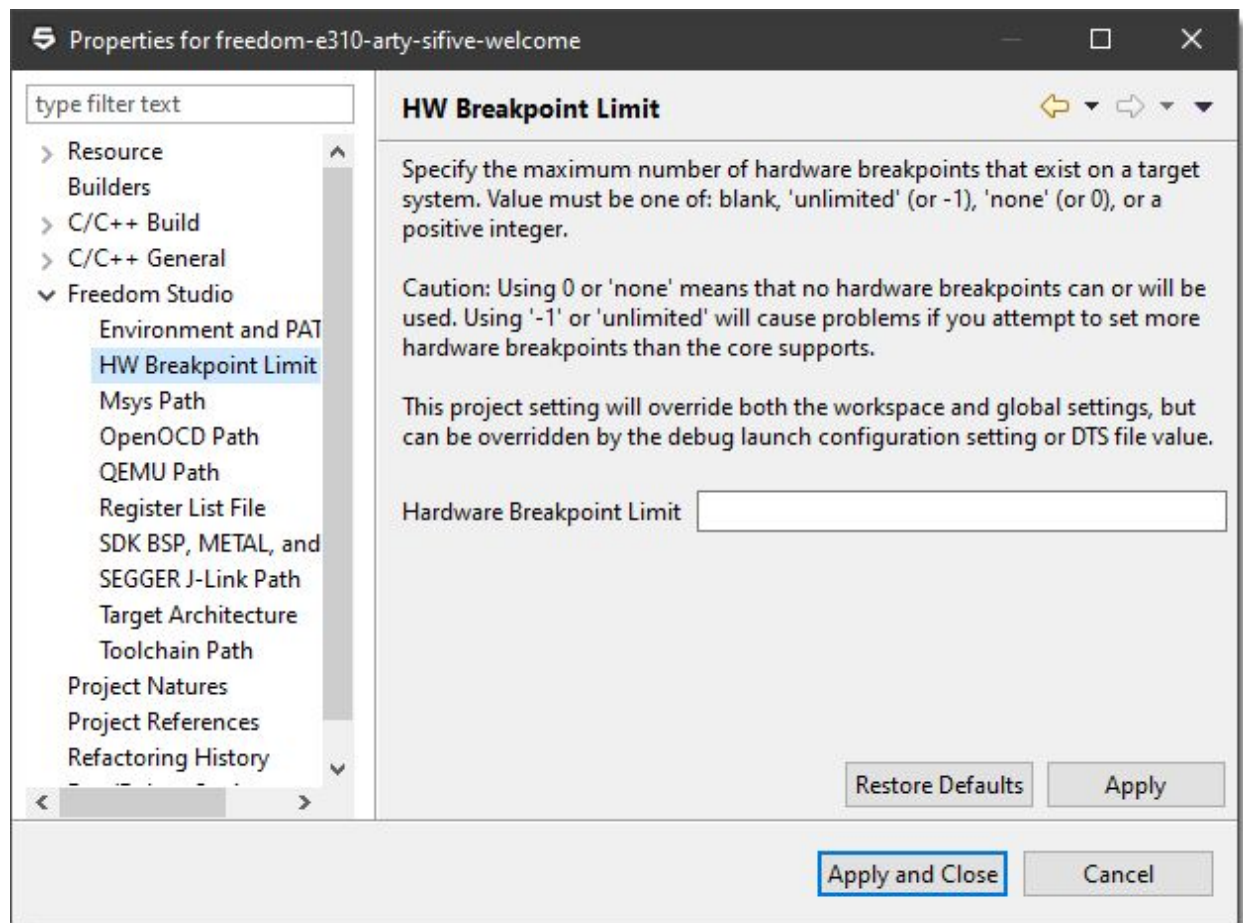




## Setting the Project Property

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.

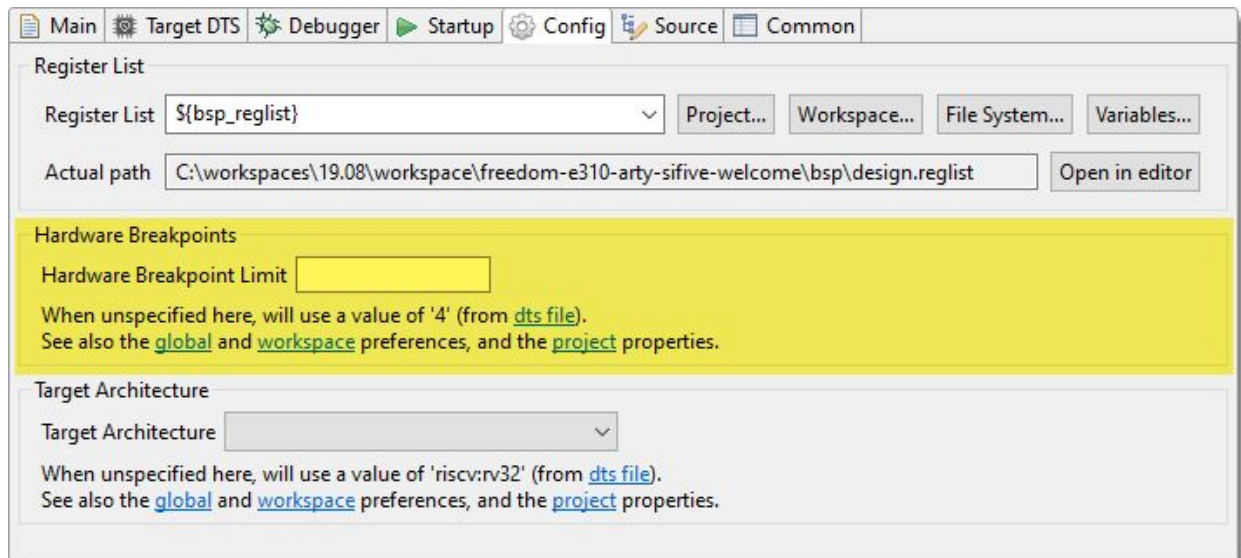
Set the project property by opening the Project Properties Dialog (Project → Properties) and navigating to the MCU | HW Breakpoint Limit page.



## 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 to 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\
      55555555555555555555555555555555\n\r\
    5555                    5555\n\r\
  5555                      5555\n\r\
5555                        5555\n\r\
5555        55555555555555555555555555555555\n\r\
5555        55555555555555555555555555555555\n\r\
```



```

    }
}

/*
 * 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

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 a 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.

## Troubleshooting

### Launch fails with “can’t add breakpoint”

This can happen if a “bad” breakpoint exists in the breakpoint view prior to the launch. Freedom Studio will try to install the breakpoint and if it at an address that does not map to the current target, you will get this error. Simply delete this bad breakpoint then relaunch.

### 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 Programming utility within Freedom Studio..

If you have used Freedom Studio to update or install an FPGA image and then decide to use Vivado, you will need to uninstall the device driver installed by Freedom Studio before Vivado will recognize the target again. You can choose to have this driver uninstalled automatically at the end of the FPGA programming process, or you can manually uninstall the driver any time from the SiFiveTools menu.

### 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 your 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

#### Important Note

Starting with Freedom Studio 2019.08 all dependencies are included or statically linked. This section is only applicable to earlier releases of Freedom Studio.

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 satisfied 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 that 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 output 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 (0x00007fbdec8f000)
```

```

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* file 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_0L150D61
```

**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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