

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.

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

- SiFive Trace Decoder

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

Freedom Studio Package Path Lengths and Windows

The Freedom Studio distribution archives contain long deep 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 and ensure that Windows long paths are enabled.

Two Important Rules

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

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 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

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 to 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.

Getting Help

Knowledge Base Buttons

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

Freedom Studio Bug Reports

See the [Freedom Studio Bug Report Generator](#) chapter for a handy way to gather many of the resources that will help to quickly resolve bugs you may have found. These bug report packages can be sent directly to SiFive through the customer support portal.

SiFive Forums

From the Help menu, select Open SiFive Community Forums. This will open your default browser to the [SiFive Forums homepage](#).

SiFive Customer Support Portal

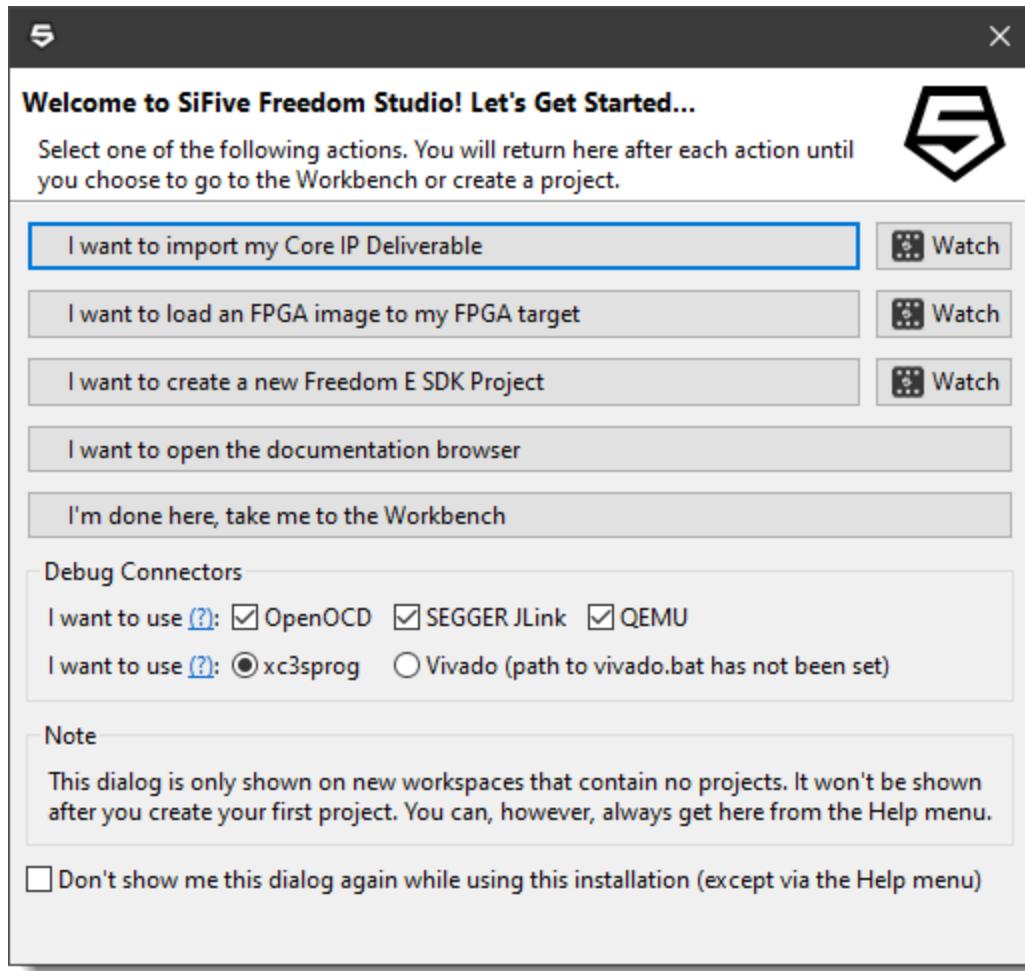
If you have a customer support portal account you can launch the support portal from the Help menu by selecting “Open SiFive Customer Support Portal”. This will open the portal in your default browser.

Other Resources

The Help menu has several other entries that can be helpful.

The Let's Get Started Dialog

When you start Freedom Studio with a new clean 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**

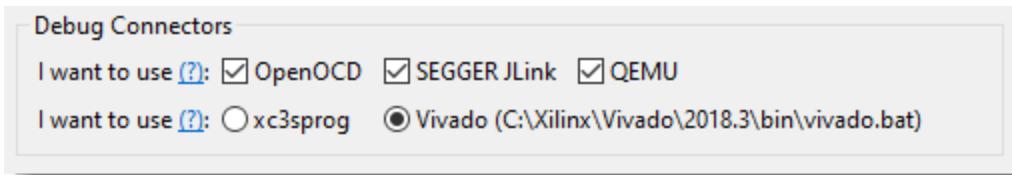
Choose this option if you have a core IP deliverable that you'd like to start working with. With this option you will select an IP Deliverable package (usually a tar.gz file) and Freedom Studio will create a new IP project from the package. The wizard will optionally offer to program an included MCS file or BIT file; create a new software project from the freedom-e-sdk embedded in the package; and create a debug launch configuration for the example program. (See: [IP Projects](#))

- **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. (See: [FPGA Programming](#))

- **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. (See: [Create a Freedom E SDK Software Project](#))
- **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 and how you prefer to program FPGA images. 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.

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.

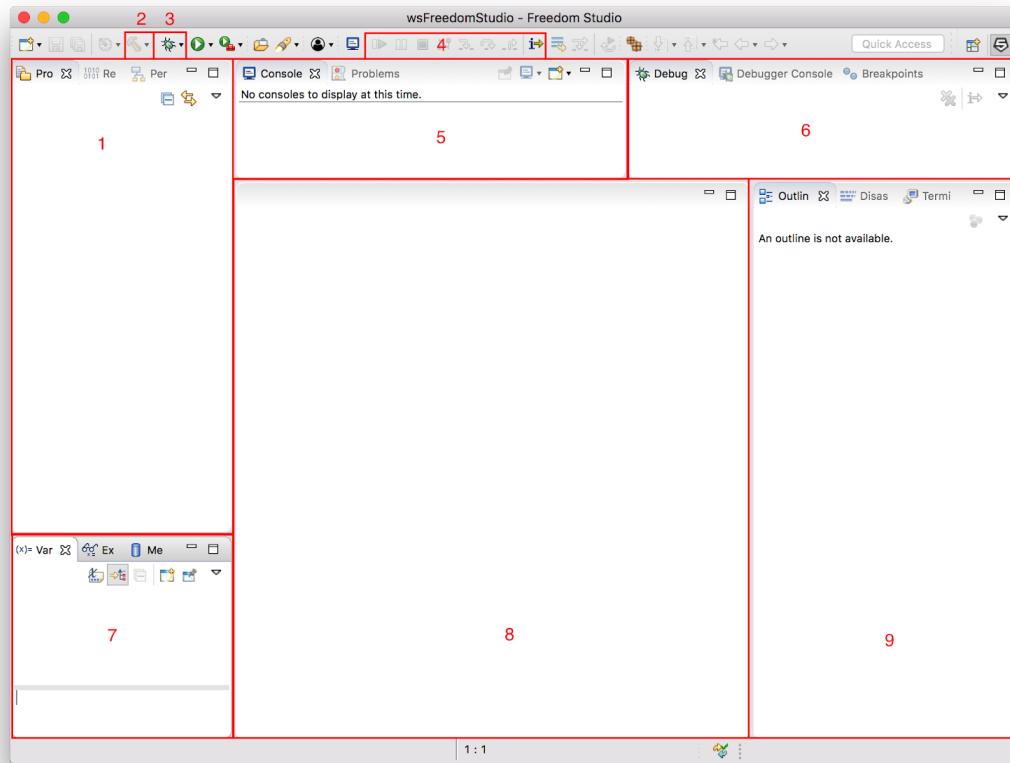
Freedom Studio ships with its own SiFive perspective which can be useful for both programming and debugging. Please see Section [The SiFive Perspective](#) for a detailed description of the SiFive Eclipse perspective.

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.

```
stdio.h
stdlib.h
platform.h
string.h
plic/plic_driver.h
encoding.h
unistd.h
g_plic : plic_instance_t
g_switch1Wins : int
g_debounce : int
debounce() : void
interrupt_function_ptr_t : void(*)(void)
localISR : interrupt_function_ptr_t[]
g_ext_interrupt_handlers : interrupt_function_ptr_t[]
set_timer() : void
mti_isr() : void
mei_isr() : void
instructions_msg : const char*
print_instructions() : void
invalid_global_isr() : void
invalid_local_isr() : void
switch_1_handler() : void
switch_2_handler() : void
pwm_0_handler() : void
debounce(int) : void
main(int, char**) : int
```

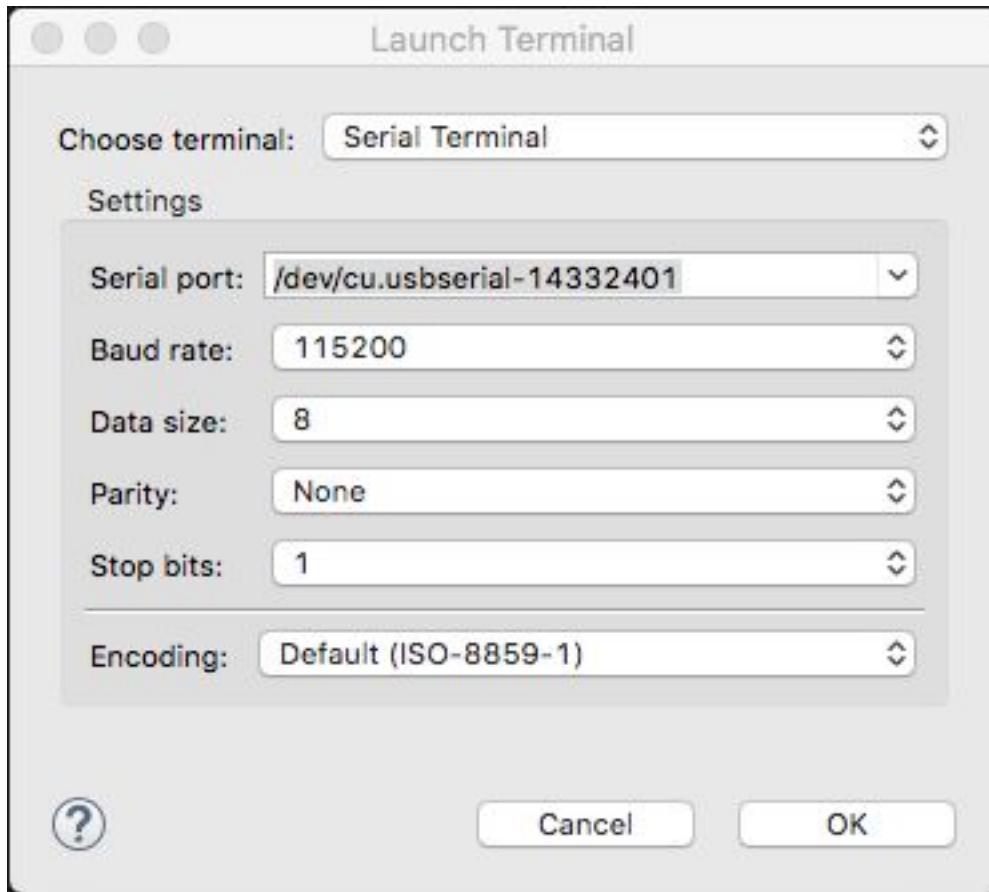
The Outline view, shown in above, gives a "top-level" view of the active file in the editor including functions, types, constants, etc... Clicking on an item in the Outline view will take you to that item's location in the source code.

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 with the following content:

```
Outline Disassembly Terminal /dev/cu.usbserial-14332401
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 #####
[REPEATED]
```

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 screenshot shows the Eclipse IDE's Registers view. The window title is "Registers". The table has three columns: "Name", "Value", and "Description". The "Name" column lists registers from x0 to x20. The "Value" column shows their current values. The "Description" column provides a brief description of each register. Registers x14 and x15 are highlighted in yellow, indicating they are being monitored or have changed.

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

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,

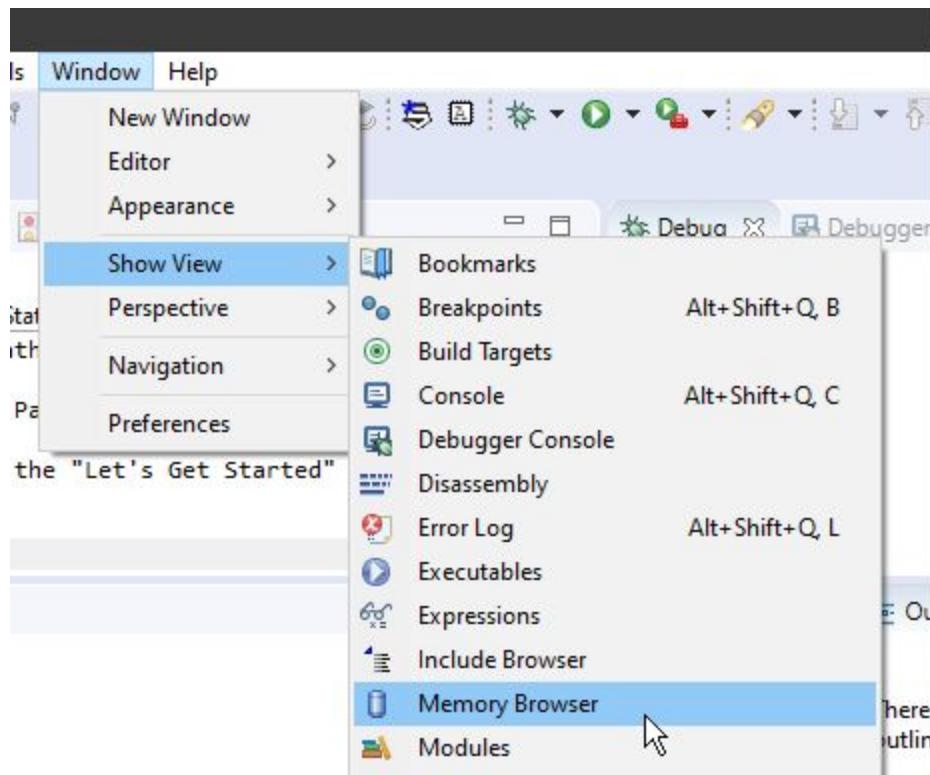
allows for changing the value format (for example to hexadecimal). The format can be changed by clicking the down arrow marked with "2" in screenshot:

Expression	Type	Value
(x)=\$mstatus	int64_t	0x1800
(x)=\$mip	int64_t	0x80
+ Add new expression		

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:



IP Projects

Alongside Software Projects, Freedom Studio uses a 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. A 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

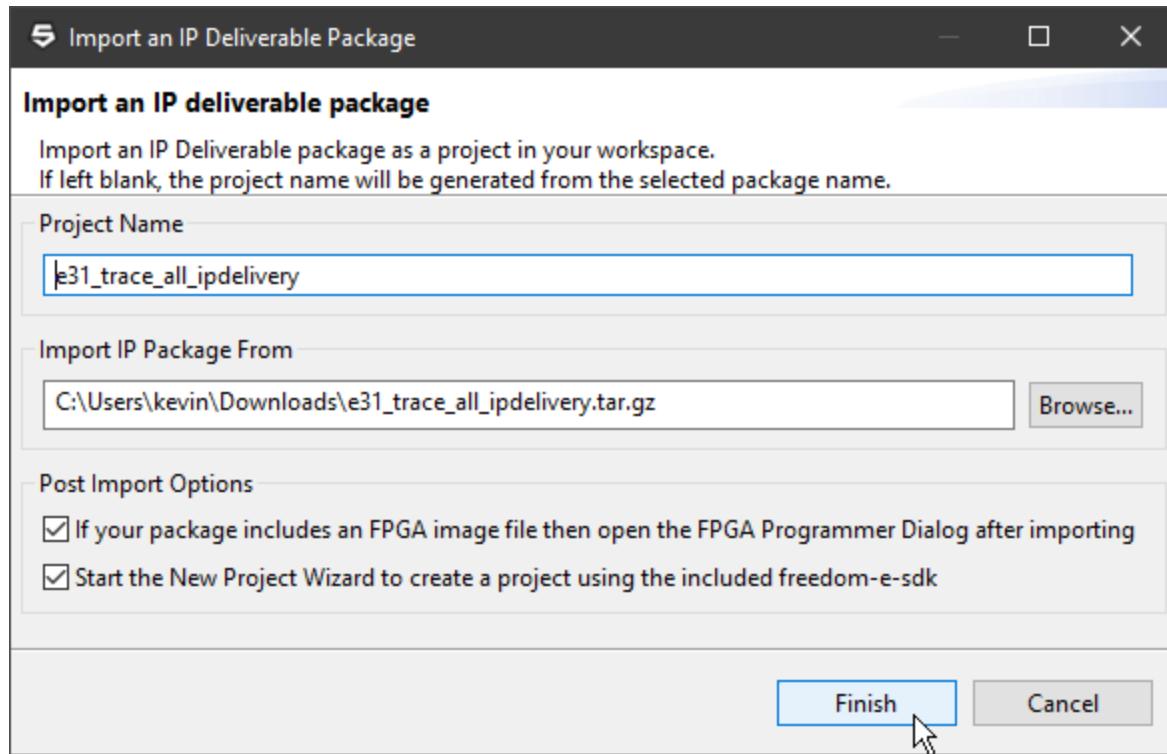
This wizard is accessible from all the usual spots in Freedom Studio:

- 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:



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:

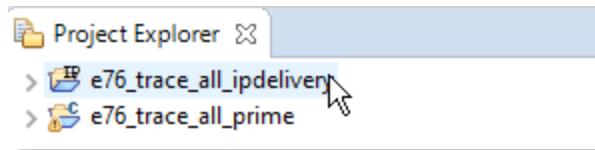
1. Option 1 tells Freedom Studio to open the Arty Programmer Dialog to program the MCS or BIT file included in the IP package. The dialog will default to the MCS file (if

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.

Use the “Browse...” button to locate and select the IP project tar.gz file. Give the project a name (or accept the generated name) and click the [Finish] button.

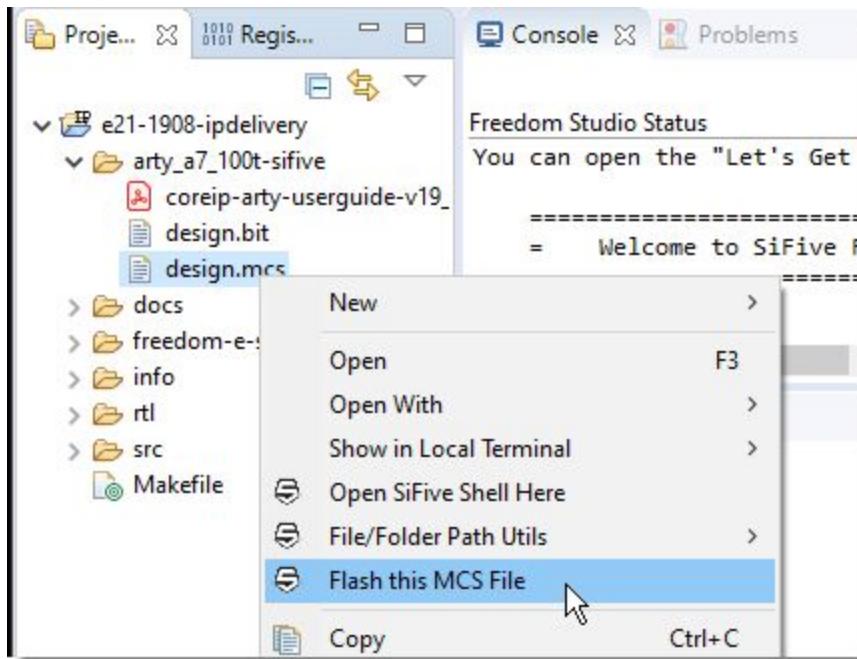
IP Projects are denoted in the Project Explorer with a small “IP” icon in the upper-right corner of the project icon.



Working with the IP Project

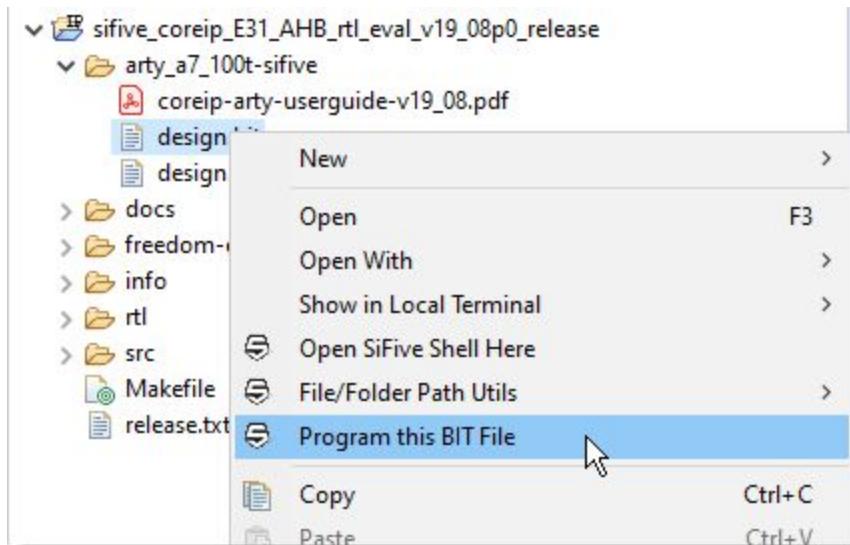
Now that you have a new IP Project, let's do stuff with it. You can:

- **Flash the included MCS file:** Double-click the MCS file, or right-click on the MCS file in the project and selecting “Flash this MCS File”



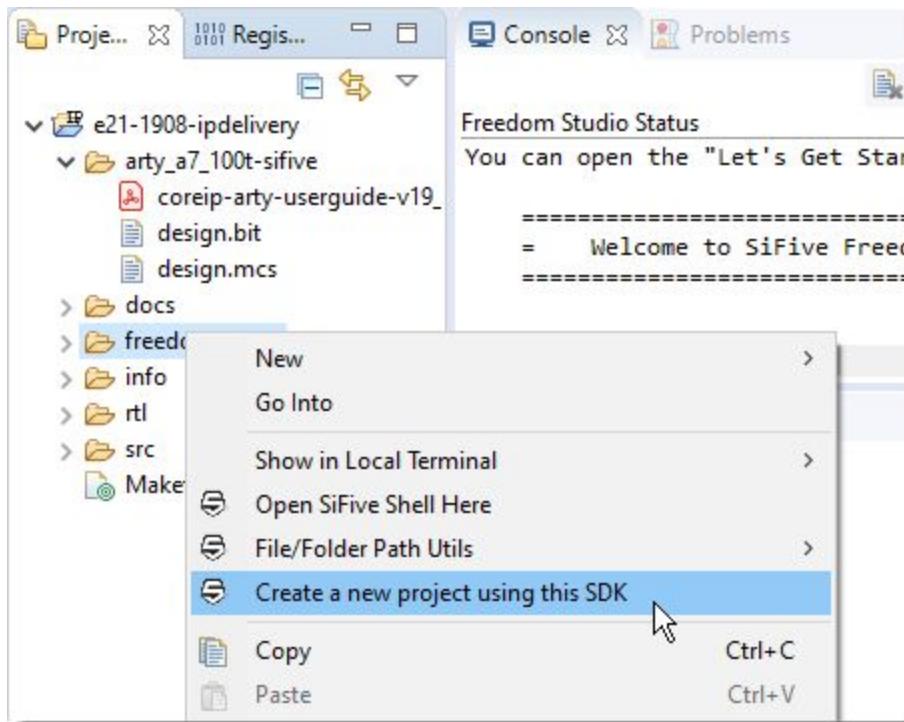
This will open the FPGA Programmer Dialog with the selected MCS file ready to go.

- **Program the included BIT file:** Double-click the BIT file, or right-click on the BIT file in the project and selecting “Program this BIT File”

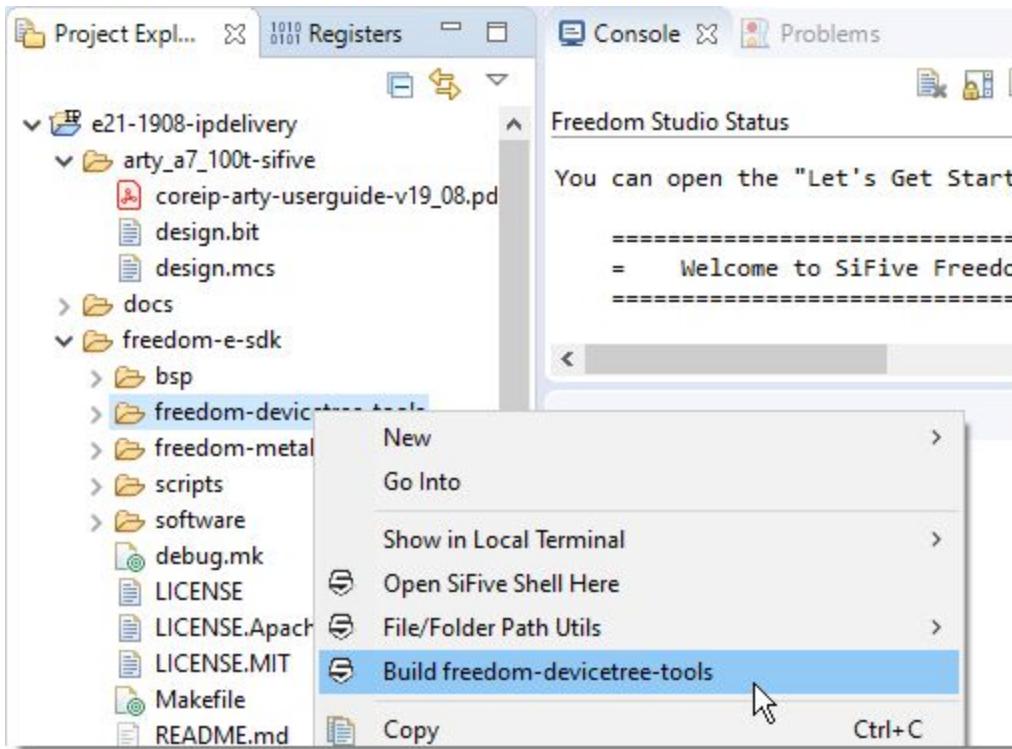


This will open the FPAG Programmer Dialog with the selected BIT file ready to go

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

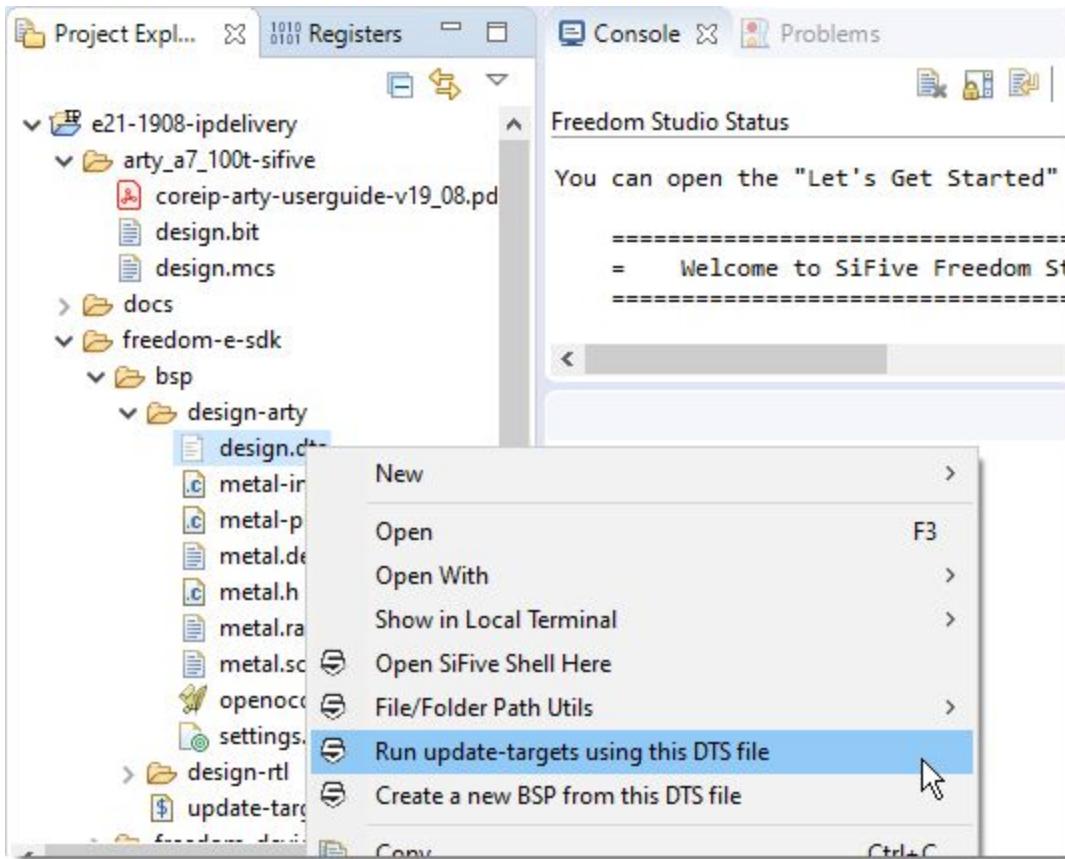


- **Build the freedom-devicetree-tools:** right-click on the “freedom-devicetree-tools” folder (found under the freedom-e-sdk folder) and select “Build freedom-devicetree-tools”



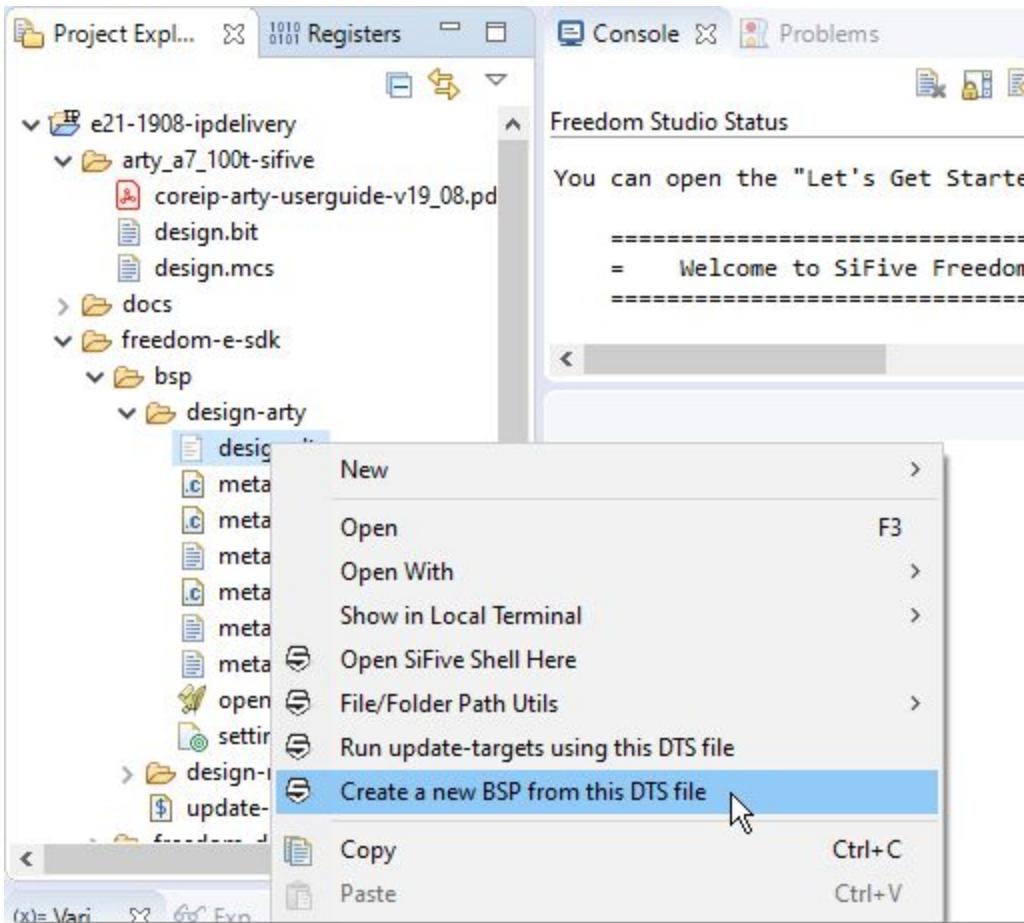
Building these tools requires that several native packages be installed on the host system. On Windows and Mac Freedom Studio will offer to install these packages if they are not detected (they are not included with the Freedom Studio installation). On Linux, manual installation of these packages is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

- **Rebuild your BSP:** [This only applies to IP packages <= 2019.08] If you have edited your BSP DTS file, right-click on the DTS file and select “Run update-targets using this DTS file”

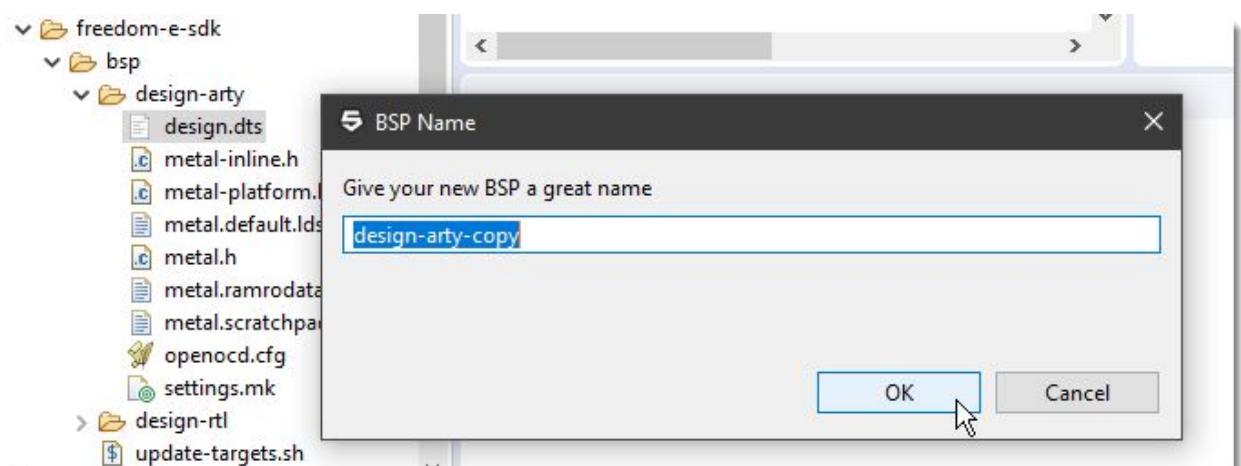


This command requires that the freedom-devicetree-tools are compiled. If they are not, Freedom Studio will ask if you'd like to compile them first, then continue updating the BSP.

- **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.

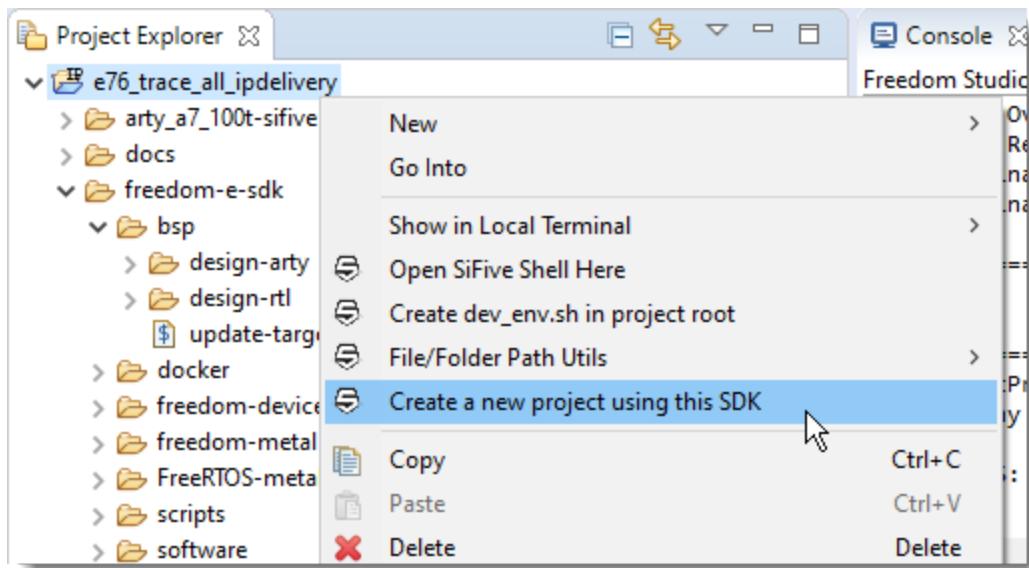
Freedom E SDK Example Software Projects

Creating an Example Software Project

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

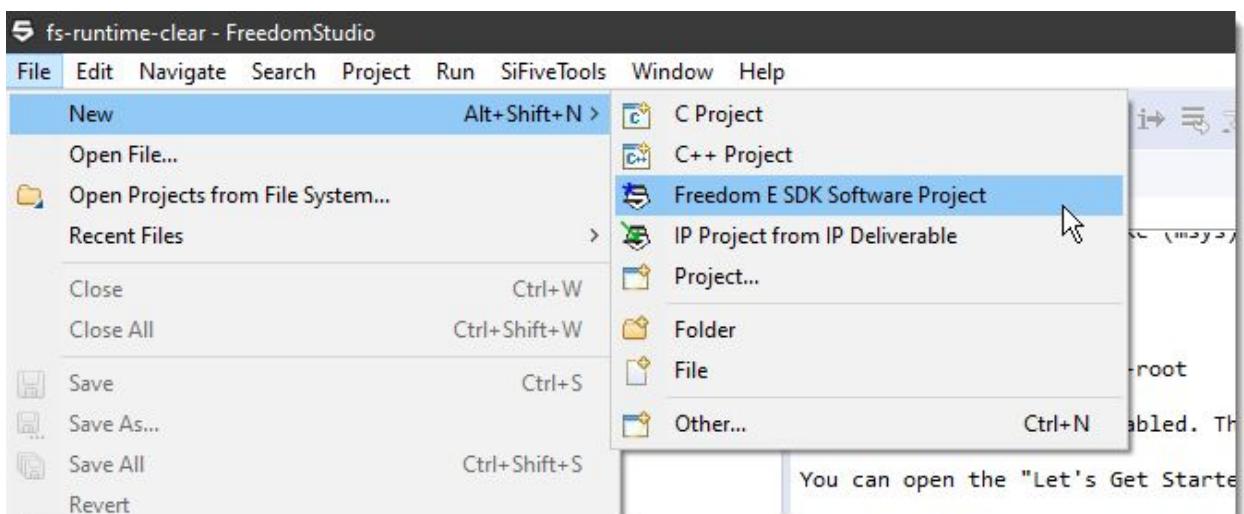
From an IP Project

If you have created an IP Project you can simply right-click on the project folder and select “Create a new project using this SDK”



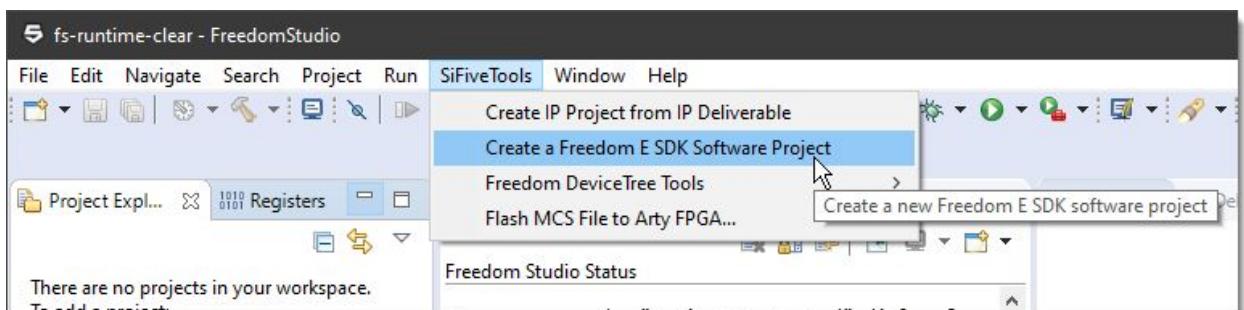
From the main menu

Select File → New → Freedom E SDK Software Project, as shown below:



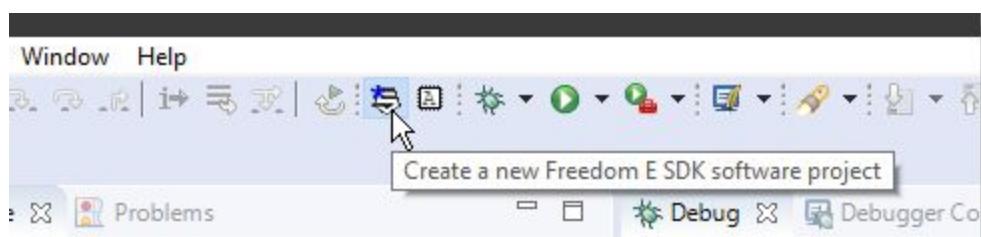
From the SiFiveTools menu

Select **Create a Freedom E SDK Software Project**:



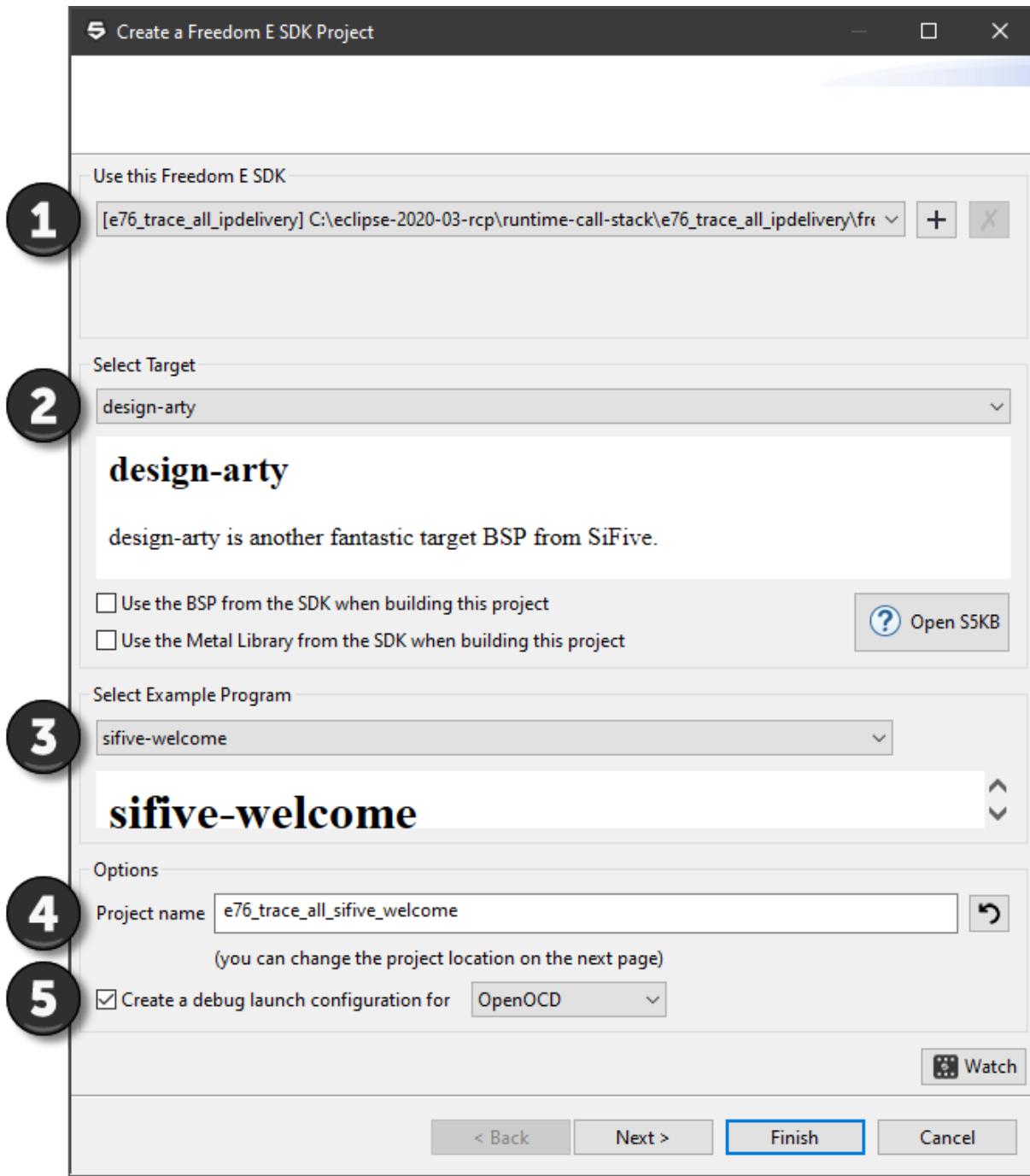
From the main toolbar

Click the "Create a New Freedom E SDK Software Project" icon, as shown:



The New Project Wizard

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

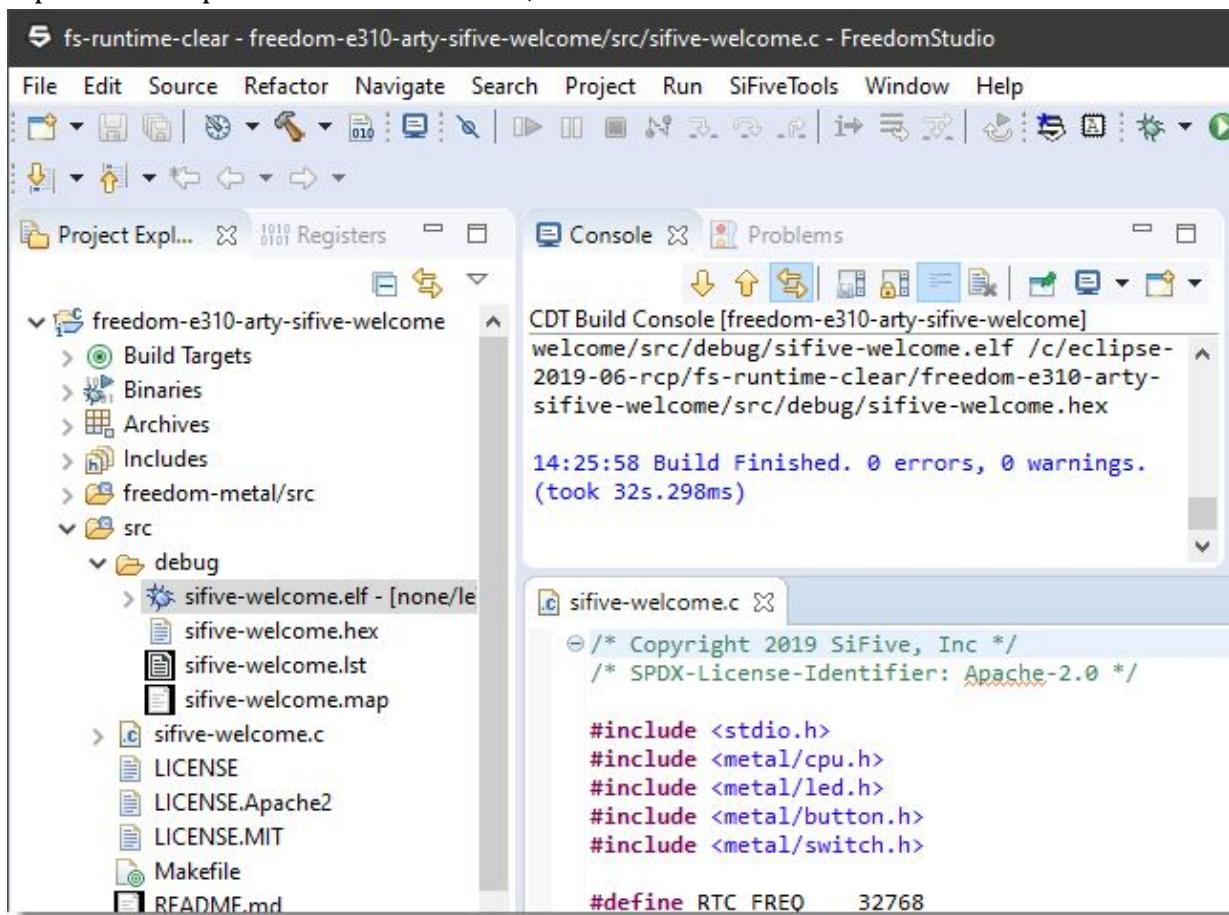
projects from the selected SDK. The drop-down box is automatically populated with any SDK instances found in your workspace projects. Using the '+' button you can also select an SDK instance that is not contained in your workspace.

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.
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 location, 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 checked the “Create a debug launch configuration” checkbox when creating your project the Debug Launch Configuration Dialog will automatically open after the ELF file is built and revealed.

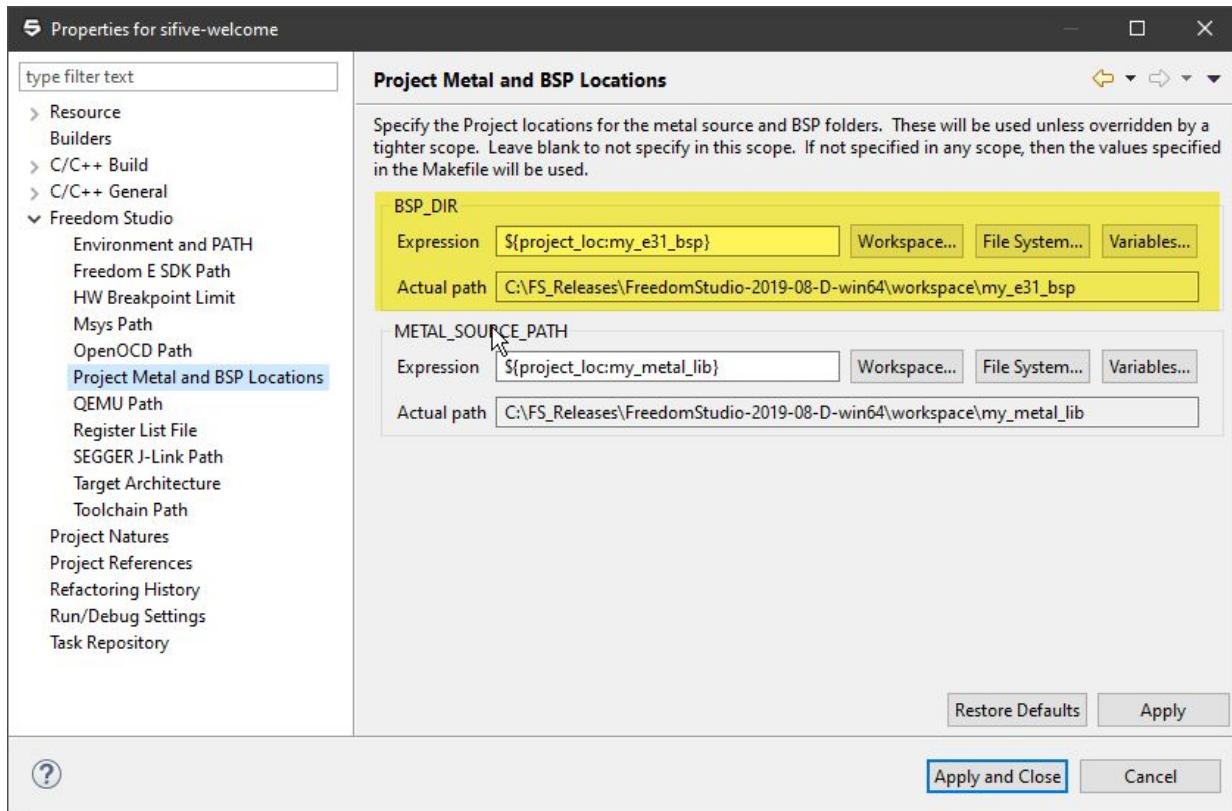
Share BSP with Multiple Projects

This is an advanced use scenario and is entirely optional.

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.



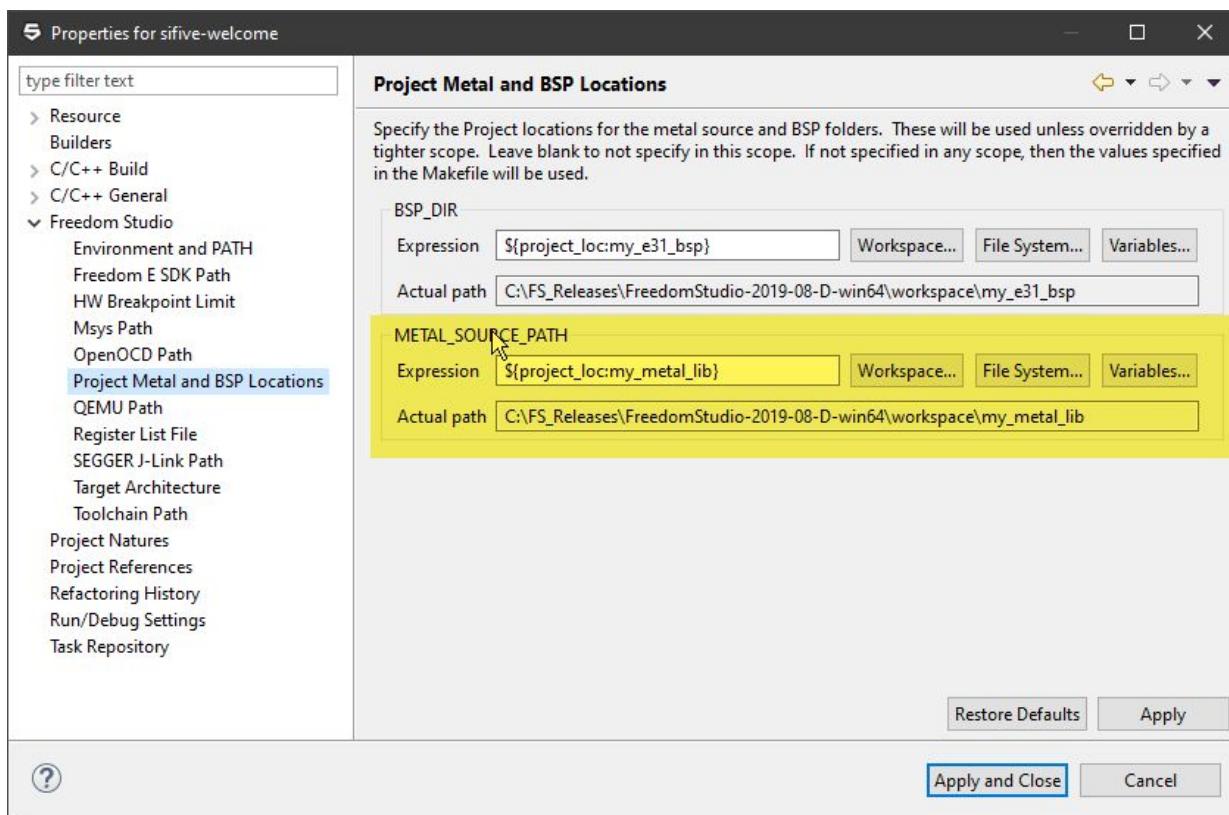
Share Metal Library with Multiple Projects

This is an advanced use scenario and is entirely optional.

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.



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.

Debug Launch Configurations

Main Tab

Generally there is no reason to adjust settings on this tab unless you are creating a new launch configuration from scratch.

See the [CDT Reference Documentation](#)

Target Tab

Name: e31_trace_all_sifive_welcome

Main Target DTS Debugger Startup Config Source Common

Program FPGA using OpenOCD/xc3sprog
NOTE: If specified, the BIT file will be programmed to the FPGA at the beginning of the launch. Leave blank to use the image currently on the FPGA.

FPGA BIT File Project... Workspace... File System... Variables...

Actual path

Programming FPGA at launch is enabled. You can also toggle this on the main toolbar. [\(?\)](#)

Target Device Tree

DTS File C:\FS\FreedomStudio-2020-05-27123159-HEAD-win64\wsFreedomStudio\e:

Actual path C:\FS\FreedomStudio-2020-05-27123159-HEAD-win64\wsFreedomStudio\e31_trace_all_sifive_welcome\bsp\design.dts

Selected cpu cpu@0

Target Device Info

Number of cpus on target: 1

Information about cpu@0:

```
Startup CPU Frequency: 32MHz
Configure GDB (unless overridden):
    set arch riscv:rv32
    set remote hardware-breakpoint-limit 4
Trace Encoder: 0x10000000
```

Information about SOC

Device Memory Map

```
0x02000000 to 0x0200FFFF as rw for clint@2000000
0x80000000 to 0x8000FFFF as rw for dtim@80000000
0x20002000 to 0x20002FFF as rw for gpio@20002000
0x0C000000 to 0x0FFFFFFF as rw for interrupt-controller@c000000
0x01800000 to 0x01801FFF as rw for itim@1800000
0x01802000 to 0x01803FFF as rw for itim@1800000
0x20005000 to 0x20005FFF as rw for pwm@20005000
0x00001000 to 0x00001FFF as rw for rom@1000
0x20000000 to 0x20000FFF as rw for serial@20000000
0x00001000 to 0x00000FFF as ro for spi@20004000
0x01000000 to 0x00FFFFFF as ro for spi@20004000
0x20004000 to 0x20003FFF as ro for spi@20004000
```

Revert Apply

Debugger Tab

Connection Status [Windows Only]



On Windows Freedom Studio can automatically monitor the target connection and warn you if either target connection is missing. Uncheck the monitoring checkboxes if you are using a custom target connection.

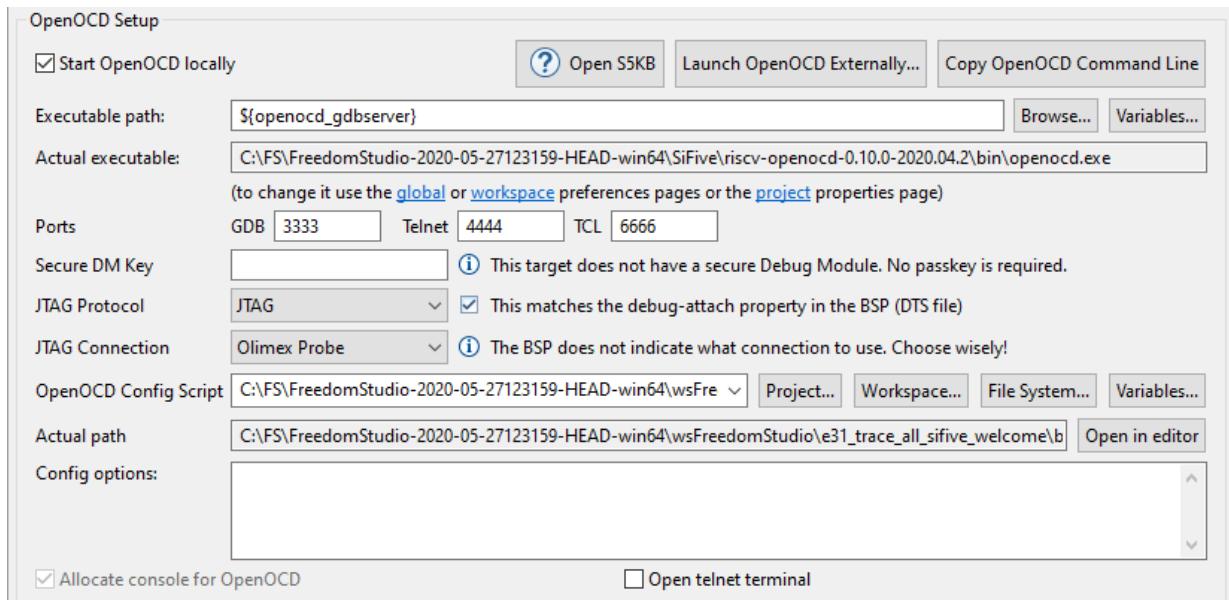
OpenOCD Setup

Generally speaking the default settings in this section will work.

See these Knowledge Base Articles for additional information:

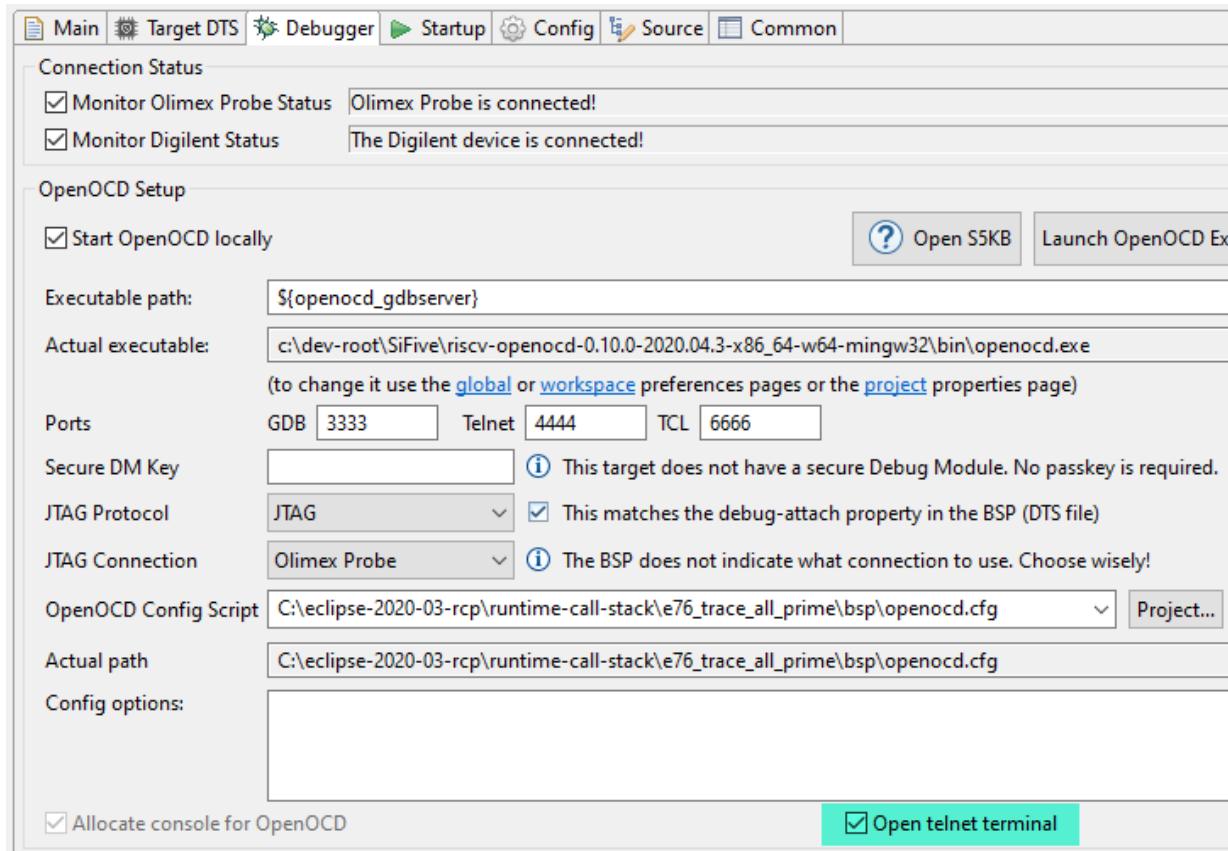
- [Logging Open OCD Output in Freedom Studio](#)
- [OpenOCD in an IDE](#)
- [Connecting to an RTL Simulator using OpenOCD](#)

Newer Knowledge Base articles may have been written since this manual was published. Click [here](#) to open the Knowledge Base and check.



Auto Open Telnet Console to OpenOCD

When using the OpenOCD debug connector, you can automatically open a telnet session to the OpenOCD TCL console.

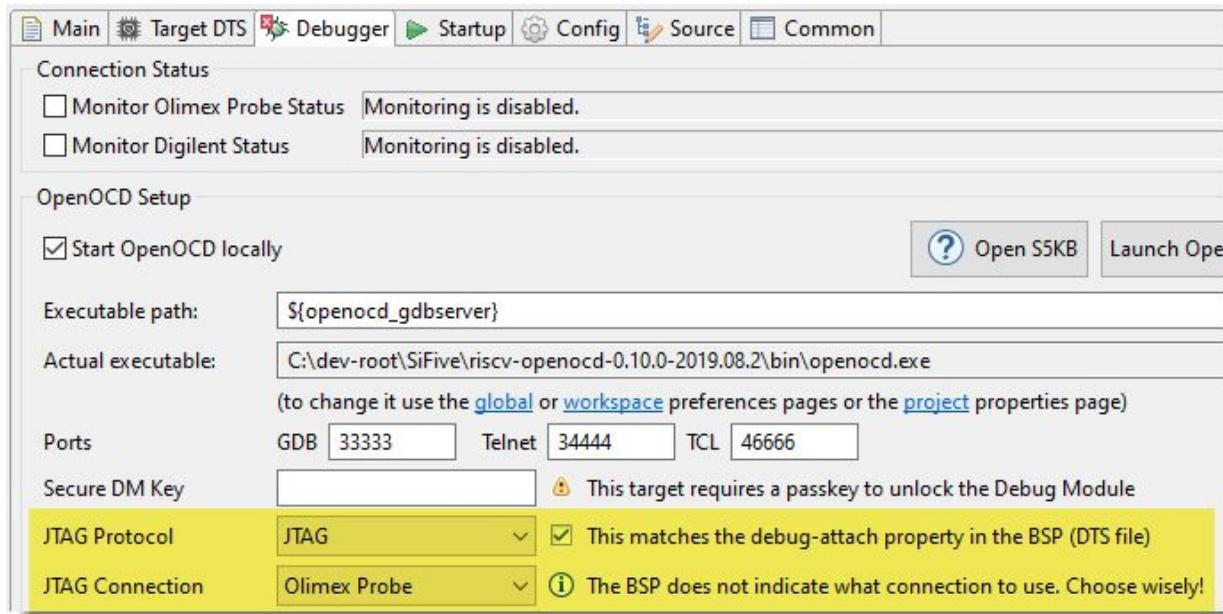


Specifying JTAG/cJTAG/BSCAN

Users no longer need to edit the openocd config script to enable cJTAG support. The launch configuration UI allows you to specify the type of connection (JTAG/cJTAG/BSCAN) and the default openocd script adapts accordingly.

This feature is only supported with IP packages and freedom-e-sdk instances newer than 2019.08. Older releases still require manual configuration of the openocd configuration script.

The Debugger Tab in the Launch Configuration Dialog is updated to more easily specify the debugger protocol and connection:

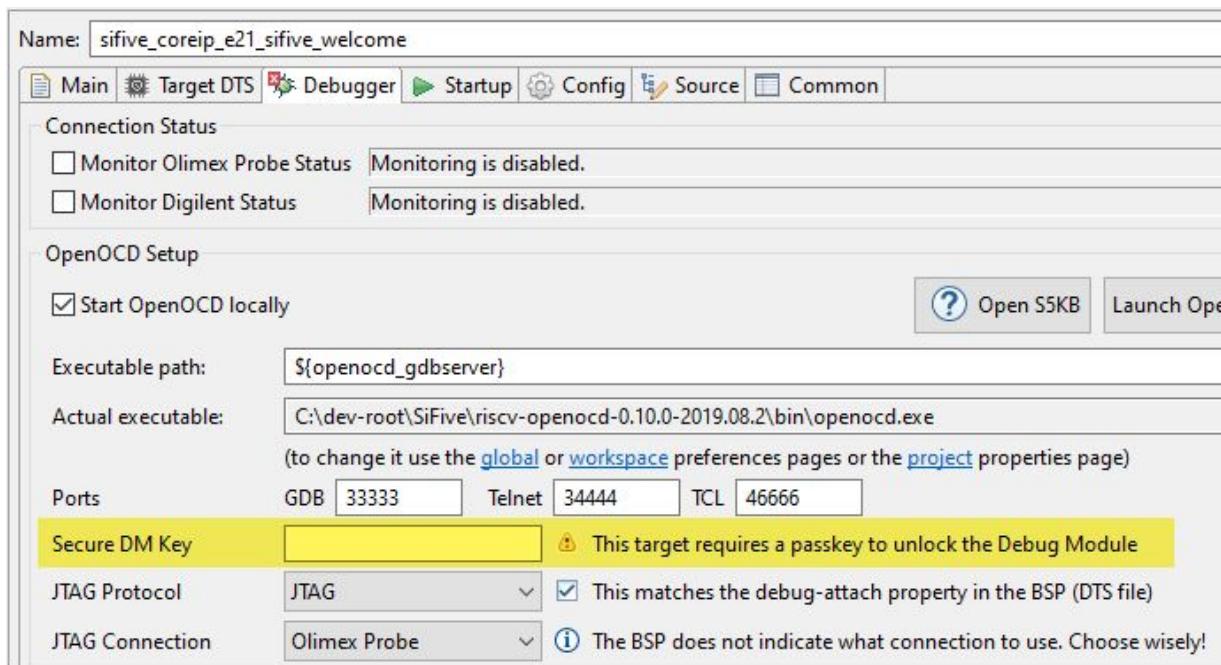


Newer IP packages (post 19.08) include information about the JTAG protocol implemented on the target. When this information is included Freedom Studio will automatically select the correct protocol. When the IP package does not contain this information you need to ensure that the correct protocol is selected.

IP packages do not yet specify the implemented JTAG connection. You need to choose the correct connection.

Secure DM Key

Freedom Studio allows for specifying a key to unlock the debug module on cores that have a secure debug module.



The secure DM key is an 8 digit hexadecimal number (without a leading '0x'). The DTS file is examined to determine if a secure DM is present and Freedom Studio will print an appropriate message. If the DTS file is not provided you will need to know if a key needs to be provided.

Auto Loading TCL Scripts

Sometimes it can be useful to have TCL scripts loaded into the OpenOCD TCL interpreter. While you can do this interactively using a telnet session to OpenOCD, doing so on every launch becomes quickly tiresome.

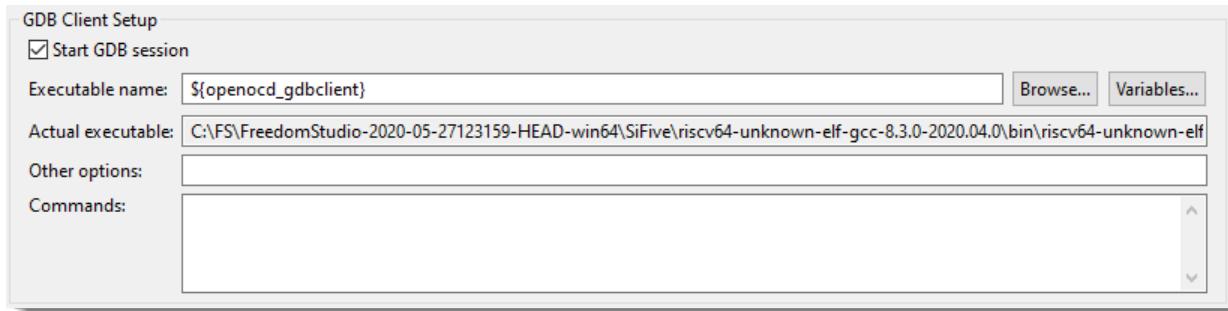
Freedom Studio can automatically load TCL scripts located in certain special folders. Before placing a TCL script into an autoload location make sure that the script does not have any syntax errors that would prevent the script from loading. Errors in the script will cause the debug launch to fail.

The following locations are examined for files ending in .tcl. Found files will be loaded.

- <project-folder>/scripts/tcl/autoload
Use this location to capture scripts that need to follow a project.
- <openocd-root>/share/openocd/scripts/autoload
Use this location to capture scripts that need to follow OpenOCD

- <fs-install-root>/SiFive/scripts/tcl/autoload
Use this location for scripts that may be needed for all projects.
- FS_AUTOLOAD_TCL_FOLDER
Define this environment variable to point to any filesystem location.

GDB Client Setup



- **Start GDB Session**

When checked, Freedom Studio will start the gdb executable. We recommend leaving this box checked.

- **Executable name**

The default variable shown will automatically use the gdb exec bundled with Freedom Studio. If you need to use a different gdb executable, use the Browse button to locate and select it.

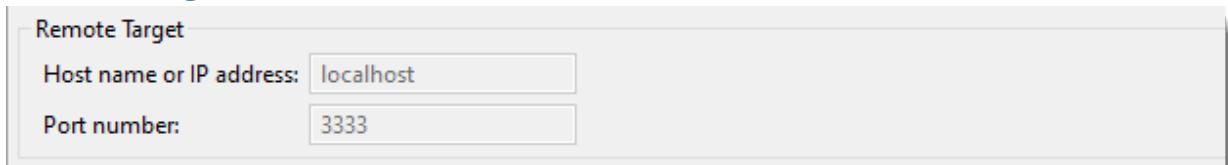
- **Other Options**

Additional command line options to be passed to the gdb client.

- **Commands**

Additional command that will be sent to gdb upon startup. These commands are executed just before the ".gdbinit." sequence and can be used to set target state when needed. Commands prefixed with "monitor" will be sent to OpenOCD. You can content assist (Ctrl-Space) to get a list of common commands.

Remote Target



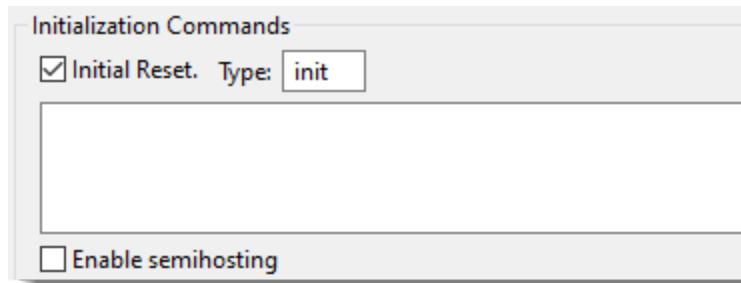
These settings are used when you want to connect to an external OpenOCD process. The external process can be running on the local machine, or any other machine that is accessible from the local network.

Other Settings

- Force Thread List Update on Suspend
Force all threads to be updated on every suspend. Usually not required.

Startup Tab

Initialization Commands



- **Initial Reset**

Perform an initial reset and halt; this will take the processor out of whatever state it was and prepare it for programming the flash. Normally the GDB server performs a reset when starting, so this is especially useful when a specific reset type is required. It is disabled when the 'Connect to running' option is used. The generated command is 'monitor reset <type>'.

- **Reset Type**

Can be one of:

- 'run' Let the target run,
- 'halt' Immediately halt the target,
- 'init' Immediately halt the target, and execute the reset-init script.

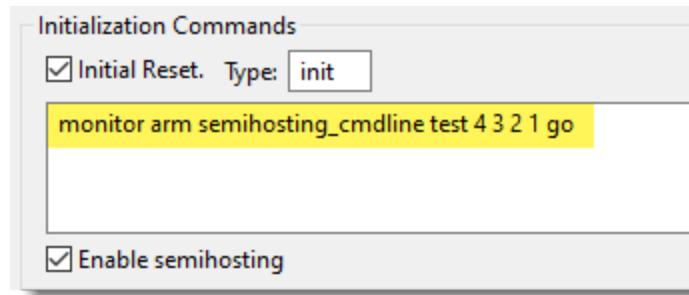
- **Initialization Commands**

Additional or alternate initialisation commands. To reach the GDB server, the commands should be prefixed with 'monitor'.

- **Enable semihosting**

Enable support for semihosting. The generated command is 'monitor arm semihosting enable'.

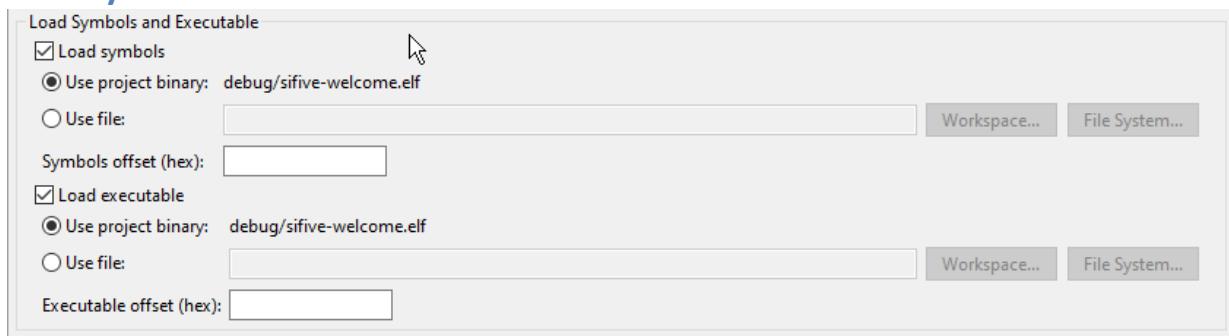
To provide argument to main, add the following command with the desired arguments specified:



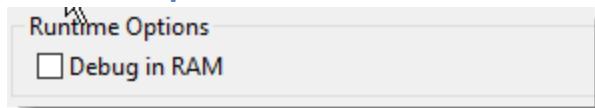
This example will result in

```
argc == 6  
argv = ["test", "4", "3", "2", "1", "go"]
```

Load Symbols and Executables

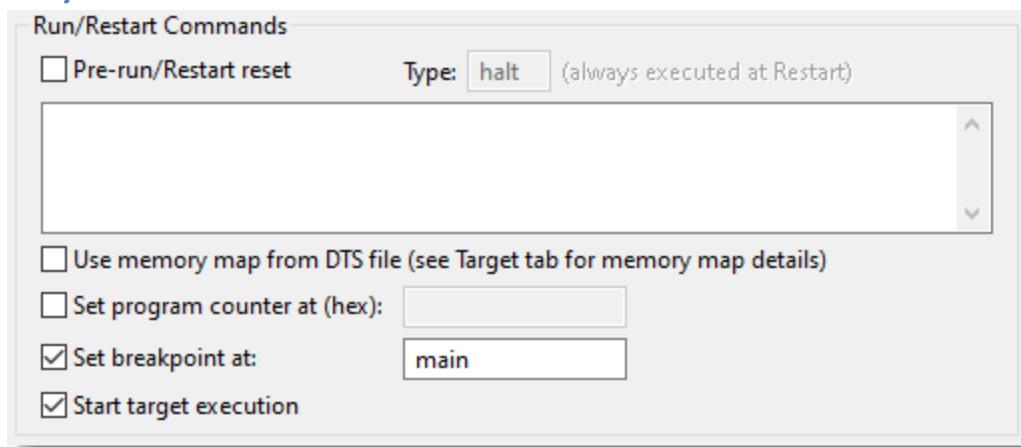


Runtime Options



When checked, load the executable and run the entire debug session in RAM. The main effect is that the executable will be loaded after each reset/restart, not only once after the initial reset.

Run/Restart Commands



- **Pre-run/Restart reset**

We recommend that this be left unchecked unless you have a specific need for a second reset. In general freedom-e-sdk software example projects do not require this. When check and additional monitor reset 'type' is issued. Doing so may affect the target state that has been previously set up.

- **Run/Restart Commands**

Add any additional command that should be run on a restart.

- **Use memory map from DTS file**

When checked gdb will be configured with the memory map extracted from the DTS file. Only use this option if your target cannot handle potentially memory accesses outside of existing memory.

- **Set program counter at (hex)**

If you need the PC set to a specific location that is not indicated in the ELF file, specify that location here. Otherwise the start address in the ELF file will be used.

- **Set breakpoint at**

The default value is "main". Sets an initial (temporary) breakpoint at this location. Common values are "main" (for debugging application code) and "_enter" (for debugging startup code)

- **Start target execution**

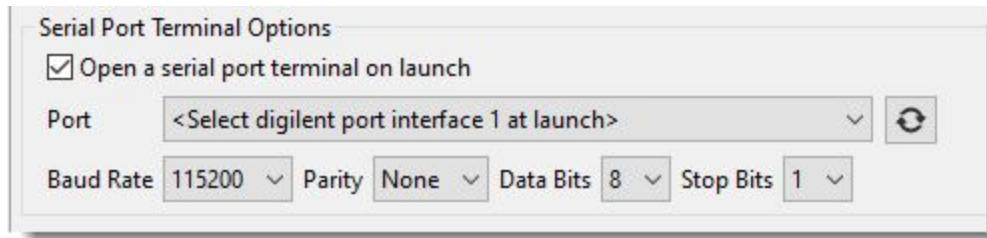
When checked Freedom Studio will start target execution. Otherwise the target will remain halted at the first instruction.

Initial Trace Setup

See [Initial Trace Setup](#)

Serial Port Terminal Options

Launch Configurations can automatically open a serial console when the launch starts. Use the following controls to specify the serial port parameters.



In most cases Freedom Studio can automatically determine the correct serial port to use. If you find that the correct port is not being used, use the drop-down to select the correct port. See also: [UART List View](#)

Config Tab

Register List

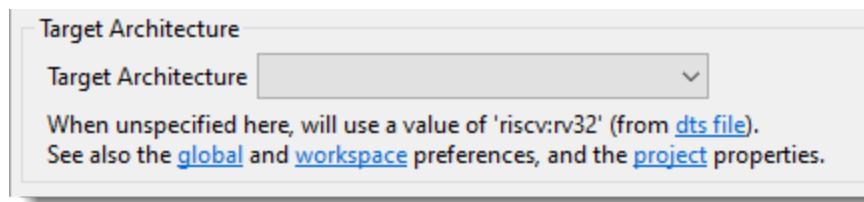
See [Register List Management](#)

Hardware Breakpoints

See [Managing Hardware Breakpoint Resources](#)

Target Architecture

The target architecture is usually extracted from the DTS file in the BSP folder. If, for some reason, you are not using a BSP, the setting can be manually specified in Preferences or directly in the debug launch configuration.



Source Tab

See the [CDT Reference Documentation](#)

Common Tab

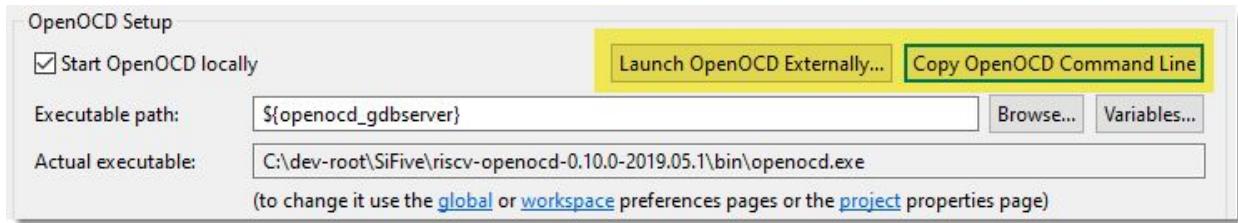
See the [CDT Reference Documentation](#)

Automatic Removal of 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 or inadvertently using precious hardware breakpoint resources.

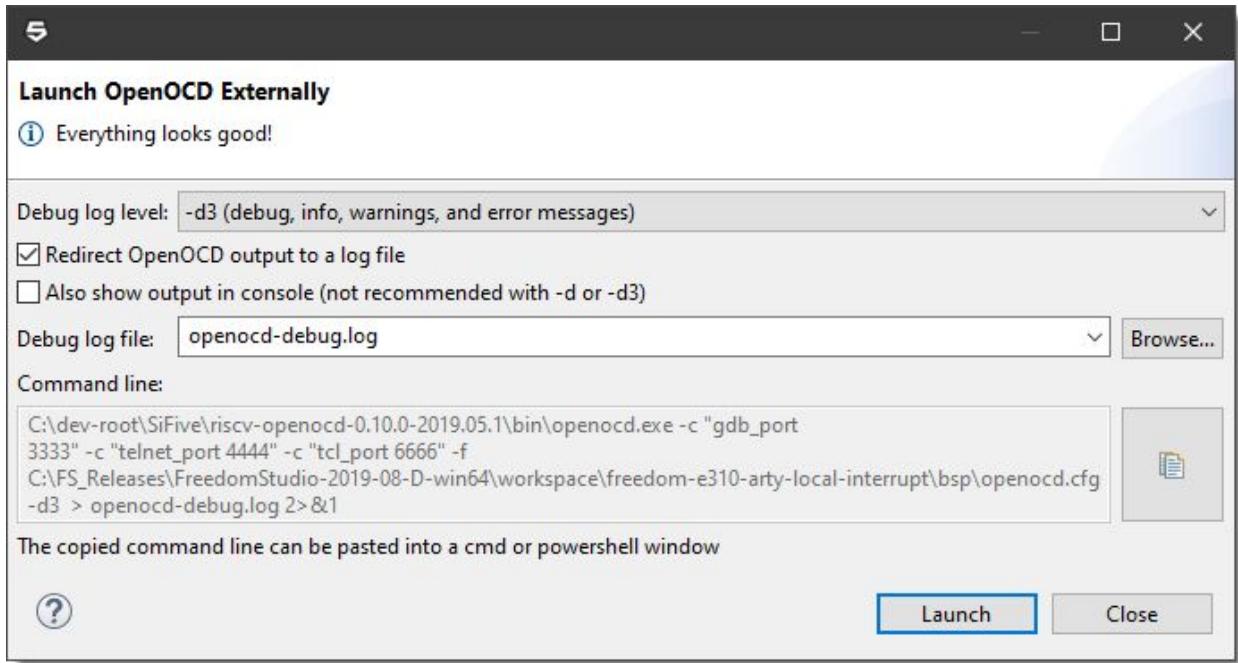
Launch OpenOCD Externally

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.

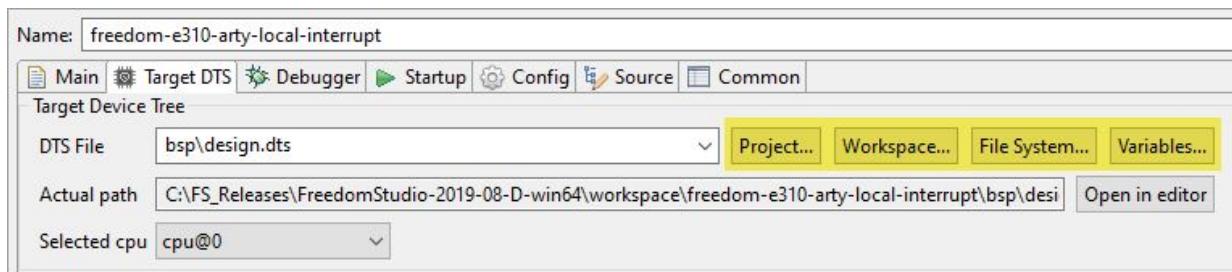
You can use the “Copy” button (to the right of the command line box) to copy the command line to the clipboard.

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. Besure to uncheck the “Start OpenOCD locally” checkbox.]

Selecting File Resources

You can select from Project, Workspace, or File System scopes, and use Eclipse variables to build expressions.



The “Open in Editor” button that will open the selected resource in a Freedom Studio editor window. You will need to close the Debug Language window to use the editor.

Processor Trace

This version of Freedom Studio introduces a brand new Trace system.

Trace Viewer

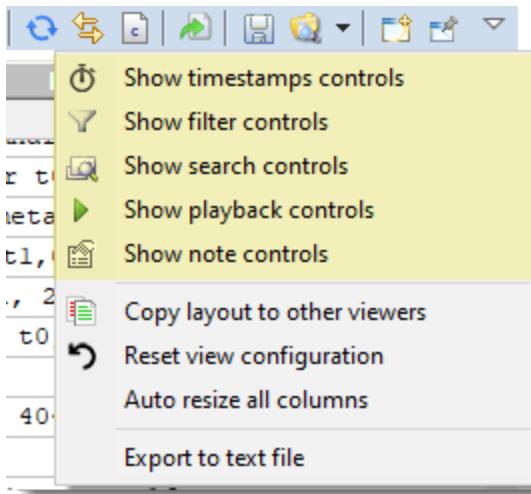
The Trace Viewer is the primary interface to the SiFive Trace system. This view shows trace data and allows for full control of the trace system. This is the Trace Viewer:

Record	RT	Com...	Addr	Dasm
0000006039			404001CC f14022f3	csrr t0,mhartid
0000006040		crt0.S:238	secondary_main(): la t1, _metal_boot_hart	
0000006041			404001D0 00000313	li t1,0
0000006042	-140,276 ns	crt0.S:239	secondary_main(): beq t0, t1, 2f	
0000006043	-140,276 ns		404001D4 00628563	beq t0,t1,404001de <secondary_ma
0000006044	-1,015 ns	crt0.S:244	secondary_main(): call main	
0000006045	-1,015 ns		404001DE 204d	jal 40400280 <main>
0000006046		prime.c:8	main(): int main() {	
0000006047			40400280 1141	addi sp,sp,-16
0000006048			40400282 c606	sw ra,12(sp)

Trace Viewer Control Bar



That's a lot of buttons. The buttons on this bar control almost all aspects of the trace system. Trace control groups can be hidden when not being used, helping to reduce the clutter of unwanted controls. The view drop down menu (on the far right) contains switches that control enablement of several command groups in the toolbar.



Each of the control groups is described below.

Primary Trace Control Commands



This control group cannot be hidden. It is the primary interface to the trace system.

1. Funnel Trace Enable

On multi-core systems with a trace funnel, this toggle button enables or disables the trace funnel. It is, in effect, a master switch for multi-core trace enable/disable. If this toggle is disabled no trace from any core will be produced.

2. Core trace enable

This toggle button enables or disables trace on a specified core. Clicking the checkbox will toggle the active core (that is the core currently selected in the Debug thread view). Using the drop-down button to the right of the checkbox allows you to toggle the enable state for other cores without having to select the core in the Debug view first.

3. Trace Control

Pressing this button will open the Trace Control Dialog for the active core (that is the core currently selected in the Debug thread view). Using the drop-down button to the right of the checkbox allows you to configure trace for other cores without having to select the core in the Debug view first.

4. Load trace data from target

Pressing this button will cause all trace data on the target to be loaded into Freedom Studio. This is a “manual” load. There are two primary uses cases:

- If you choose not to have trace loaded on each halt, this button allows you to load trace on demand.
- If you have a large trace buffer on the target, Freedom Studio will only load part of the trace buffer when halting (for performance reasons). Pressing this button will cause the entire buffer to be loaded.

5. Load Trace on Halt

This toggle button controls loading trace when the target halts (either due to breakpoint, or user suspend request). When enabled, trace will be loaded at each halt. If you have more than 4KB of trace, only the first or last 4KB will be loaded on halt. [This size can be changed in Freedom Studio preferences.]

6. Accumulate Mode

This toggle button controls how trace is accumulated when collected. When toggled

off, the previous trace data is discarded before collection being. [Internally, this toggle controls when the trace write pointer gets reset.] When toggle on the trace buffer on the target will continue where it left off on the previous halt.

Filtering Commands

The filter command, and the filter row header in the trace data view table, control how trace data is filtered in the view.

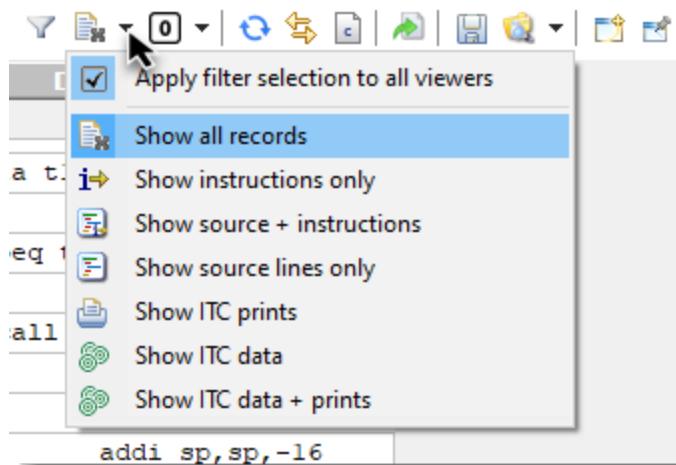


1. Toggle filter row visibility

This toggle button shows or hides the filter row in the Trace Data table. The filter row is located just below the column headers. When enabled, the filter row allows you to type regular expressions in the column filter to control which records are displayed.

2. Predefined Filter Select

This dropdown menu allows you to select from several predefined filters.



Options include:

a. Apply filter selection to all viewer

This toggle button, when checked, will apply any filter selection to all open Trace Data Views. When not checked, filter selection will only apply to the current view.

- b. **Show all records**
This is the default filter. It shows all trace records with no filtering applied.
- c. **Show instructions only**
Shows only instruction execution records
- d. **Show source + instructions**
Show instruction records with source lines interleaved. Each source line will be shown followed by all the instructions that make up the source line.
- e. **Show source lines only**
Shows only source lines. Instruction records are not displayed.
- f. **Show ITC prints**
Shows ITC print records only.
- g. **Show ITC data**
Show ITC data records only (ITC prints will not be displayed)
- h. **Show ITC data + prints**
Show both ITC data and ITC print records.

3. Core Context Selector

Use this dropdown selector to select which core to display.

Timestamp Commands

The timestamp section controls how timestamp information is reported.



1. Reset the timestamp counter on the target

Write 0 to the timestamp counter register on the target. Not required for general timestamping of trace. Provided for special cases, when needed.

2. Set clock frequency for timestamps

Opens a dialog so that you can specify the clock frequency of the timestamp counter. This is required in order to translate timestamp values into real time. The timestamp clock can originate from different clock sources so it is important to know where the source clock is located and what frequency it is running.

3. Timestamp unit select

This button cycles through different time units. You can also use the 't' key in the Trace View to cycle through the units.

- a. picoseconds
- b. nanoseconds
- c. microseconds

- d. millisecond
 - e. seconds
 - f. clock cycles
4. **Set relative timestamp origin**
Pressing this button with a timestamped trace record selected will set the relative timestamp origin to the selected record. All other timestamp values in the Relative Timestamp [RT] column will be reported relative to this record. You can also use the 'o' key to set the origin.

Search Commands

These search commands provide basic facilities for searching through trace data.



1. Search expression status
This icon reflects the status of the search expression. If a mal-formed regular expression is entered, the tooltip for this icon will report the expression error. If the search expression is valid a green checkmark is displayed.
2. Search expression
The search expression is a regular expression that will be used to find matches in the trace data. All displayed trace data is searched.
3. Search expression management
This drop down menu contains commands for saving, and forgetting search expressions. A saved search expression will become available in the search term dropdown combo box.
4. Previous/Next search result
Use the previous and next search result to locate the previous or next search result in the trace view. Search result records will be highlighted green for a short duration to more clearly indicate the result.

Sync Commands

The sync command controls how the Trace Data view synchronizes with other parts of Freedom Studio.



1. Sync viewports

When toggled on all views looking at the same trace data set will be synchronized such that scrolling in one view will also cause other viewers to scroll so that the same trace record (or closest match) is selected and shown in all synchronized views.

2. Toggle sync to editor

This toggle button controls synchronization to the editor and disassembly view. When toggled on, selecting a trace record in the trace data view will also show the selected source line in an editor and show the corresponding instruction in the disassembly view.

3. Goto source

If “toggle sync to editor” is turned off, then this button will manually sync the selected record to the editor and disassembly view. You can also do this by double-clicking any trace record.

Note Commands

Notes are a simple way of marking and noting trace records in a trace capture. Notes are extremely ephemeral. Any notes created are lost on the next trace capture. Notes are intended for navigating around a trace capture in real time during a debug session. Using notes requires enabling the Note column in the Trace Data View. When enabled you can enter a simple note in the note column for a given trace record.



1. Note selector

This is a drop down menu that will list all notes created in this trace capture. Selecting a note in the menu will take you to the noted trace record.

2. Goto previous note

Press this button to go to the previous noted record.

3. Goto next note

Press this button to go to the next noted record.

Save Trace Commands

These commands provide the ability to save trace data, and reload saved data.



1. Save trace data

Saves the current trace data so that it can be reloaded at a later time. Saved trace data consists of multiple files including the raw trace data, a metadata file that captures target state, and a copy of the ELF file. These files are required to decode the trace. All files are saved to a directory that constitutes the saved trace.

2. Load trace data

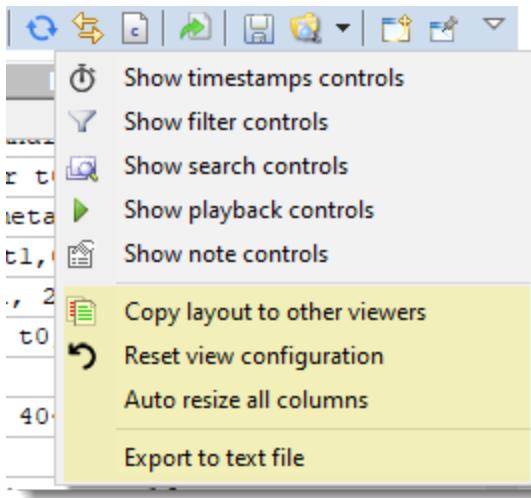
Loads a previously saved trace data set.

View Management Commands



Other Commands

The Trace Data view dropdown menu contains a few additional commands.



- **Copy layout to other views**

This command copies the column layout of this view to any other trace viewers.

- **Reset view configuration**

This command resets the trace data view to the default configuration.

- **Auto resize all columns**

This command automatically sizes all displayed columns to completely fit displayed data.

- **Export to text file**

This command exports the current trace capture to a text file. The text file content will reflect the currently displayed columns in the Trace Data view.

Trace Data Columns

The trace data view is highly configurable. Showing and hiding columns is controlled by:

- Right-click on any column header and select “hide column” to hide a displayed column.
- Right-click on any column header and select “manage column”. This will bring up a column manager dialog where you can add and remove columns.
- From the view drop-down menu, select “reset view configuration” to only show columns that are displayed by default.

The following columns can be displayed (or hidden):

These columns are shown in the default configuration:

- **RT**

Reports the relative timestamp for a trace record that includes a timestamp. The reported time is relative to the “origin” record. By default the origin record is the first time-stamped record when “stop trace on buffer full” is enabled, and the last trace record when “stop trace on buffer full” is disabled.

- **Composite Output**

This column is a general purpose column that reports data relevant to the trace

record type. Source lines are reported here, as well as ITC prints, and formatted ITC data records, including channel information.

- **Addr**
Shows the address of executed instruction records.
- **Dasm**
This column shows the opcode and disassembly for all executed instructions.

The following columns are not shown by default. These must be manually turned on.

- **Note**
The note column contains manually entered notes for a trace record.
- **Core**
Shows the core index of the trace record.
- **ISR**
Shows the ISR nesting level. A nesting level of 0 indicates normal program execution.
- **ISR Time**
If timestamps are configured to mark every branch message, then this column will report total time spent in each ISR. The time is reported on the last instruction of the ISR before returning from the interrupt.
This column is not shown by default.
- **C/R Type**
This column shows the Call/Return type of a record.
- **Type**
This column shows the “type” of trace record (i.e. instruction, source, itc...). Mostly useful for debugging trace.
- **DT**
This column reports delta time between timestamped records.
- **Opcode**
This column reports the instruction opcode. This data is already included in the Dasm column so this column is not shown by default.
- **Chan**
Shows the originating ITC channel for an ITC message. This information is included in the Composite Output column.
- **ITCData**
Shows ITC data record data values. This information is included in the Composite Output column.

Trace Control Dialog

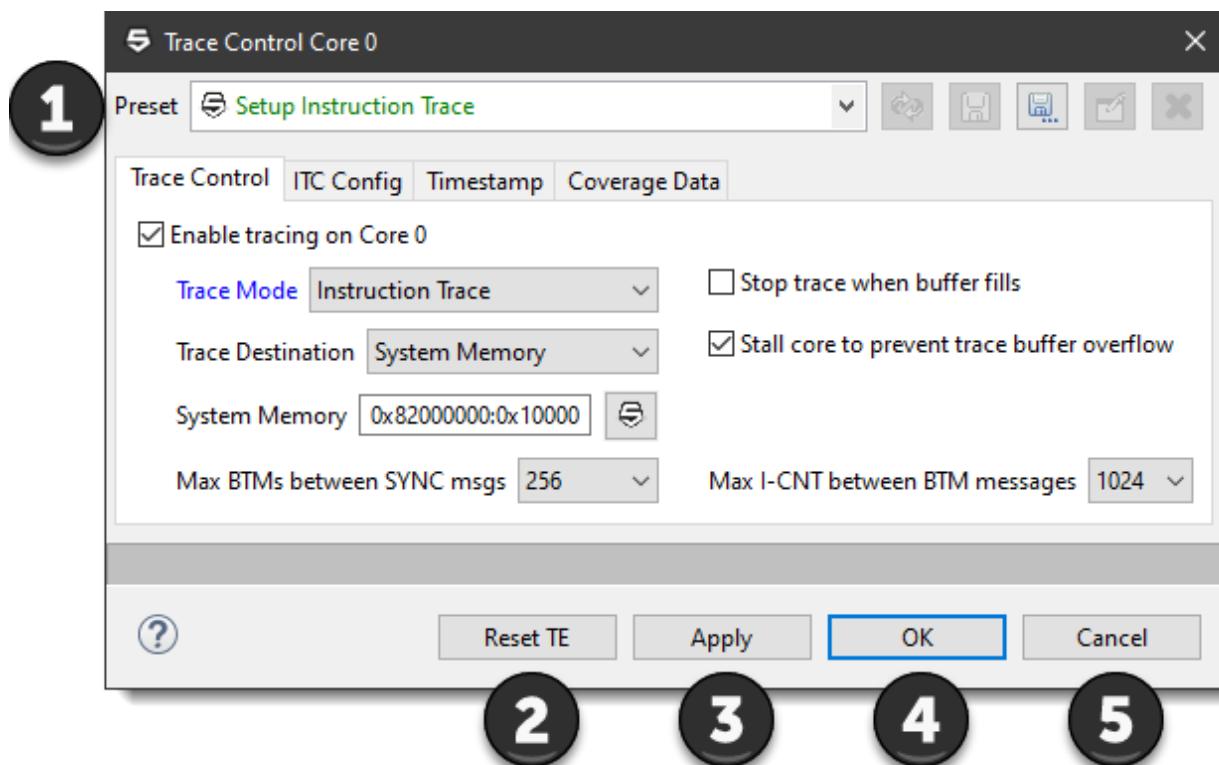
The trace control dialog is where all trace configuration happens. When the trace configuration dialog opens, all trace control state from the target system is loaded. This

ensures that the dialog will always reflect the actual target state when opened. This is especially important if the software running on the target actively manages trace control.

The trace control dialog is generally organized as tabs for each major functional block. If a target system does not contain the functional block (for instance: timestamps), the corresponding tab will not be displayed.

Changes in the Trace Control dialog are not written to the target until either the Apply button or the OK button is pressed. You can cancel any changes by pressing the Cancel button.

Before describing each of the function block tabs, let us go over the general trace controls (those controls outside of the functional tabs)



1. Trace Presets

Trace presets are described in detail in the [Trace Control Presets](#) section.

2. Reset TE Button

This button resets the trace encoder on the target system. This button is applied immediately to the target and is provided as a way to easily reset the trace system when needed.

3. Apply Button

Write any changes you've made to the target without closing the dialog.

4. OK Button

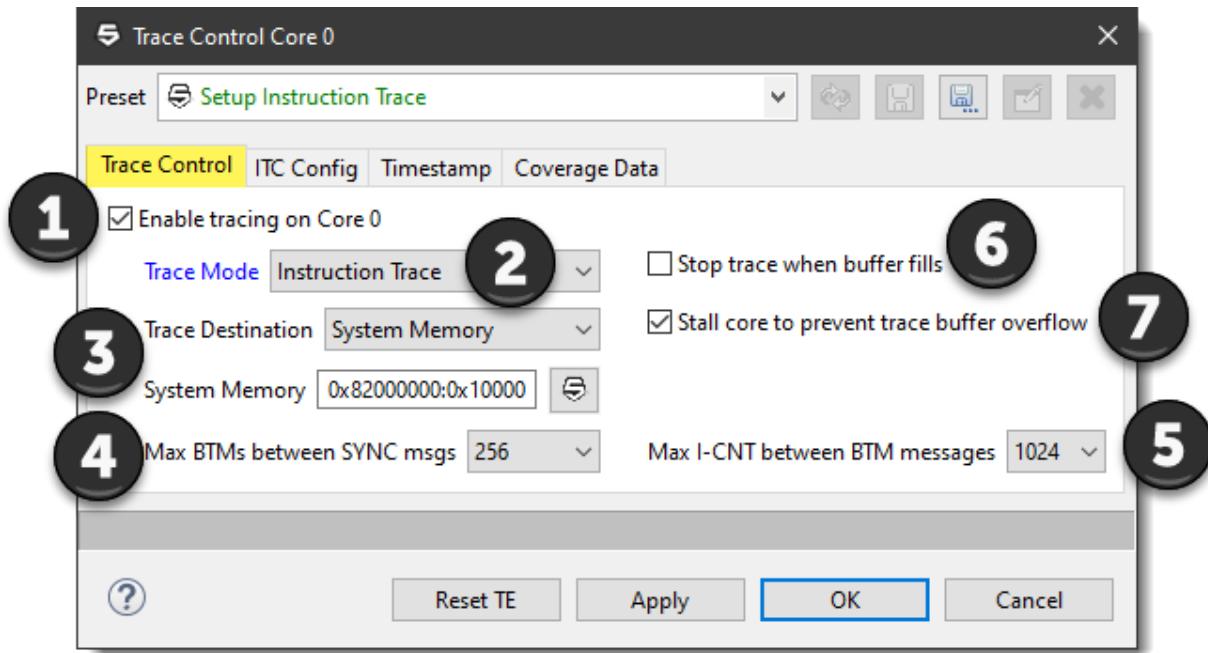
Write any changes you've made and close the dialog.

5. Cancel Button

Closes the dialog without writing any changes to the target.

Trace Control Tab

The Trace Control tab is the primary control center for the trace system. This tab is always present.



1. Enable Tracing on Core X

This check box controls trace encoder enablement on that active core. This is the same as the Core Enable checkbox on the toolbar. Replicated here for convenience.

2. Trace Mode Selector

Select the trace mode. There are three modes available:

a. Instruction Trace

Generates instruction trace capturing instructions executed on the core. ITC messages are also generated.

b. Off (ITC w/o Instructions)

No instruction trace or SYNC messages are generated, but ITC messages are generated.

c. Periodic PC Sampling

Generates SYNC messages periodically as a trace based form of PC sampling. Each SYNC message contains a full PC value. When this mode is selected the "Max I-CNT between BTM messages" controls changes to become "Cycles between PC samples".

3. Trace Destination/System Memory

Control where trace data is stored. Only options present of the target core will be displayed. Options include:

a. **SRAM**

SRAM is a dedicated chunk of RAM on the core. This option must be selected at design time. This option is not displayed if the target core does not have a dedicated SRAM buffer. The buffer size is also specified at design time.

b. **System Memory**

Trace can be captured in system memory. Using system memory allows for specifying where and how much trace should be captured. When this destination is selected the System Memory control must specify both the destination address and size of the trace buffer. In the simplest form this can be specified as “0x<buffer-start-addr>:0x<length>”. This can also be specified symbolically. See the section [Specifying the System Memory Buffer](#) for more detail.

c. **PIB**

Probe Interface Block. Specify this option when trace should be sent to the PIB block. This is used to send trace data to external probes that can capture trace directly to probe or host memory.

d. **ATB**

[Advanced Trace Bus](#) Select this if the target use an ATB to route trace to another device.

4. **Max BTMs between SYNC msgs**

Maximum number of BTMs between periodic Sync messages. A Sync emitted for another reason will reset this timer. For small trace buffers a smaller value should be used otherwise a wrapped trace buffer may not provide much, if any trace, since a SYNC message is required to start decoding trace.

5. **Max I_CNT between BTM message/Cycles between PC Samples**

a. **Instruction trace mode**

The maximum number of instruction messages between BTM messages. A BTM emitted for another reason will reset this timer. The maximum setting is dependent on the configuration.

b. **Periodic PC Sampling mode**

Specifies the number of clock cycles between PC (SYNC) messages.

6. **Stop trace when buffer fills**

Present only in systems with SRAM or System Memory sinks. When checked, disable trace when the trace buffer fills. Use this mode when you want to capture trace starting at the current PC and ending when the buffer fills. Let us call this “trace-from” mode. When unchecked the trace buffer will “wrap” overwriting older trace data with new trace data. This mode ensures that you capture trace up to the current PC when the target halts. Let us call this “trace-to” mode.

The state of this checkbox affects what part of trace is displayed when the target halts. When checked the trace viewer will download and show the beginning of trace. When unchecked the trace viewer will download and show the end of trace.

7. **Stall core to prevent trace buffer overflow**

When checked the core will be stalled in the event the trace encoder cannot accept a new message. This mode ensures that every instruction is captured in trace. This

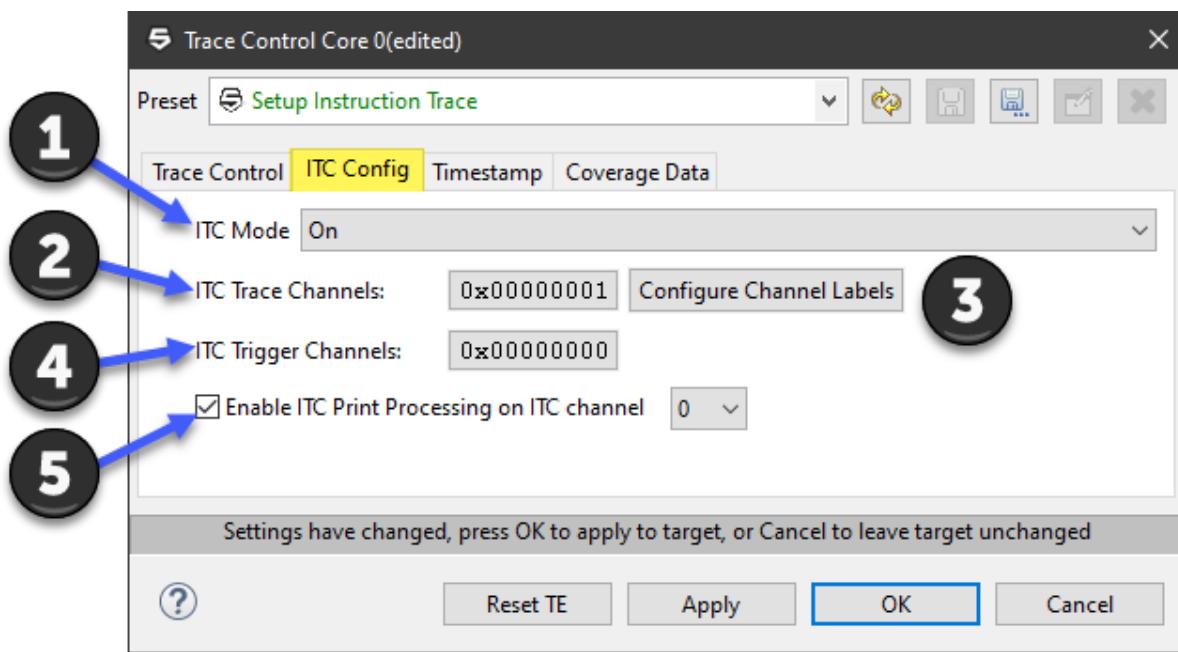
mode may not be acceptable in time-critical applications where stalling the core is unacceptable. When unchecked, an overflow message is generated and trace data upto the next SYNC message will be lost. The Trace Data viewer will indicate when this happens with an overflow record.

ITC Config Tab

The Instrumentation Trace Component allows software running on the target system to inject data into the trace stream. This can be used, for example, to capture the change history of a variable, or to send important variable values along with related trace. ITC can also be used to send “printf” style output.

ITC messages are transmitted on “channels”. There are 32 channels (only 16 physical channels, where channels 16-32 map directly to channels 0-15, but with slightly different behavior.) Data transmitted on channel 0 will also show up on channel 16.

The ITC tab controls everything related to the Instrumentation Trace Component. This tab is not displayed if your target does not include ITC.



1. ITC Mode Selector

The following ITC modes are provided:

a. **None**

ITC message generation is turned off. Instrumented code will not produce ITC messages in trace.

b. **On**

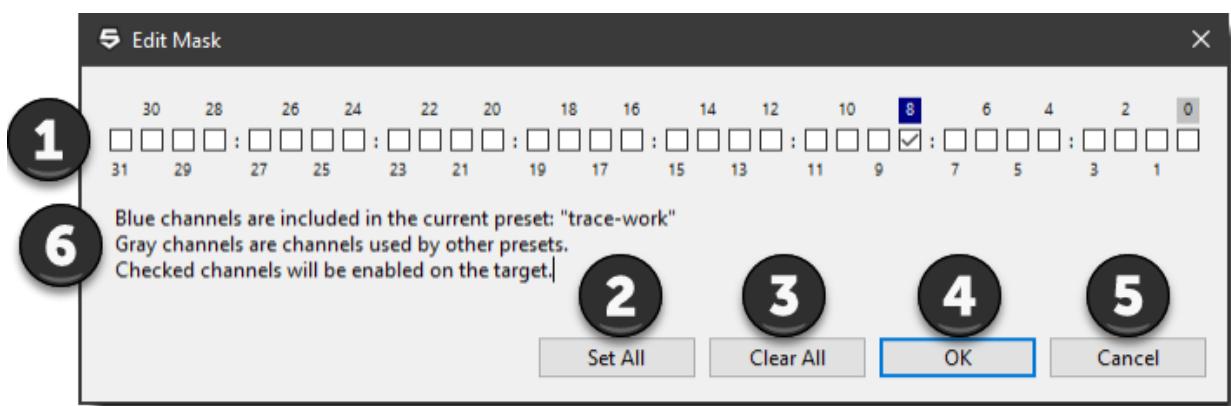
ITC message generation is on. Enabled ITC channels will generate ITC messages in trace.

- c. **Only ownership messages**
All ITC Channels generate ownership messages.
- d. **On and 15/31 generate ownership messages**
Channel 15 generates ownership message with no timestamp
Channel 31 generates ownership messages with a timestamp
All other channels generate not ITC data messages

2. ITC Trace Channel Enables

This field controls which ITC data channels are enabled. The code running on the target may use many ITC channels, but only enabled channels will be encoded in the trace output. This allows for controlling output at debug time rather than compile time.

The channel enable is expressed as a 32bit hex value where each '1' bit denotes an enabled ITC channel. Pressing the button will open the ITC channel editor:

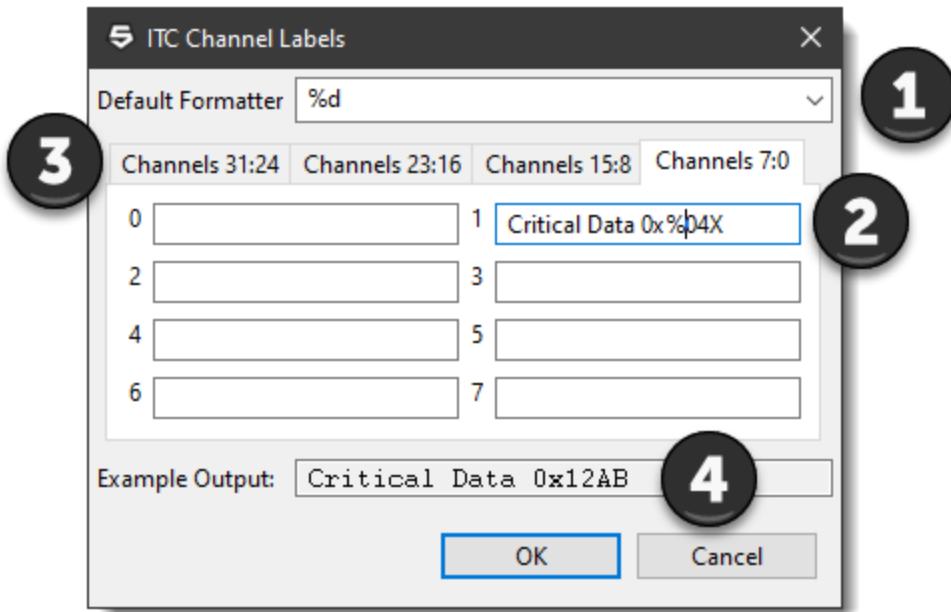


- a. (1) Channel enable checkboxes. A checked channel will generate ITC messages in trace output.
- b. (2) Set All: Enables all channels
- c. (3) Clear All: Disables all channels
- d. (4) Close the dialog, applying the channel enables.
- e. (5) Close the dialog, ignoring any changes made.
- f. (6) Notes describing visual indicators on the dialog.

3. ITC Channel Formatters

Channel formatters can be used to label and format ITC data in the trace viewer. You can assign a different format and label to each channel, as well as a default format and label to any channel that does not have a specific formatter. Formatters are simply printf-style format strings with a single "%d" or "%x" value specifier.

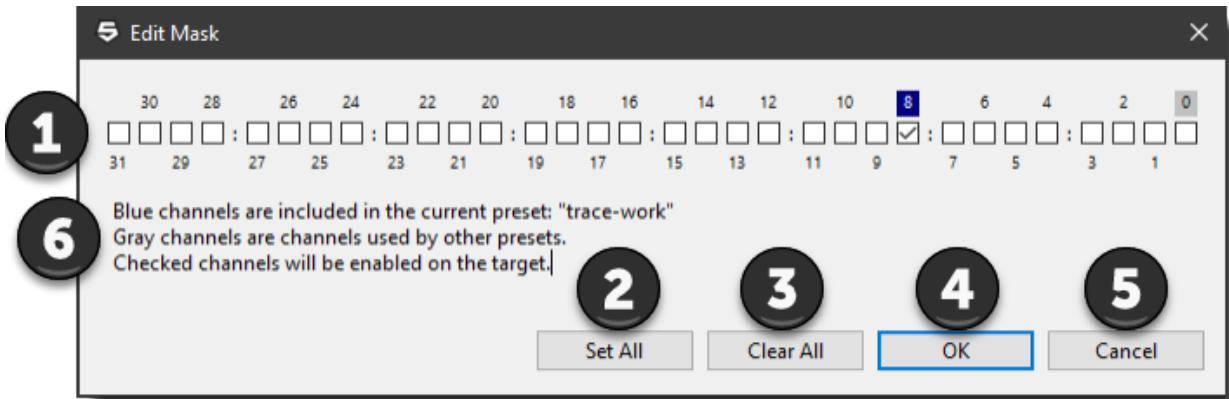
Pressing the button opens the ITC Channel Labels dialog box:



- a. (1) Specify a default formatter. Use the dropdown to select from some predefined formats, or type your own custom format. The example field will show how your formatter will display.
 - b. (2) An example formatter for a specific ITC channel.
 - c. (3) Channel tabs. Use these tabs to navigate among the 32 ITC channels.
 - d. (4) Example output. This box shows how the currently editing channel formatter will be displayed using some sample data. If there is an error in the formatter string, the error message will be displayed here.
4. **ITC Trigger Channels**

This field controls which ITC trigger channels are enabled. The code running on the target may use many ITC channels, but only enabled channels will be encoded in the trace output. This allows for controlling output at debug time rather than compile time.

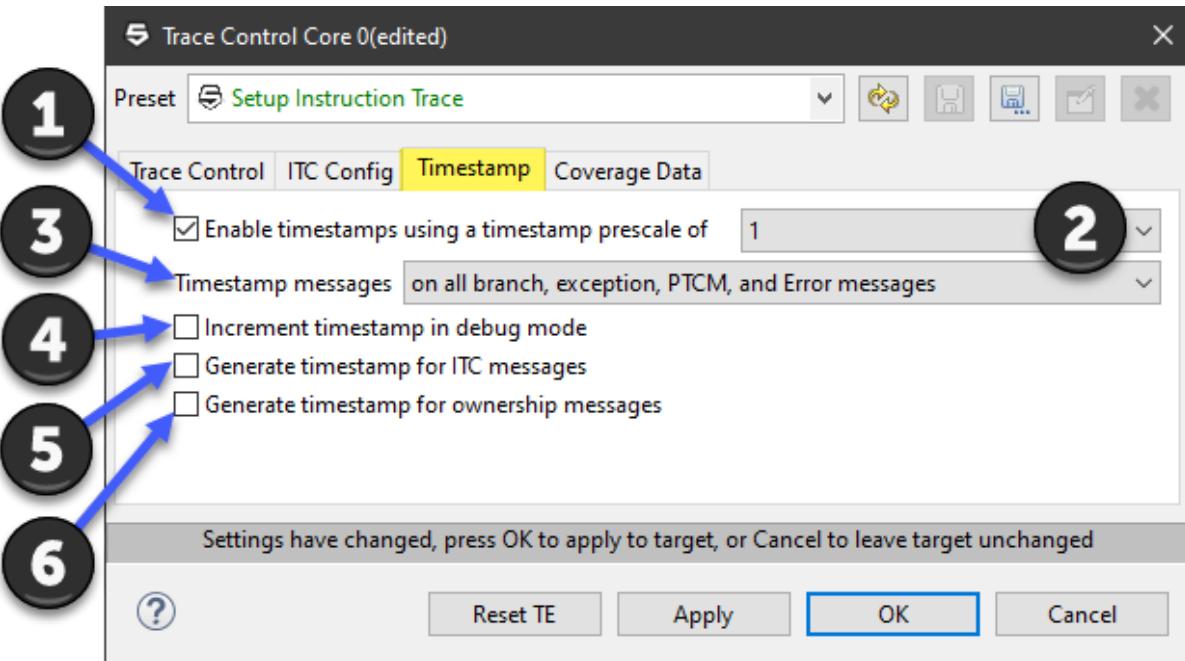
The channel trigger enable is expressed as a 32bit hex value where each '1' bit denotes an enabled ITC trigger channel. Pressing the button will open the ITC channel mask editor:



- a. (1) Channel enable checkboxes. A checked channel will generate ITC trigger outputs.
 - b. (2) Set All: Enables all channels
 - c. (3) Clear All: Disables all channels
 - d. (4) Close the dialog, applying the channel enables.
 - e. (5) Close the dialog, ignoring any changes made.
 - f. (6) Notes describing visual indicators on the dialog.
5. **Enable ITC Print Processing on ITC Channel**
 Use this control to specify which ITC channel will be used for “print” processing.
 Only a single channel can be used to send “print” style messages.

Timestamp Tab

The Timestamp tab controls how and when timestamps are generated on the target. This tab is not displayed if your target system does not include timestamping.



1. Enable timestamp generation

The master switch that controls generation of timestamp data in the trace output for the selected core. When checked, timestamp data will be generated as specified by the remaining controls.

2. Timestamp prescale selection

Prescale timestamp clock by the selected value. The timestamp clock is divided by the selected scale factor, effectively slowing the timestamp clock. This can be useful for measuring longer intervals (the timestamp clock will run longer before wrapping), and allow for using a narrower timestamp (which conserves power).

3. Timestamp message generation mode

This setting determines when (on what types of messages) timestamps are generated. Options are:

- a. are not generated for branch messages
- b. are generated on all indirect branch and exception messages
- c. are generated on all branch, exception, PTCM, and Error messages

4. Increment timestamp in debug mode

When checked the timestamp clock will continue to increment while in debug mode. When not checked, the clock will stop while in debug mode.

5. Generate timestamp for ITC messages

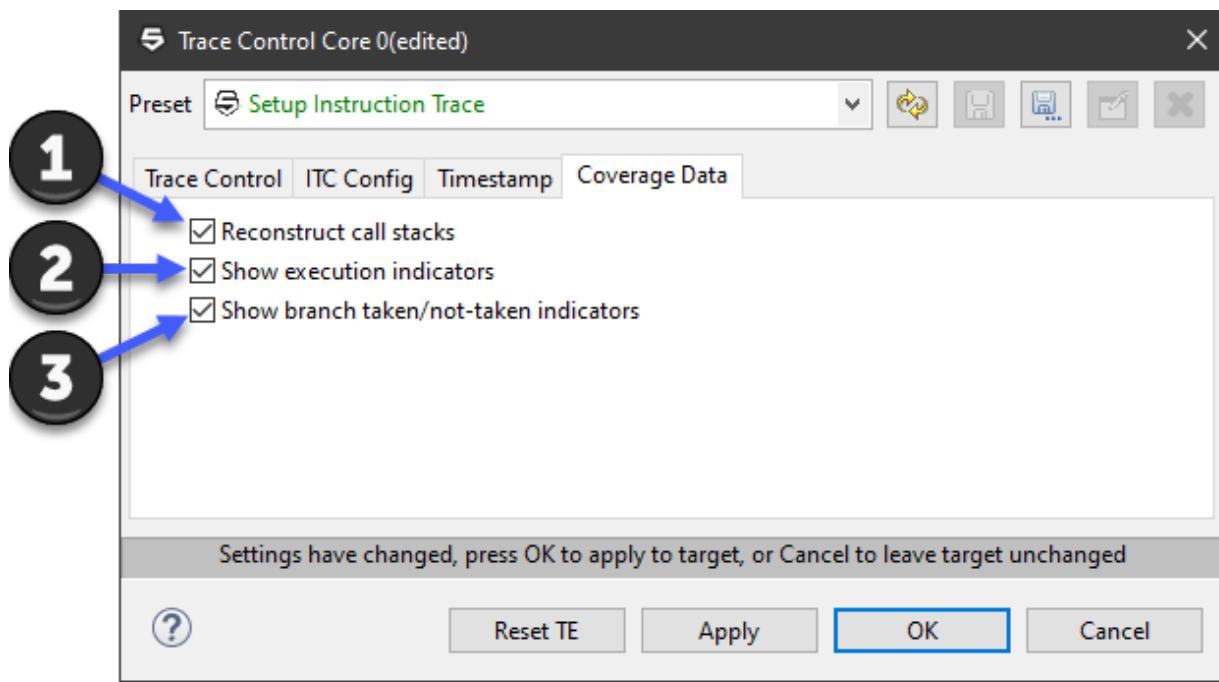
When checked, timestamps will be generated for all ITC messages on channels 16 to 31 (Channels 0-15 do not generate timestamps). When not checked, ITC messages will not include timestamps.

6. Generate timestamp for ownership messages

When checked, timestamps will be generated for all ownership messages. When not checked, ownership messages will not include timestamps.

Coverage Tab

The coverage tab controls generation of code coverage and call stack reconstruction data. The controls on this tab do not directly control any target state. The controls are described here. Trace based code coverage is described in more detail in a later section.



1. Reconstruct call stacks

When checked, call stack data is reconstructed from trace data. Call stack reconstruction lets you examine the call stack from any trace record. This data is required to use the Freedom Studio Call Stack views.

2. Show execution indicators

When checked, execution indicators are displayed in the source editors and disassembly view.

3. Show branch taken/not-taken indicators

When checked, branch taken indicators are displayed in the source editors and disassembly view. Branch taken indicators show, for every branch, whether the branch was always taken, never taken, or fully covered.

Trace Control Presets

Trace control presets allow you to set up custom trace configuration and save them for future use. Trace presets can also be applied at debug launch time to fully configure trace from the start of code execution.

Freedom Studio includes a selection of built-in trace presets that can be used as-is, or as starting points for new presets.

Trace Presets are “cumulative”, meaning that any given preset may only specify a subset of trace settings, and that multiple presets can be applied simultaneously. This allows you to build various custom presets for different use-cases and then apply one or more of them depending on your immediate needs while debugging.

Presets are managed using the control at the top of the trace control dialog.



1. Preset selector

The preset selector is a drop-down list of all known presets. Selecting a preset from the list will update the trace configuration dialog with the setting included in the preset. The selected preset (that is, the one shown in the box) is considered the “Active” preset for editing. Changes made to settings included in this preset can be saved to the preset.

2. Undo preset changes

This button reverts any changes you've made to the selected preset settings while the Trace Configuration dialog is open. This button is disabled for built-in presets as they cannot be edited.

3. Save preset

This button saves any changes you made to the selected preset. This button is disabled for built-in presets as they cannot be modified.

4. Save a new preset

Use this button to create a new preset. See the [Editing & Creating Trace Presets](#)

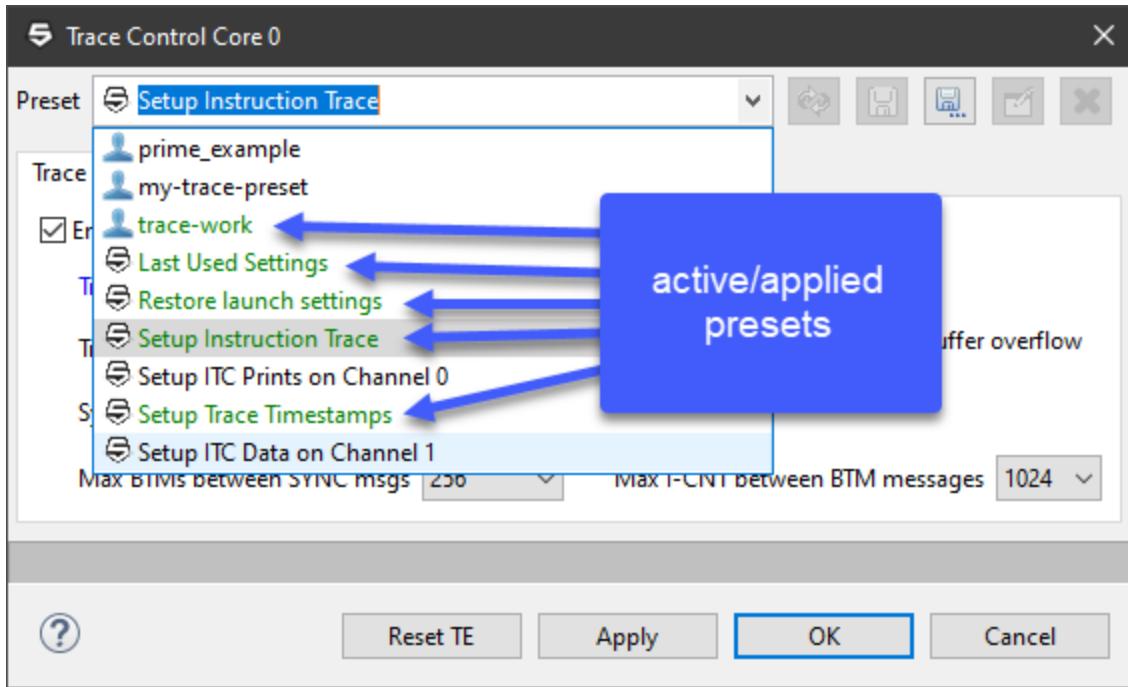
5. Edit Preset Mode Toggle

Edit mode is a special mode for editing which trace control settings are included in a preset. See the [Editing & Creating Trace Presets](#)

6. Delete User Preset

Deletes the selected user preset. This button is disabled for built-in presets.

When dropping down the Preset Selector you may notice that some presets are green while others are black. Green presets are those that match the current trace configuration settings and values. That is, all settings from a blue preset are active and current.



This provides a quick way of verifying which presets have been applied.

Presets with a “person” icon are user defined presets. Those with a SiFive icon are built-in presets.

Special Built-in Presets

There are a selection of special built-in presets that may be handy in some use-cases.

- **Last Used Setting**

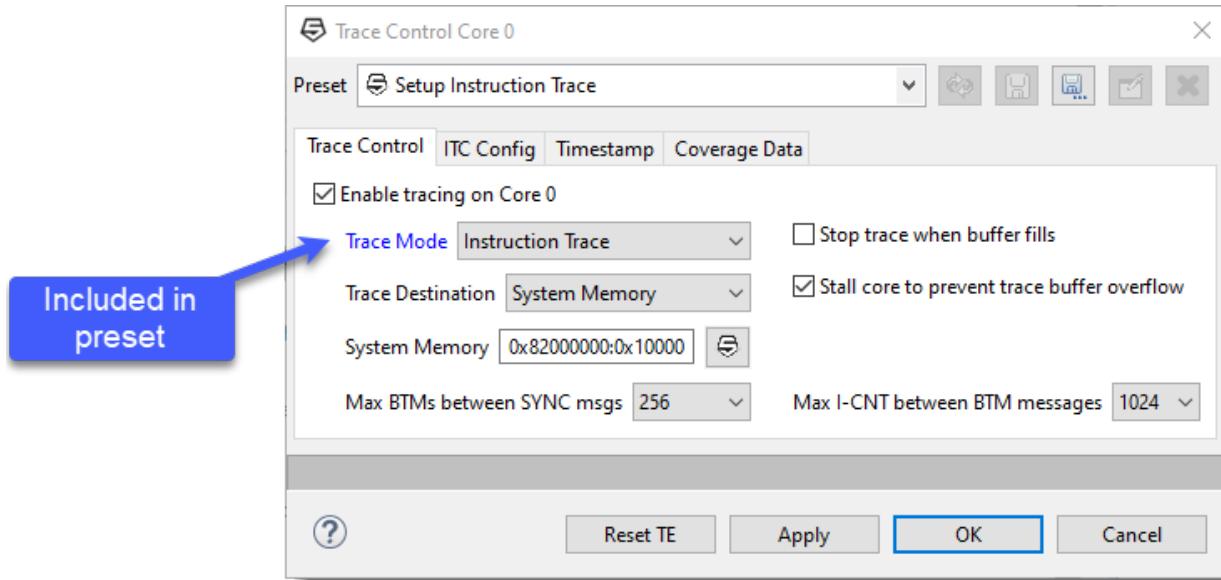
This built-in preset is created each time the Trace Configuration dialog is closed. It contains all of the trace configuration settings that were just written to the target.

- **Launch Settings**

This preset captures all of the trace configuration settings that were applied at the start of the debug session. It is a handy way of “reverting” to the launch settings.

What is included in a Trace Preset

The Trace Control dialog indicates settings that are included in a preset using blue labels. For instance, in this example the built-in “Setup Instruction Trace” preset includes the “Trace Mode” setting because the Trace Mode label is blue.



All other settings (those with black labels) are not included in this preset. Their values remain unchanged when this preset is selected.

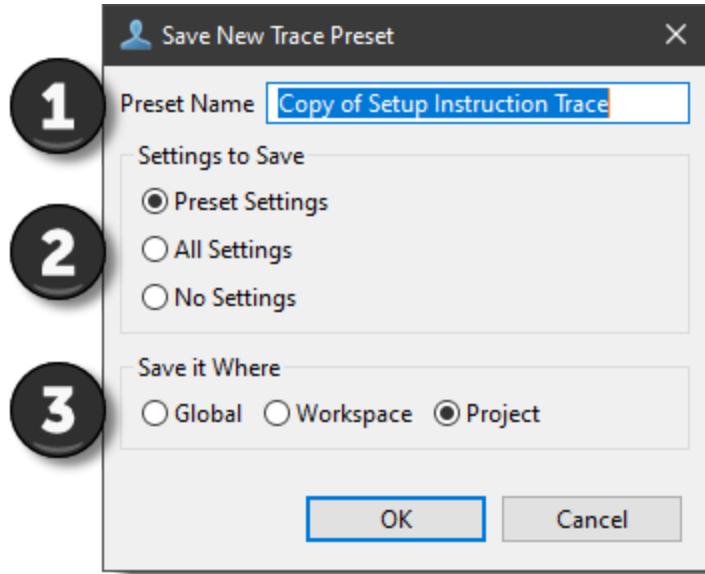
Editing & Creating Trace Presets

Creating Trace Presets

Freedom Studio ships with a selection of basic built-in trace presets. You will quickly want to develop your own custom presets. When creating presets you can start with the settings of an existing preset, start with a blank preset, or start with a preset that includes all trace control settings.

Changes to built-in presets cannot be saved back to the built-in preset. To save these changes you will need to create a new custom preset.

To create a new preset press the New Preset button to open the new preset dialog.



1. Preset Name

Give your new preset a meaningful name. This is the name that will be listed in the preset selector drop-down.

2. Settings to Save

These radio button determine which setting will initially be included in the preset:

a. Preset Settings

If a preset was selected when this dialog is opened, then this option will be enabled and selecting it will include all settings from the current preset into the new preset. Once created you can simply add or remove settings, and change setting values as needed.

b. All Settings

Selecting this option will include all trace control settings (and values) in the preset. Use this if you want to simply save everything into a single preset. Once created you can easily remove specific settings if desired.

c. No Settings

Start with a blank preset that includes no setting (and no values). Use this when you want to create a new preset that does not easily derive from an existing preset. After you have created a blank preset you need to add settings to the preset before it will be useful.

3. Save it Where

Trace presets are saved as simple text files. Trace preset can be saved to different locations depending on the desired scope of usage:

a. Global

Global presets are saved in a subfolder of the Freedom Studio installation folder. These presets are available in any workspace associated with the Freedom Studio installation.

b. Workspace

Workspace presets are saved in the workspace metadata folder and are

available to all projects in the workspace. They are not available to projects in other workspaces.

c. **Project**

Project presets are saved in the project .settings folder and are only available in the project. This is the best option if you want to commit a trace preset setting so a revision control system so that other users will have access to it.

Once you save your new preset it becomes the selected and active preset in the Trace Control dialog. You can now add or remove settings and update the values of included settings. Remember to save any changes you make to settings inclusion or setting values.

Editing Trace Presets

There are two aspects to editing trace presets. The first is simply editing the value of a trace preset setting. This is simple. Just change the setting value to the desired value and save the preset.

The second aspect is adding or removing settings from the preset. There are three ways to do this:

1. **Ctrl-click on the Settings Label**

Ctrl-clicking on a setting label will toggle inclusion of the setting in the selected/active preset. You will see the label color toggle between the blue (indicating inclusion) and black (not included). This is the easiest way to manage which settings make up a preset.

2. **Use Edit Mode**

Pressing the Edit Mode button in the Preset Control area causes the Trace Control dialog to enter “edit” mode. In edit mode all trace settings gain a checkbox next to the label. The checkbox state indicates inclusion (check) or exclusion (not checked). While in edit mode, setting values cannot be changed.

3. **Edit the Preset Settings File in a Text Editor**

For adventurous users only! If you hold the Ctrl key down when pressing the Edit Mode button Freedom Studio will open the preset file in a text editor. Now you can edit the preset file directly. Be forewarned, it is easy to render the preset unusable by making bad edits. Many comments are provided to help guide you, but you are really on your own here.

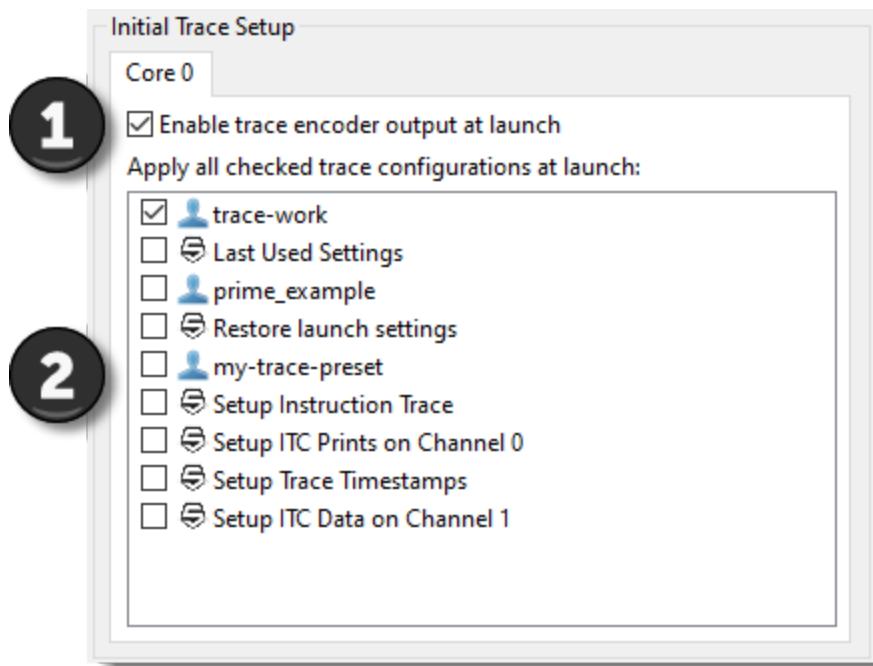
Every setting in the Trace Control dialog can be included in a preset. ITC Trace Channels and ITC Trigger Channels can be included/excluded in a preset on an individual channel basis. So you can have one preset that configures channels 1,3, and 5; and another preset that configures channels 2 and 4. These presets can be applied simultaneously without interfering/overwriting each other. Configuring preset channels is done the same way as any other preset setting, but you do need to open the channel editor to do so.

ITC Channel Formatters are also stored in the preset. In this case a given ITC channel formatter is considered included in the preset when the corresponding ITC channel is included.

Tracing at Startup

Trace can be configured at the start of a debug launch so that no user intervention is required to configure and enable tracing.

The Debug Launch Configuration dialog Startup Tab has controls for enabling and configuring trace on all cores. Look for the **Initial Trace Setup** section:



On a single core target there is only one tab (for Core 0). Multi-core target will include a tab for each core. Each core's trace can be configured independently. On a multi-core target you have the option to apply the same trace configuration setting to all cores, or different settings to each core.

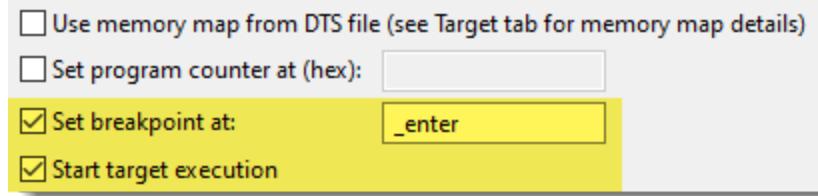
1. Enable trace encoder output at launch

This checkbox tells Freedom Studio to enable (or disable) the trace encoder for the indicated core at launch.

2. Preset List

Any checked presets will be applied to the target at launch. Note that if you do not check any presets, then the current target settings will be used.

The trace configuration is programmed to the target after the target halts and hands control to the debugger. Typically this will be after hitting the temporary breakpoint at `main()`. If you want to trace the code execution starting at the program entry point the debug launch needs to be configured differently. On the Debug Launch Configuration dialog Startup tab, make these settings:



Now the target will halt at `_enter` and the trace configuration will be programmed. Go ahead and set a normal breakpoint at the entry to `main()` and run the target. You will capture the entire startup sequence in trace. This is a great way to get familiar with the startup sequence.

Specifying a System Memory Buffer

When storing trace data to system memory the trace encoder must be configured to know where the buffer starts and how big the buffer is. This can be done in code (requiring code to do so). Or it can be done at the beginning of a debug session using a trace preset.

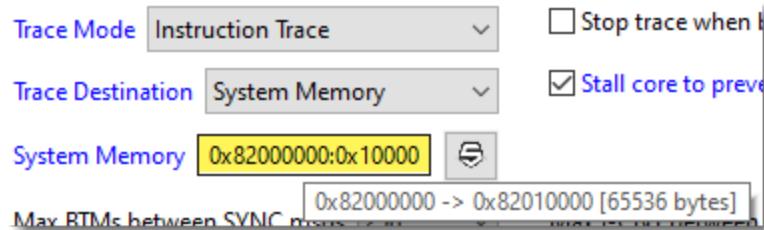
Below are three methods of specifying a system memory buffer for the trace-encoder using Freedom Studio.

Use a hard coded address and length

This is perhaps the easiest method to configure, but it does require detailed knowledge of the target memory map. Use this method to specify that absolute start address and length of the trace buffer. Just be very sure that no other code or data will be placed in this region.

Specify the region as `0x<start-address>:0x<length>`

For example:



In this example I'm absolutely sure that no code or data will be located in the specified memory.

Reserve a Section using the Linker Script

This is the best method as it ensures (automatically) that the linker will not place code or data into the section dedicated for trace capture. It is also the most complicated method to setup initially. Using this method you will create a dedicated section in the memory map, define linker symbols that denote the start and end address of the buffer, then use these symbols in the trace configuration to configure the trace encoder.

First (optional) create a copy of the linker script. In most cases this will be a copy of `metal.default.lds` (it is located in the `bsp` folder of any example software project). Call the copy something like `metal.trace.lds`

Now modify your makefile to use this linker script. In an example software project you will want to edit the Makefile in the project root folder. For instance, make the following edit:

```
ifeq ($(LINK_TARGET),)  
LINK_TARGET = defaulttrace  
endif
```

Now open `metla.trace.lds` in the text editor and add the highlighted text to the “MEMORY” block:

```
MEMORY  
{  
    itim (airwx) : ORIGIN = 0x1800000, LENGTH = 0x8000  
    ram (arw!xi) : ORIGIN = 0x80000000, LENGTH = 0x10000000  
    rom (irx!wa) : ORIGIN = 0x40400000, LENGTH = 0xc00000  
/*  
 * Reserve 64KB for trace-encoder  
 */  
    trace (arw!xi): ORIGIN = 0x82000000, LENGTH = 0x10000  
}
```

Adjust the address and length to suit your target system.

Just below the “MEMORY” block is the “PHDRS” block. Add the highlighted text:

```
PHDRS  
{  
    rom PT_LOAD;  
    ram_init PT_LOAD;  
    tls PT_TLS;  
    ram PT_LOAD;  
    itim_init PT_LOAD;  
/*  
 * Do not load this section  
 */  
    trace PT_NULL;  
}
```

At the very bottom of the file (just before the last closing brace) add this highlighted text:

```
.heap (NOLOAD) : ALIGN(4) {  
    PROVIDE( __end = . );  
    PROVIDE( __heap_start = . );  
    PROVIDE( metal_segment_heap_target_start = . );  
    /* If __heap_max is defined, grow the heap to use the rest of RAM,
```

```

        * otherwise set the heap size to __heap_size */
        . = DEFINED(__heap_max) ? MIN( LENGTH(ram) - (. - ORIGIN(ram)) ,
0x10000000) : __heap_size;
        PROVIDE( metal_segment_heap_target_end = . );
        PROVIDE( __heap_end = . );
        PROVIDE( __heap_end = . );
} >ram :ram



```

You are done with the linker script. Save it and go back to the makefile. We will configure the build to not remove the tb_start and tb_end symbols. Add the highlighted text:

```

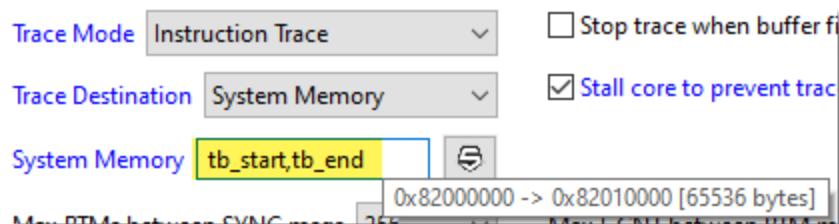
RISCV_LDLIBS += -Wl,--start-group -lc -lgcc -lm -lmetal $(LIBMETAL_EXTRA)
-Wl,--end-group

# Dont remove this symbol
RISCV_LDLIBS += -u tb_start -u tb_end

```

A full rebuild is required. Save the makefile and do a full clean and rebuild.

Now, in the Trace Configuration dialog you can specify the trace region as:



Use a static char buffer allocated in code

You can define a large static char[] in your code. For instance:

```
char trace_area[4096] __attribute__ ((aligned (8)));
```

This defines a 4KB buffer that can be used to capture trace. But the linker will likely remove this symbol since it will be detected as unused. You need to configure the build to not remove this symbol. You can do this in code by simply creating a “use” of it, like this:

```
int main() {
```

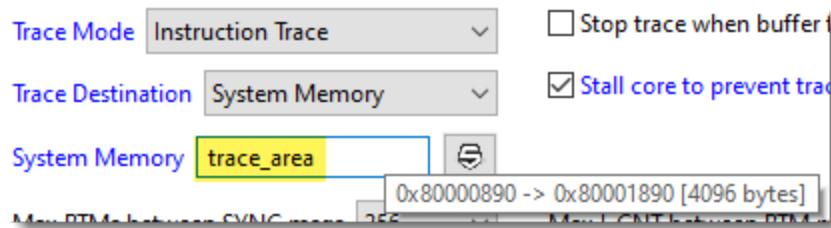
```
    trace_area[0]=0;  
    primes();  
}
```

Where simply writing a 0 to the first element is enough to convince the toolchain not to remove the symbol.

Or you can modify the Makefile to provide “-u trace_area” to the linker, for instance:

```
# Do not remove this symbol  
RISCV_LDLIBS += -u trace_area
```

With such an array defined (and not removed), you can specify this in the trace configuration dialog as:



When applied to the target, trace will be written to the specified memory region. Hovering the mouse pointer over the box will display a tooltip with the resolved address and length of the buffer.

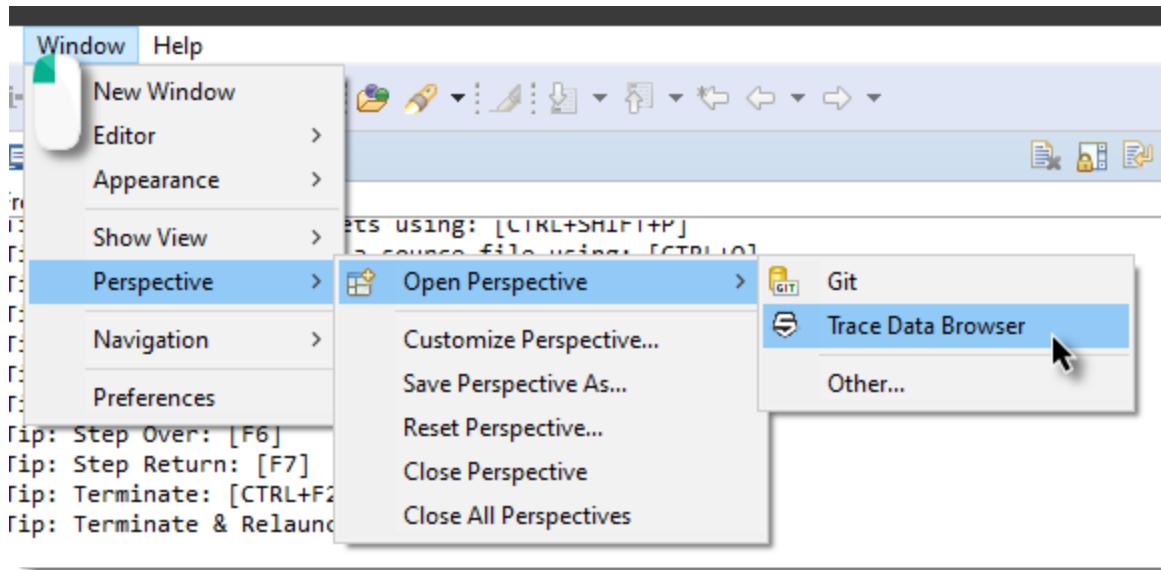
WARNING

The main drawback of this approach is that you cannot use it to trace startup code. A buffer allocated in this way get initialized to 0s during startup. If the trace encoder is writing to the buffer while the startup code is also writing to the buffer, the trace data will be corrupt.

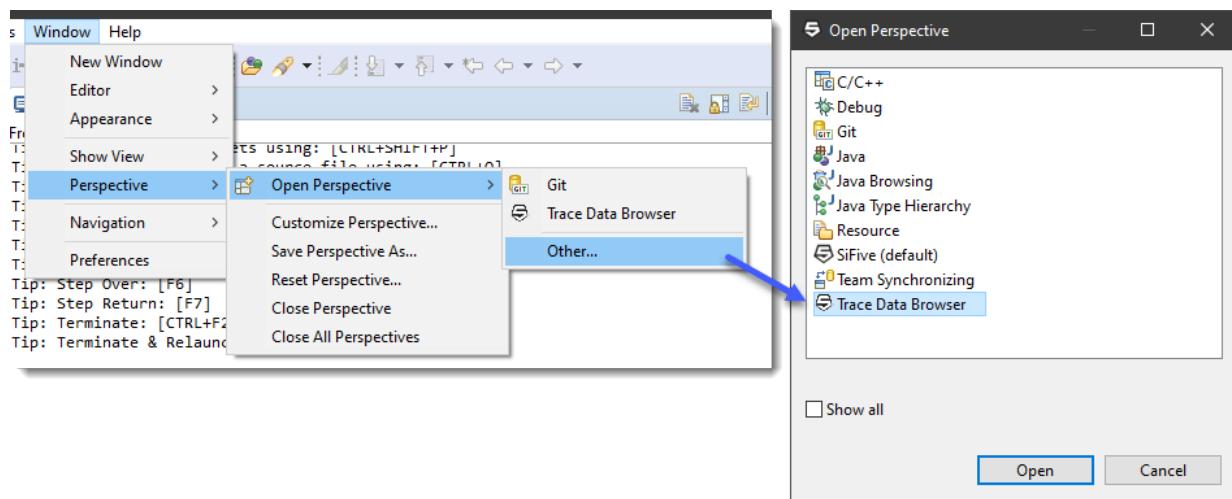
Trace Perspective

Freedom Studio provides a dedicated perspective for examining trace data. Using this perspective is entirely optional, but provides a cleaner workspace with most of the normal debug views removed.

If you are in the SiFive or Debug perspectives, you can open the Trace Data Browsing perspective from the Window → Perspective → Open Perspective → Trace Data Browser



From any other perspective, you can open the Trace Data Browser using Window → Perspective → Open Perspective → Other... and selecting the Trace Data Browser from the list.



The perspective toolbar provides quick access to the Open Perspective dialog.

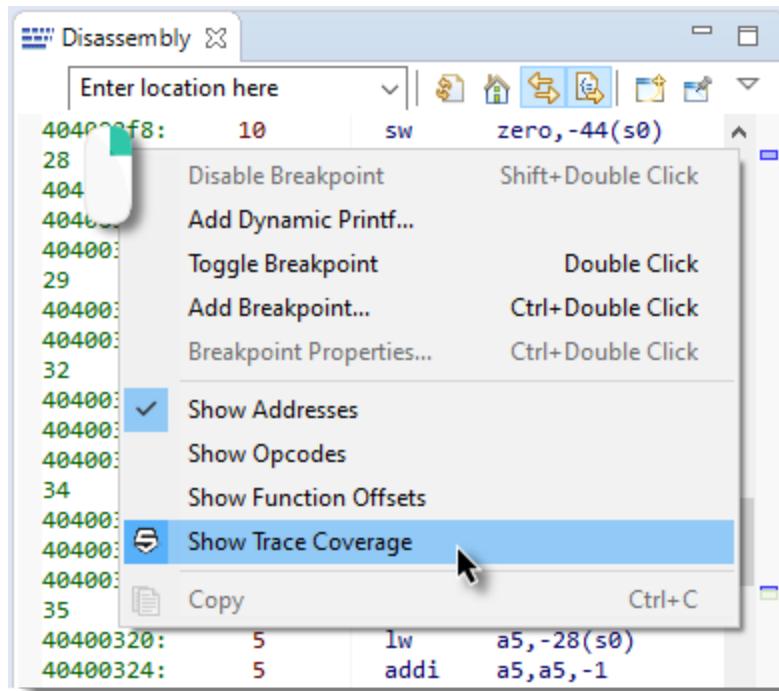


Trace-based Code Coverage

Code execution and branch taken/not-taken coverage data can be reconstructed from trace data. The following Trace Configuration settings are required:

- **Trace Control : Trace Mode : Instruction Trace**
- **Coverage Data : Show execution indicator**
- **Coverage Data : Show branch taken/not-taken indicators**

By default the Disassembly view does not display the coverage ruler. You can turn this on by right-clicking on the “address” column and selecting “Show Trace Coverage”



This screenshot shows examples code execution and branch coverage indicators:

The screenshot displays two windows from a debugger. On the left is the 'main.c' source code editor, and on the right is the 'Disassembly' window.

Source Code Editor (main.c):

- Execution indicator:** A green gutter marker on the left indicates executed source lines.
- Branch coverage icons:** Blue arrows point to specific branches in the code:
 - branch always taken:** An arrow points to the first iteration of the inner loop.
 - branch fully covered:** An arrow points to the condition of the inner loop.
 - branch never taken:** An arrow points to the condition of the outer loop.

Disassembly Window:

- instruction exec counter:** A blue box highlights the instruction at address 40400312, which is 10. This is also indicated by a green bar above the instruction in the assembly view.
- branch coverage gauge/percent:** A blue box highlights the instruction at address 40400312, which has a value of 50.0. This is also indicated by a red bar above the instruction in the assembly view.

Executed source lines are indicated (by default) using a green gutter marker on the left hand gutter in source editors. The color can be changed in Preferences.

Executed instructions in the disassembly view are indicated using counts.

Branch coverage in source files is indicated with gutter icons that indicate always-taken, never-taken, and fully-covered (as shown in the screenshot above).

Branch coverage in the disassembly view is indicated using a bar gauge where green indicates the percentage taken, red indicates the percentage not-taken. And a percentage taken value is displayed at the right edge of the gauge.

Trace Call Stacks

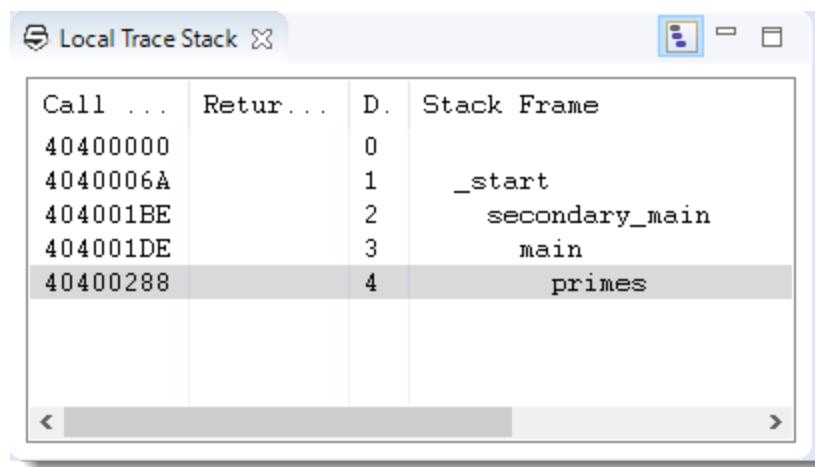
Call stack information can be reconstructed from trace data. The following Trace Configuration settings are required:

- **Trace Control : Trace Mode : Instruction Trace**
- **Coverage Data : Reconstruct call stacks**

Freedom Studio includes two viewers to display reconstructed call stack information. Both call stack views react to selection of trace records in the Trace Viewer.

Local Call Stack View

The Local Call Stack view shows the call stack above the currently selected trace record. Each frame in the call stack also shows the address where the frame was called from, and the address where the frame returns to. You can click on the called-from and return-to addresses and the corresponding trace frame will be selected in the Trace Viewer (and if editor synch is enable the source and disassembly views will also show the context of the trace record)



A screenshot of the "Local Trace Stack" window. The window has a title bar with the title "Local Trace Stack" and standard window controls. The main area is a table with four columns: "Call ...", "Retur...", "D.", and "Stack Frame". The table contains the following data:

Call ...	Retur...	D.	Stack Frame
40400000		0	
4040006A		1	_start
404001BE		2	secondary_main
404001DE		3	main
40400288		4	primes

The stack frame column can be displayed with an indent or flat using the toolbar button.

Full Call Stack View

The Full Call Stack view shows the entire call-stack reconstruction from trace. You can follow the calling hierarchy up and down the call stack from the beginning of trace to the last instruction traced. Each frame in the call stack also shows the address where the frame was called from, and the address where the frame returns to. You can click on the called-from and return-to addresses and the corresponding trace frame will be selected in the Trace Viewer (and if editor synch is enable the source and disassembly views will also show the context of the trace record)

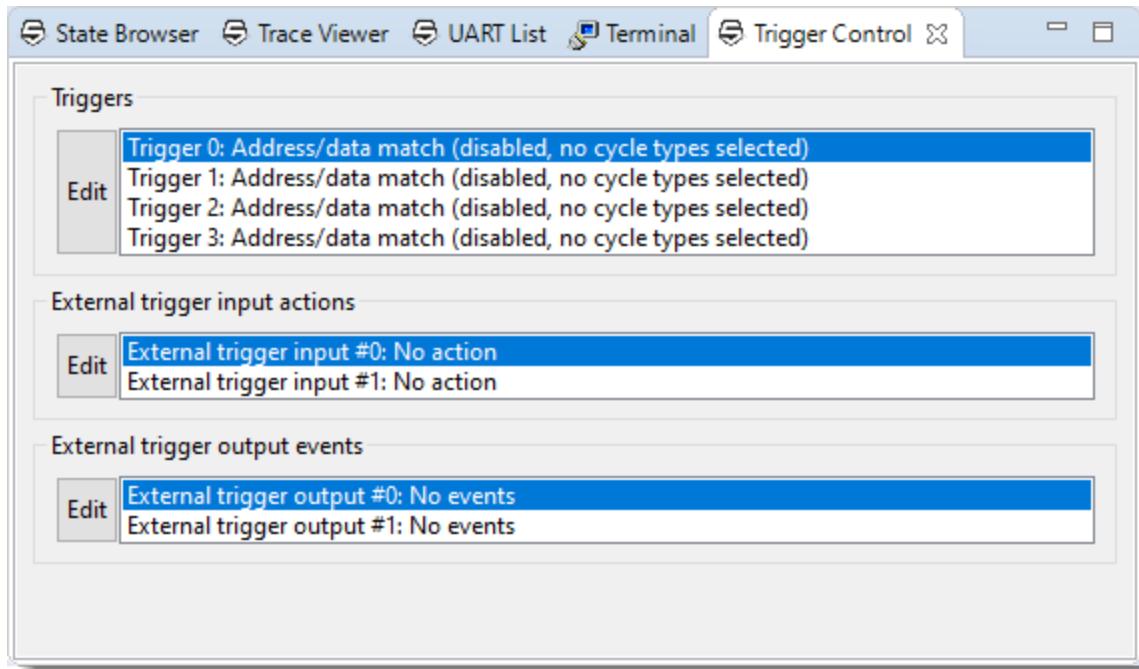
Full Trace Stack

Call ...	Retur...	D.	Stack Frame
40400000		0	
4040006A		1	_start
40400154	40400156	2	atexit
40400156	40400158	2	__libc_init_array
40400160	40400162	2	atexit
40400162	40400164	2	metal_init_run
40400676	40400678	3	metal_init
404005CA	404005CC	4	metal_tty_init
40400202	40400204	5	metal_uart_init
404006B6	404006B8	6	__metal_driver_sifive_uar
40403CA0	40403CA4	7	__metal_driver_sifive_i
40403CAC	40403CB0	7	__metal_driver_sifive_i
40403CDE	40403CE0	7	metal_clock_register_pc
40403DC6	40403DC8	8	__metal_clock_append_t
40403D04	40403D06	7	metal_clock_register_pc
40403DF6	40403DF8	8	__metal_clock_append_t
40403D10	40403D14	7	metal_uart_set_baud_ra
404006E2	404006E4	8	__metal_driver_sifive
40403AFE	40403B00	9	__metal_driver_sif:
40403B0A	40403B0C	9	__metal_driver_sif:
40403B2C	40403B2E	9	__metal_driver_fixe
40403FBE	40403FC0	10	__metal_driver_f:
40400164	40400166	2	__metal_synchronize_harts
404001BE		2	secondary_main
404001DE		3	main
40400288		4	primes

The stack frame column can be displayed with an indent or flat using the toolbar button.

Hardware Triggers

The Trigger Control View allows configuration of target platform hardware triggers. The Trigger Control View enumerates all trigger resources on the target system.



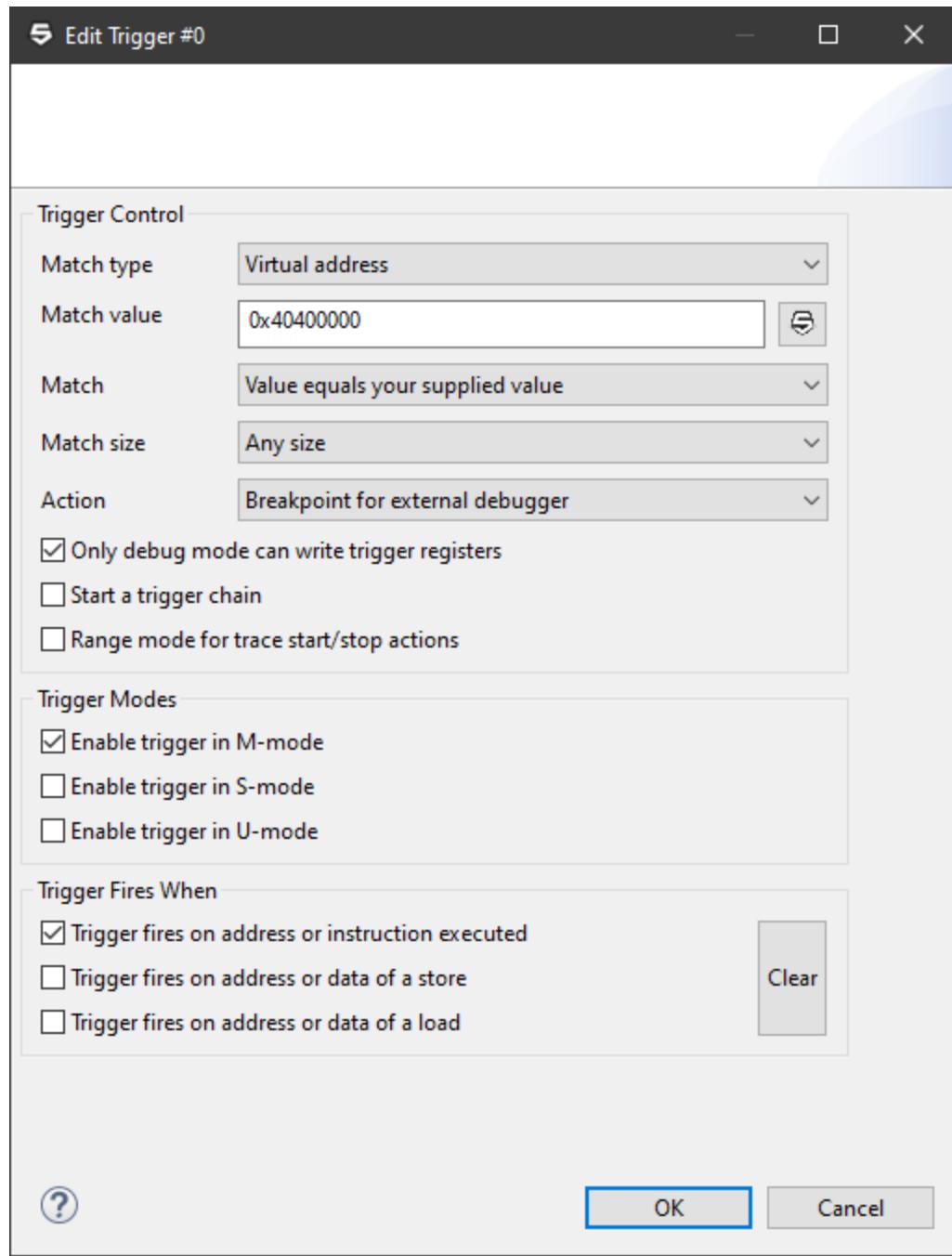
How to configuring a trigger using either:

- Double-click on a trigger line.
- Select the trigger, then press the “Edit” button on the left side of the list.

Configuring a trigger opens the Trigger Configuration dialog for the selected trigger..

Configuring Triggers

While simple hardware breakpoints are automatically supported via normal breakpoints, advanced configuration of hardware triggers must be done using the Trigger Configuration Dialog.



- **Match Type**

Determines the type of match required for this trigger. Only options available on the target will be selectable. Option are:

- **Virtual Address**

A trigger is considered matched when the virtual address is matched.

- **Data loaded/stored or instruction executed**

A trigger is considered matched when a load or store occurs and the data value being loaded or stored is equal to the match value. It is also considered matched when an instruction is executed and the instruction encoding is equal to the match value.

- **Match Value**

This is the address that must be matched in order to fire an address trigger, or a data value that must be matched in order to fire a data trigger. You can enter a hex address or data value, or you can use the Symbol Picker dialog (via the SiFive button) to find and select a symbol from the ELF file.

- **Match**

This field determines how a match is made. Only options supported on the current target will be selectable. Options are:

- Value equals your supplied value
 - Top M bits of value match those of your supplied value
 - Value is greater than or equal to your supplied value
 - Value is less than your supplied value
 - Lowerhalf(value) & upperhalf(yourvalue) == lowerhalf(yourvalue)
 - Upperhalf(value) & upperhalf(yourvalue) == lowerhalf(yourvalue)

- **Match Size**

Determines the size of the match required in order to qualify the trigger. Only options available on the target will be selectable. Option are:

- Any Size
 - 8 bit
 - 16 bit
 - 32 bit
 - 48 bit
 - 64 bit
 - 80 bit
 - 96 bit
 - 112 bit
 - 128 bit

- **Action**

Determine what action is taken when this trigger fires. Only options supported on the current target will be selectable. Options are:

- **Breakpoint for on-target debugger**

- **Breakpoint for external debugger (i.e. OPenOCD, JLink)**

Use this action for normal Freedom Studio debug session triggers

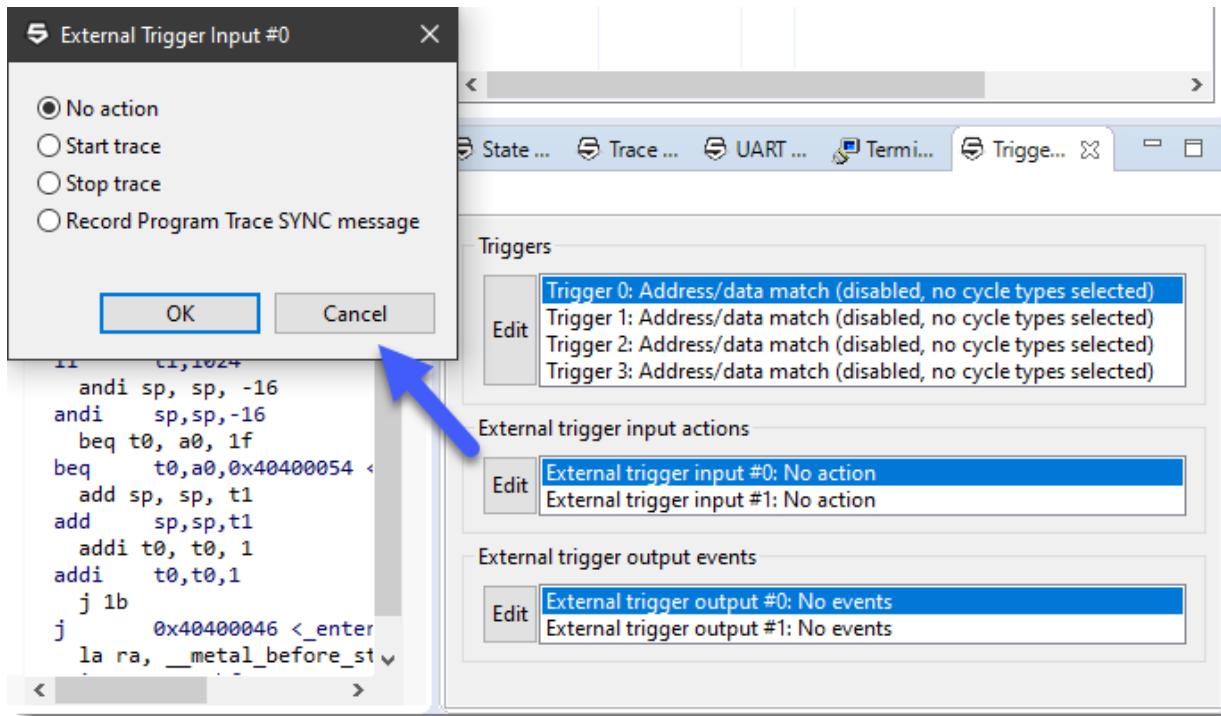
- **Start trace**

- **Stop trace**

- **Record program trace Sync message**
 - **Generate an External Trigger Out**
- **Only debug mode can write trigger registers**
Selecting this option reserves the trigger registers exclusively for the external debugger driving the Debug module; machine mode software won't be able to write to the trigger registers. This is the recommended option except for very specialized and uncommon cases (e.g. the software being debugged is a machine-mode debug agent).
- **Start a trigger chain**
Form a chain between the current trigger with the trigger at the next highest trigger index, which itself may in turn be chained with its successor (although cores may limit maximum chain length, in which case the checkbox will refuse an attempt to 'check' it). The largest-indexed trigger in a chain is the trigger whose actions will be fired if and only if all triggers in the chain have met their match criteria.
- **Range mode for trace start/stop actions**
Select this option to set up trace start/stop matched pair action across the range of addresses associated with this trigger (and predecessor if part of a chain), and specify "Start trace" as the trigger action. This scenario doesn't require an explicit "Stop trace" action, but rather the corresponding trace stop will be implicit when execution leaves the trigger match area. Another possibility is to leave this option unchecked, and specify "start trace" and "stop trace" actions on separate triggers or chains, explicitly, although that will generally tie up more trigger slots.
- **Trigger Modes**
Triggers can be configured to trigger only in the selected modes. Check the modes that you want to trigger to fire in.
- **Trigger fires on address or instruction executed**
Fire the trigger if an instruction fetched from an address of interest, or with a specific encoding of interest, executes.
- **Trigger fires on address or data of a store**
Fire the trigger if data is stored to an address of interest, or if a particular value of interest is being stored to any address.
- **Trigger fires on address or data of a load**
Fire the trigger if data is loaded from an address of interest, or if a particular value of interest is being loaded from any address.
- **Clear**
The [Clear] button simply clears the three mode checkboxes, effectively disabling the trigger.

Configuring External Trigger Inputs

External trigger inputs (if present on the target design) can be configured to start or stop trace; or record a sync in trace output. When configuring an external trigger input you can select the desired action:



- **No action**

No action is taken, effectively disabling this input signal.

- **Start trace**

Start tracing when the input signal is asserted.

- **Stop trace**

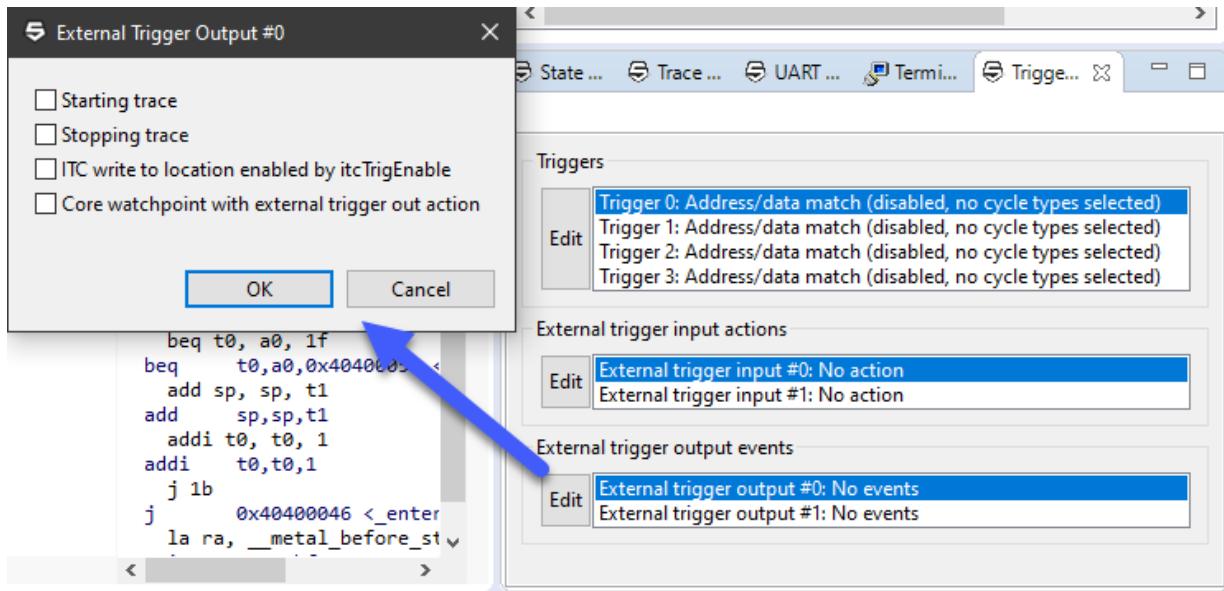
Stop tracing when the input signal is asserted.

- **Record Program Trace SYNC message**

Records a SYNC message into the trace stream when the signal is asserted.

Configuring External Trigger Outputs

External trigger outputs (if present on the target design) can be configured to assert an external signal when specified conditions are met. The external trigger output dialog allows configuration of these conditions:



- **Starting Trace**

This option asserts the external trigger signal when trace is started.

- **Stop Trace**

This option asserts the external trigger signal when trace is stopped.

- **ITC write to location enabled by itcTrigEnable**

itcTrigEnable is a 32-bit bitmap register with 1's in positions that correspond to ITC stimulus registers that you want to cause an external trigger out when written. For those stimulus registers that are enabled in this way, all external trigger out with this box checked will fire when that stimulus is written. You need to program both the source (itcTrigEnable) and sink (xtoControl) to actually generate a trigger.

- **Core watchpoint with external trigger out action**

When a core watchpoint is hit, and programmed with the action "Generate an External Trigger Out" all triggers with this checkbox checked will fire.

State Browser

The State Browser provides a view for browsing the registers and register fields of all the peripherals in the system under debug and for reading and writing their state.

The screenshot shows the State Browser window with a table of peripheral registers. The columns are Name, R, Dec, Hex, Offset, and Description. A context menu is open over the 'Description' column for the first row of the 'sifive_test0_0' section. The menu items are:

- Write State
- Read State
- Read State and Enable State Refresh
- Enable State Refresh
- Disable State Refresh
- Table Customization
- View Table Report
- View Selected Cell Data
- Copy Selected Cell Data
- Copy Selected Row(s) - Ctrl-C
- Copy Selected Column - Ctrl-Shift-C

The table data includes:

Name	R	Dec	Hex	Offset	Description
peripherals					
sifive_test0_0					Fro
sifive_aon0_0					Fro
sifive_fe310_g000_pr...					Fro
riscv_clint0_0					Fro
riscv_plic0_0					Fro
sifive_pwm0_0					Fro
sifive_gpio0_0					Fro
input_val		0	0x0	0x10012000	Pin
input_en		0	0x0	0x10012004	Pin
output_en	R	26624	0x6800	0x10012008	Pin
output_val	R	2048	0x800	0x1001200C	Out
pue		0	0x0	0x10012010	Int
ds		0	0x0	0x10012014	Pin
rise_ie		0	0x0	0x10012018	Ris
rise_ip		0	0x0	0x1001201C	Ris
fall_ie		0	0x0	0x10012020	Fall
fall_ip		0	0x0	0x10012024	Fall
high_ie		0	0x0	0x10012028	Hig
high_ip		0	0x0	0x1001202C	Hig
low_ie		0	0x0	0x10012030	Lov
low_ip		4294967295	0xFFFFFFF	0x10012034	Lov
iof_en		768	0x300	0x10012038	I/O
iof_sel		0	0x0	0x1001203C	I/O function select
out_xor		0	0x0	0x10012040	Output XOR (invert)
sifive_uart0_0					From sifive_uart0,control perip...
txdata				0x10013000	Transmit data register
rxdata				0x10013004	Receive data register
txctrl				0x10013008	Transmit control register
rxctrl				0x1001300C	Receive control register
ie		0	0x0	0x10013010	UART interrupt enable
txwm		0	0x0	0x10013010	Transmit watermark interrupt...
rxwm		0	0x0	0x10013010	Receive watermark interrupt e...
ip				0x10013014	UART interrupt pending
div				0x10013018	Baud rate divisor
sifive_spi0_0					From sifive_spi0,control periph...

The contents of the State Browser is available when a system is under debugging, just like for most of the other views in Freedom Studio. The peripherals, their registers and their register fields are accessible through a tree structure with their name in the Name column, memory address in the Offset column and a human readable summary in the Description column. The state of an element is shown in decimal notation in the Dec column and in hexadecimal notation in the Hex column. The Dec and Hex column background turns yellow if the value has changed since the last state update of an element. The activation of state reading and writing is available through the popup menu on any of the elements:

- **Write State:** Rewrite the state shown in the Dec/Hex columns for the selected elements. If a peripheral node is selected then all it's registers are written.

- **Read State:** Read the state for the selected elements and show it in the Dec and Hex columns. If a peripheral node is selected then all its registers are read.

The state of a register or register field can be updated by clicking in the Dec or Hex cell for it and then write in the new value and press return afterwards. The value in the Dec cell must be in decimal notation and the value in the Hex cell must be in hexadecimal notation (starting with 0x). Press ESC to revert to the old value in the cell.

Refreshing of Register State

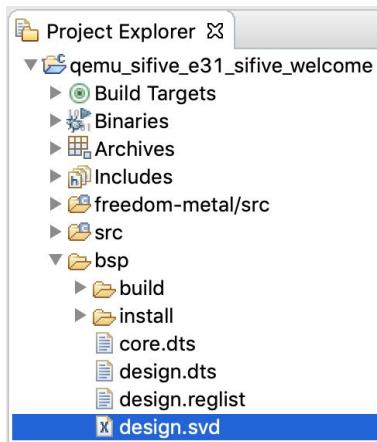
The state of all the registers are not by default automatically updated when the debugging session suspends, like it is in the Registers view. This is because some registers might have side effects when being read, just like the rxdata register in the uart or an interrupt pending register in some other peripherals. So in order to avoid this, it is up to the user to enable state refresh on the elements. The activation and deactivation of state refreshing is available through the popup menu on any of the elements:

- **Enable State Refresh:** Enable automatic refresh at suspend of state for the selected elements. If a peripheral node is selected it's enabled for all its registers.
- **Disable State Refresh:** Disable automatic refresh at suspend of state for the selected elements. If a peripheral node is selected it's disabled for all its registers.
- **Read State and Enable State Refresh:** This is a quick way to do a read state and enable automatic refresh at the same time.

If automatic refresh at suspend is enabled for a register it's shown by a 'R' in the R column. The refresh enablement is kept across debug sessions, but not between restarts of Freedom Studio. For more info on the other popup menu entries, the State Browser is based on <https://www.eclipse.org/nebula/widgets/xviewer/xviewer.php>

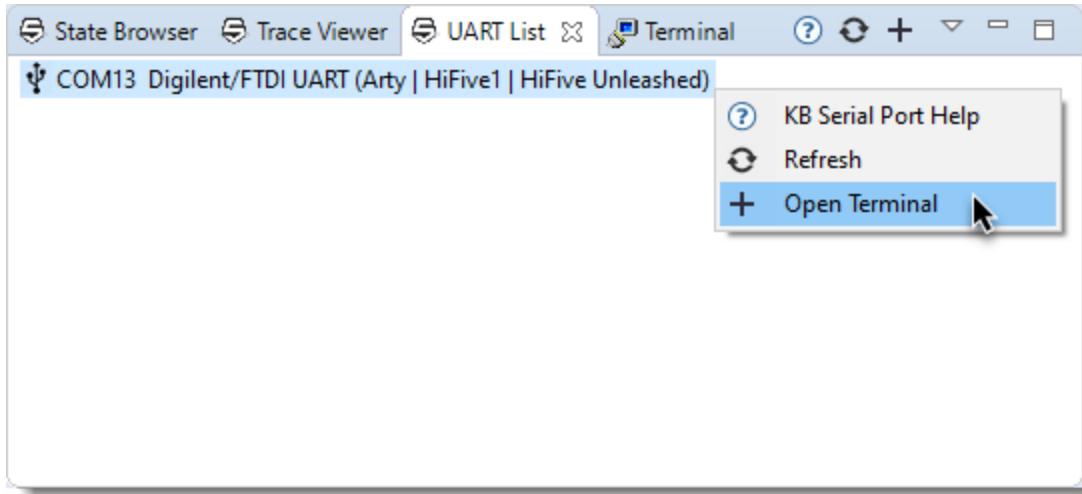
Design.SVD file

The State Browser gets all the description of registers and registers fields in the system from the design.svd file if it exists in the BSP. The format of the file is the standard CMSIS-SVD: <http://www.keil.com/pack/doc/CMSIS/SVD/html/index.html>



UART List View

The UART List View shows a list of all serial ports (virtual and real) on the host system and will identify the correct serial ports for connected targets.



This view does not automatically refresh the list. Refreshes must be done manually. After connecting a target cable, press the use the “refresh” command to refresh the list.

Once the desired serial port is shown, you can open a serial terminal on the port by using the “Open Terminal” command.

You can also configure a debug launch to [automatically open the terminal](#).

This feature works by running custom shell scripts for each host platform that know how to examine the system serial ports, extracting device ID information from the device. The script uses the device IDs for commonly supported target platforms and can thus identify which port belongs to which target.

FPGA Programming

FPGA Programming Using xc3sprog/openocd

Before you continue

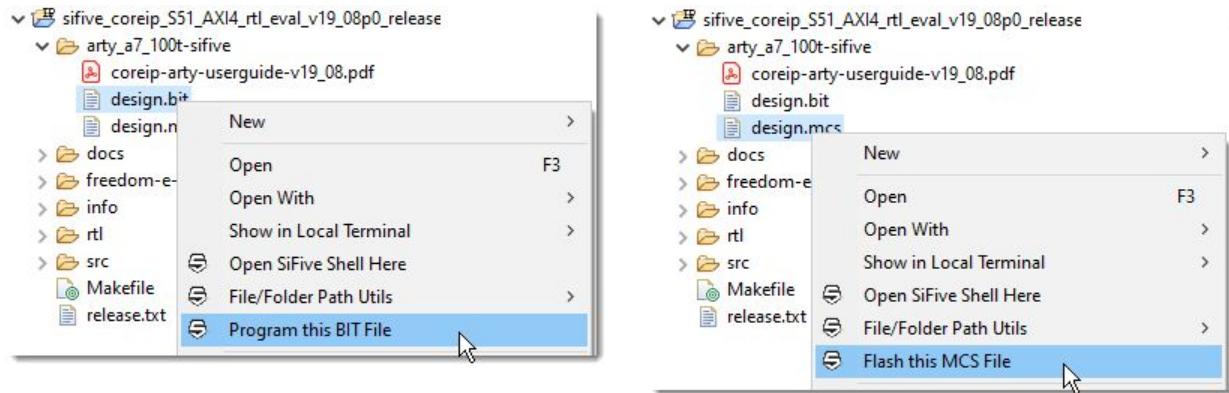
Before continuing with this section please review the [Target Board Setup](#) instructions to ensure that everything is properly configured and all host dependencies have been installed.

Flashing an MCS file on the FPGA 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.

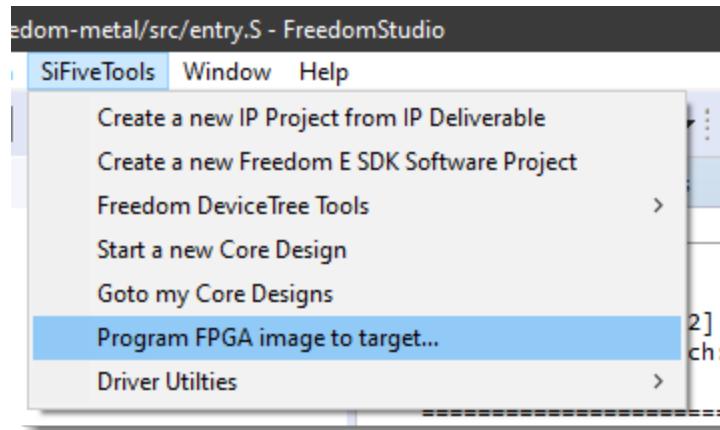
Programming a BIT file to the Arty requires only the Arty board USB connection be connected to your PC. The Olimex probe is not used in the programming process, however, having the Olimex connected will ensure that the correct device drivers for debugging with the Olimex are installed.

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

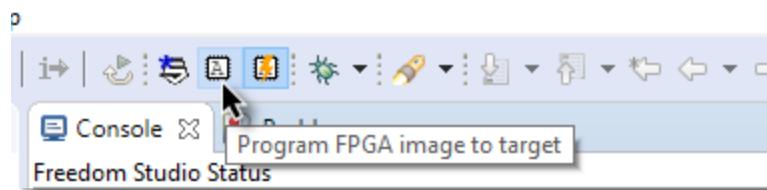
The easiest way to program an MCS or BIT file onto the Arty board FPGA is to right-click on the file in the project explorer (you can also simply double-click the MCS or BIT file):



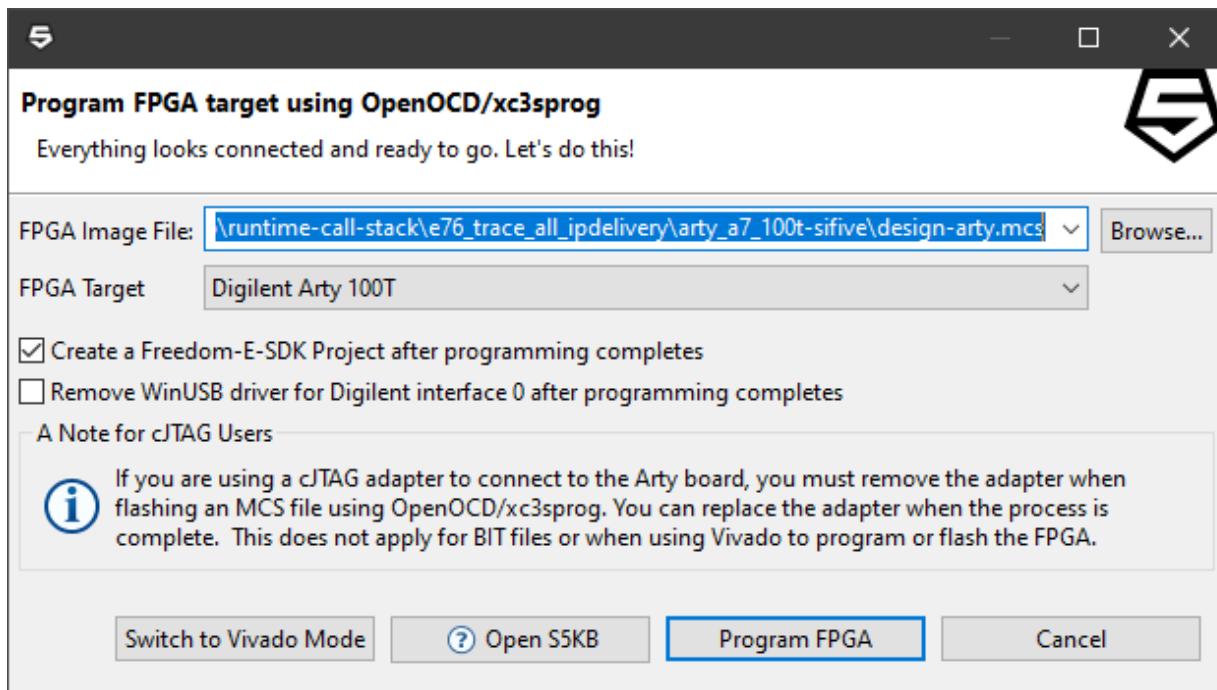
If the FPGA image file is not in a workspace project, you can open the programmer dialog from the main menu by selecting **SiFiveTools → Program FPGA image to Arty...**



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



Selecting either of these will open the FPGA 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 xc3sprog. 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 FPGA 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. Freedom Studio can be configured to program BIT files as part of a debug launch (See [FPGA Programming at Launch](#))

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 immediately programmed to the Arty board.

It is important that you know that everything is set up 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.

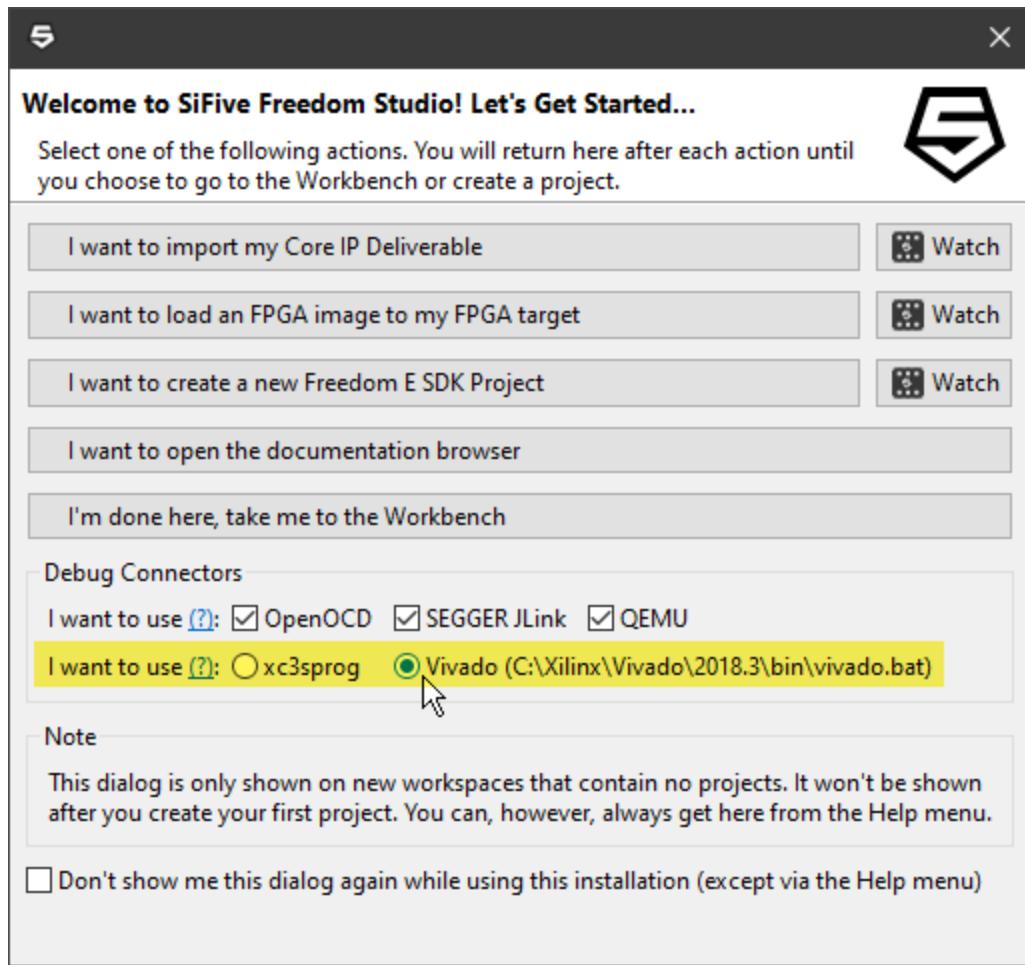
FPGA Programming Using Vivado

Windows and Linux users now have a choice of using Vivado or xc3sprog/openocd to flash MCS files or program BIT files to the FPGA. Freedom Studio has two "modes", "Vivado" mode, and "xc3sprog/OpenOCD" mode.

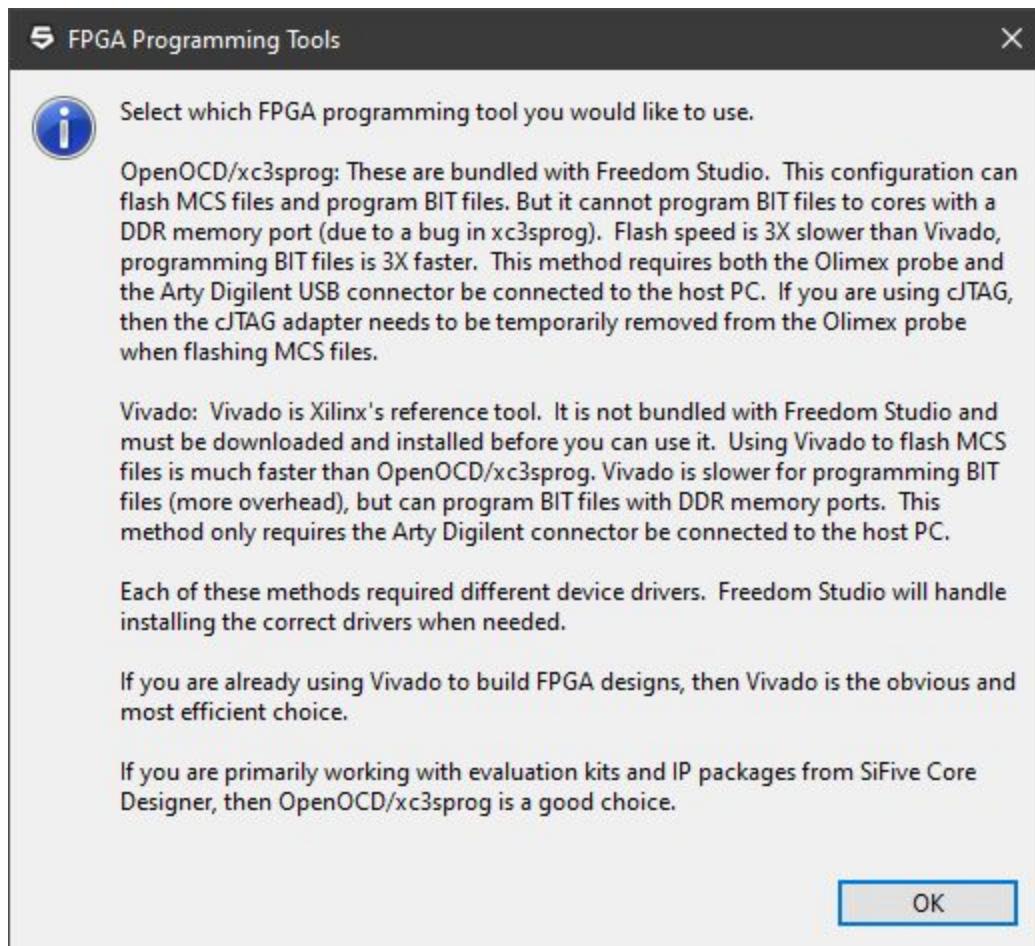
NOTE: Vivado is not available on MacOS.

NOTE: Vivado is not bundled with Freedom Studio. Before you can use "Vivado" mode you must download and install Vivado on your host system. This mode is most useful for users that are actively developing FPGA images (and will probably already have Vivado installed). This mode is also recommended if your are using an FPGA target other than an Arty board (i.e. VC707, VCU118, or other Xilinx FPGA target), as xc3sprog and OpenOCD may not support programming or flashing these other targets.

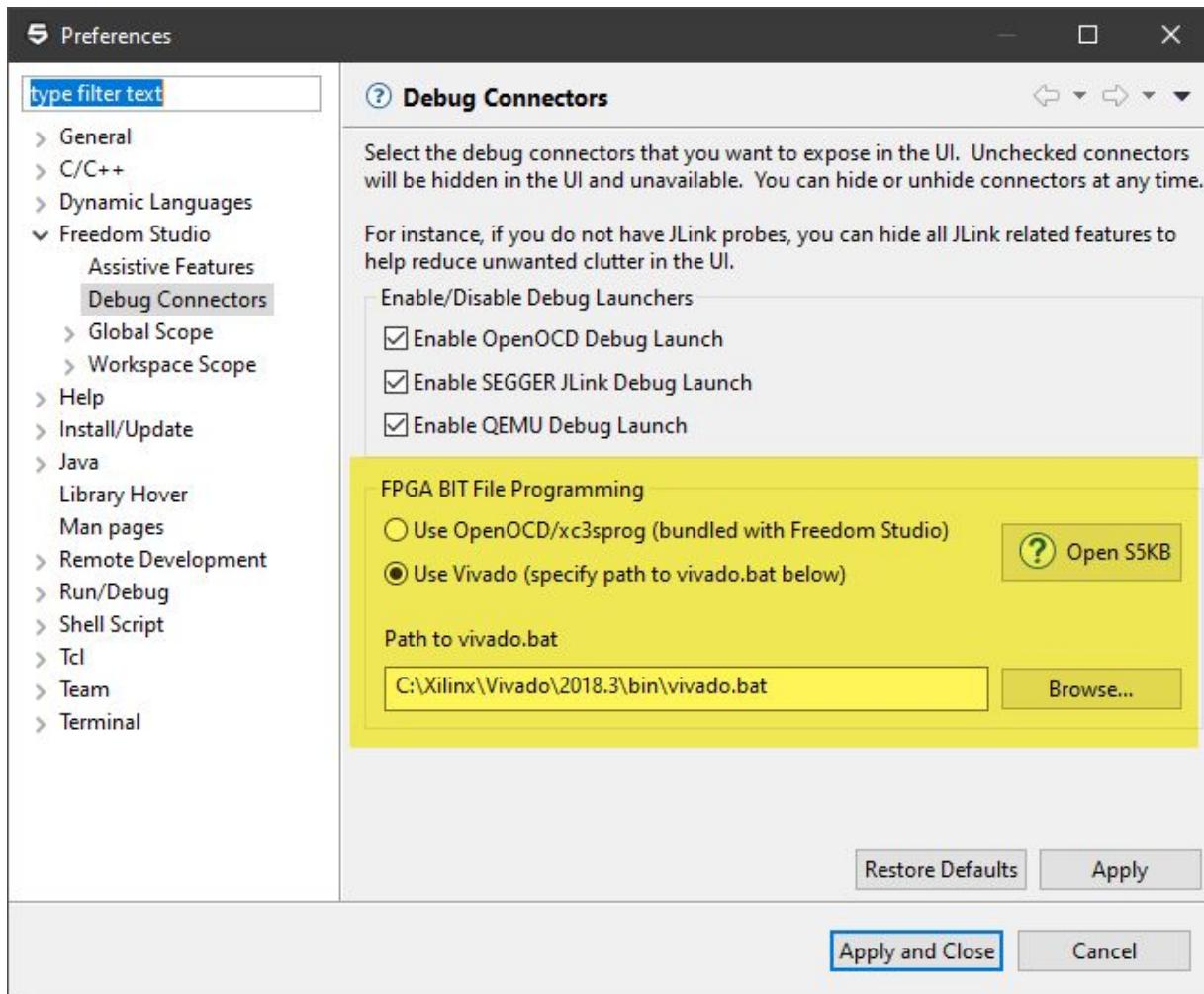
Selecting the mode to use is done using the Getting Started Dialog:



Pressing the little (?) link brings up a summary explanation of the two modes:



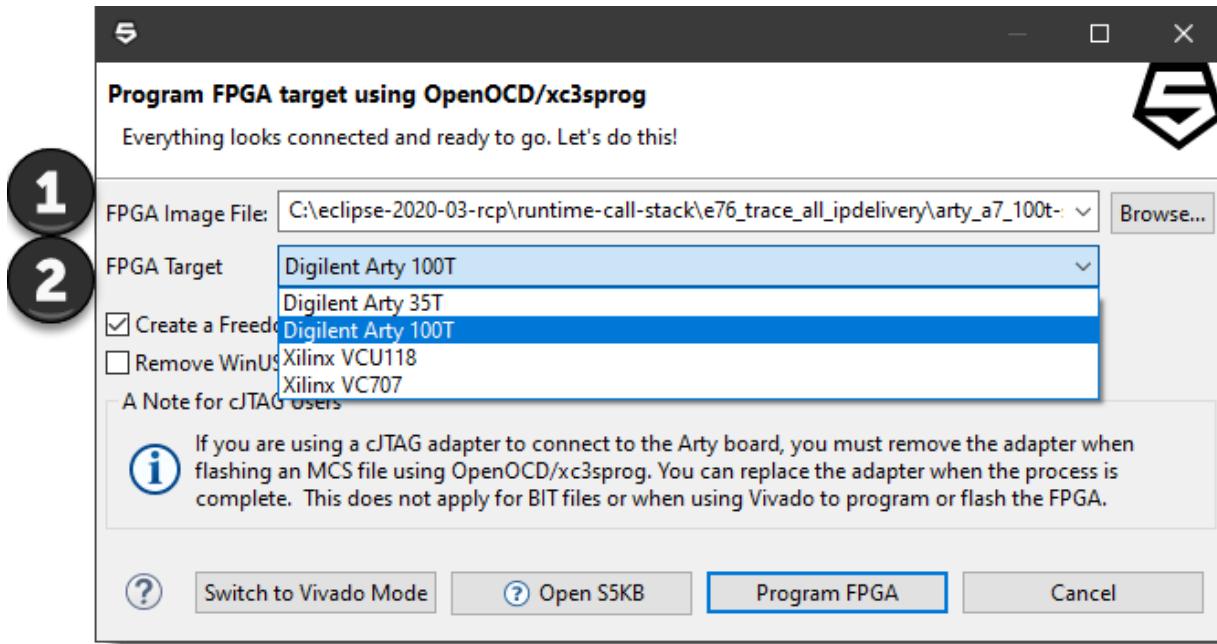
You can also select the mode via the Freedom Studio Preference Dialog:



In order to use Vivado mode you need to specify the path to the vivado.bat (on Windows), or vivado.sh (on Linux).

The Flash Programming Dialog is updated to support both programming modes and to support programming BIT files.

When using "Vivado" mode the Flash Dialog looks like:



1. Specify the FPGA MCS or BIT file
2. Specify the FPGA target type

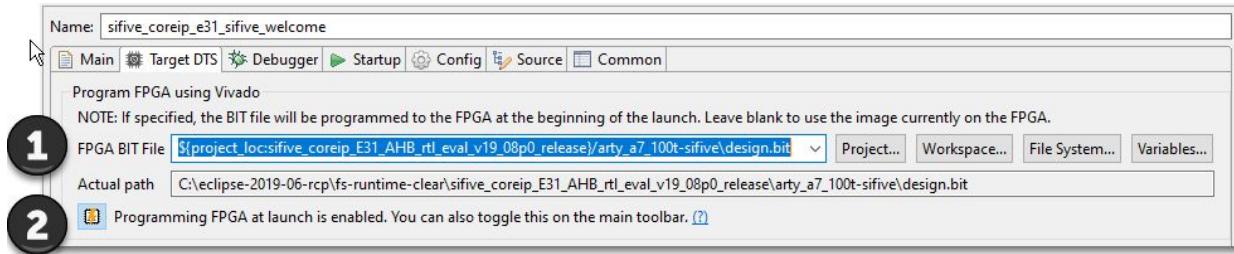
Additional FPGA targets can be added easily. Contact support for instructions on how to add more.

If required, you can switch between Vivado mode and Xc3sProg mode right from the Flash Programming dialog box.

FPGA Programming at Launch

Debug launch configurations now allow for specifying an FPGA bit file to be programmed at the start of a launch. FPGA bit files can be programmed very quickly (compared to flashing MCS files). This feature allows a developer to easily work with multiple FPGA images without having to separately flash or reprogram the FPGA image between launches.

Specifying a BIT file to program at launch is done on the “Target DTS” tab of the launch configuration dialog:



1. Specify the BIT file here. You can use any of the resource picker buttons to easily locate the correct BIT file.
2. Global Switch: There is a global switch that enables or disables programming the FPGA at launch. The switch is shown here (the small icon) and is also present in the main toolbar. You can use this switch to temporarily disable FPGA programming at launch when you know the FPGA is already programmed. This will save you time during the launch when you may need to launch debug sessions often with the same FPGA image.

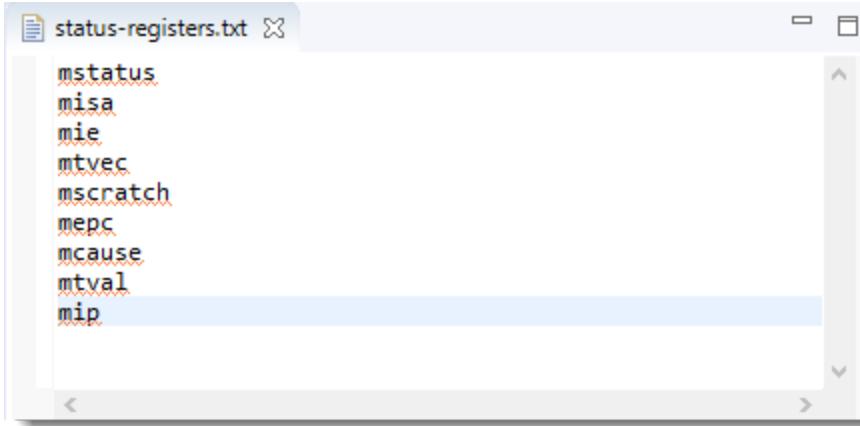
NOTE: Programming BIT files to the FPGA target is not “permanent” like flashing an MCS file. If the target is reset (via reset button) or power-cycled, then the FPGA image will be lost and need to be reprogrammed. If you are primarily using a single FPGA image then flashing the MCS file may be a better approach.

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.

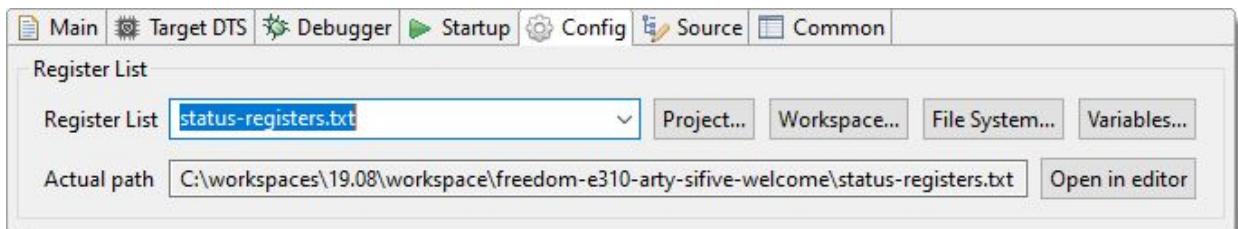
A Quick Example

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

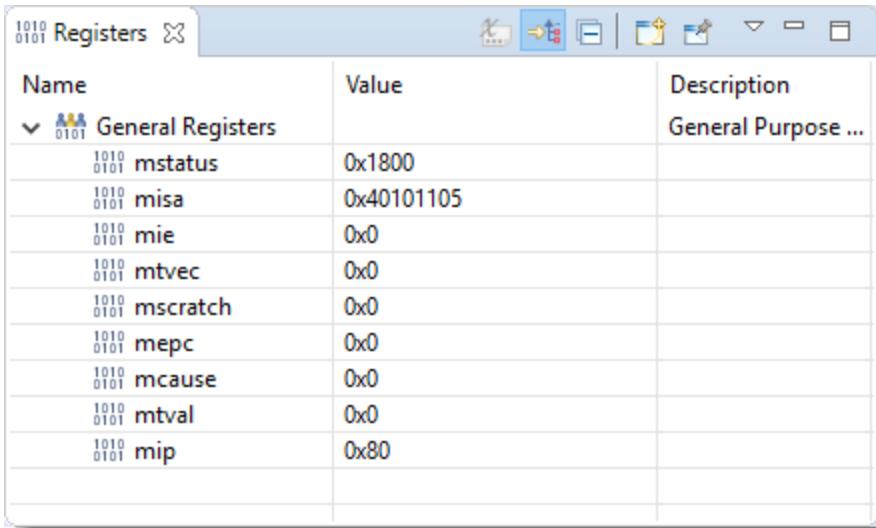


```
mstatus
misa
mie
mtvec
mscratch
mepc
mcause
mtval
mip
```

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
fpu_registers	Floating Point Registers
smode_registers	Supervisor Mode Registers
gdbregisters	Include all known 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.

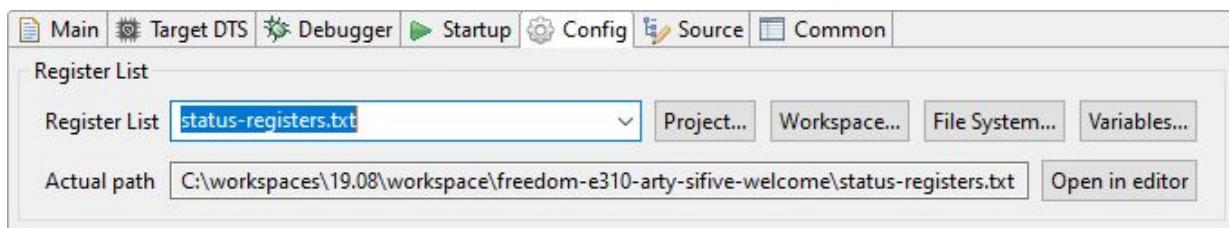
A register list file can be specified in 4 places. These four locations are prioritized such that a specification in a higher priority location will override any specification in a lower priority location. The four locations are, in descending priority order (highest priority first):

Prioritized Register List Specification Locations

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:



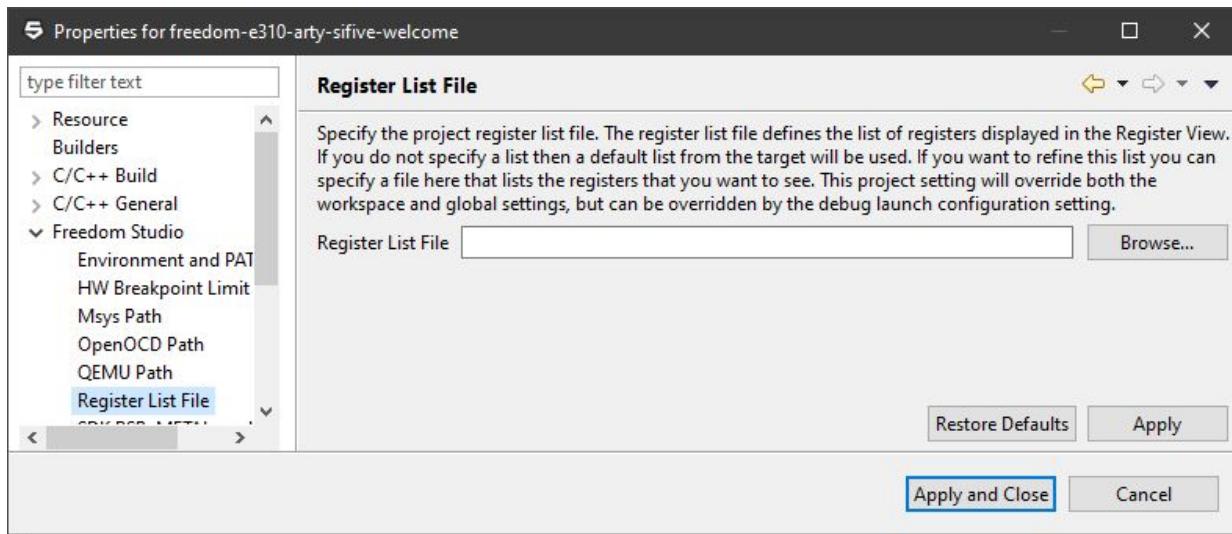
When you specify a register list file in a debug launch configuration the path displayed in the Actual Path box will always reflect the fully resolved path to the register list file. If you

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.

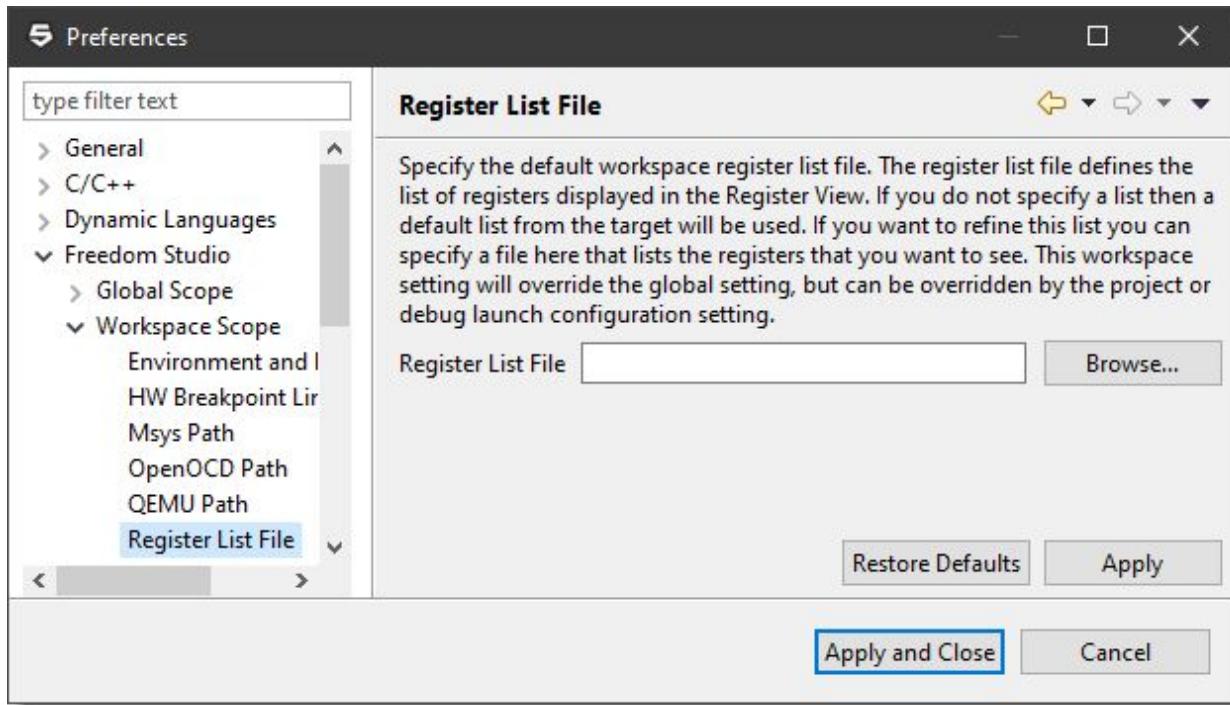
You can setup the project register list file specification by opening the Project Properties dialog and navigating to the `MCU → Register List` property page:



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.

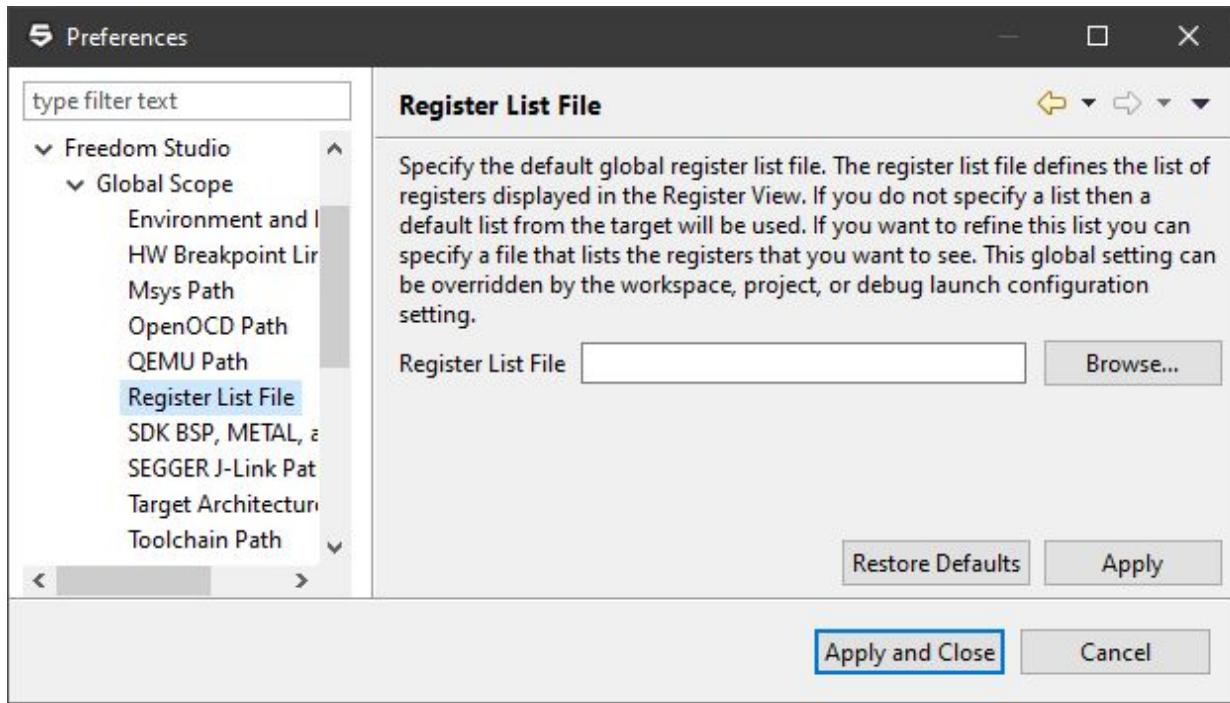
You can specify the workspace preference by opening the Freedom Studio Preference Window and navigating to the `MCU → Workspace Register List` page:



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.

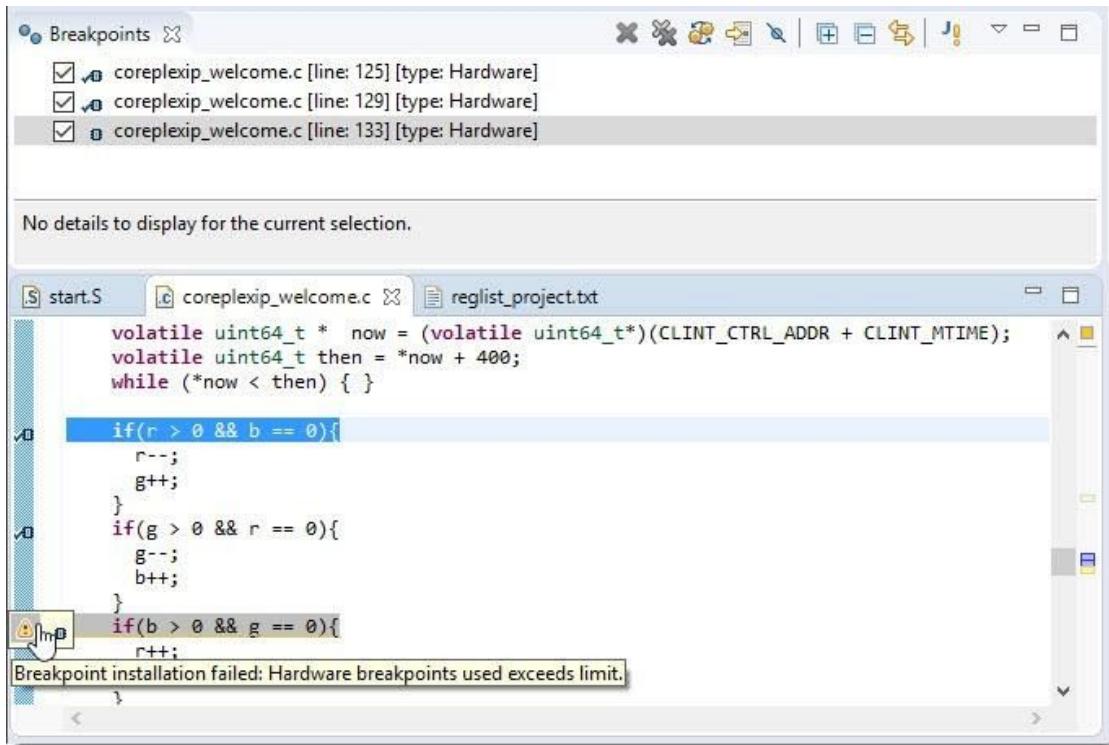
You can specify the global preference by opening the Freedom Studio Preference Window and navigating to the `MCU → Global Register List` page:



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 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.



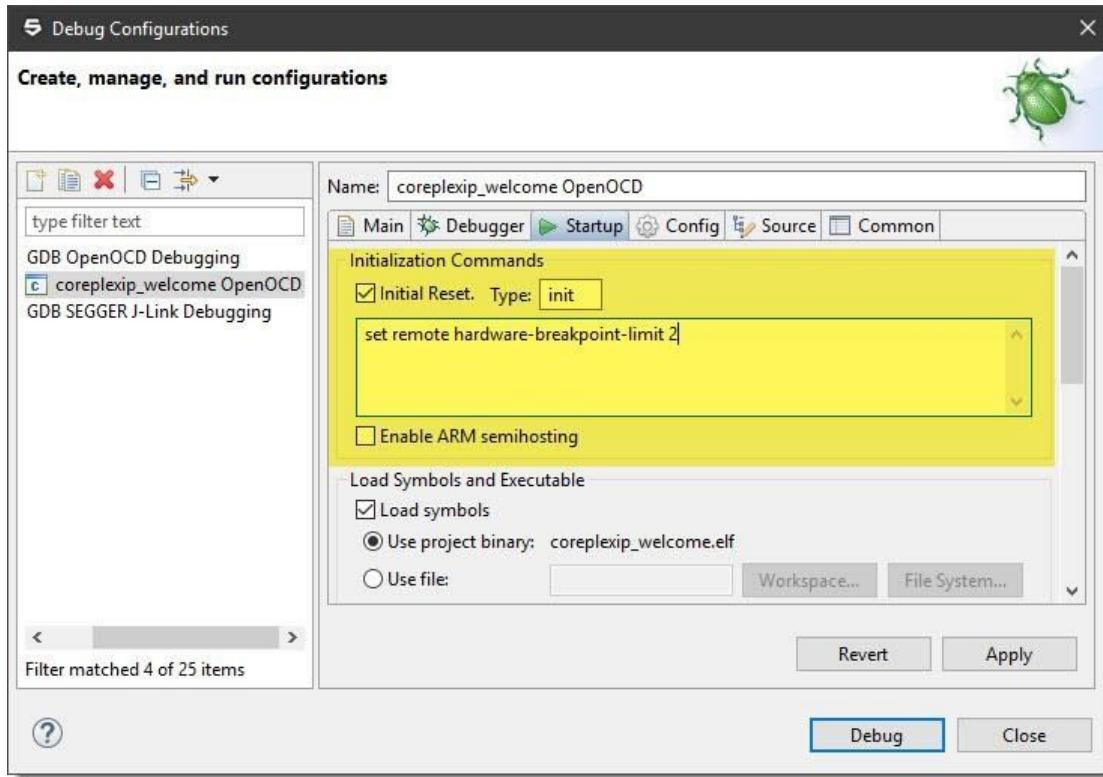
Too Many Hardware Breakpoints

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

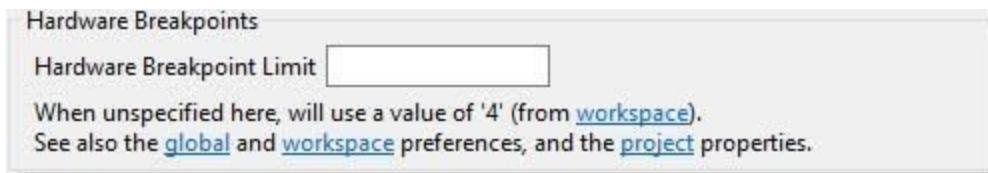
You can set global and workspace preferences to define the number of hardware breakpoints on your target system. You can also set this in your project properties and in a launch configuration.

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

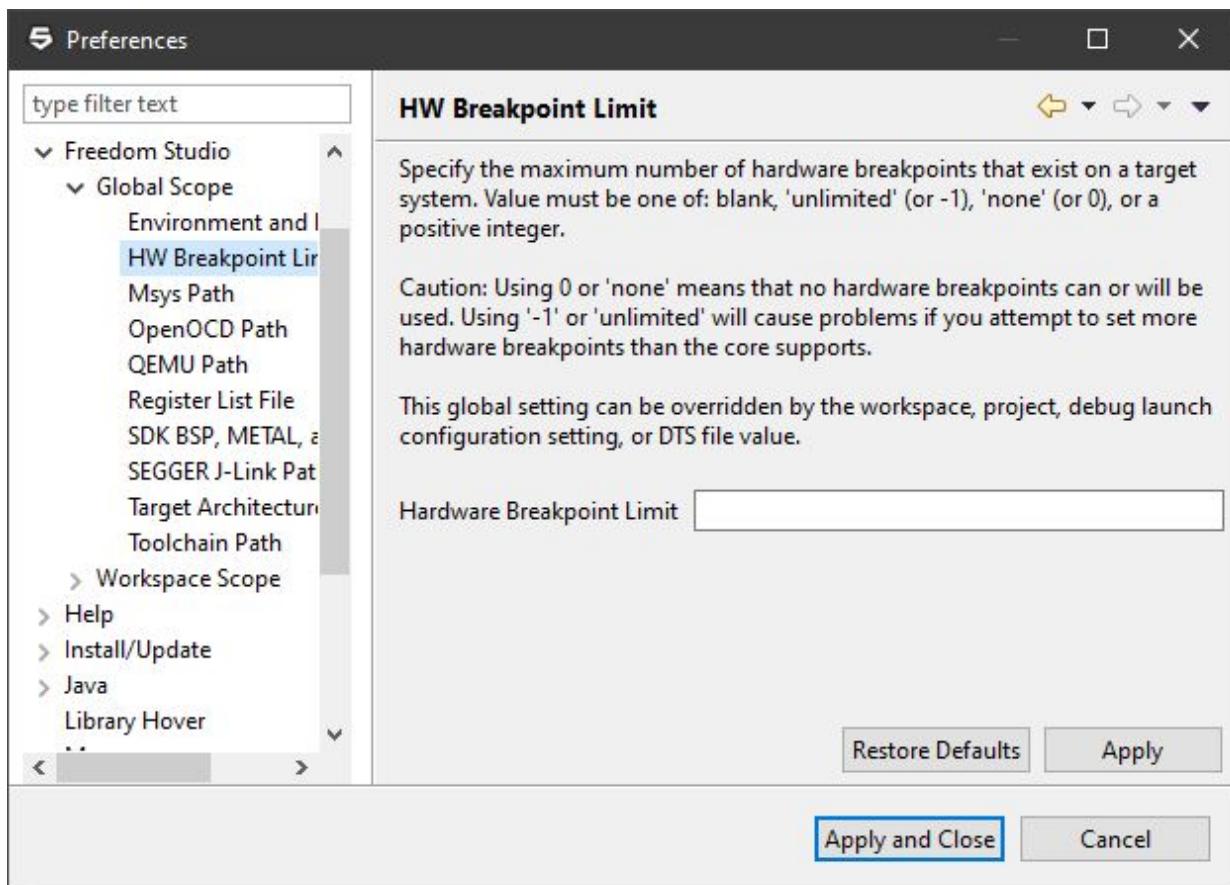
Value	Description
blank	Leave the setting blank and it will not be used.
'unlimited', or -1	Tells GDB that you have unlimited hardware breakpoints.
'none', or 0	Tells GDB that you have no hardware breakpoints.
x , a positive integer	Tells GDB that you have x hardware breakpoints.

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.

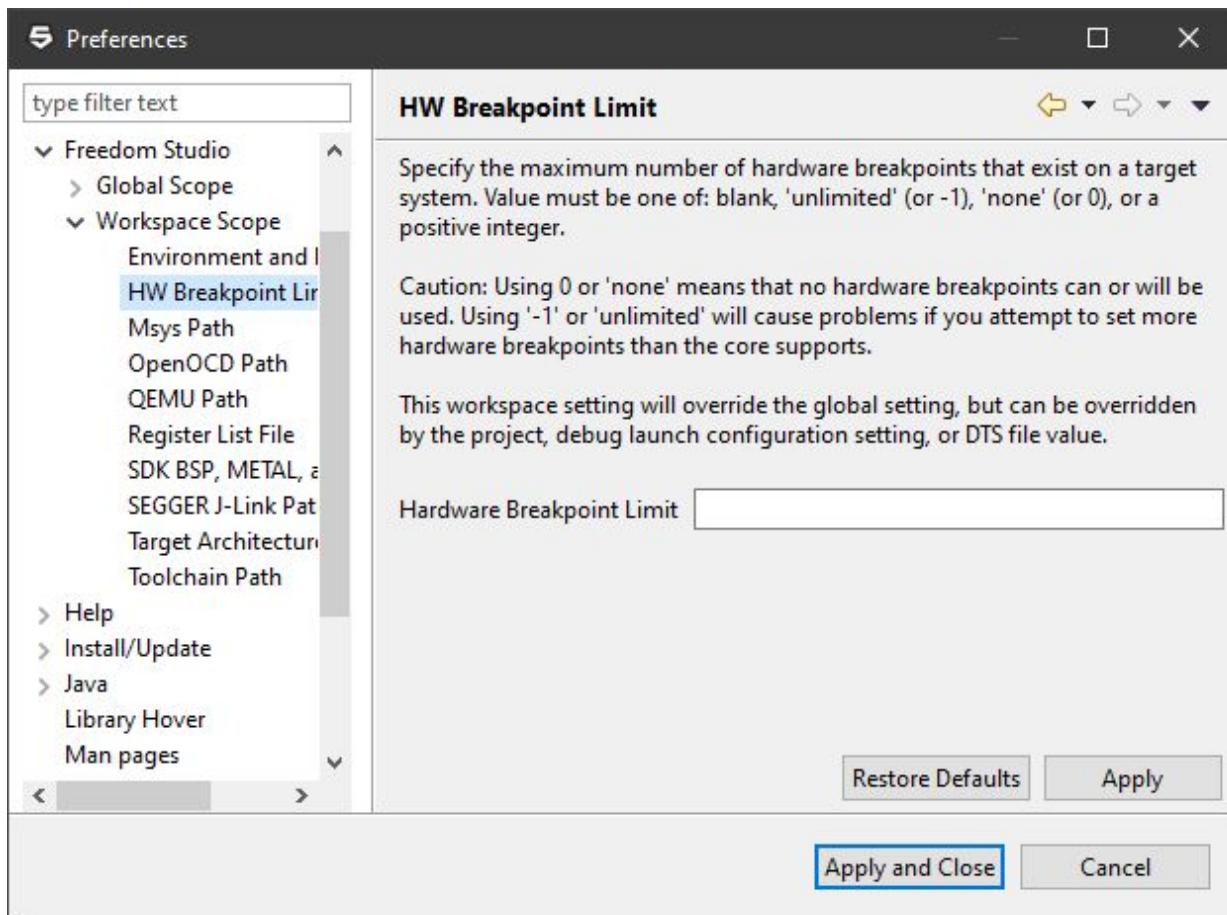
Set the global preference by opening the Preferences Dialog (Windows → Preferences) and navigating to the MCU | Global HW Breakpoint Limit page.



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.

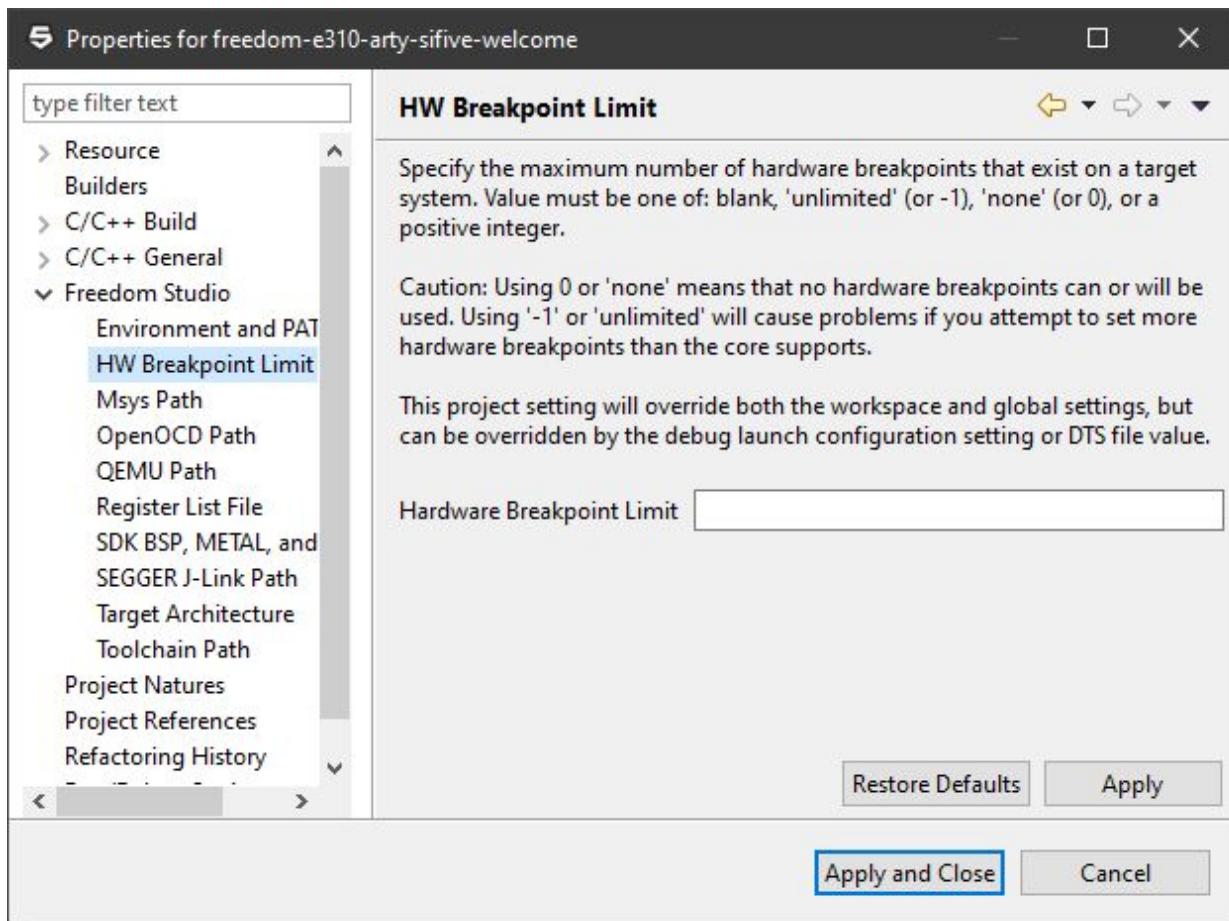
Set the workspace preference by opening the Preferences Dialog (Windows → Preferences) and navigating to the MCU | Workspace HW Breakpoint Limit page.



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.

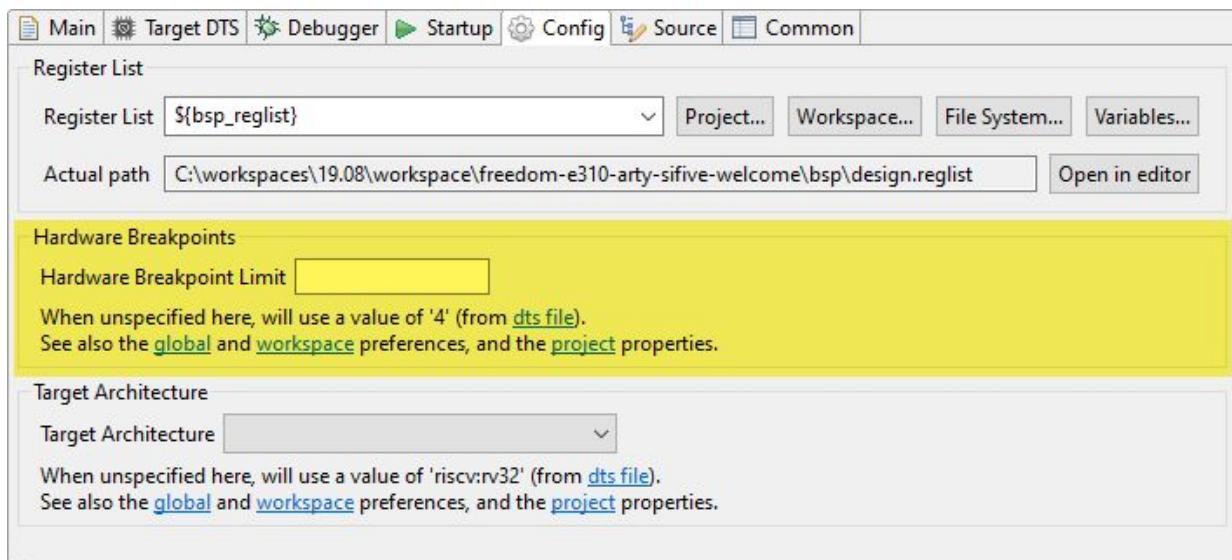
Set the project property by opening the Project Properties Dialog (Project → Properties) and navigating to the MCU | HW Breakpoint Limit page.



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 do use the `#pragma` statements.

Example source code.

```
// See LICENSE for license details.

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

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

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

static const char sifive_msg[] = "\n\r\
\n\r\
SIFIVE, INC.\n\r\
\n\r\
      555555555555555555555555\n\r\
  5555          5555\n\r\
  5555          5555\n\r\
  5555          5555\n\r\
  5555 555555555555555555\n\r\
```



```

        _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

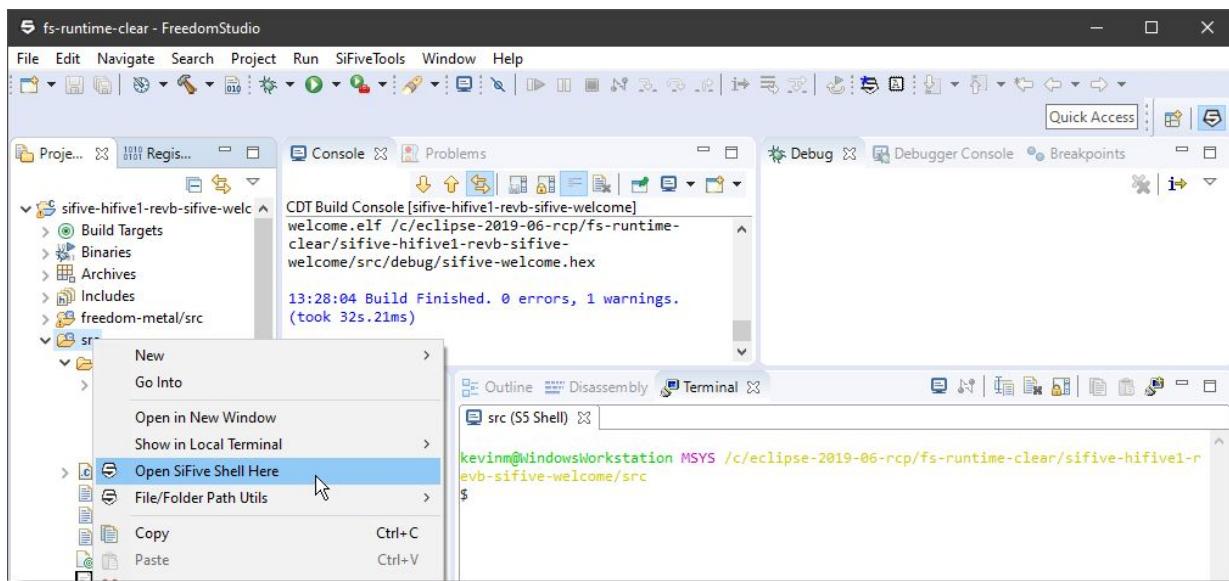
/*
 * Enable maximum optimization. The 'result' variable would normally be
optimized out.
*/
#pragma GCC push_options
#pragma GCC optimize ("3")
uint16_t option2(uint16_t p1, uint16_t p2) {
    /*
     * Use 'volatile' keyword to ensure variable does not get optimized out.
     */
    volatile int result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

The SiFive Shell

The SiFive Shell refers to both the shell environment that Freedom Studio uses to build example software projects and to the interactive shell that can be opened in the terminal view.

Opening an Interactive Shell

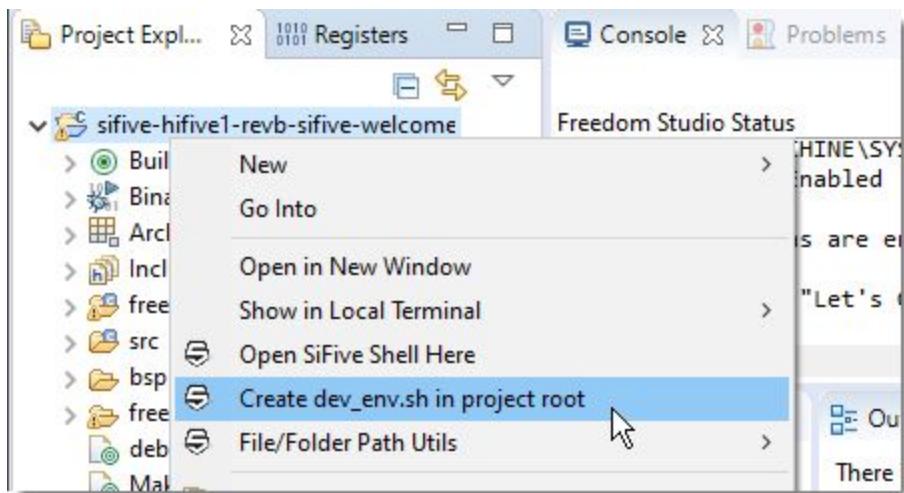
You can now open a shell in the Terminal View at any location in a project by right-clicking on the location in the Project Explorer and selecting “Open SiFive Shell Here”



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.

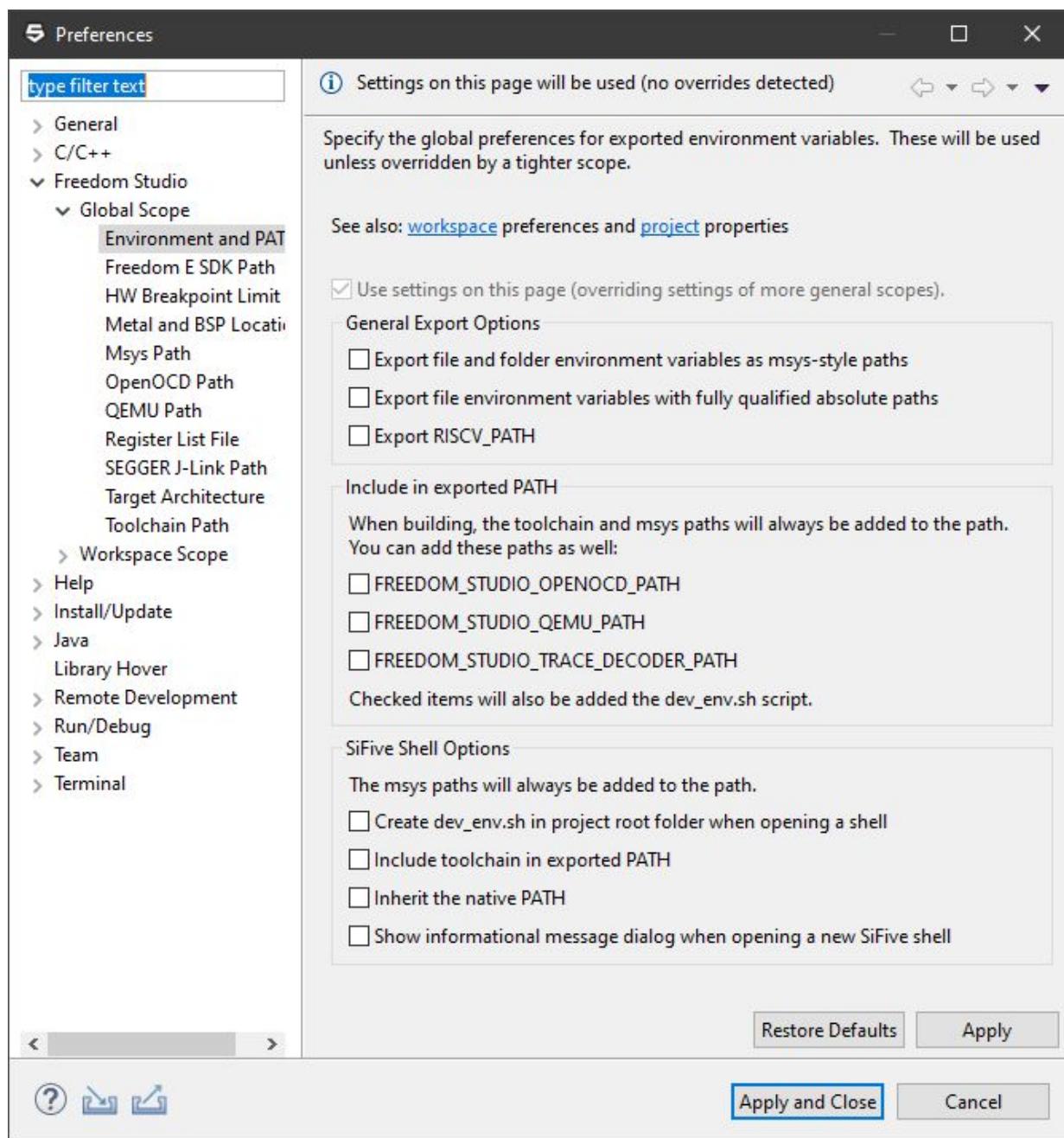
Create dev_env.sh for Your Project

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.



Environment and PATH Exports

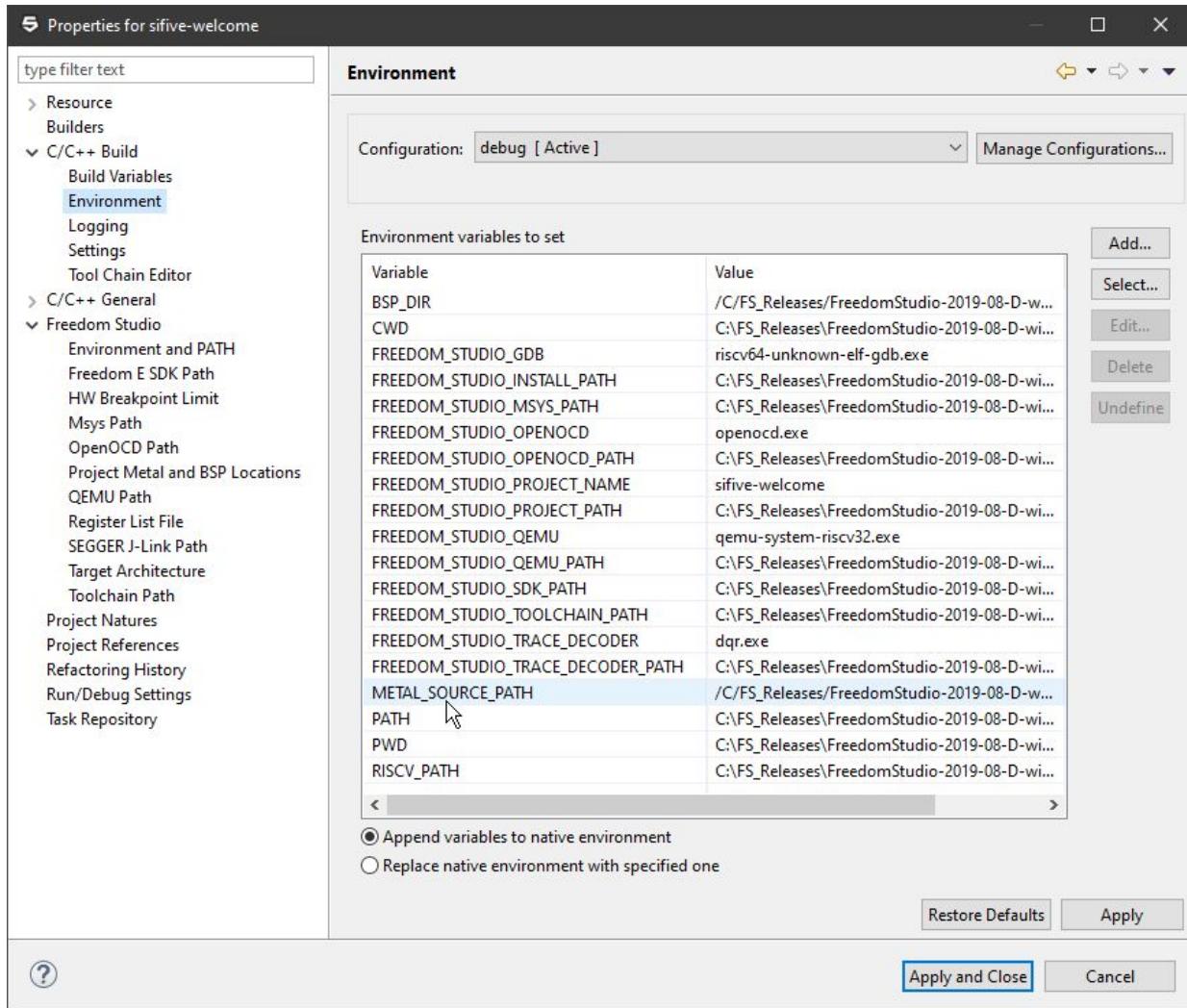
When you build a freedom-e-sdk based project several environment variables can be exported and the PATH can be changed to include various tool locations. This is controlled in the new “Environment and PATH” node of the Global Preferences, Workspace Preferences, or Project Properties.



Notes:

- **Export RISCV_PATH**
If checked, RISCV_PATH is exported into 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.

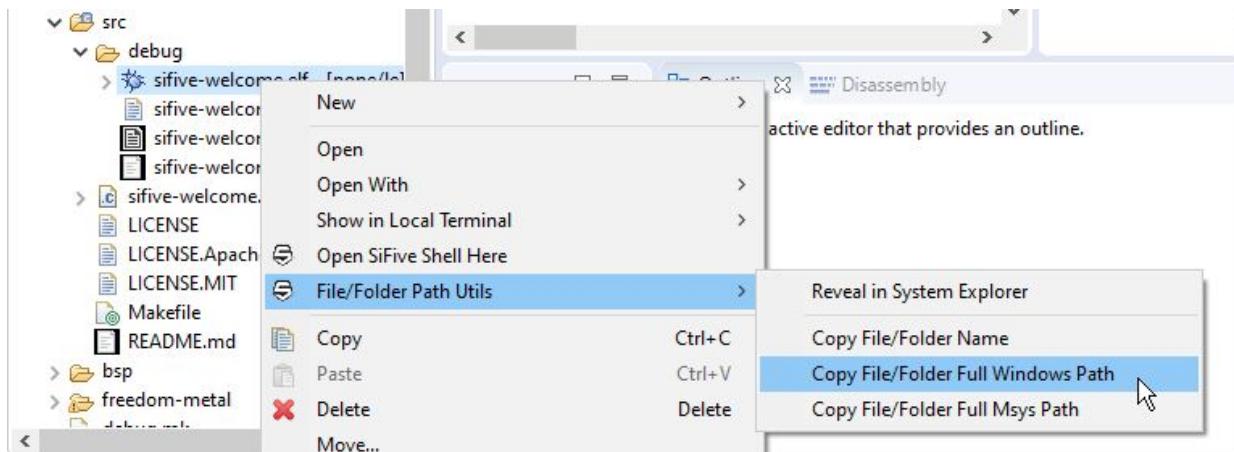
A complete list of exported environment variables can be viewed on the “C/C++ Build/Environment” project property node. For example:



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.

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.

Migrating Freedom Studio 2019.08 to Freedom Studio 2019.12

Workspaces, projects and launch configurations created in 2019.08 can be opened in 2019.12

Launch configurations in 2019.12 allow for specifying an FPGA “bit” file that will be flashed at the start of a launch. Existing launch configuration from 2019.08, when used in 2019.12, will default to no “bit” file specified.

Windows MSYS Environment

On Windows Freedom Studio uses a bundled MSYS environment to create a Linux-like environment required by the freedom-e-sdk.

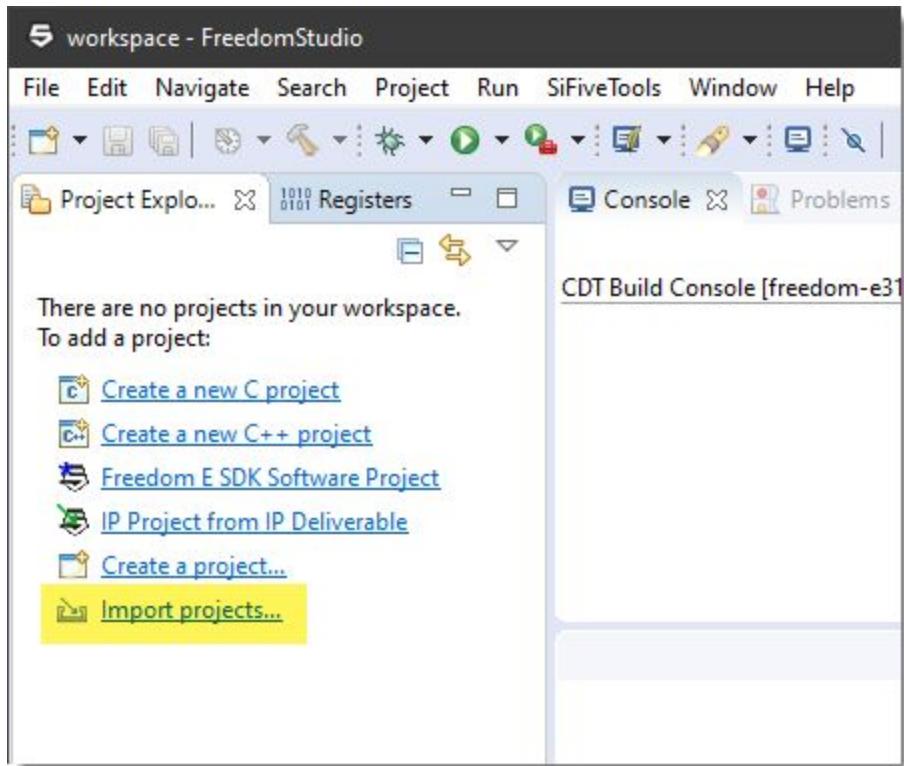
The Windows MSYS environment has been expanded to include many new tools and the ability to install additional MSYS packages using the 'pacman' tool. This expands the ability to write sophisticated Makefiles that can be used on all three host platforms.

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.

Migrating Freedom Studio 2019.05 to Freedom Studio 2019.08

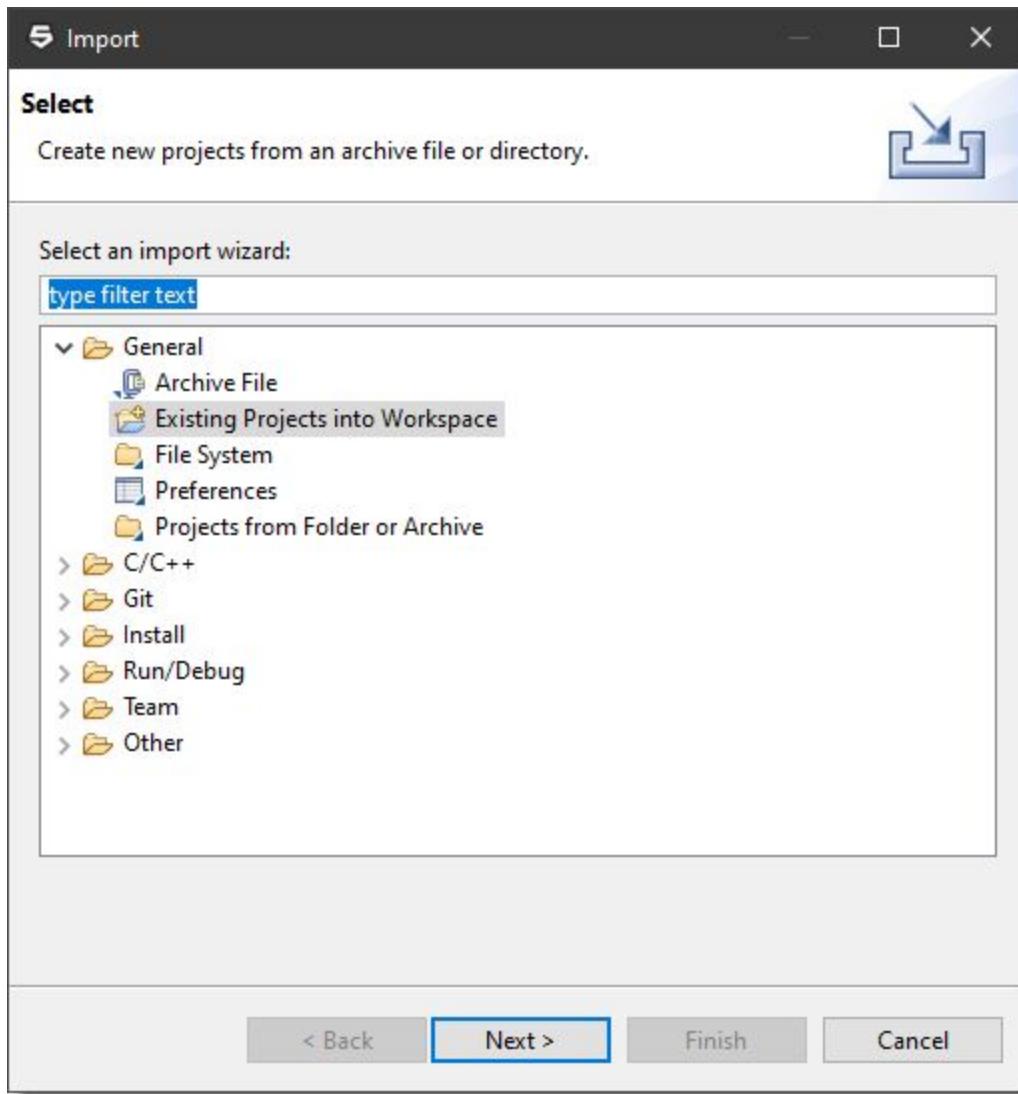
Migrating Projects

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..."



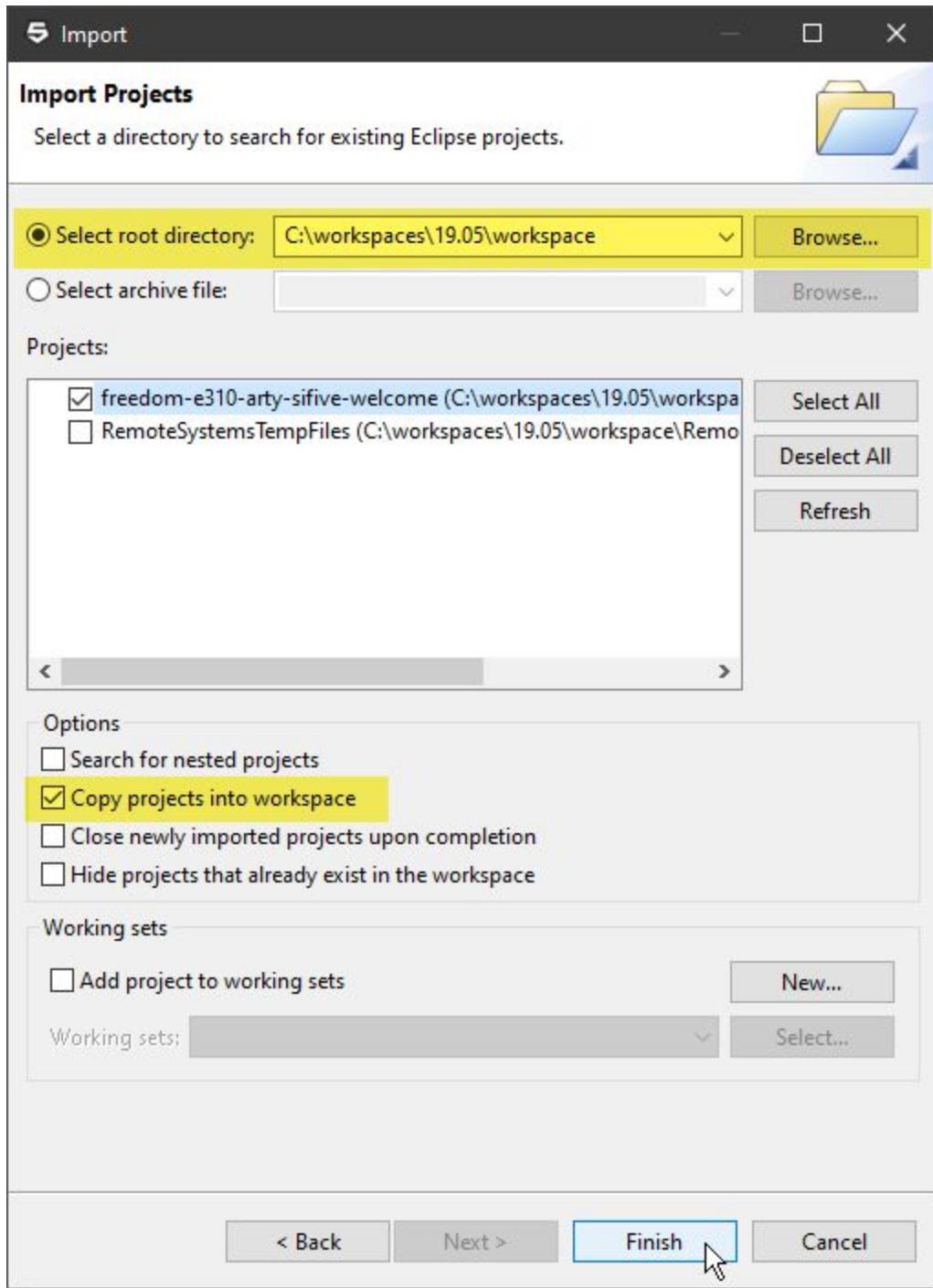
If you already have one or more projects in your workspace then open the Import dialog from the main menu: File → Import.

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.



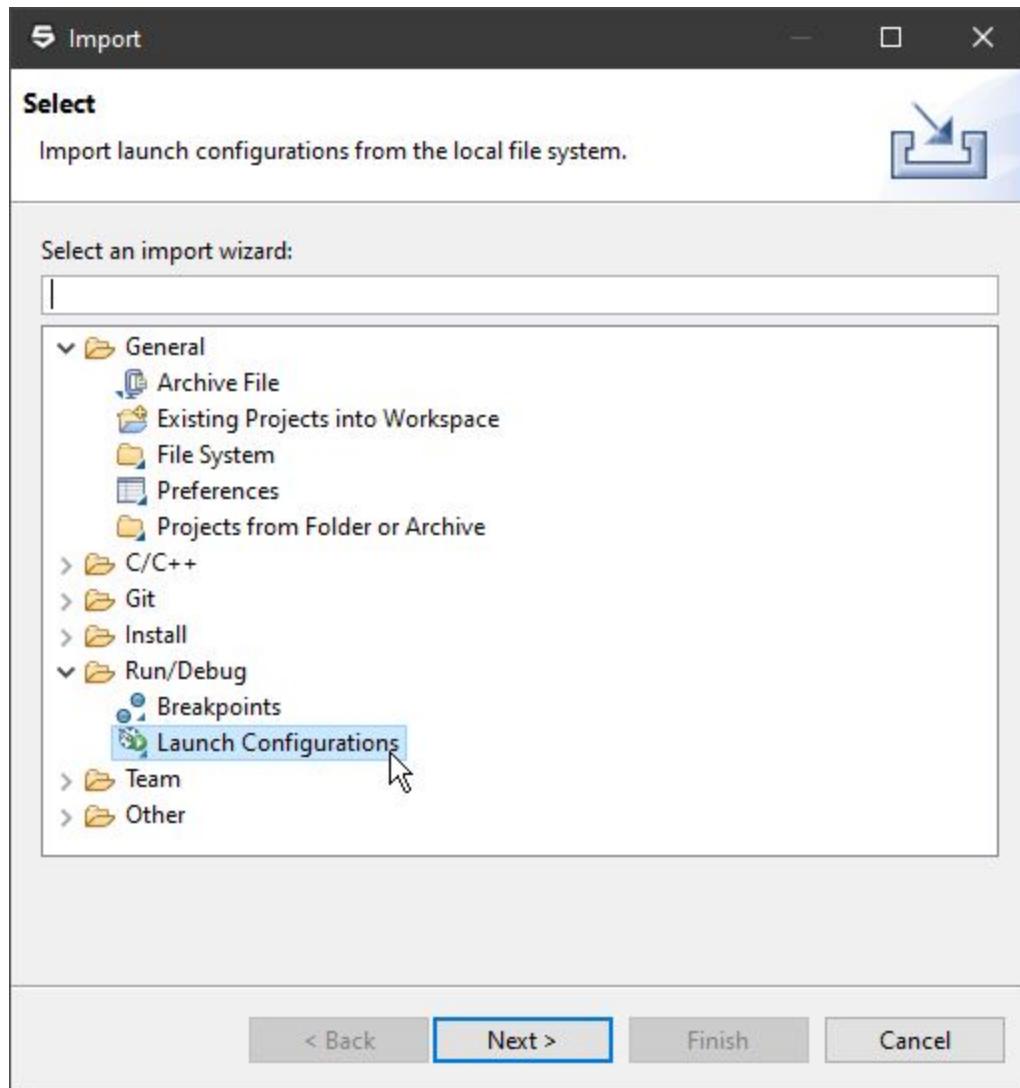
Once you've checked that all imported projects are functioning correctly you may then decide to delete the Freedom Studio 2019.05 workspace and projects.

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:

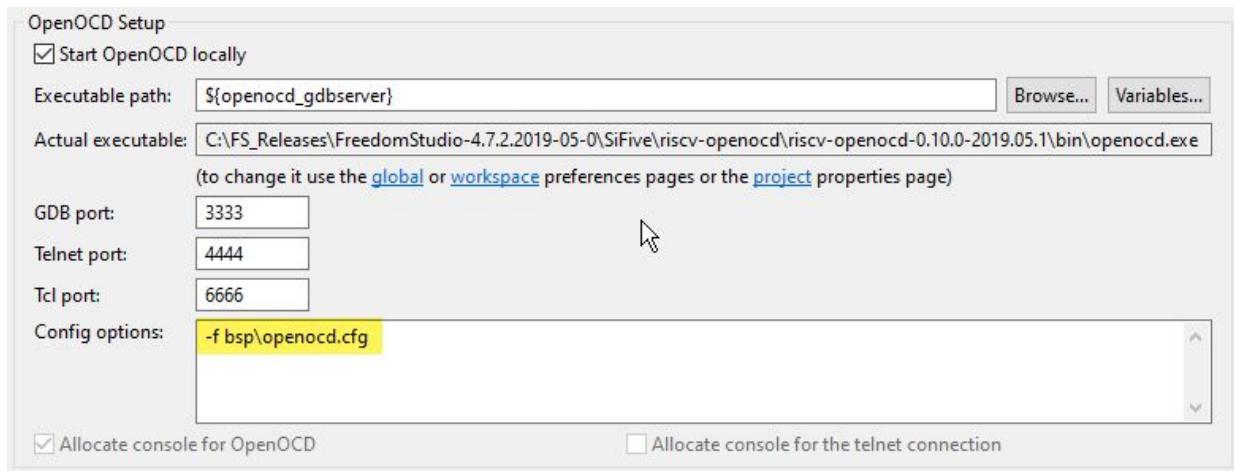
```
<2019.05-workspace-dir>/.metadata/.plugins/org.eclipse.debug.core/.launches
```

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]

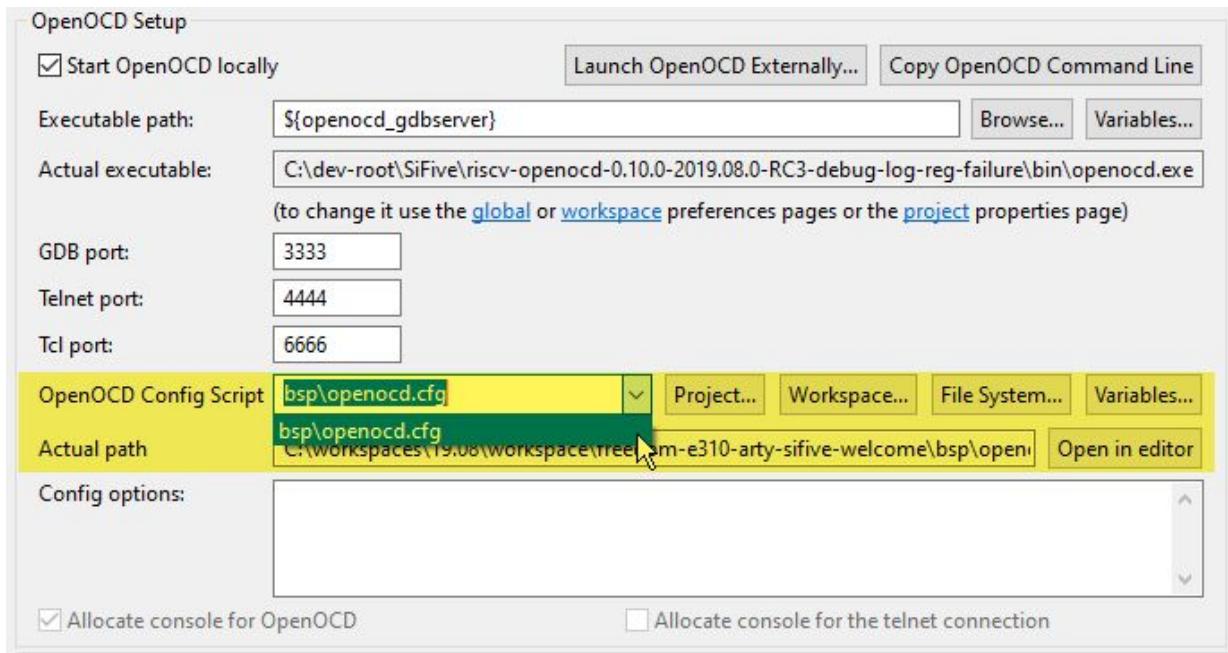
Updating Debug Launch Configurations

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 anywhere else on your host system if you need to.

What's New in Freedom Studio 2020.04.0

Bundled Tools

- OpenOCD
 - BSCAN tunnel support (passes riscv-tests against Arty)
 - Properly support large flash devices
 - Add support for 64bit memory reads/writes
 - A warning is displayed if “-rtos riscv” is used in a config script.
 - SBA memory reads are now twice as fast as before.
- JLink
 - Support flashing to Arty 100T
 - Updated HiFive1RevB OB driver to fix baud rate issues.
 - Fix to workaround (older SiFive) FPGA images with the KEEPER bug.

Improved Driver Management

These changes apply to the Windows version only.

- Freedom Studio will check the FTDI driver for Digilent Device Interface 1 (the virtual com port). This driver is usually installed automatically by Windows, but some Windows versions do not. Freedom Studio will install the driver if Windows does not. The correct FTDI driver is bundled with Freedom Studio.

Other Improvements

- Better progress dialogs at launch and during project creation.
- Multiple IP projects can be imported in a single operation. The only caveat is that you cannot choose a custom name for imported IP projects, only the default generated name will be used.
- You can right-click on an IP project node and create a new software project from there (previously you had to open the project and right-click on the “freedom-e-sdk” folder).
- When using the context menu to program a FPGA image, holding the <shift> key down will start the programming operation immediately, bypassing the Programming Dialog box. Only use this when you know that everything is hooked up properly and ready to go.
- Several bug fixes, of course!

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"

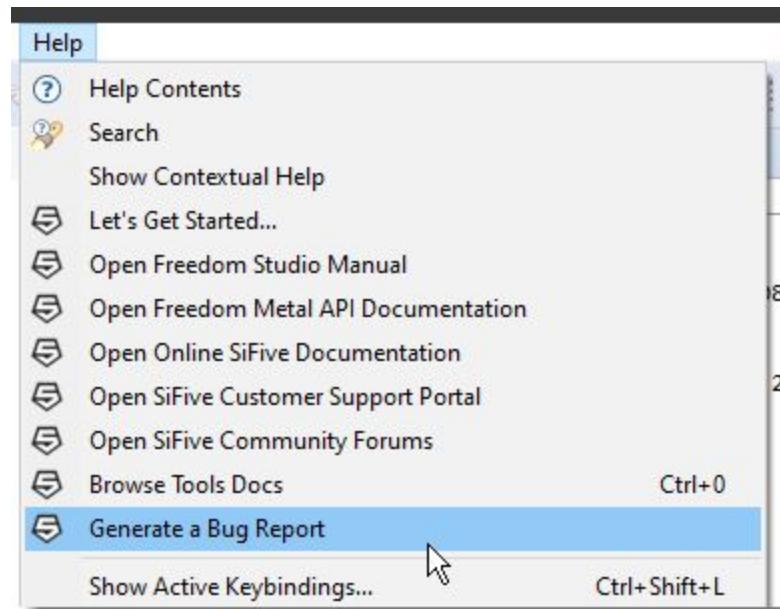
This occurs when instructing the debugger to halt immediately after connecting to the target. It is safe to ignore this message. Stepping/Running the target will work as expected from this point.

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

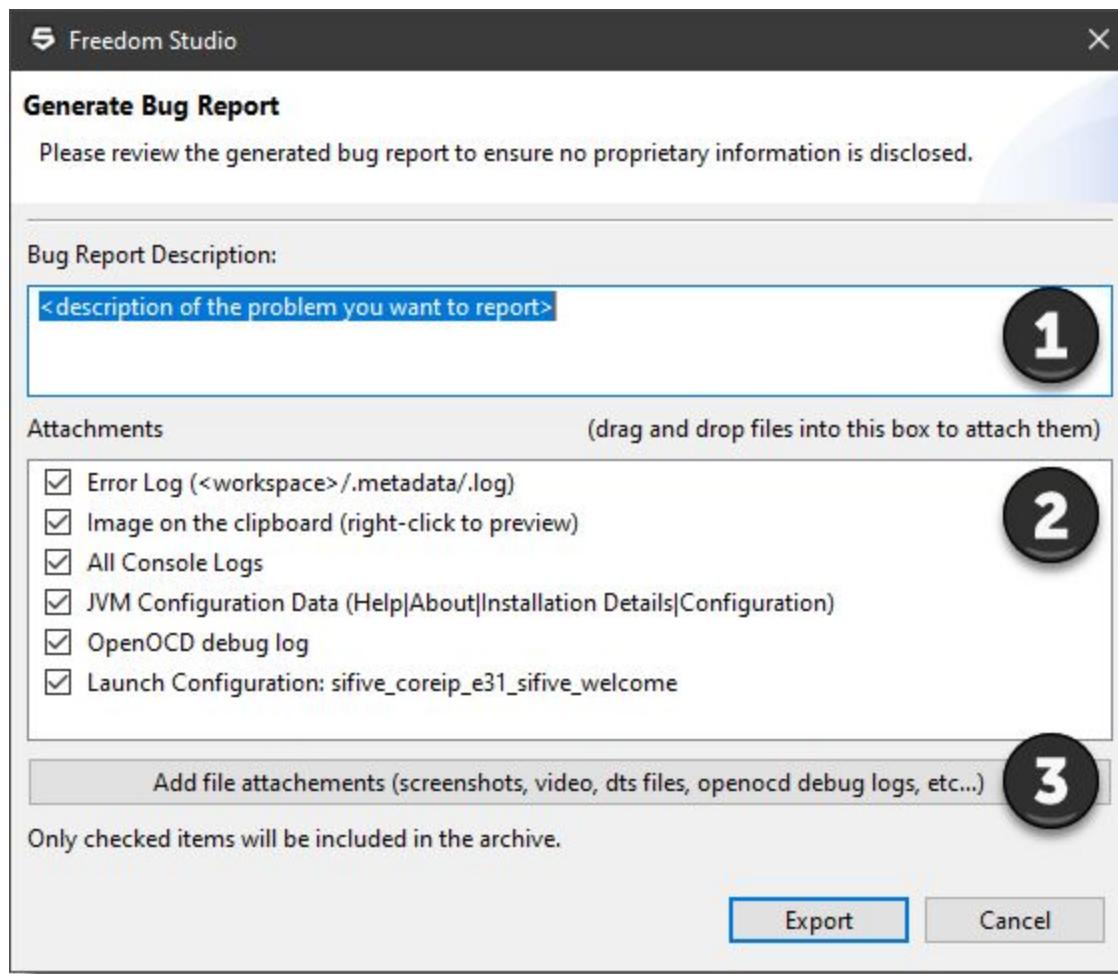
While red font can be scary, it is generally benign debugging output. This happens because OpenOCD output status message through stderr and Freedom Studio renders stderr in red. You can change this color in the Freedom Studio Preference, but be aware that this will affect all consoles that accept and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

Freedom Studio Bug Report Generator

Freedom Studio gains a Bug Report Generator dialog that will help gather and bundle information for reporting bugs to SiFive support. This dialog is accessible from the Help menu:



Selecting this will open the Bug Report Generator Dialog:



The Bug Report Generator collects information from the Freedom Studio environment that may be useful in diagnosing a problem. You have full control over what information is collected. Please ensure that you are not sending any proprietary information.

The sections of the dialog are described:

1. This text box allows you to provide a description of the problem you are reporting.
2. The Attachments List: This list is prepopulated with several entries gathered from the Freedom Studio Environment:
 - a. Error Log: This is the main Freedom Studio application error log. It contains stack traces for any exceptions that occur.
 - b. Image on the clipboard: If your system clipboard contains an image it will be detected and added. The intent is to easily include a screenshot showing the problem you are reporting. If you have multiple screenshots or a video, you can easily attach them as well using the button below the table.
 - c. All Console Logs: This will include the text from all console logs (build logs, debug logs, trace console, etc....)

- d. JVM Configuration Data: This log contains a complete snapshot of the process environment Freedom Studio is running. This includes all environment variables, JVM properties, and general host system information.
 - e. OpenOCD debug log: If the root of your project contains a file named “openocd-debug.log” then include this file. This is the default log file name used when you use the “Launch OpenOCD Externally” feature to capture an openocd debug log. If your captured log is named differently or located elsewhere you can drag the file into the list, or use the “attach” button to attach it.
 - f. Launch Configurations: All launch configurations are listed individually for inclusion. These are XML files that fully describe a launch configuration.
3. Add Attachments Button
- a. Press this button to open a file browser from which you can add any additional files to the bug report.
 - b. You can also simply drag and drop files from your file explorer application into the attachment list to attach them.

Press the “Export” button to choose a destination folder and export the bug report as a ZIP file. The ZIP file name will be automatically generated using the form:

```
freedomstudio_bug_report_<YYYY>_<MM>_<DD>_<HH>_<MM>
```

After exporting Freedom Studio will ask if you’d like to visit the Support Portal to submit the bug report. Before submitting, please review the contents of the bug report before submitting it to ensure that you are not providing any proprietary information.

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 is 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 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 (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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This be the placeholder! Aarg!

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