



Lattice Propel 2022.1 SDK

User Guide

FPGA-UG-02176-1.0

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Glossary

A glossary of terms used in this document.

Terms	Definition
ASCII	American Standard Code for Information Interchange.
BSP	Board Support Package, the layer of software containing hardware-specific drivers and libraries to function in a particular hardware environment.
DUT	Design Under Test.
CDT	C/C++ Development Tools.
CPU	Central Processing Unit.
GUI	Graphical User Interface.
FPGA	Field Programmable Gate Array.
HDL	Hardware description language.
IBIS	Input Output Buffer Information System.
IDE	Integrated Development Environment.
IP	Intellectual Property.
JEDEC	Joint Electron Device Engineering Council.
OCD	On-Chip-Debugging.
OEM	Original Equipment Manufacturer.
OpenOCD	Open On-Chip Debugger.
Perspective	A group of views and editors in the Workbench window.
Programmer	A tool can program Lattice FPGA SRAM and external SPI Flash through various interfaces, such as JTAG, SPI, and I ² C.
RISC-V	Reduced Instruction Set Computer-V. A free and open instruction set architecture (ISA) enabling a new era of processor innovation through open standard collaboration.
RISC-V MC	Lattice RISC-V for Micro-Controller Soft IP.
SDK	Software Development Kit. A set of software development tools that allows the creation of applications for software package on the Lattice embedded platform.
SoC	System-on-Chip. An integrated circuit that integrates all components of a computer or other electronic systems.
SRAM	Static Random Access Memory.
UART	Universal Asynchronous Receiver/Transmitter.
UI	User Interface.
UFM	User Flash Memory.
VHDL	Very-High-Speed Integrated Circuit Hardware Description Language.
Workspace	The directory where stores your work, it is used as the default content area for your projects as well as for holding any required metadata.
Workbench	Refers to the desktop development environment in Eclipse IDE platform.

1. Introduction

Lattice Propel™ is a complete set of graphical and command-line tools to create, analyze, compile, and debug both FPGA-based hardware and software processor systems.

1.1. Purpose

Embedded system solutions play an important role in FPGA system design allowing you to develop software for a processor in an FPGA device. It provides flexibility for you to control various peripherals from a system bus.

To develop an embedded system on an FPGA, you need to design the System-on-Chip (SoC) with an embedded processor and develop system software on the processor. Lattice Propel helps you develop your system with a RISC-V processor, peripheral IP, and a set of tools.

The purpose of this document is to introduce Lattice Propel SDK tool and flow to help you quickly get started to build a small demo system. You can find recommended flows of using Lattice Propel SDK in this document as well.

1.2. Audience

The intended audience for this document includes embedded system designers and embedded software developers using Lattice FPGA devices. The complete list of supported devices can be found at Lattice Propel Release Notes. The technical guidelines assume readers have expertise in the embedded system area and FPGA technologies.

2. Lattice Propel Development Suite

Lattice Propel development suite includes:

- an integrated development environment (IDE), which is the framework of Propel;
- Lattice Propel Builder, which is for SoC design;
- Lattice Propel SDK, which is for system software development.

2.1. Eclipse IDE

Eclipse IDE provides the Propel development suite a platform to manage the SoC project and the Embedded C/C++ Project in the same workspace.

The SoC project, which extends from the Propel Builder project, provides easy interaction with other Lattice design tools, such as Lattice Diamond® within Propel.

The Embedded C/C++ Project provides a platform for developing or debugging application code within Eclipse IDE. The project can be created directly from the SoC project with a pre-set Board Support Package (BSP) and applications by using Propel development suite.

2.2. Lattice Propel Builder

Lattice Propel Builder allows you to assemble the larger functional blocks of the design hierarchy. Propel Builder enables you to instantiate modules and IP from the IP Catalog in a schematic view, and can easily connect the modules. Propel Builder also helps you customize address spaces within modules, such as a processor. In Propel development suite, Propel Builder is used to create a microprocessor integrated platform for both hardware and software development.

Refer to [Lattice Propel 2022.1 Builder User Guide \(FPGA-UG-02177\)](#) for more detailed information.

2.3. Lattice Propel SDK

Lattice Propel SDK is based on Eclipse Embedded C/C++ Development Tools (CDT). It allows you to create, build, and debug software application projects that drive the platform within the Eclipse framework.

The main features are:

- Create, build, debug, or manage embedded applications for Lattice RISC-V CPU/SoC solution.
- Provide extra build steps to generate the binary and memory files required for deployment.
- Build using the latest industry standard open source components and tools for RISC-V firmware development and debugging.
- Support Picolibc for RISC-V, and provide lightweight standard library implementation.
- Provide fully-configurable toolchain definitions.

3. Lattice Propel Tool Flows

The Propel tool flows including SoC project design flow, C/C++ project design flow, system simulation flow, and programming and On-Chip-Debugging (OCD) debugging flow, are discussed in detail in the following sections.

3.1. Propel Environment

3.1.1. Running Lattice Propel

After installing Lattice Propel, you can launch Propel from the desktop shortcut icon or from the Windows Start menu. When Propel is invoked, a dialog (Figure 3.1) pops up. You can browse to select where to locate the workspace. For normal needs, just click **Launch** to pick the default location and continue running Propel.

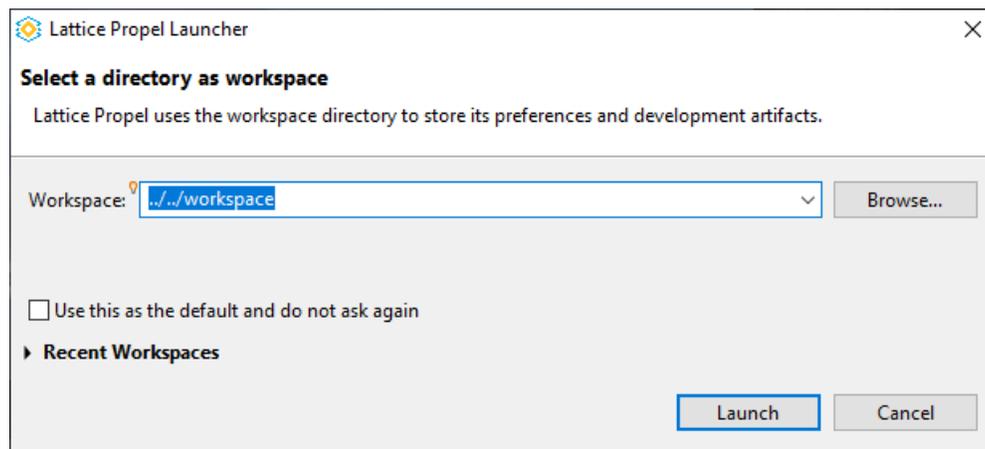


Figure 3.1. Select Workspace Dialog

After the workspace location is chosen, a single workbench window is displayed using default Propel SDK perspective. The default Propel SDK perspective contains following five functional areas (Figure 3.2).

1. Menu bar and Toolbar.
2. Project Explorer view: displays projects in the workspace.
3. Editor view: provides capability of editing source files.
4. Outline view: displays an outline of a file that is currently open in the editor area.
5. Log area includes these views: Problem view, Tasks view, Console view, Properties view, and Terminal view.

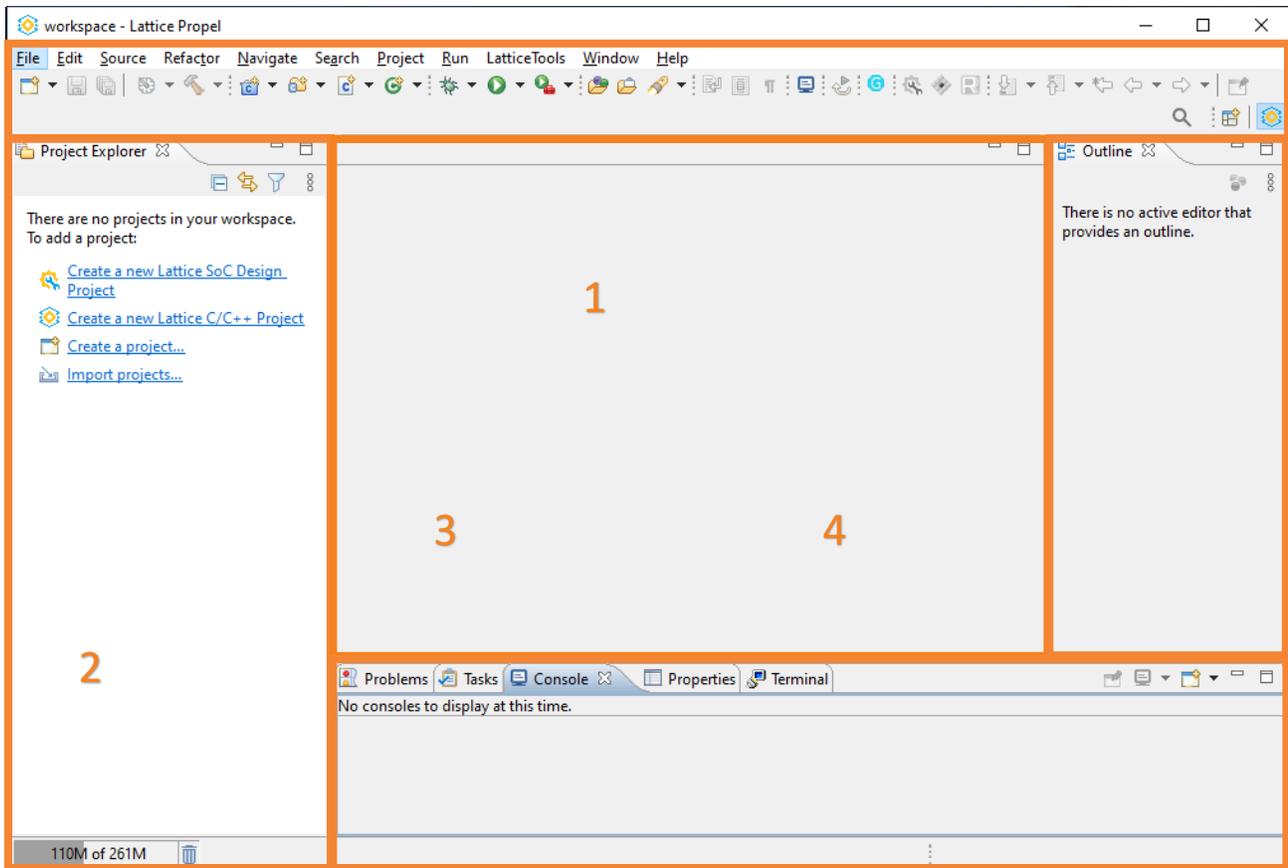


Figure 3.2. Propel Workbench Window

3.1.2. Importing General Projects

In Propel SDK, you can use the importing project wizard to import existing projects into workspace except for Lattice SoC design created by Lattice Propel Builder.

Note: You can only import projects which are created or managed by Propel SDK by choosing **General > Existing Project into Workspace** in Propel SDK.

1. In Lattice Propel (SDK), choose **File > Import....**
The **Select** wizard opens (Figure 3.3).

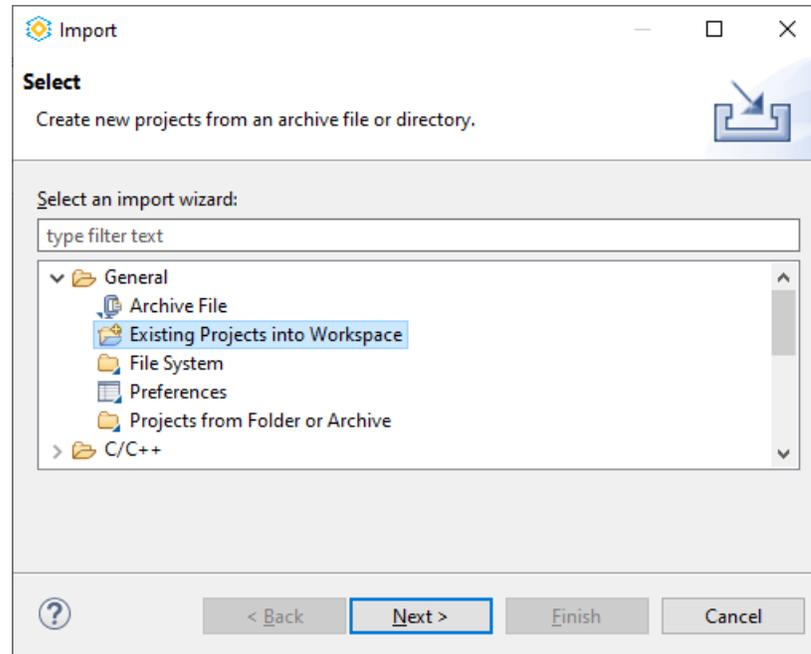


Figure 3.3. Import Projects Wizard — General

2. Select **General > Existing Project into Workspace**. Click **Next**.
The Import wizard switches to **Import Projects** wizard (Figure 3.4).

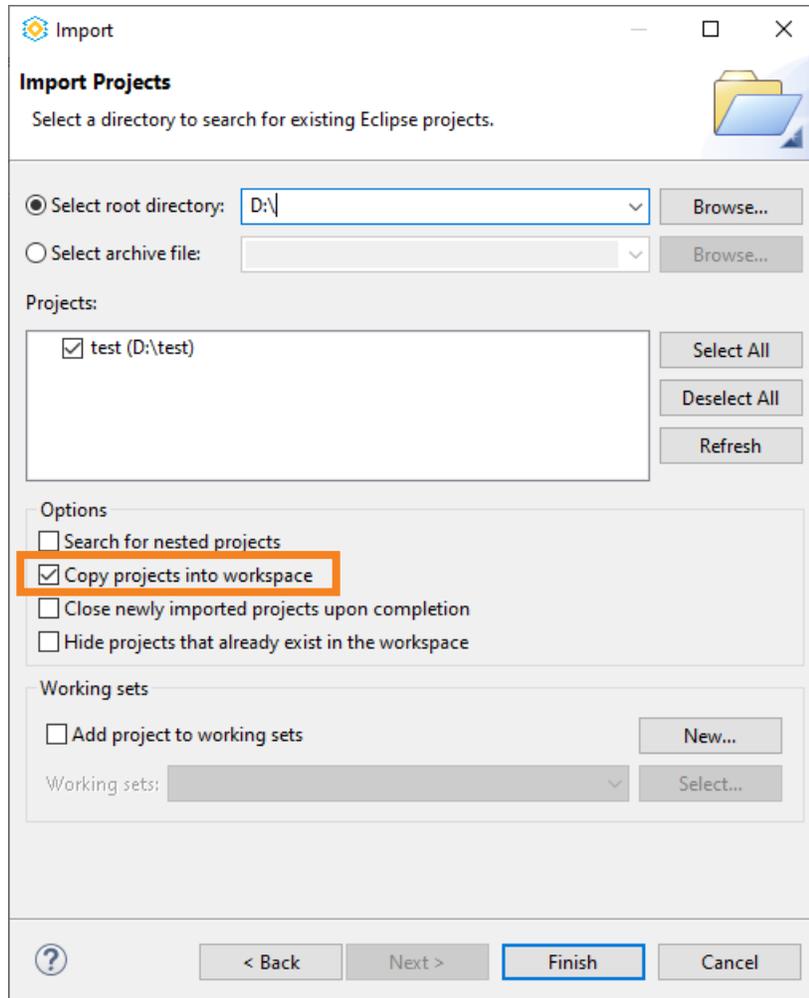


Figure 3.4. Import Existing Projects Wizard

3. Choose either **Select root directory** or **Select archive file**, clicking the associated **Browse** button to locate the directory or file containing the project.
4. **Select** the project or projects you want to import in the **Projects** area.
5. Be sure to check the **Copy projects into workspace** option so that your original projects do not get updated.
6. Click **Finish** to start the importing process.

3.1.3. Importing Lattice SoC Design Projects

In Propel SDK, you can use the Import Wizard to import Lattice SoC design projects into workspace. Existing SoC design projects created by either Propel SDK or Propel Builder can also be imported into Workspace by choosing **Lattice Propel > Lattice SoC Design Projects**.

1. From Lattice Propel SDK, choose **File > Import...**
The **Select** wizard opens (Figure 3.5).

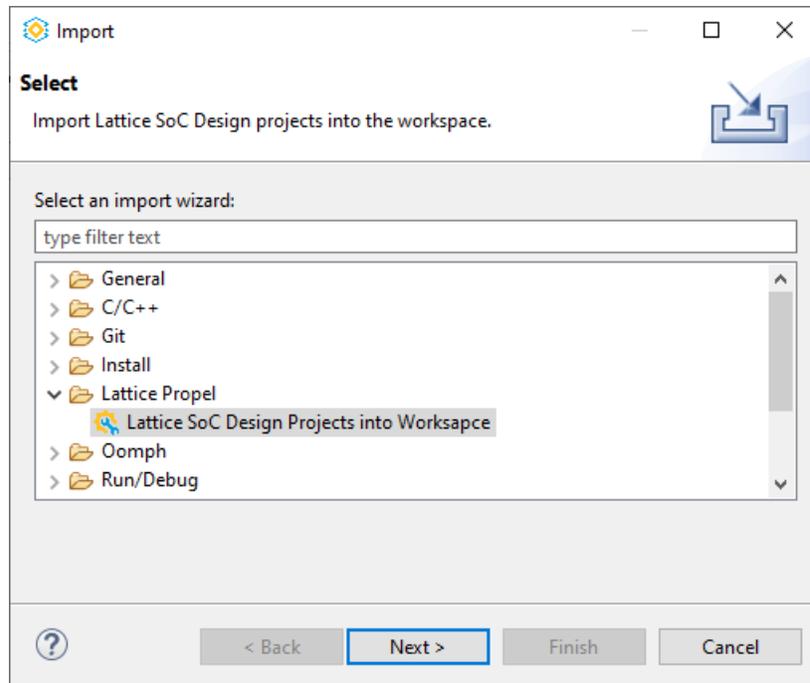


Figure 3.5. Import Projects Wizard – Lattice Propel

2. Select **Lattice Propel > Lattice SoC Design Projects into Workspace**. Click **Next**.
The **Select** wizard switches to **Import Lattice SoC Design Projects** wizard page (Figure 3.6).

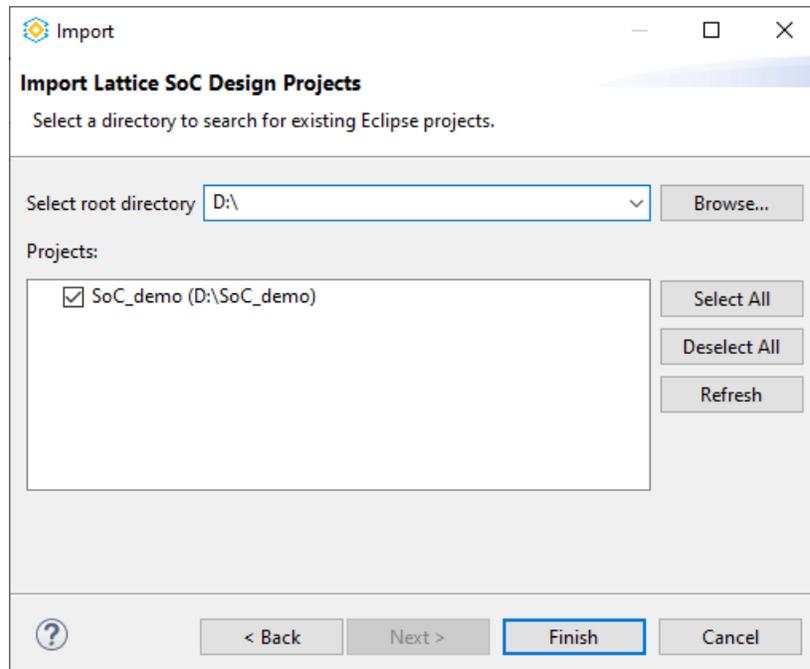


Figure 3.6. Import Lattice SoC Design Projects Wizard

3. Locate the directory containing the projects by clicking the **Browse** button.
4. In **Projects** area, select the SoC design project or projects you want to import.
5. Click **Finish** to start the importing process.

3.2. SoC Project Design Flow

A new SoC design project including a Propel Builder design can be started from the Lattice Propel sets. Follow the steps below to create a new SoC design project.

3.2.1. Creating a SoC Design Project

To start a Lattice SoC Design Project from Propel:

1. In Lattice Propel, choose **File > New >** **Lattice SoC Design Project**. The **Create SoC Project** wizard opens (Figure 3.7).

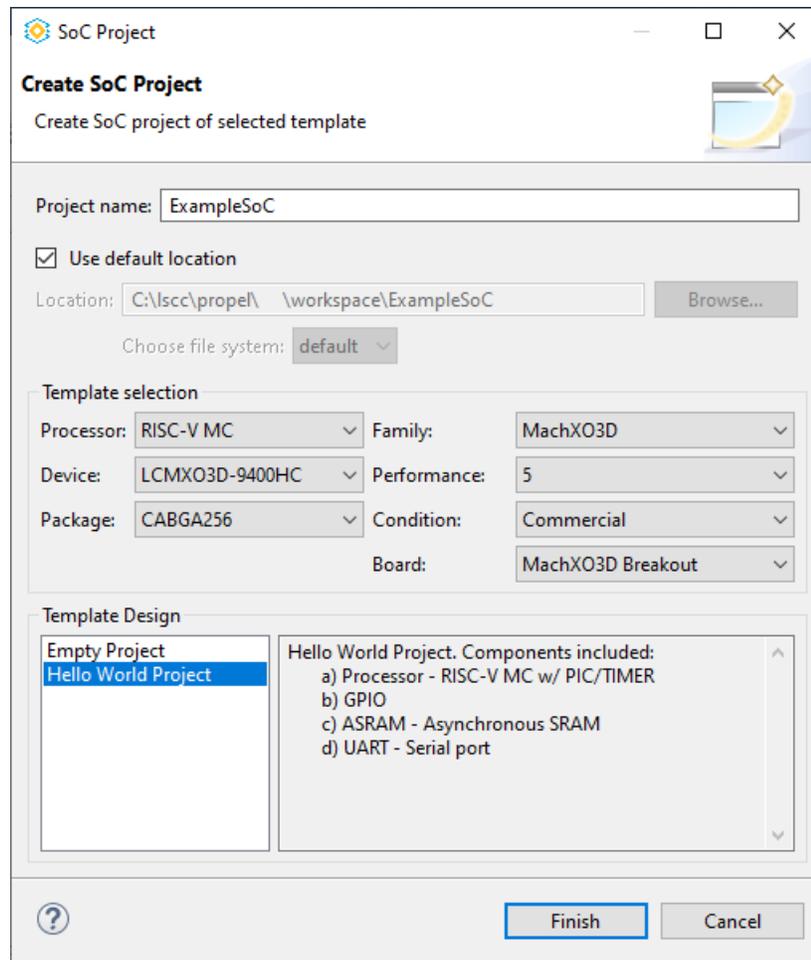


Figure 3.7. Create SoC Project Wizard

2. Enter a project name.
Note: Do not include periods, colons, or spaces in the project name.
3. (Optional) To change the default location, clear the **Use default location** option, then browse to another location. Choose a file system.
4. Select a desired platform template design. In particular, select empty project for building system from scratch.
5. Click **Finish**.

The SoC design project is created in workbench, and its design is opened and displayed in Propel Builder (Figure 3.10).

3.2.2. Open a SoC Design in Propel Builder

Within a SoC project, there is a Propel builder design.

To open Propel Builder for a SoC project:

1. In the **Project Explorer** view, select a SoC project.
2. Open the SoC project in one of the following three ways from Propel:
 - Choose **LatticeTools** >  **Open Design in Propel Builder** (Figure 3.8).

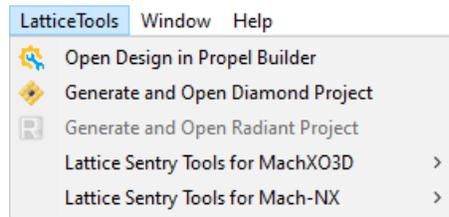


Figure 3.8. LatticeTools Menu

- Click the **Propel Builder** icon  on the toolbar.
- Right-click the SoC project from **Project Explorer**. Choose **Open Design In** >  **Propel Builder** from the popup menu (Figure 3.9).



Figure 3.9. Project Explorer Popup Menu

3. SoC Design is opened and displayed in Propel Builder (Figure 3.10).

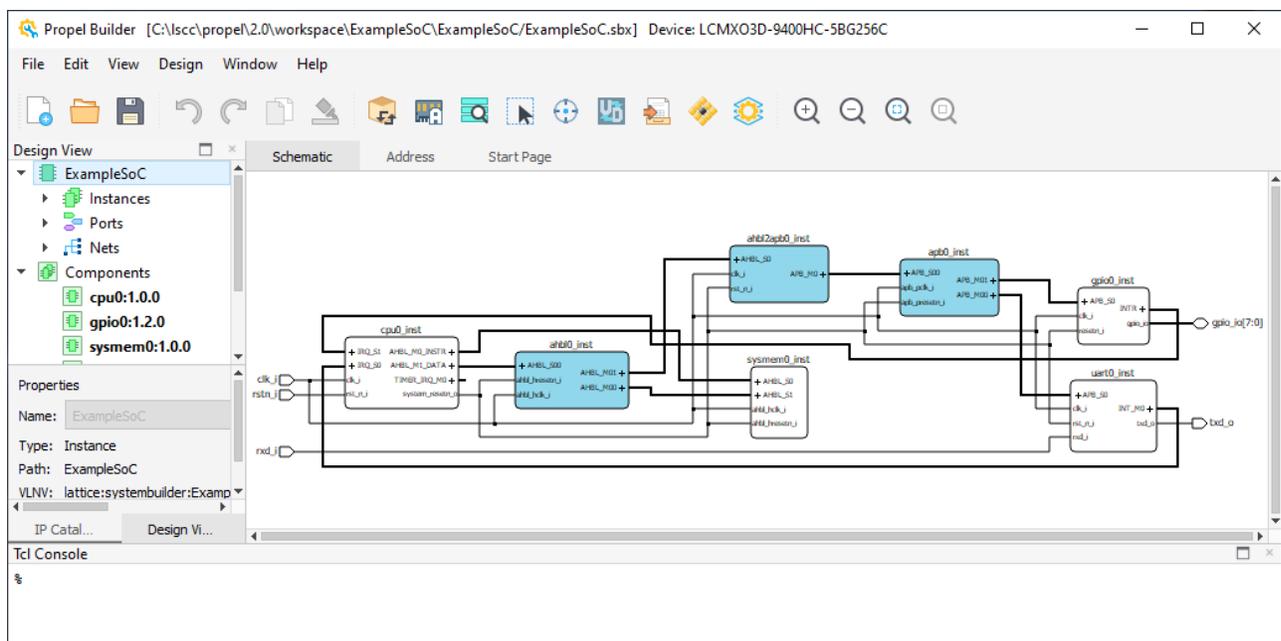


Figure 3.10. Propel Builder Window

- (Optional) Modify the design in Propel Builder as desired. Most of the templates include a functional-ready SoC design.

Note: You can only create a SoC design using **Empty Project** template inside the Propel Builder. Refer to [Lattice Propel Builder 2022.1 User Guide \(FPGA-UG-02177\)](#) for more details on how to create a SoC design using Empty Project template.

3.2.3. Open Design in Lattice FPGA Design Software

Within a SoC project, you can create a Lattice FPGA design project including a Propel Builder design, and then open the FPGA design project in appropriate software. There are two FPGA Design Software available, Lattice Diamond and Lattice Radiant™. Depends on the device family used in the SoC project, only one of the FPGA Design software can be selected from the User Interface (UI), the other is grayed out. If MachXO3D or LFMNX device family is used, the Lattice Diamond related menu items are active from Propel UI. If LIFCL or LFD2NX device family is used, the Lattice Radiant related menu items are active from Propel UI.

To open FPGA Design Software for a SoC project from Propel:

- (Optional) Set Lattice FPGA design software installation location from Propel. By default, Propel can find the proper Lattice FPGA design software installation location, usually the latest version installed on the PC. You can overwrite it following steps below.

Choose **Window > Preferences**. The Preferences dialog opens ([Figure 3.11](#)).

Select **Propel Setting** from the left pane. Click the **Browse** button to pick up the installation location of Diamond or Radiant. Or, leave the **Radiant Location** area and **Diamond Location** area blank, as default. Propel can find the location atomically.

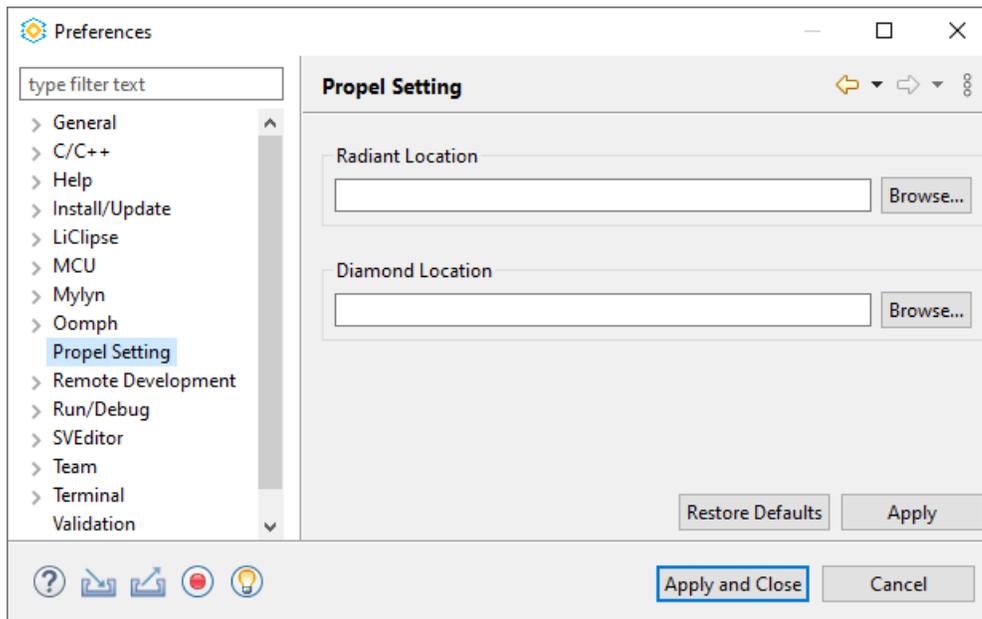


Figure 3.11. Propel Preferences Dialog

- In the **Project Explorer** view from the Propel main Graphical User Interface (GUI), select a SoC project.
- Open the SoC project in one of the following ways:

- Choose **LatticeTools > Generate** and open a Diamond project; Or, choose **LatticeTools > Generate** and open a Radiant project.
- Click the **Diamond icon** or the **Radiant icon** from the toolbar.

- Right-click a SoC project from the **Project Explorer**. Choose **Open Design In** > **Diamond**. Or, choose **Open Design In** > **Radiant** from the right-click menu.

4. Diamond/Radiant project for SoC is generated at background and is launched ([Figure 3.12](#)/[Figure 3.13](#)).

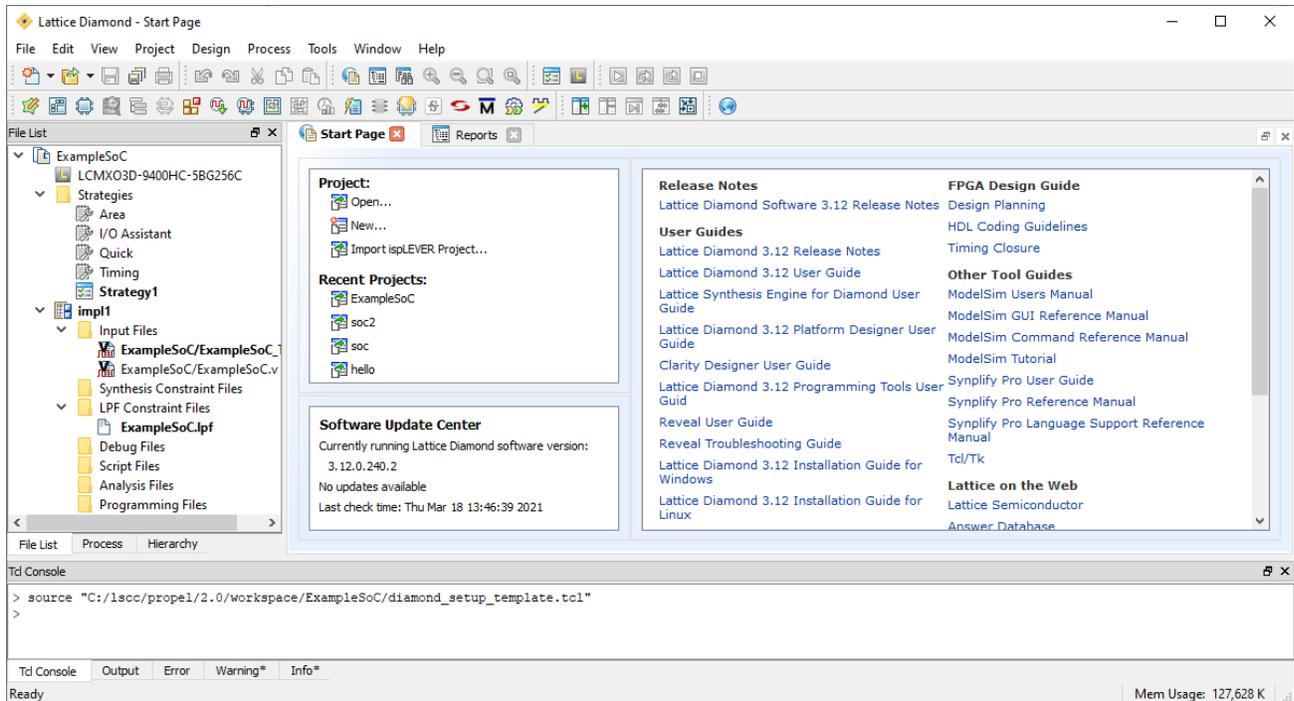


Figure 3.12. Diamond Project

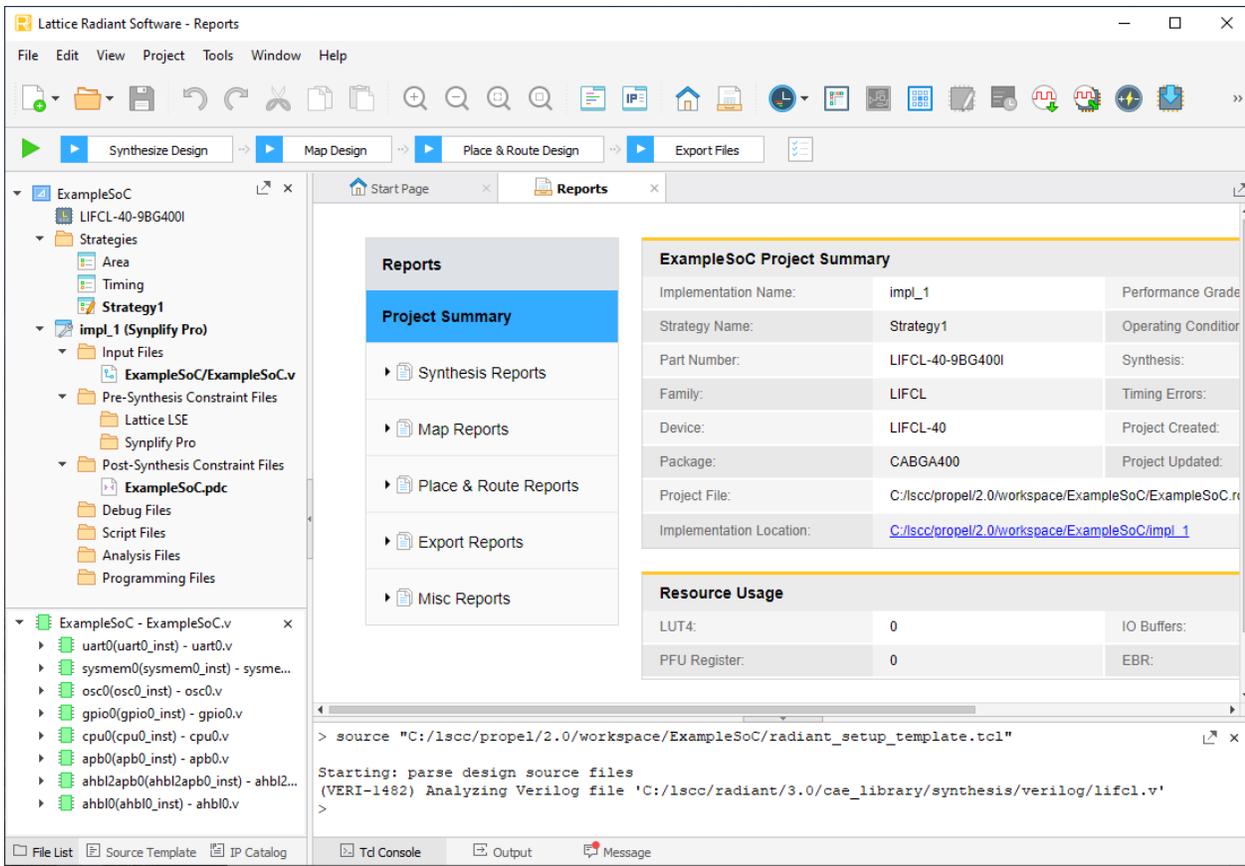


Figure 3.13. Radiant Project

5. (Optional) From the **File List** view of the Diamond/Radiant software:
 - modify the top-level RTL file (<proj_name>_Top.v) to match the SoC design, presupposition of which is that there is a top-level RTL file in your SoC design; or
 - create a top-level RTL file (<proj_name>_Top.v) to match the SoC design, if the SoC design is created from an Empty Project template and there is no top-level RTL file in your SoC design.
6. (Optional) Modify constraint file (<proj_name>.lpf/<proj_name>.pdc) to match the SoC design, if you have modified the SoC design.

Note: This step is a must to the SoC design that is created from Empty Project template.

7. Process the design in Lattice Diamond/Radiant.

In Diamond software, switch to **Process** view of the project (Figure 3.14). Make sure at least one file, IBIS Model, Verilog Simulation File, VHDL Simulation File, Bitstream File, or JEDEC file, is checked in the **Export Files** section for programming. Choose **Process** > **Run**.

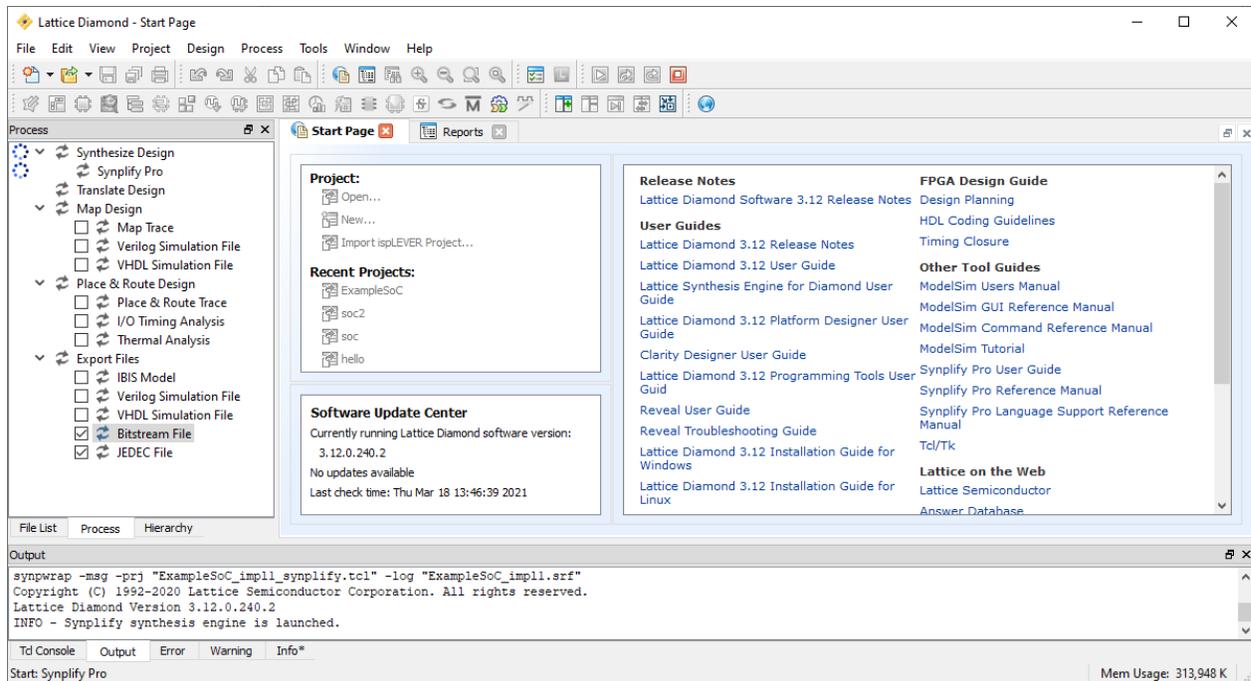


Figure 3.14. Generate Programming File in Lattice Diamond

In Radiant software, from the **Process** Toolbar, click **Export Files** (Figure 3.15).

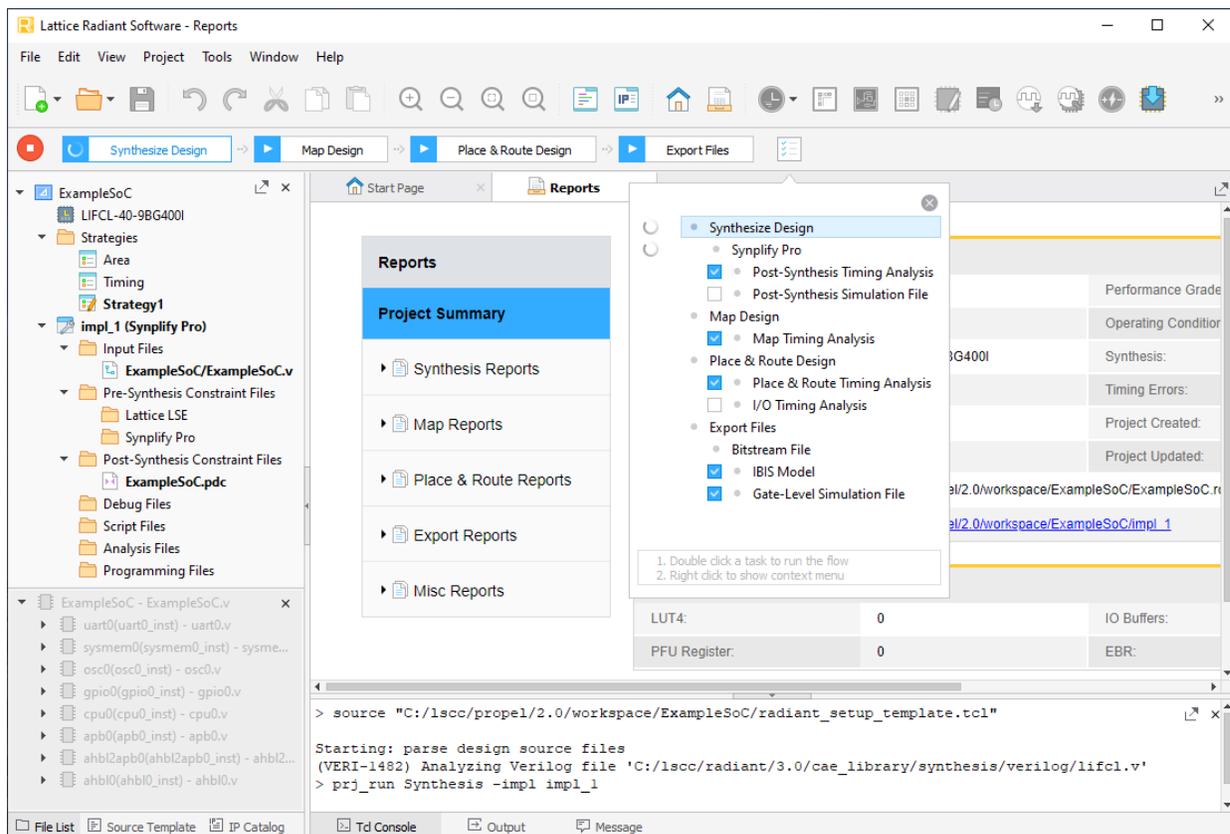


Figure 3.15. Generate Programming File in Lattice Radiant

The Programming file is generated. The generated programming file can be used in the Programmer.

3.2.4. Generating System Environment by Building Project

System environment package including the system environment file and the BSP package is required for the embedded C/C++ project.

To generate system environment package from Propel:

1. In the **Project Explorer** view, select a SoC project.
2. Choose **Project > Build Project**.
3. Check the building result in the **Console** view (Figure 3.16).

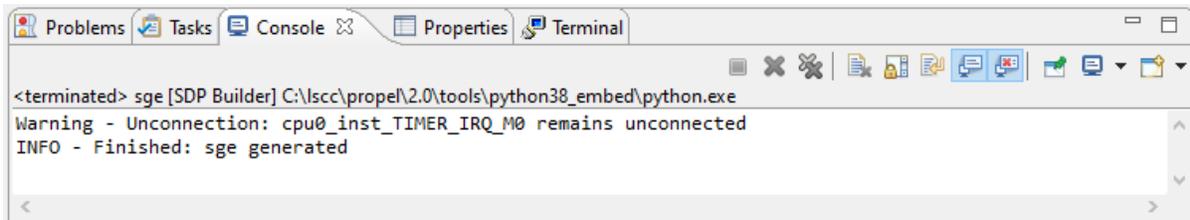


Figure 3.16. Build Result of SoC Project

3.2.5. About SoC Design Project

The SoC project creating starts with a functional-ready SoC design and a default simulation environment. In the **Project Explorer** view, open a SoC project folder and all its sub-folders. The project contains the following files but not limited to the following files (Figure 3.17), some of which may vary upon your opening the SoC design project in Diamond or Radiant software:

- `<proj_name>`: Folder contains a Propel Builder design including the .sbx file.
- `<proj_name>/application`: Folder contains functional-ready embedded application source codes.
- `impl1`: Folder contains the implementation of Diamond/Radiant project.
- `sge`: Folder contains generated package necessary for creating C/C++ project.
- `verification`: Folder contains the SoC verification project.
- `verification/sim`: Folder contains the simulation environment.
- `<proj_name>.ldf`: Diamond project file.
- `<proj_name>.lpf`: Diamond project logical preference file.
- `<proj_name>.rdf`: Radiant project file.
- `<proj_name>.pdc`: Radiant project post-synthesis constraints.
- `<proj_name>.txt`: Description file from the template.

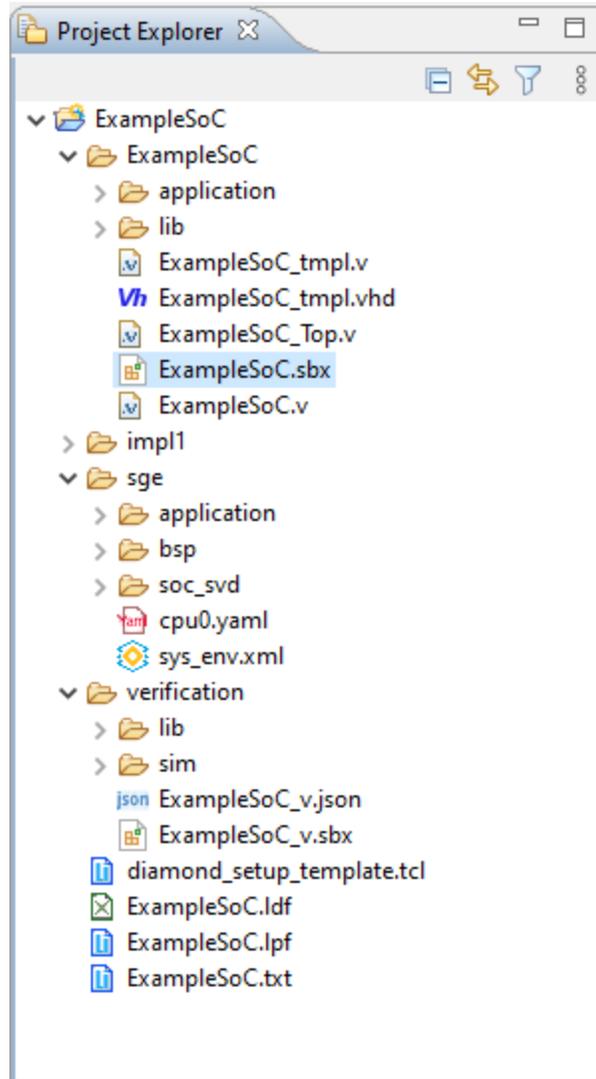


Figure 3.17. Contents of SoC Project

3.3. C/C++ Project Design Flow

3.3.1. Creating a Lattice C/C++ Project

To start a Lattice C/C++ Project from Propel:

1. Choose **File > New >**  **Lattice C/C++ Project**.

The C/C++ Project wizard opens with the **Load System and BSP** page (Figure 3.18).

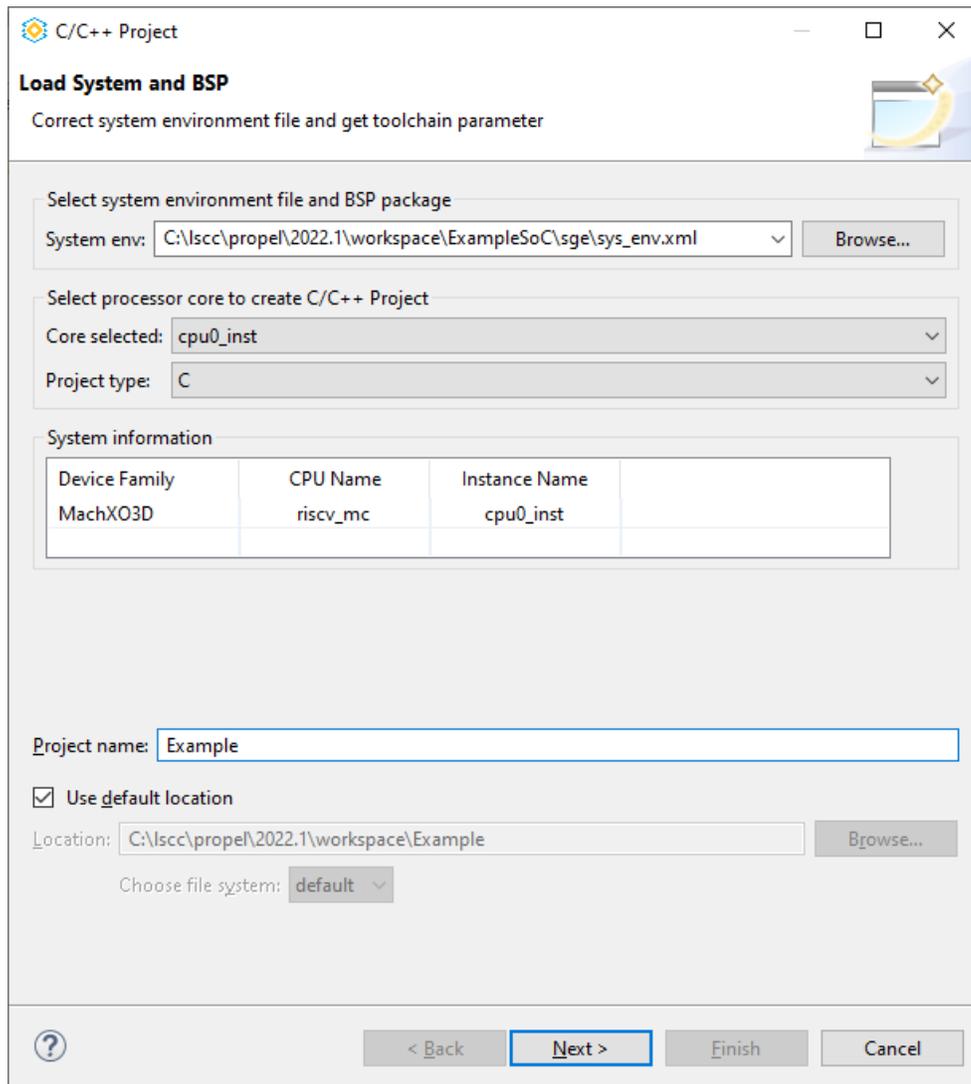


Figure 3.18. Load System and BSP Dialog

2. Browse to the SoC project folder and select the system environment file `sys_env.xml`.
All system environment files available in the current workspace can be selected from the **System env:** drop-down menu.
3. If the platform has more than one processor, choose one core.
4. Choose the project type, C or C++.
5. Enter a project name. Suggest not using periods, colons, or spaces in your project name. Though spaces are allowed, they may cause certain issue with some tools.

6. By default, the Use default location option is checked. The default file system is selected automatically. Suggest using the default location unless you have special need to a special location.
7. Click **Next**.

The **Lattice Toolchain Setting** dialog opens ([Figure 3.19](#)).

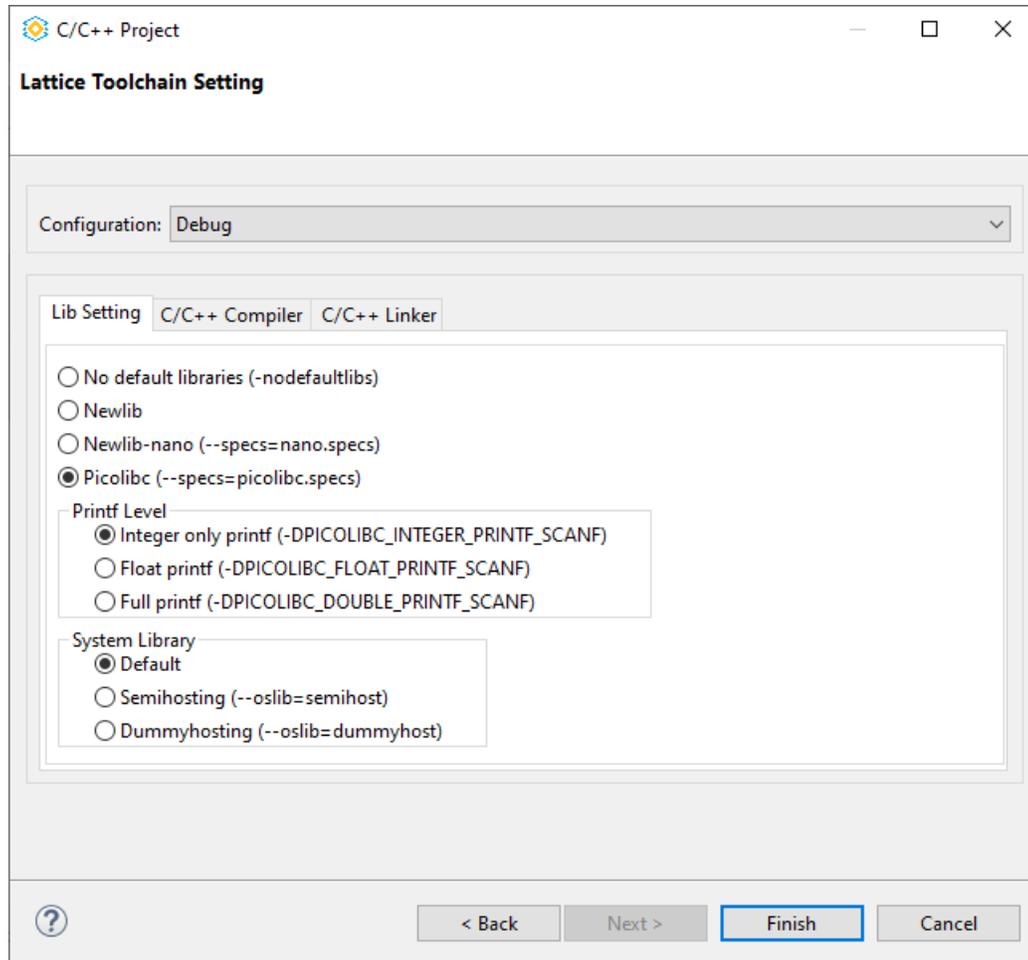


Figure 3.19. Lattice Toolchain Setting Dialog

8. By default, two toolchain configuration modes, **Debug** and **Release**, can be chosen from the Configuration drop-down menu.
 - **Debug** configuration creates executables containing additional debug information that lets the debugger make direct associations between the source code and the binary files generated from the original source.
 - **Release** configuration provides the tools with options setting to create an application with the best performance.

You can modify frequently-used library, compiler, and linker options for each configuration. For a complete toolchain setting, go to project properties after creating the project. Refer to the [Advanced Tool Chain Setting](#) section.

- In **Lib Setting** tab, standard C library can be reconfigured. Picolibc (C Libraries for Smaller Embedded Systems) is selected by default and it supports different printf levels.
- In **C/C++ Compiler** tab, optimization level and debug level can be reconfigured for each toolchain configuration.
- In **C/C++ Linker** tab, Remove unused code (--gc-sections) is checked by default for garbage collection of unused code.

9. Click **Finish**.

The Lattice C/C++ project is created and is displayed using the Propel SDK perspective. A perspective is a collection of tool views for a particular purpose. The Propel SDK perspective is for creating Lattice C/C++ programs.

3.3.2. Updating a Lattice C/C++ Project

When you make changes to a SoC project, sometimes you want to synchronize the changes to an existing Lattice C/C++ project instead of creating a new Lattice C/C++ project. In this case, you can use the update C/C++ project feature.

Note: This feature overwrites the corresponding files or settings of your existing C/C++ project. Be sure to back up your C/C++ project before using this feature.

To update a Lattice C/C++ Project from Propel:

1. Generate the latest system environment package according to the [Generating System Environment by Building Project](#) section.
2. In the **Project Explorer** view, select a C/C++ project.
3. Choose **Project > Update Lattice C/C++ Project...**

The C/C++ Project wizard opens for updating system and BSP ([Figure 3.20](#)).

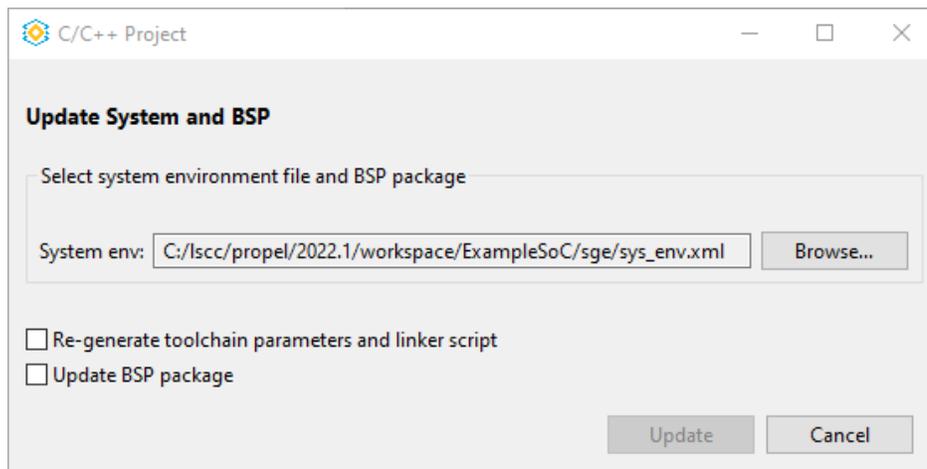


Figure 3.20. Update System and BSP Dialog

4. Browse to the SoC project folder and select the system environment file sys_env.xml.
5. Select the checkbox for what you can update:
 - Re-generate toolchain parameters and linker script: check this option if you want to modify CPU or memory in the system.
 - Update BSP package: check this option if you want to add additional IP components into the system.
6. Click **Update** to make changes for the selected C/C++ project.

3.3.3. Building a Lattice C/C++ Project

To build a Lattice C/C++ project in Propel:

1. In the **Project Explorer** view, select a C/C++ project.
2. Follow steps below if you want to change the active build configuration:
 - a. Choose **Project > Build Configurations > Manage...** Or, click the **Configuration** icon  on the toolbar.
 - b. The Manage Configurations dialog opens ([Figure 3.21](#)) for choosing active configuration. By default, a **Debug** configuration creates executables containing additional debug information that lets the debugger make direct associations between the source code and the binary files generated from the original source. A **Release** configuration provides the tools with options setting to create an application with the best performance.

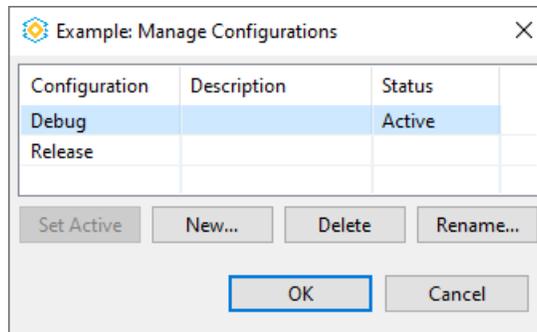


Figure 3.21. Manage Configurations Dialog

3. Choose **Project > Build Project**. Or, click the **Build** icon  on the toolbar.
4. The results of the build command are displayed in the **Console** view (Figure 3.22).

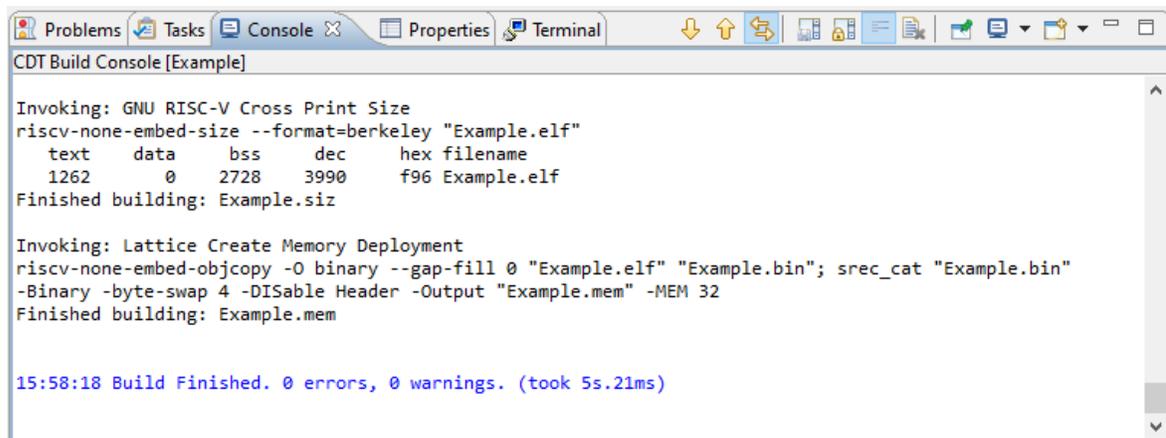


Figure 3.22. Build Result of C/C++ Project

3.3.4. About Lattice C/C++ Project

The Lattice C/C++ project starts with source code. In the Project Explorer view, open a C/C++ project folder and all its sub-folders. The project contains:

- `src/bsp/driver`: Folder contains driver codes from the IP in the platform.
- `src/bsp/sys_platform.h`: Header file that defines `DEVICE_FAMILY` (the Lattice FPGA), address mapping, and any IP parameters that can be used by the drivers.
- `src/main.c`: Source file contains the main routine, which is the entry-point of a C/C++ program.
- `src/cpu0.svd`: System view description file used for peripherals registers view at debug perspective.
- `src/cpu0.yaml`: Processor description file used at debugging time.
- `src/linker.ld`: Linker script file.
- `src/sys_env.xml`: System environment file describing aspects of the platform, such as memory spaces.

After building the project, the build output can be found in each build configuration folder, the **Debug** folder or the **Release** folder (Figure 3.23). The Debug or Release folder contains:

- `<proj_name>.elf`: Executable file used in on-chip debugging.
- `<proj_name>.bin`: Binary file used in deploying the application to flash memory.
- `<proj_name>.lst`: Extended listing file generated by tool objdump.
- `<proj_name>.map`: Linker map file.
- `<proj_name>.mem`: Lattice system memory initialization file used in System_Memory IP.

Note: Some of the files listed in [Figure 3.23](#) are intermediate files that you do not need to take care of.

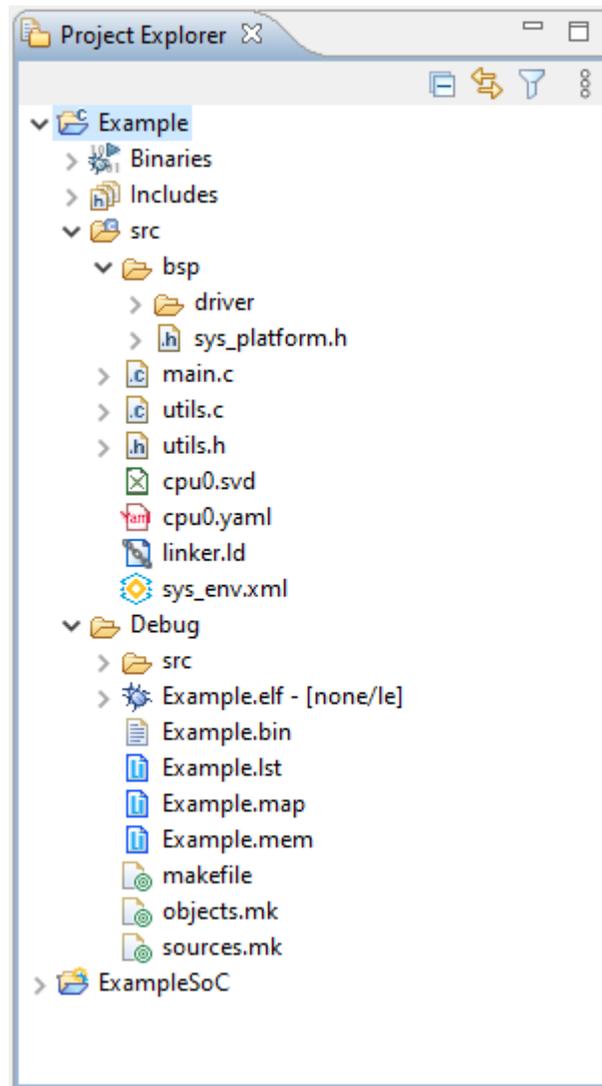


Figure 3.23. Contents of C/C++ Project

3.3.5. Writing Code

Lattice Propel is based on Eclipse IDE. You can write application code following the process and usage of the same tools as any in Eclipse IDE. You can get more detailed information regarding Eclipse IDE from the Propel online help.

For writing code, Lattice Propel SDK provides two extra aids:

- Lattice System Platform: An overview of the processor platform can be displayed ([Figure 3.24](#)).
- Linker Editor: An overview of the memory regions of linker script can be displayed. You can modify key linker parameters via the graphical interface ([Figure 3.25](#)).

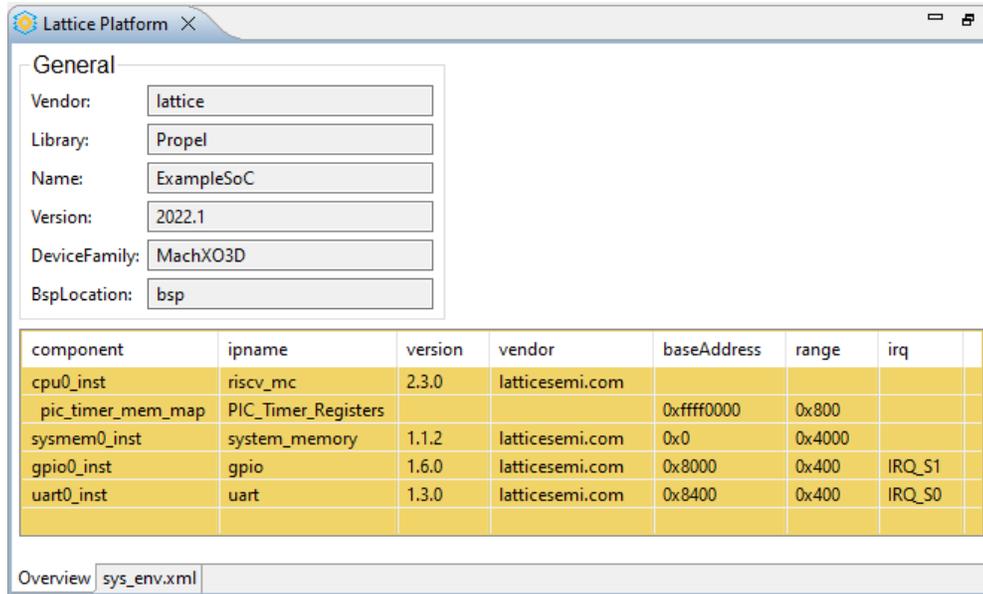


Figure 3.24. Lattice System Platform

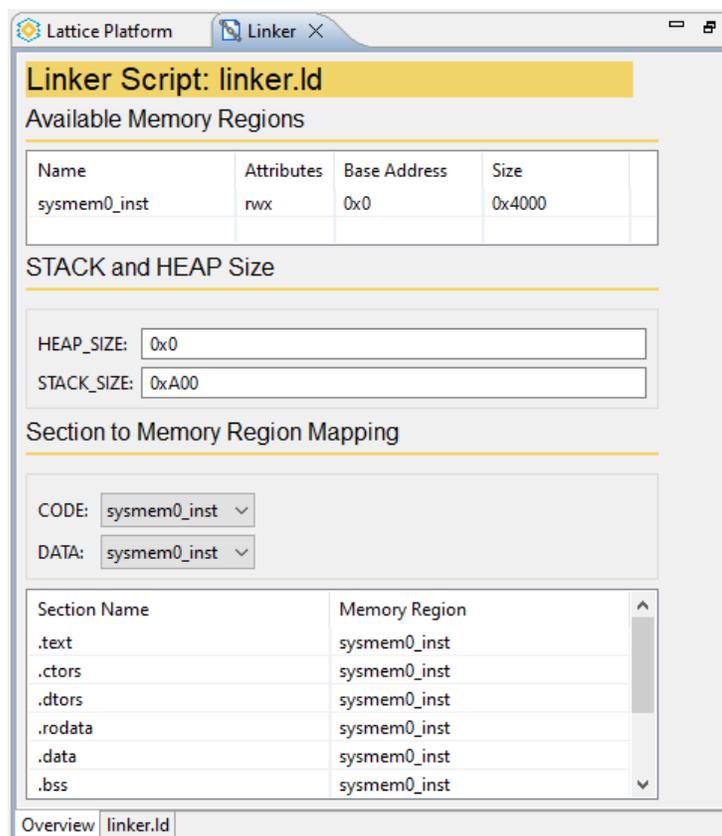


Figure 3.25. Linker Editor

3.3.6. Advanced Tool Chain Setting

Follow the process below to modify the tool chain settings of a C/C++ project.

To change tool chain setting in Project Properties in Propel:

1. In the **Project Explorer** view of Propel, select a C/C++ project.
2. Choose **Project > Properties**. The Properties for current project opens (Figure 3.26).
3. Select **Settings** of **C/C++ Build** category from the left pane. Select the **Tool Settings** tab.

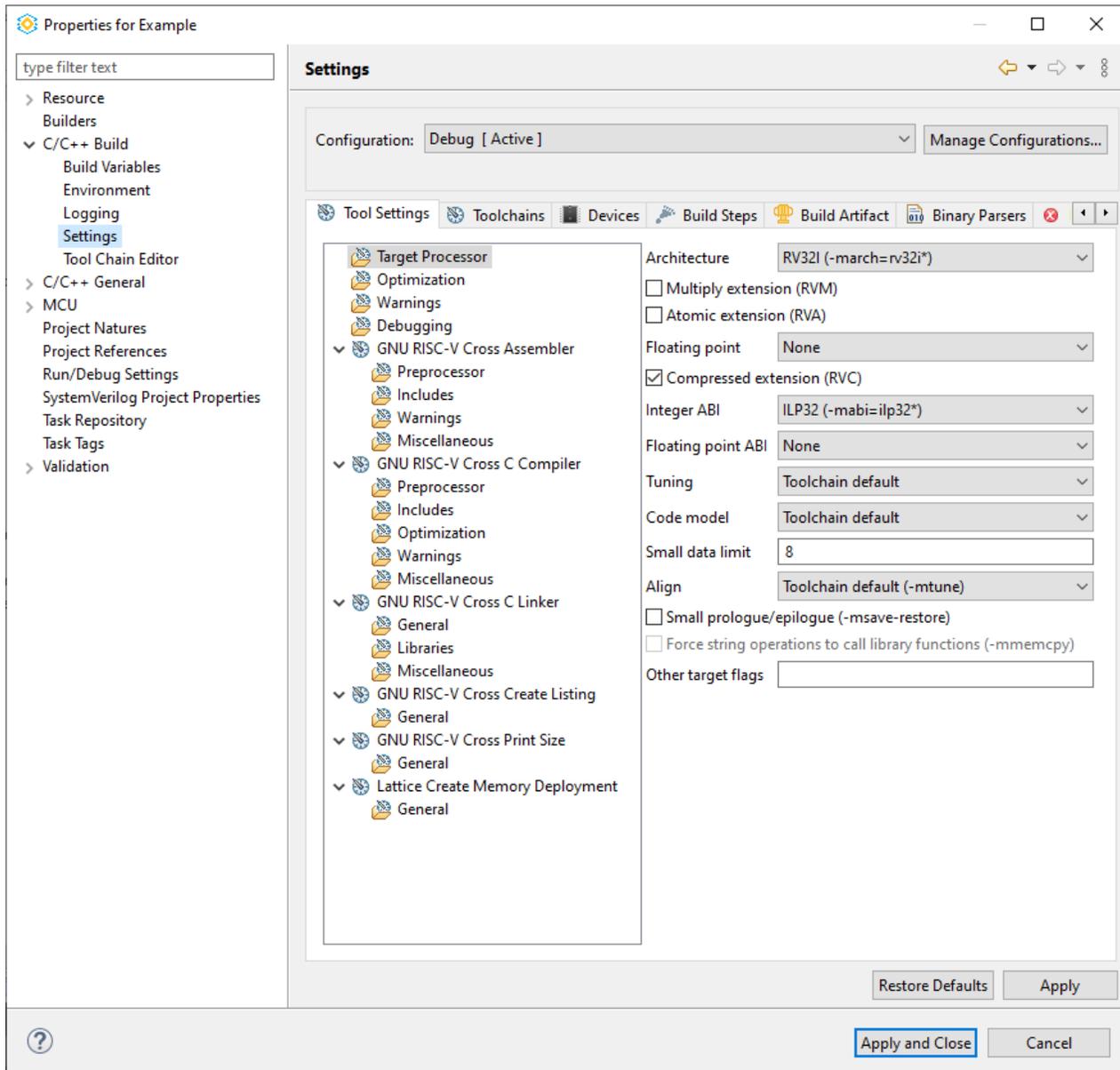


Figure 3.26. Properties of C/C++ Project

4. Customize the tools and tool options. All your customization can be resulted in the build configuration in the **Tool Settings** properties tab. The build configuration is used during your C/C++ project building.

Note: Setting for each configuration, **Debug** or **Release**, is independent.

5. Click **Apply and Close** to save the change.

Note: You may need to clean the project to make the new setting take effect for the whole project.

3.4. System Simulation Flow

The SoC Project created from template has a default simulation environment for you to setup and start functional simulation. It is generated automatically along with the SoC project creation. You can use it as a start point and customize accordingly.

The default simulation environment is with the following features:

- Provides similar user experience as real board-level debugging, such as for Hello World SoC, key components including RISC-V MC, System memory, and UART.
- Simulates user-modified template SoC with extended HDL designs.
- Simulates the whole system using real C/C++ projects as stimulus with the necessary modification and with all the details for debugging.
- Supports user extension with a friendly and flexible approach.

3.4.1. Launch Simulation

To launch simulation:

1. In Propel Builder, update the SoC design to enable simulation features.
 - Enable the checkbox for **Simulation Mode**, and disable the checkbox for **Debug Enable** for *RISC-V MC* module in the **General** area (Figure 3.27).

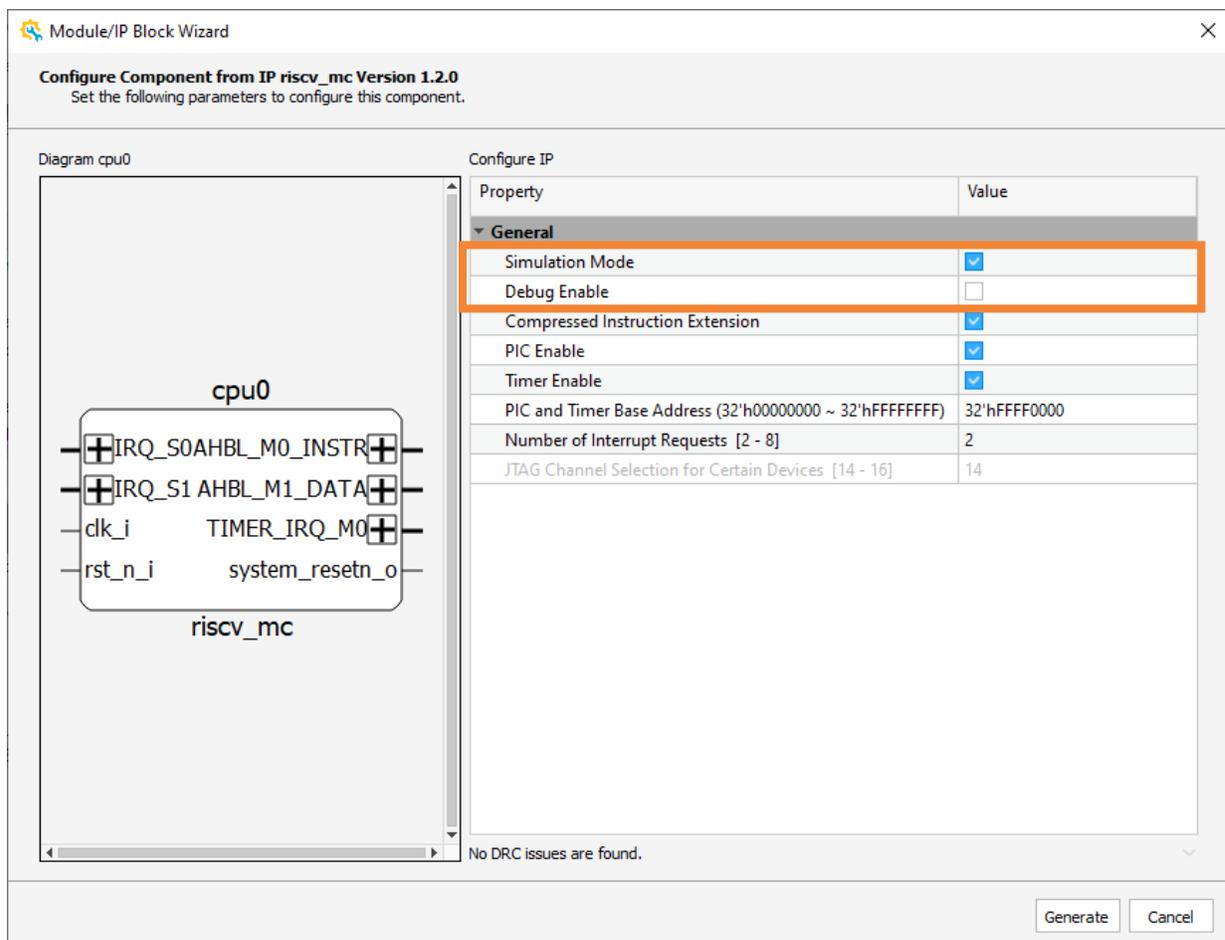


Figure 3.27. Configure Module RISC-V MC

- Enable the checkbox for **Initialize Memory** for *system_memory* IP module from the **Initialization** area of the **General** tab, and set **Initialization File** generated from the corresponding C/C++ project (Figure 3.28).

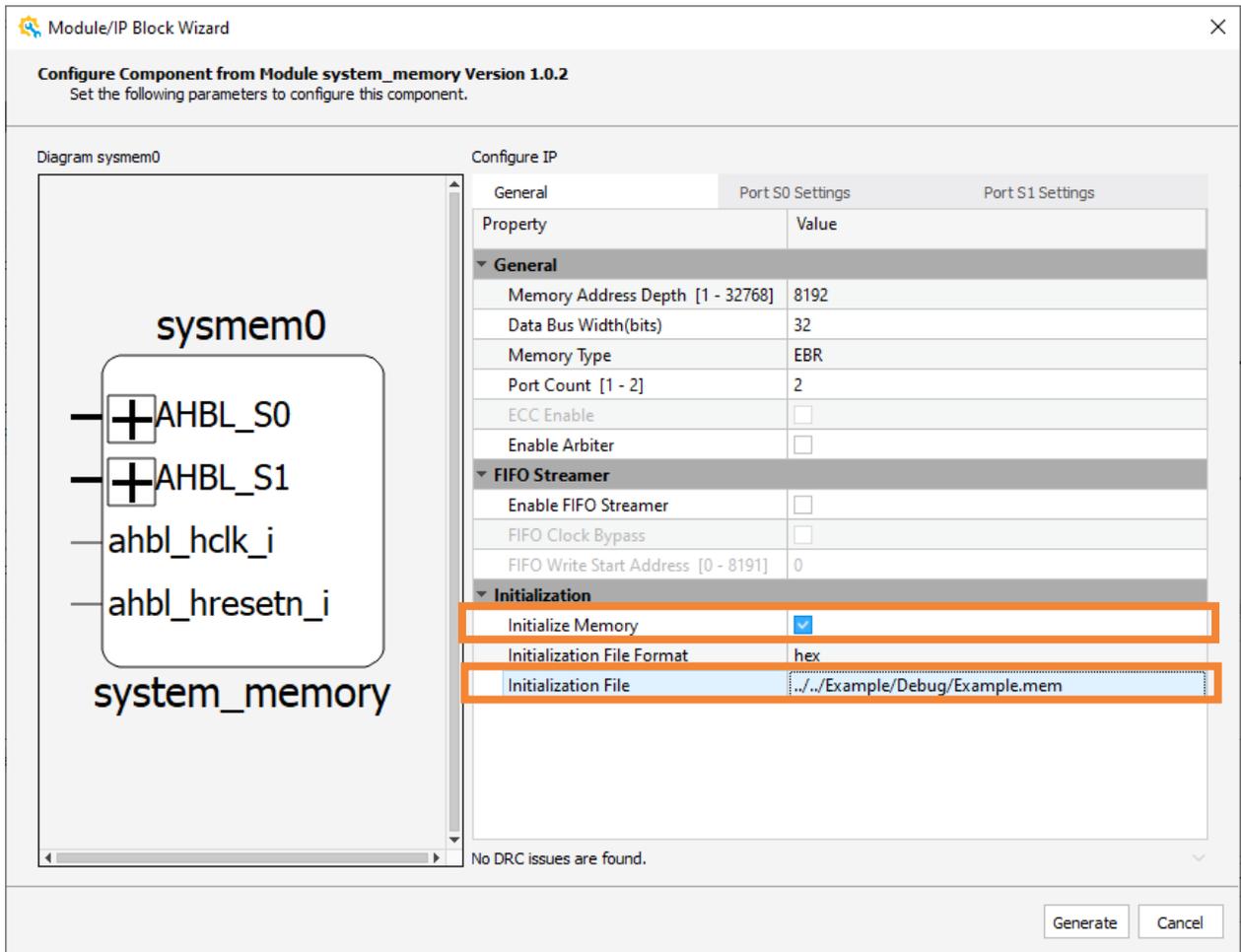


Figure 3.28. Configure Module System Memory

2. Click the **Switch** icon on the toolbar to switch between SoC design and SoC verification project (Figure 3.29).
3. After the SoC design is switched to a SoC verification project, click the **Generate** icon to generate the simulation environment for OEM ModelSim. Click the **Launch Simulation** icon (Figure 3.29).

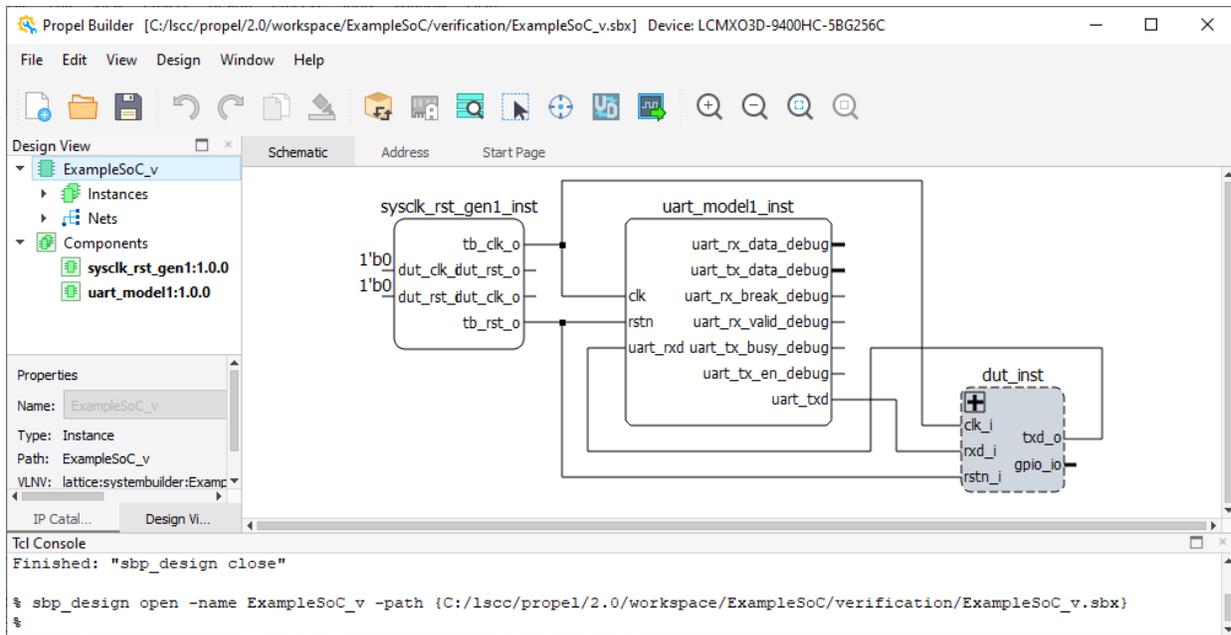


Figure 3.29. SoC Verification Project

- ModelSim is launched running simulation for the SoC verification project. The corresponding waveform of the SoC verification project for the Hello World project is shown (Figure 3.30). Check the waveform.

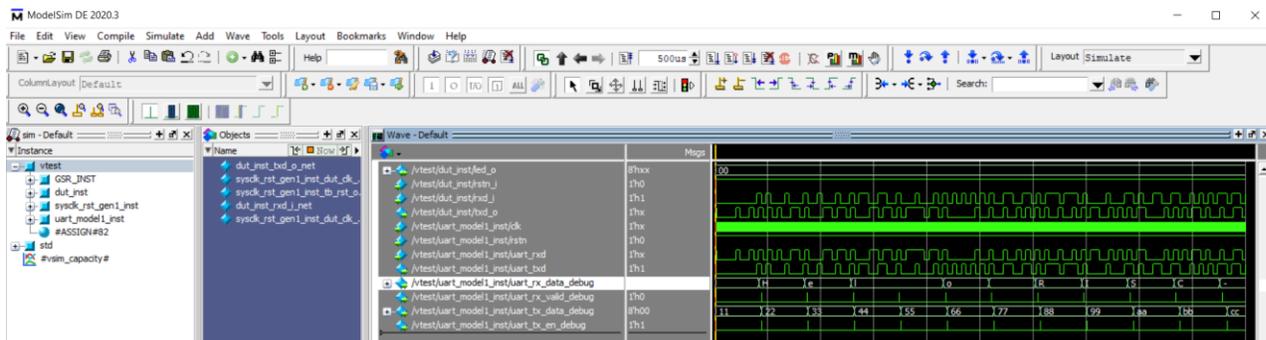


Figure 3.30. Waveform of Hello World Project

3.4.2. Simulation Details

The default simulation environment is located at the generated sim folder inside the SoC verification project in Propel. It contains:

[sim]	-- generated simulation environment
[hdl_header]	
soc_regs.v	-- register definitions of all the components in DUT/SOC
sys_platform.v	-- base address, user settings of all the components in DUT/SOC
[misc]	
.	-- all the mem, hex, txt files will be copied here
flist.f	-- file list for HDLs
msim.do	-- do script for simulator, it can be qsim for Questasim
wave.do	-- do script for adding signals in waveform window
<project_name>.sv	-- top testbench, SystemVerilog based

You can extend more verification features in the top testbench.

About Hello World Project

The Hello World Project is designed to print some strings using a top-level UART port. The testbench instantiates a UART model to receive these data. Each byte (refer to `uart_rx_data` shown in [Figure 3.30](#)) can be checked using ASCII format. Meanwhile, this UART model also supports sending the data to Design Under Test (DUT). The data is stored in a text file and enabled by `STIMULUS_GEN` parameter.

3.5. Programming and On-Chip-Debugging Flow

This section describes the process of testing and debugging application code on the actual hardware including the Lattice FPGA with the hardware design installed. Debugging with Propel SDK follows the same process and uses of the same tools of any of those in Eclipse IDE.

Before debugging, download the hardware design created from Diamond/Radiant Programmer. Refer to the User Guide of the specific evaluation board for more details on the evaluation board.

3.5.1. Creating a Debug Launch Configuration

To debug a program, a debug launch configuration must be created. Most of the settings for a debug launch configuration can be automatically entered. Only a few settings need to be manually configured.

To create a debug launch configuration:

1. In the **Project Explorer** view of Propel, select a C/C++ project.
2. Build the project and ensure the executable file is available. Refer to the [Building a Lattice C/C++ Project](#) section for details on the process.
3. Choose **Run > Debug Configurations...**

The **Debug Configurations** dialog opens ([Figure 3.31](#)).

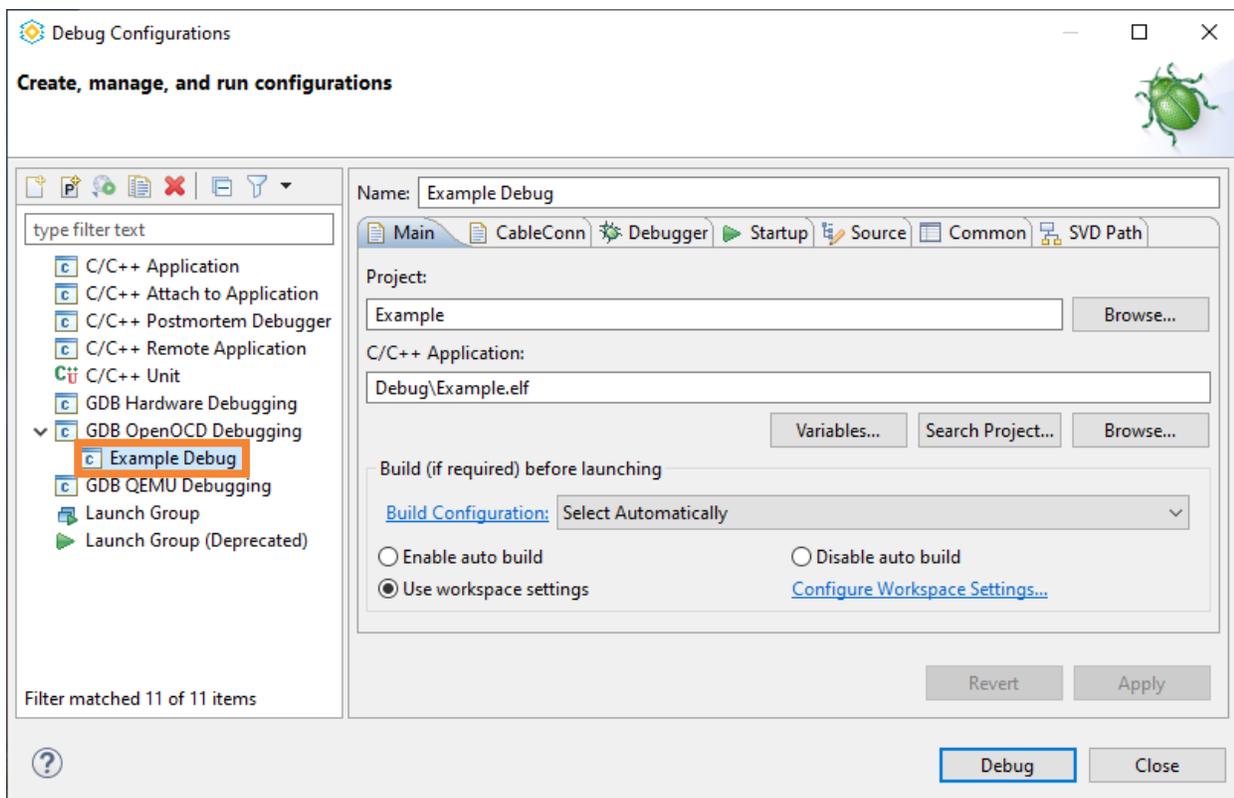


Figure 3.31. Debug Configurations Page

4. Double-click **GDB OpenOCD Debugging** to create a new launch configuration.
A multi-tab page is displayed. The Main tab should already be filled in with the project name, application file name, and location.
5. Select the **CableConn** tab (Figure 3.32). This tab enables you to select a specific device on a specific cable port.
Click the **Detect Cable** button. Select the specific cable port from the **Port** drop-down list. By default, the first available cable port: FTUSB-0 is selected.
Click **Scan Device** button. Select the specific device from **Device** drop-down list. By default, the first available device on selected cable port is selected.
Select the jtag channel number from **Channel** drop-down list. By default, channel 14 is selected with the same value as the processor preset.
Keep the cable speed so that you can use the default clock divider.

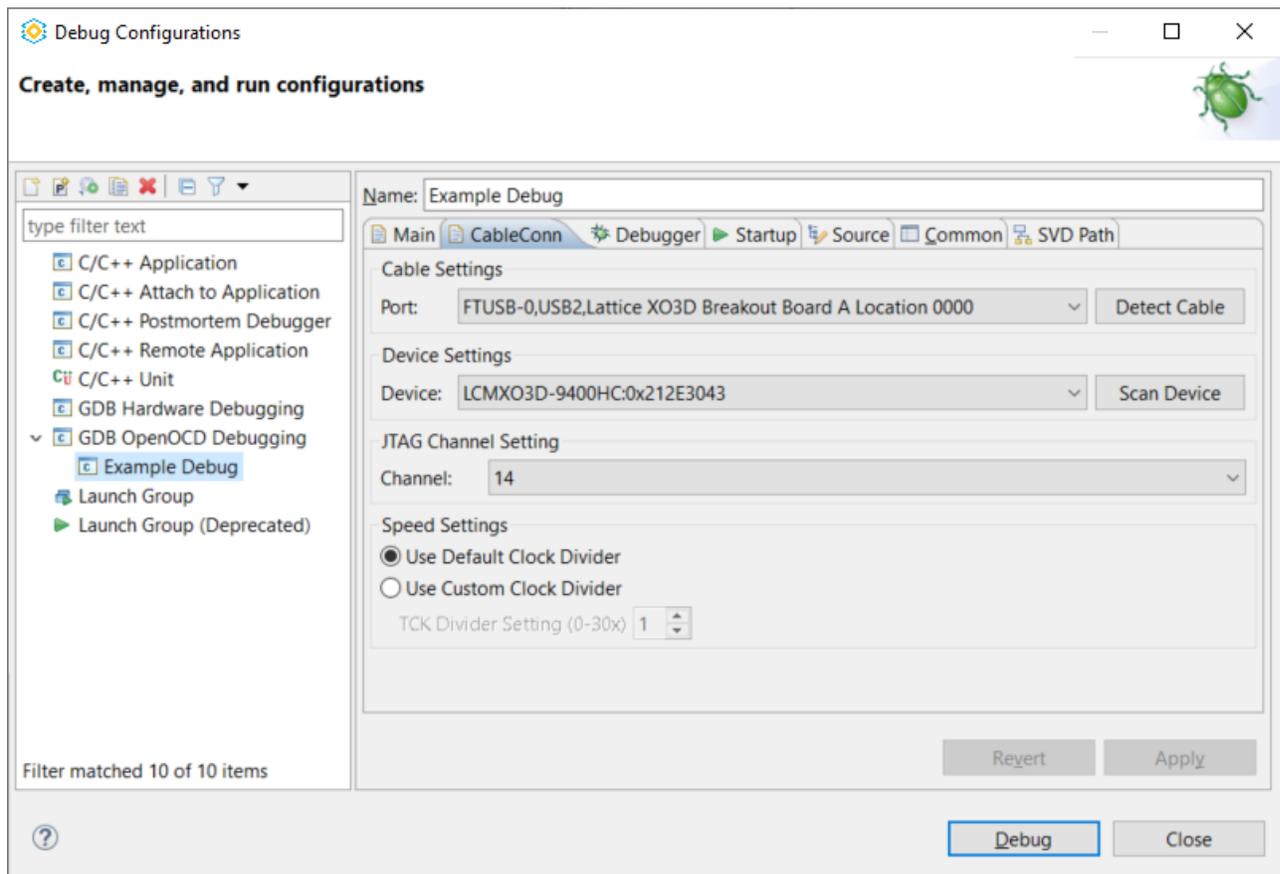


Figure 3.32. CableConn Tab of Debug Configurations

6. Select the **Debugger** tab (Figure 3.33). It is critical that the **Config options** field contains the correct command line options to be passed to OpenOCD.
 - c "set port $\${PORT}$ " is required for the selection connected to Lattice cable. The value of variable " $\${PORT}$ " comes from the cable settings of CableConn tab.
 - c "set target $\${DEVICE}$ " is required for the selection specific device on the Lattice cable. The value of variable " $\${DEVICE}$ " comes from the device settings of CableConn tab.
 - c "set channel $\${CHANNEL}$ " is required for setting JTAG channel. The value of variable " $\${CHANNEL}$ " comes from the jtag channel setting of CableConn tab.
 - c "set tck $\${TCKDIV}$ " is required for setting clock divider of the Lattice cable. The value of variable " $\${TCKDIV}$ " comes from the speed setting of CableConn tab.

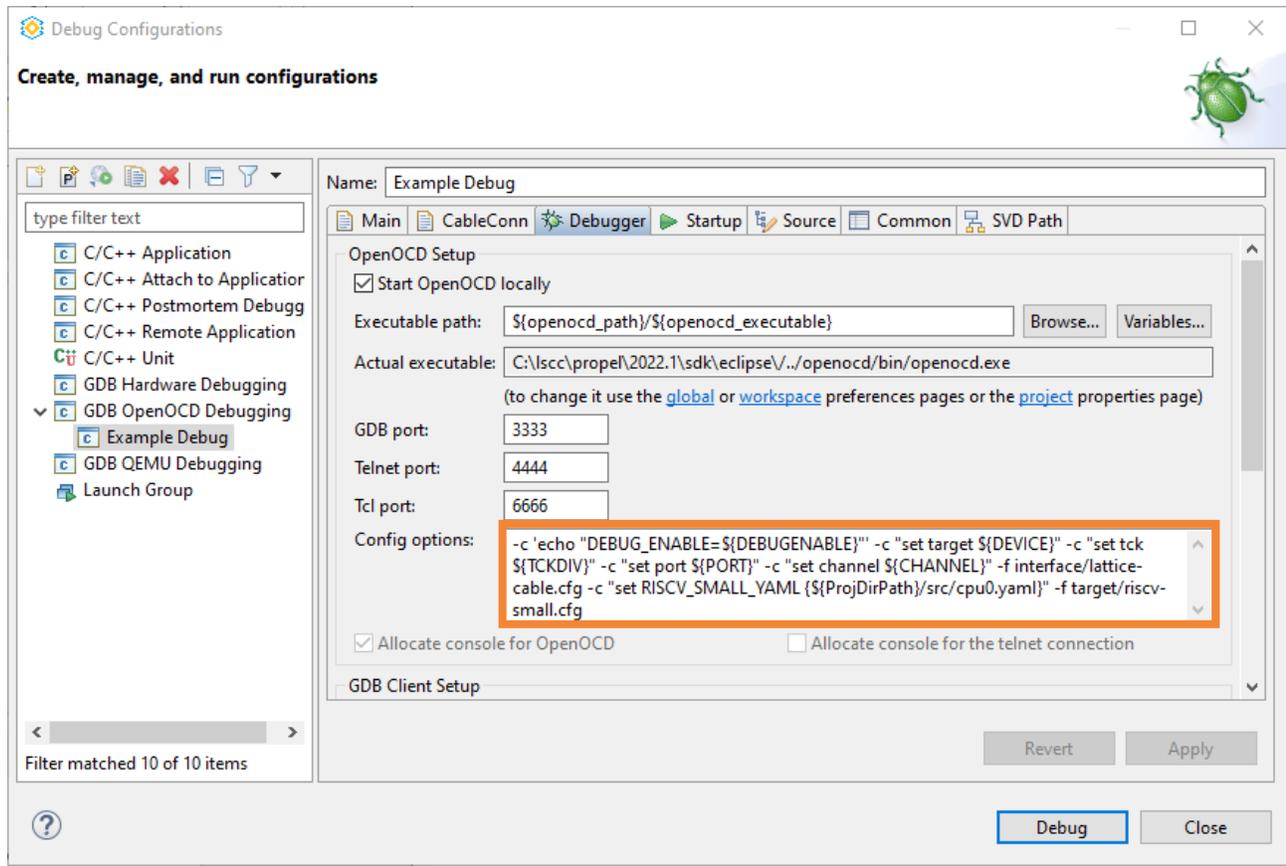


Figure 3.33. Debugger Tab of Debug Configurations

- (Optional) Select the **Common** tab (Figure 3.34). The **Save as > Local file** option is selected by default. This causes the debug launch configuration to be saved into the workspace.
Change setting the **Save as** field to **Shared file** to let the debug launch configuration saved into the project that aids the project portability.

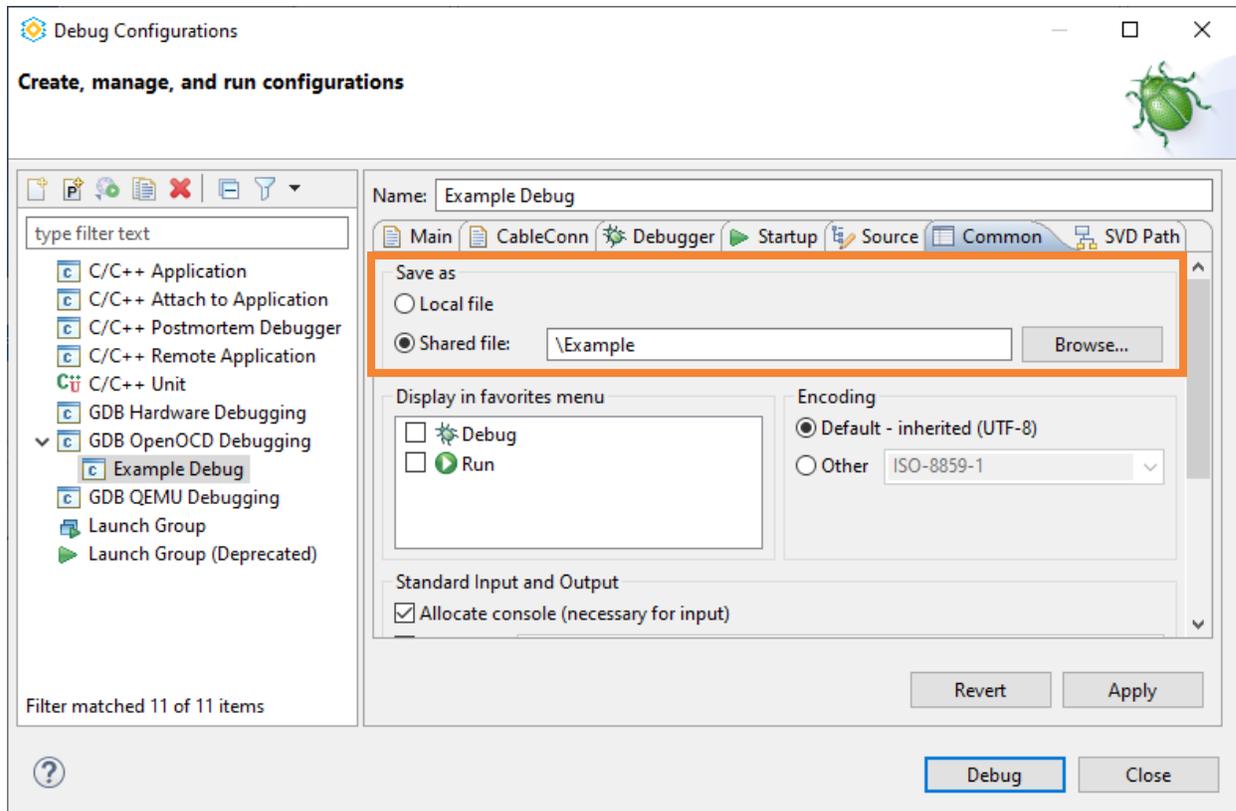


Figure 3.34. Common Tab of Debug Configurations

8. Remain settings as default. Do not change the settings unless necessary, or unless you understand what effect these changes may have.
9. Click **Apply** to keep the current settings.
10. Click **Close**.

3.5.2. Starting a Debug Session

Before starting a debug session, be sure that:

- Lattice cable is connected to the computer.
- The target device is power ON.
- The hardware design has a debug enabled processor module and already programming into the target device.

With the above steps completed properly, follow the steps below to start the debug session from Propel.

1. Choose **Run > Debug Configurations...**
2. If necessary, expand the **GDB OpenOCD Debugging** group.
3. Select the newly-defined configuration.
4. Click the **Debug** button (Figure 3.34).

Alternatively, for later sessions, use the **Debug** icon  on the toolbar. Do not click the Debug icon directly. Instead, click the down arrow beside the **Debug** icon. Select the desired debug configuration from the drop-down menu (Figure 3.35).

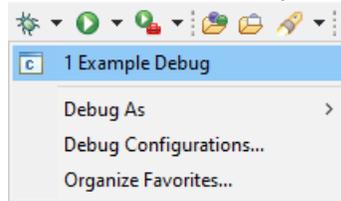


Figure 3.35. Debug Icon on Toolbar

5. Wait for a few seconds for switching to debug perspective, starting the server, connecting to the target device, starting the gdb client, downloading the application and starting the debugging session.
6. The Propel Window displays as shown in Figure 3.36 The execution stops right at the beginning of the *main()* function.

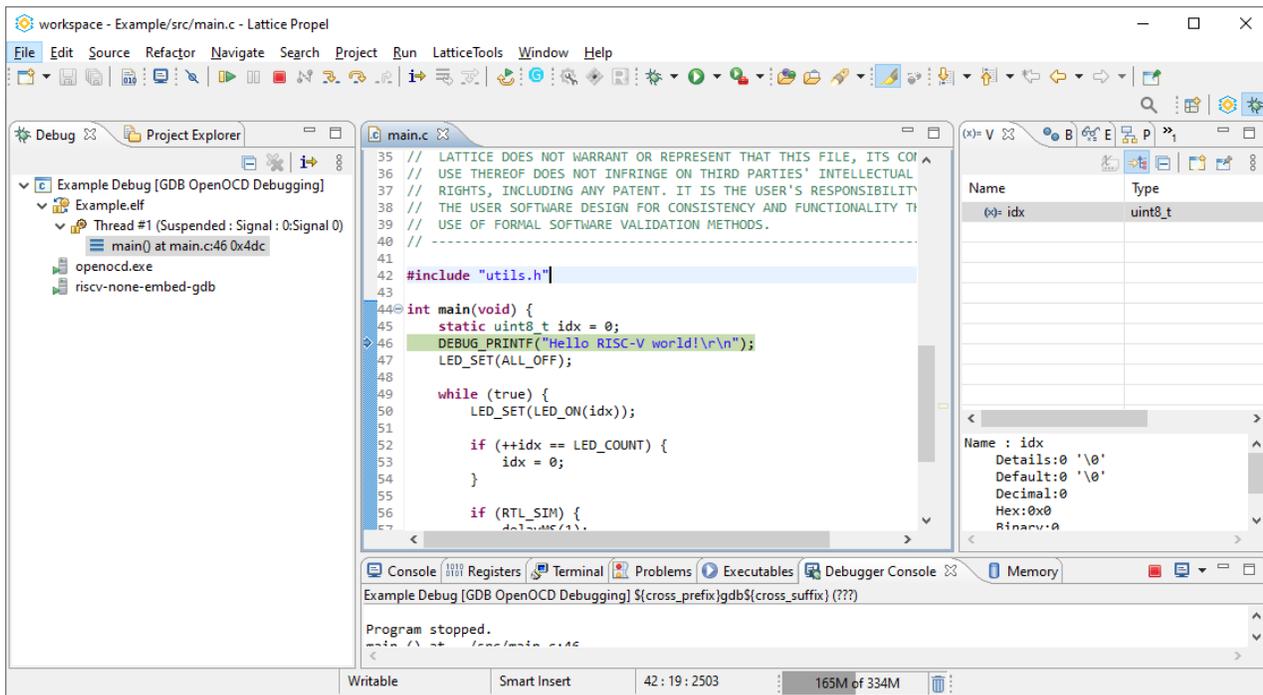


Figure 3.36. Debug Perspective

3.5.3. Peripherals Registers View

Peripherals registers view provides an easy-to-use interface for examining or modifying the values of peripheral registers during a debug session.

To use peripherals registers view in Propel (Figure 3.37):

1. Make sure an active debug session is run and shown in the debug perspective.
2. Find the **Peripherals** view which is in the same window with the **Variables** and **Breakpoints** views. For any reason, if not found, re-open from **Window > Show View > Peripherals**.
The **Peripherals** view lists all peripherals available in the system view description svd file within the C/C++ Project.
3. Selecting a peripheral in the **Peripherals** view can open a **Memory Monitor** that is mapped to the corresponding peripheral memory area.
4. You can examine and modify the value of the peripherals register in the memory view.

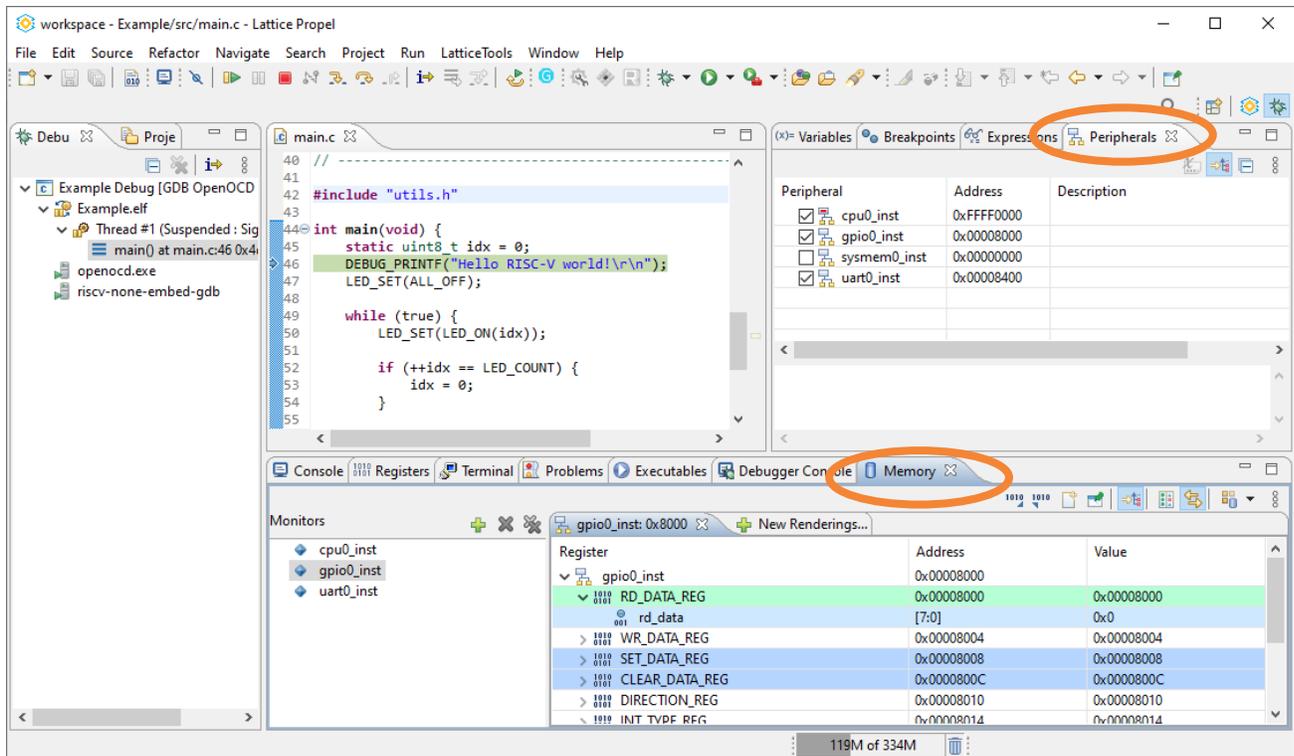


Figure 3.37. Peripherals View in Debug Perspective

3.5.4. Serial Terminal Tool

Serial port communication is frequently used during the microcontroller debugging. Propel SDK provides a built-in terminal tool including serial support for debugging.

To launch a serial terminal:

1. Find the **Terminal** view nested to the **Console** view. If not found, re-open from **Window > Show View > Terminal**.
2. In the **Terminal** view, click the **Open a Terminal** icon . The **Launch Terminal** dialog opens (Figure 3.38).
3. Choose the **Serial Terminal** and configure the **Serial port** with **Baud rate**.

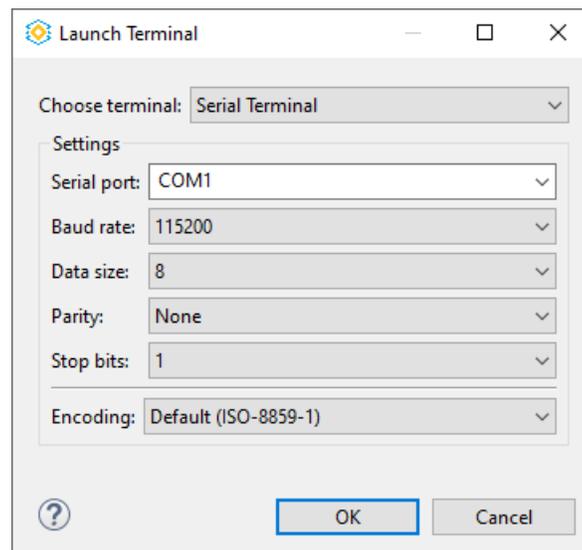


Figure 3.38. Launch Terminal Dialog

4. Click **OK**. A connection opens.
5. (Optional) Click the **Toggle Command Input** icon that adds an edit box to enter text (Figure 3.39).

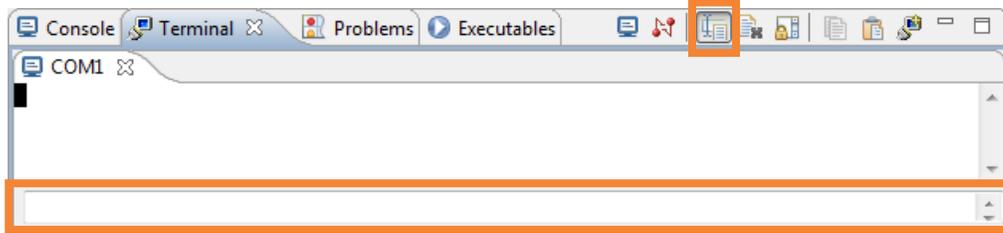


Figure 3.39. Terminal View

4. Propel Tutorial – Hello World

This “Hello World” project can be found from the template. The “Hello World” project provides a template of using hardware and software design with the minimal resource required.

Following this tutorial, you can easily create a hardware and software project. After that, you can run the project on your evaluation board.

The tutorial uses a MachXO3D breakout board as demonstration. It uses RS232 UART function. To enable RS232 UART function on the MachXO3D breakout board, the following reworks on the boards are required.

1. Hardware reworks on MachXO3D breakout board.

Short R14 and R15 using 0 Ω resistors, as shown in [Figure 4.1](#).

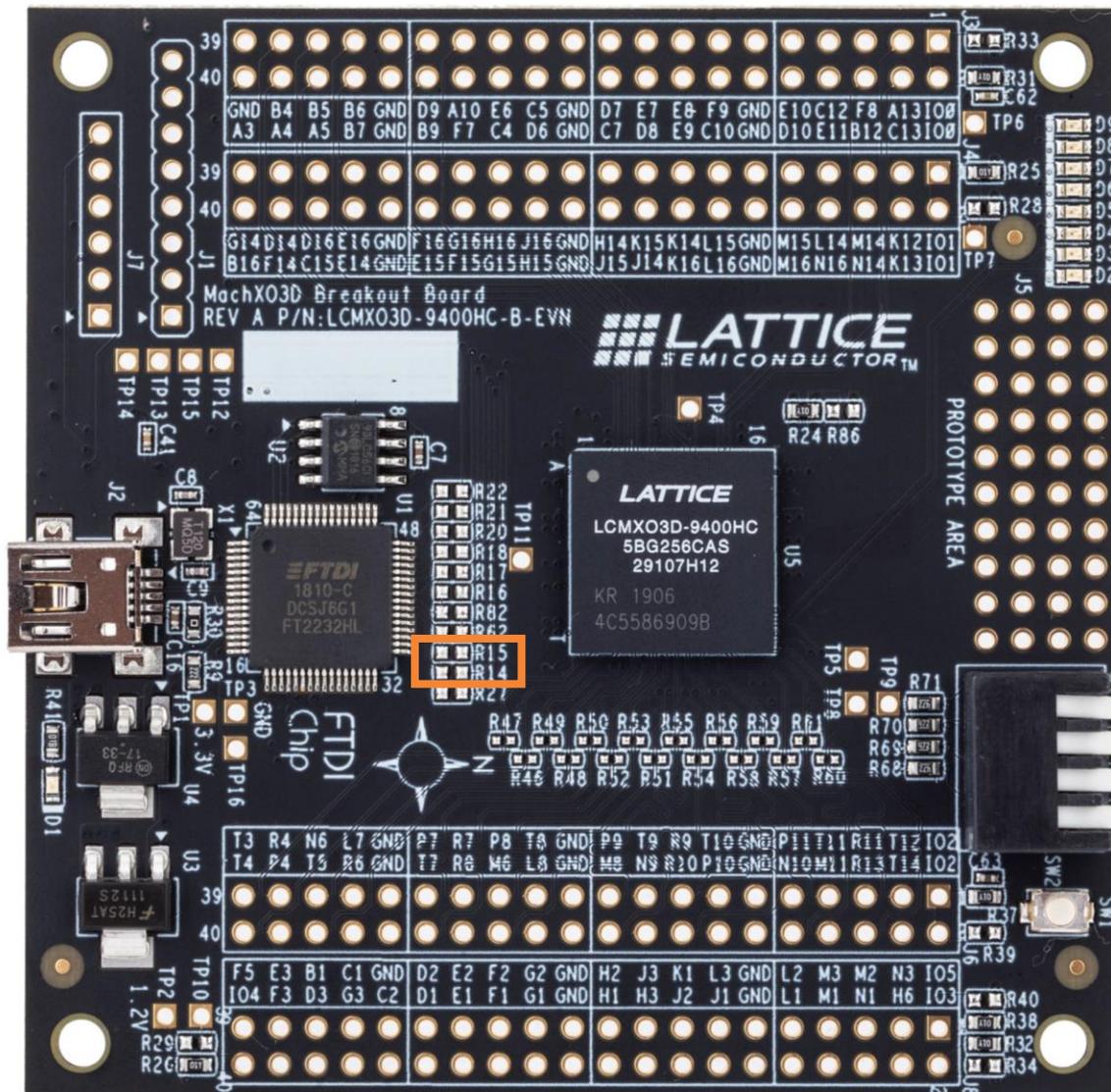


Figure 4.1. MachXO3D Breakout Board

- Configure the FTDI device with FT_Prog software to enable UART function.
Connect the MachXO3D breakout board to host PC and power ON.
Open FT_Prog software. Select **DEVICES > Program**.
Make sure Port B is configured as RS232 UART in Hardware and Virtual COM Port in Driver. See [Figure 4.2](#).
Select **DEVICES > Program** from the FT_Prog software again. From the opened Program Devices dialog, click **Program**.

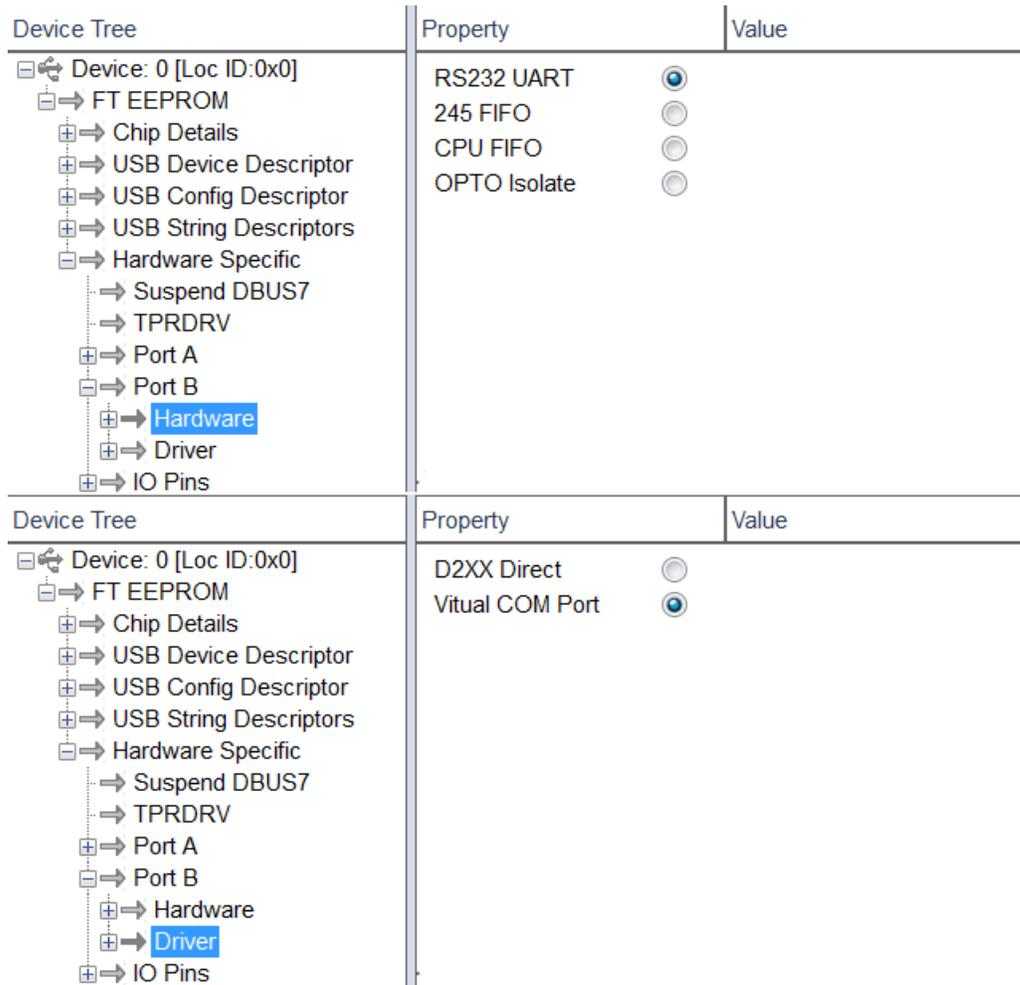


Figure 4.2 Configure the FTDI Device

- All the reworks for the MachXO3D breakout board are completed.

4.1. Creating SoC Design Project and Preparing Hardware Design

To start a SoC Design Project from Propel:

- Choose File > New >  Lattice SoC Design Project.
- The **Create SoC Project** wizard opens ([Figure 4.3](#)). Enter a project name, such as **HelloWorldSoC**. Select the **Hello World Project** template.
- Click **Finish**. A SoC project is created.

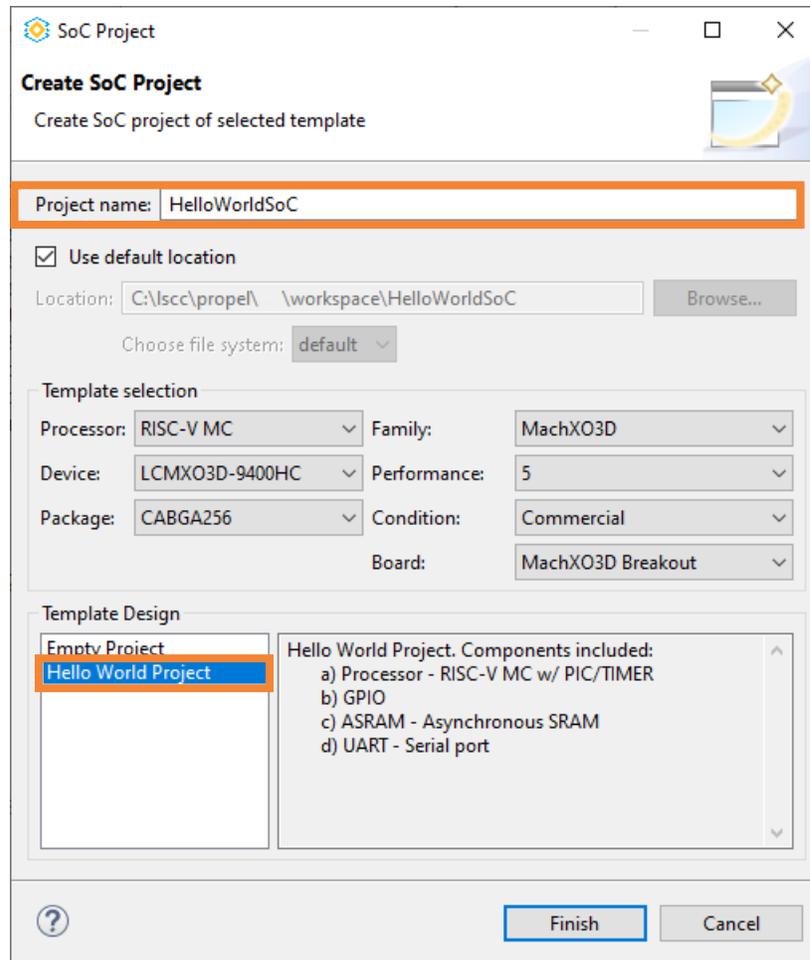


Figure 4.3. Create SoC Project Wizard

- The created SoC project can be found in the workbench. Its design is opened and displayed in Propel Builder for review (Figure 4.4).

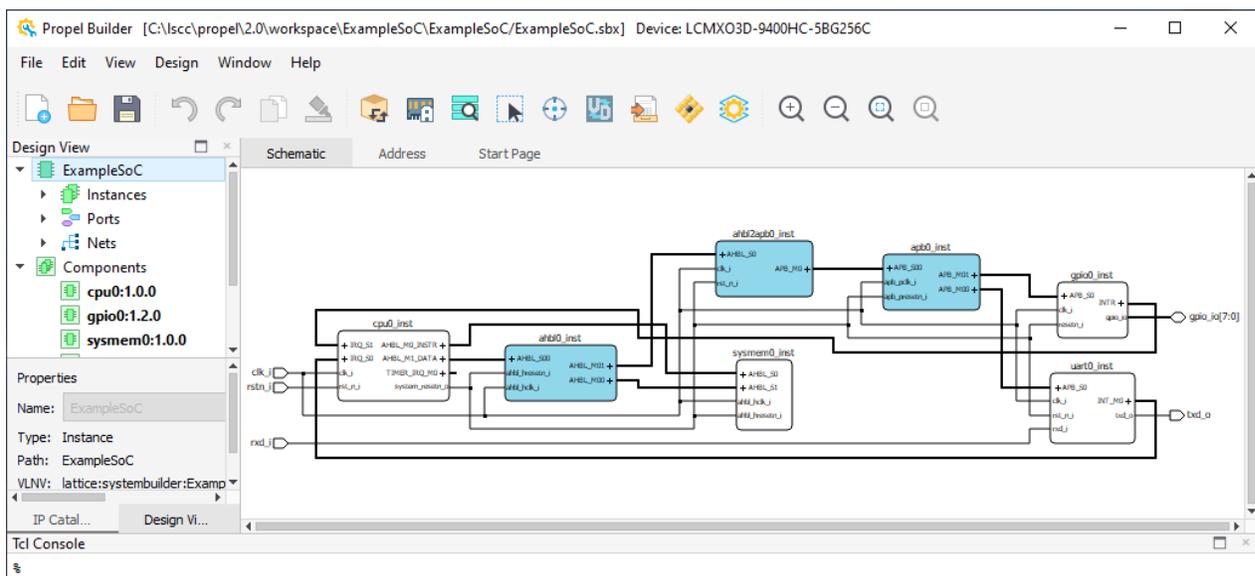


Figure 4.4. Propel Builder Window

- (Optional) In Propel Builder, update the SoC design to set the preloaded software. Enable the checkbox for **Initialize Memory** for *system_memory* IP module from the **Initialization** area of the **General** tab, and set **Initialization File** (Figure 4.5) generated from the corresponding Hello World C project in the [Creating Hello World C Project](#) section.

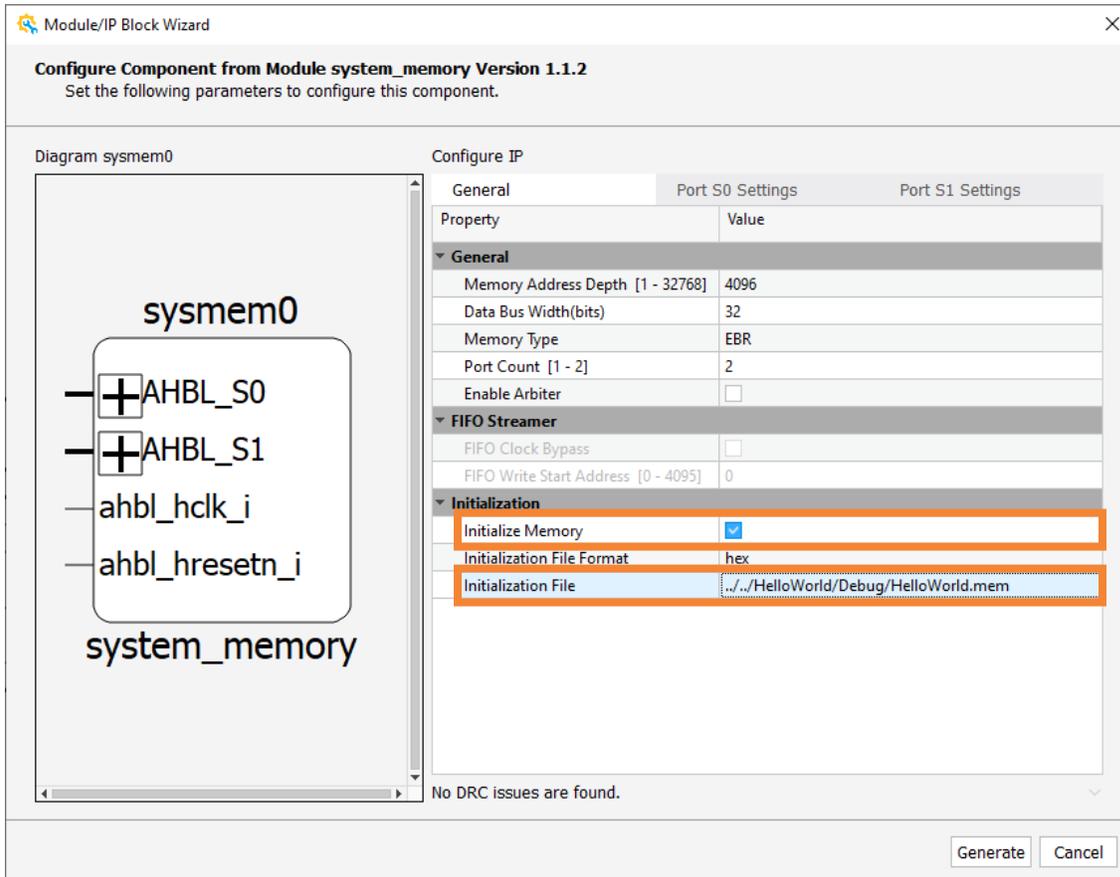


Figure 4.5. Configure Module System Memory

4.2. Launching Lattice Diamond

Launch Lattice Diamond from the created SoC project. To do that:

- In Propel **Project Explorer** view, select the SoC project *HelloWorldSoC*.
- Click the Diamond icon  on the toolbar. A Diamond project is created and thus opened automatically in **Lattice Diamond**.
- Switch to **Process** view of the Diamond project and make sure **Bitstream File** or **JEDEC File** is checked in the **Export Files** section (Figure 4.6).
- Choose **Process** >  **Run**. Wait for generating programming file successfully. You can see a green checkmark before each successfully completed process.

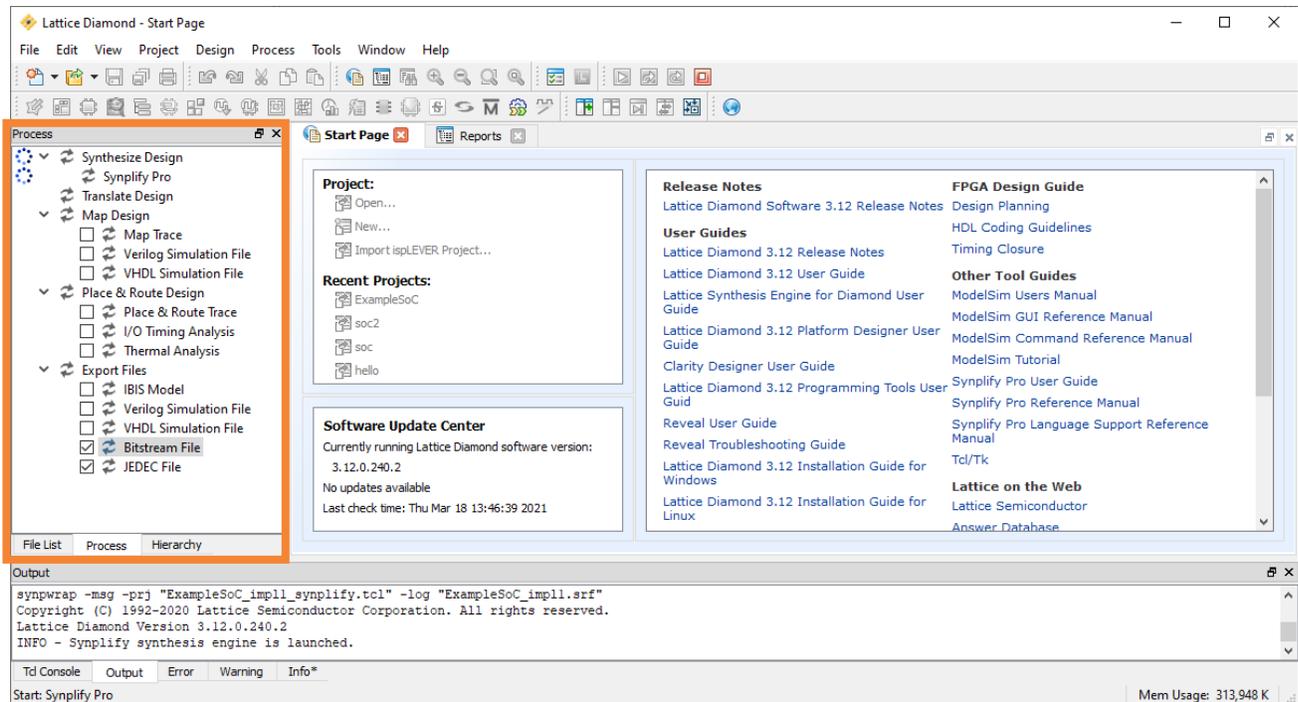


Figure 4.6. Generate Programming File

4.3. Programming the Target Device

Once the programming file is exported successfully in last section, it is ready to program the target device. Make sure the evaluation board is powered ON and connect correctly to host PC before performing the following procedure.

1. Click the **Programmer** icon  on the toolbar of the Lattice Diamond Project Explorer.
2. The **Programmer: Getting Started** dialog pops up (Figure 4.7). Click **OK**.

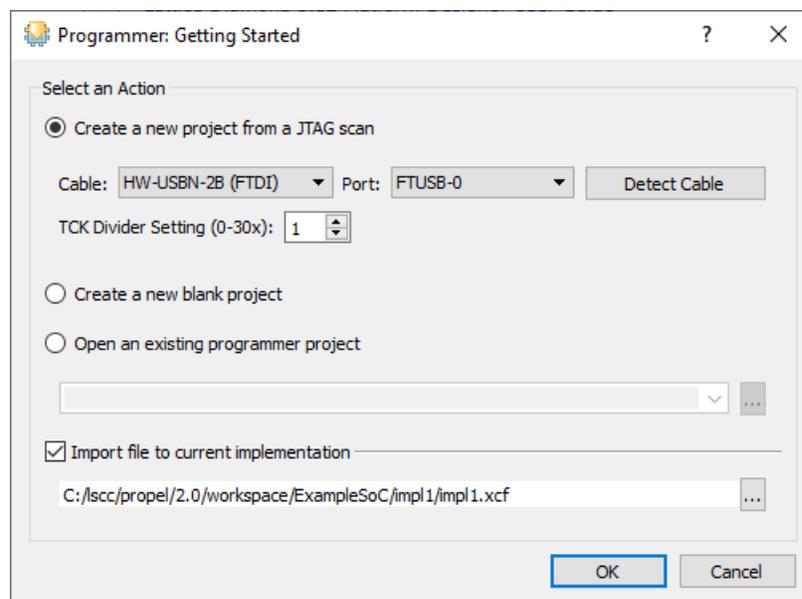


Figure 4.7. Programmer Getting Started Dialog

3. Review the **Device Family**, **Device**, **Operation**, and **File Name** in the Programmer window (as shown below).

Enable	Status	Device Family	Device	Operation	File Name
1	<input checked="" type="checkbox"/>	MachXO3D	LCMXO3D-9400HC	SRAM Fast Configuration	...e/HelloWorldSoC/impl1/HelloWorldSoC_impl1

- Click the **Program** icon  to download the programming data file to the device.

4.4. Creating Hello World C Project

Creating C project requires a system environment from SoC project as input.

- In Propel **Project Explorer** view, select the SoC project *HelloWorldSoC*.
- Choose **Project > Build Project**.

System environment of the select SoC project is generated under the SoC project folder. Check the result from the Console view ([Figure 4.8](#)).

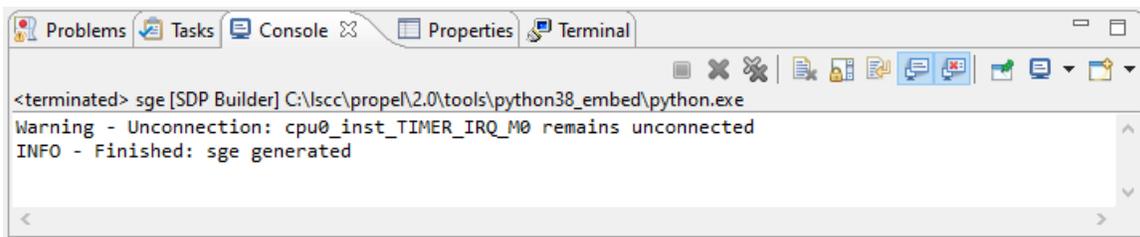


Figure 4.8. Build Result of HelloWorld SoC Project

- Choose **File > New >**  **Lattice C/C++ Project**.
The C/C++ Project wizard opens with **Load System and BSP** page ([Figure 4.9](#)).

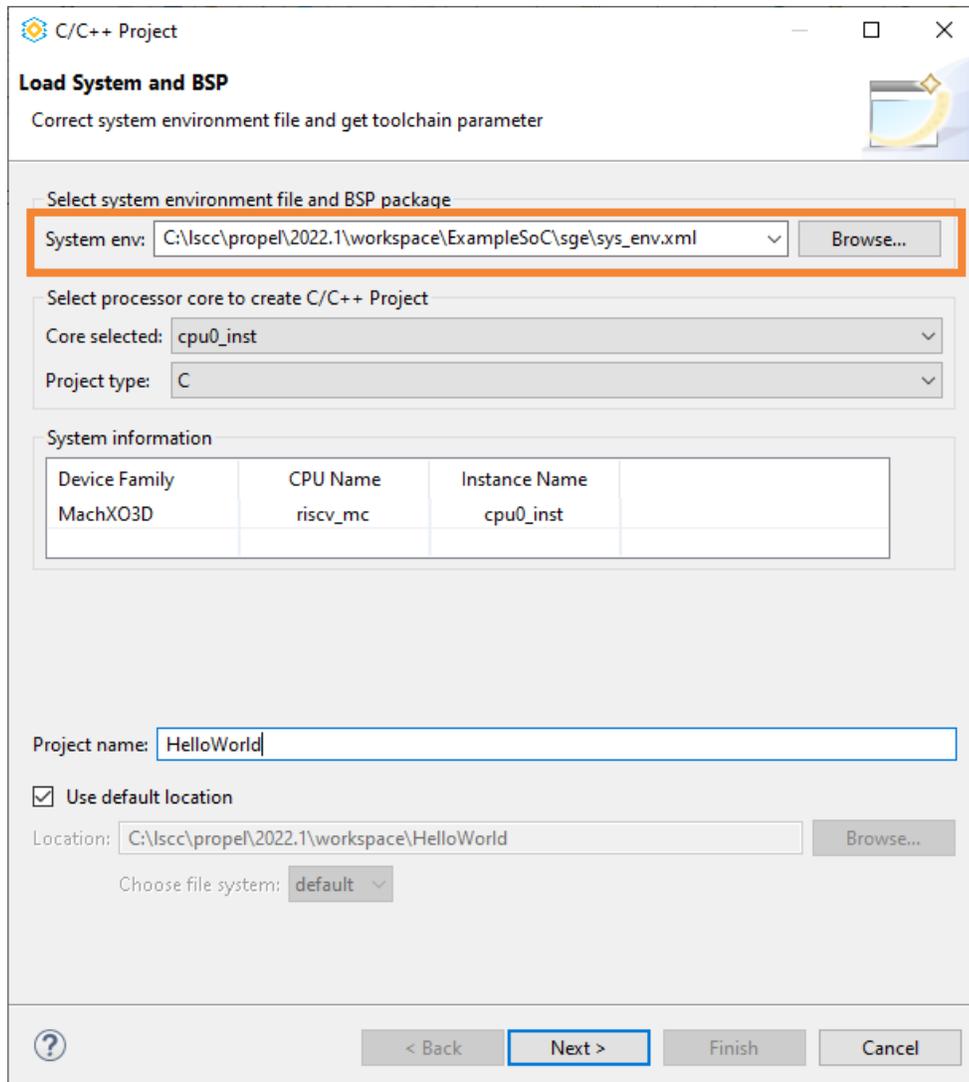


Figure 4.9. Load System and BSP Page

4. Select the system environment file just generated (Figure 4.9).
5. Enter project name “HelloWorld” (Figure 4.9). Click **Next**. Then click **Finish**.
The C project is created and displayed in workbench.
6. Choose **Project > Build Project**.
7. Check the build result from the Console view (Figure 4.10).

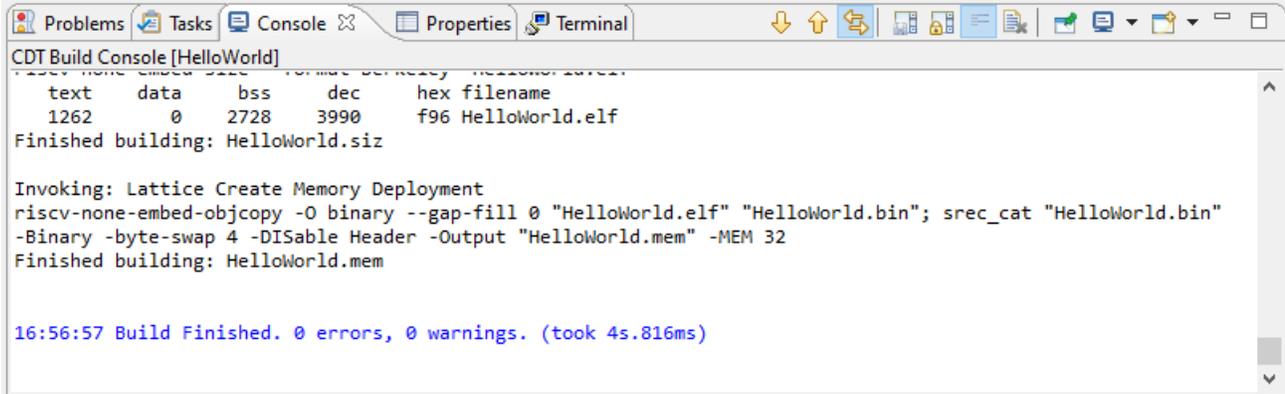


Figure 4.10. Build Result of HelloWorld C Project

4.5. Running Demo on MachXO3D Breakout Board – Hello world

1. Find the **Terminal** view next to the **Console** view. If not found, re-open from **Window > Show View > Terminal**.
2. In the **Terminal** view, click the **Open a Terminal** icon .
3. Choose the **Serial Terminal** and configure the **Serial port** with **Baud rate** 115200 (Figure 4.11).

Note: Serial port number depends on specific PC.

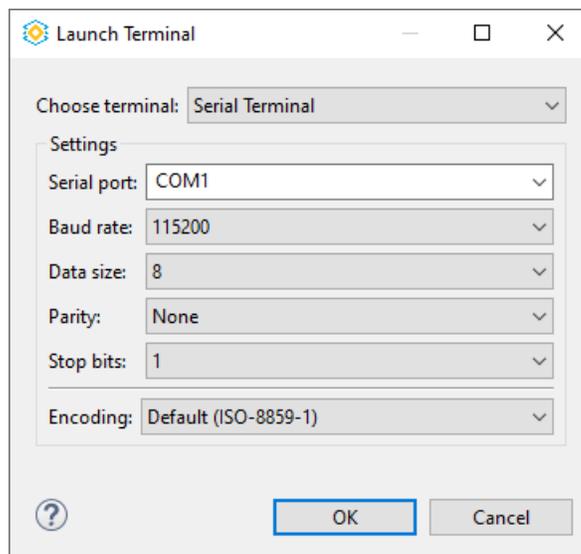


Figure 4.11. Launch Terminal Dialog

4. Click **OK**. A serial connection communicate with UART is ready.
5. In the **Project Explorer** view, select C project “HelloWorld”.
6. Choose **Run > Debug Configurations...**
7. Double-click **GDB OpenOCD Debugging** to create a new launch configuration (Figure 4.12).
8. Click the **Debug** button.

Wait for a few seconds for switching to debug perspective, to start the server, and to allow it to connect to the target device, start the gdb client, download the application, and then start the debugging session.

Note: This demo uses default debug configuration options.

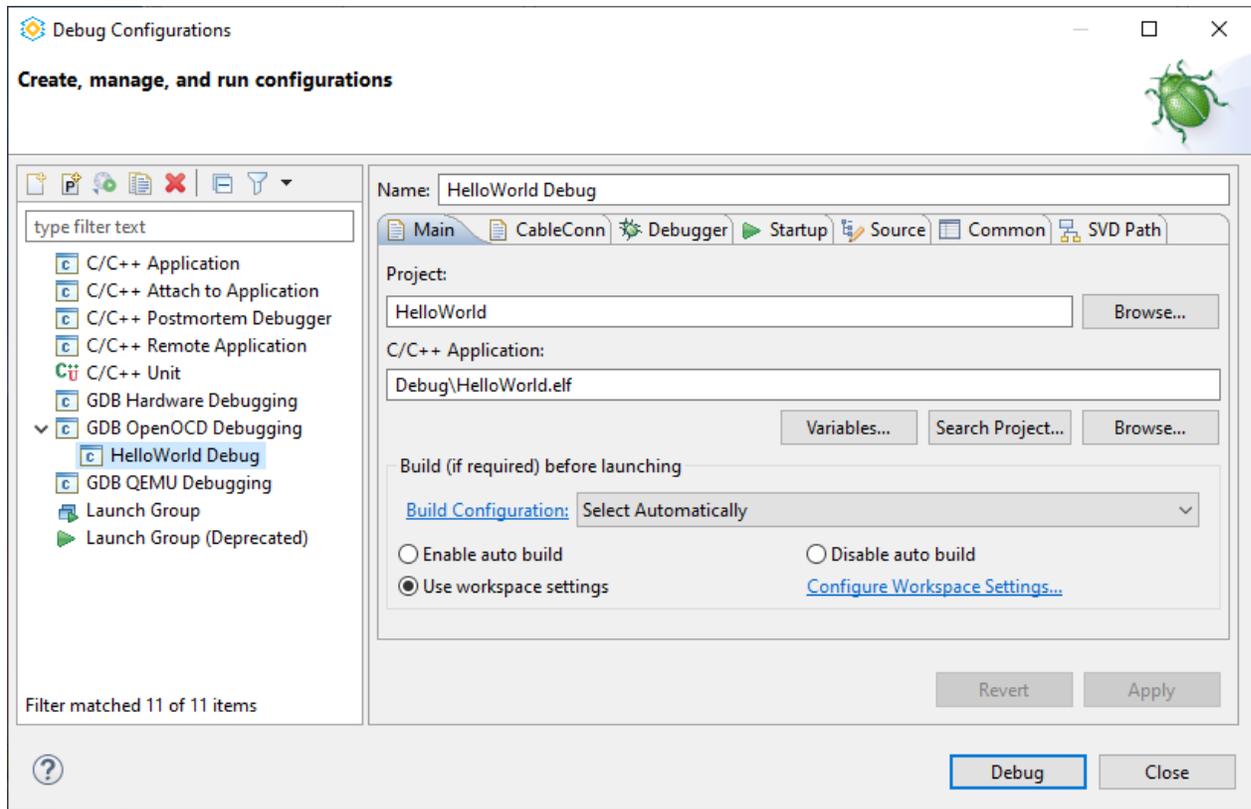


Figure 4.12. Debug Configurations Page

9. Click the **Resume** icon  on the toolbar. The serial terminal outputs “Hello RISC-V world!” (Figure 4.13).

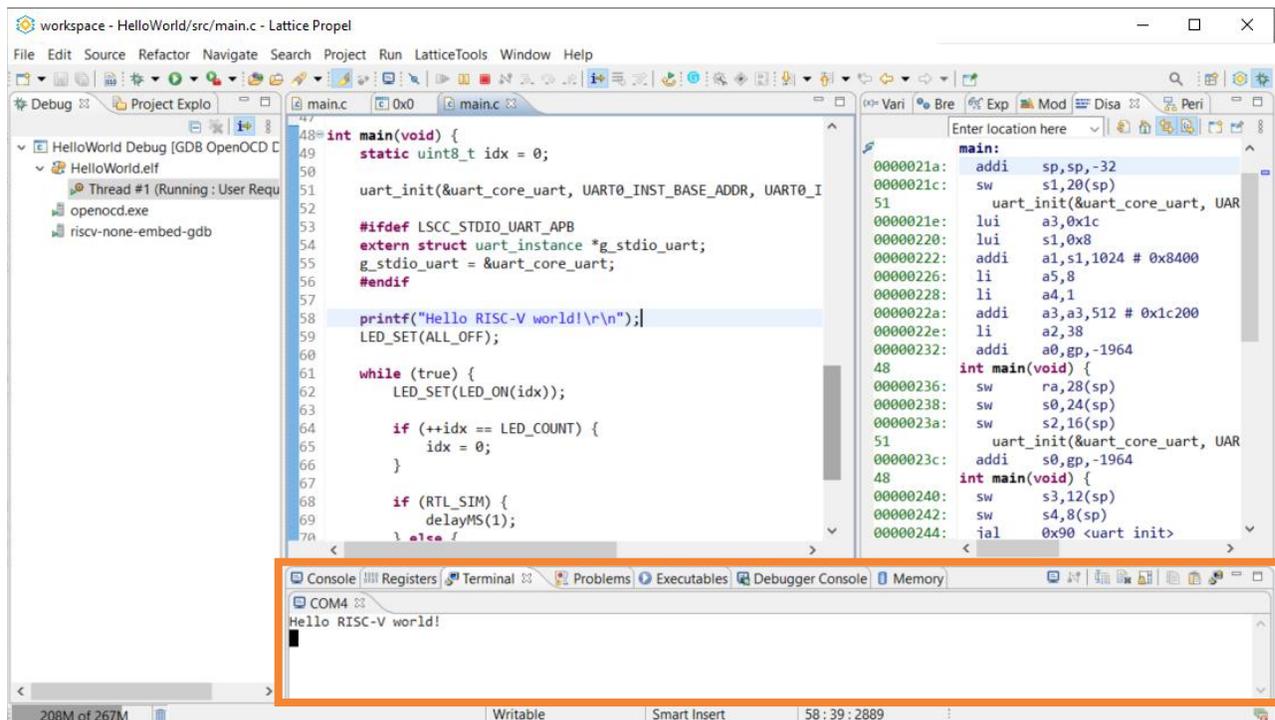


Figure 4.13. Run Result of Hello World Project

Appendix A. Linker Script and System Memory Deployment

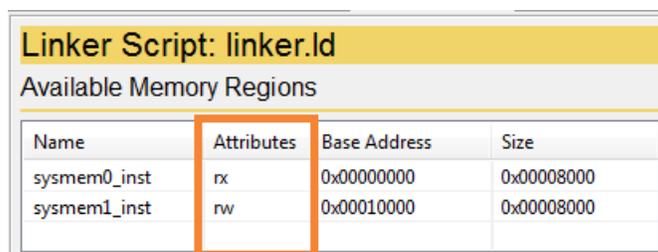
During the Lattice C/C++ Project creation, Propel SDK generates a linker script file, linker.ld, within the project. This linker script file contains a memory region list parsing from the corresponding SoC design.

Note: Illegal memory regions are not imported to linker script. A memory region is considered illegal if it has any of the following conditions:

- No connection to CPU
- Address space conflict

Each memory region has a list of attributes to specify whether or not use a particular memory region for an input section (Figure A. 1).

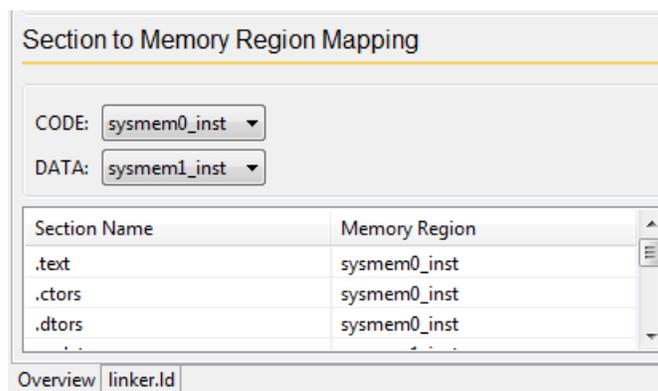
- r: Read-only section.
- w: Read/Write section indicating the memory region is connected to the data port of CPU.
- x: Executable section indicating the memory region is connected to the instruction port of CPU.



Name	Attributes	Base Address	Size
sysmem0_inst	rx	0x00000000	0x00008000
sysmem1_inst	rw	0x00010000	0x00008000

Figure A. 1. Memory Regions in Linker Script

The generated linker script contains a mapping table of section pointing to memory region (Figure A. 2). Depending on the attributes of each memory region, code section and data section can point to the same or different memory regions.



Section Name	Memory Region
.text	sysmem0_inst
.ctors	sysmem0_inst
.dtors	sysmem0_inst

Figure A. 2. Section to Memory Region Mapping

During the Lattice C/C++ Project building, Propel SDK generates Lattice system memory initialization files. Depending on the number of the memory regions used, it generates single memory initialization file or multiple memory initialization files. The following picture (Figure A. 3) shows an example of multiple memory files being generated, separate for code and data segments.

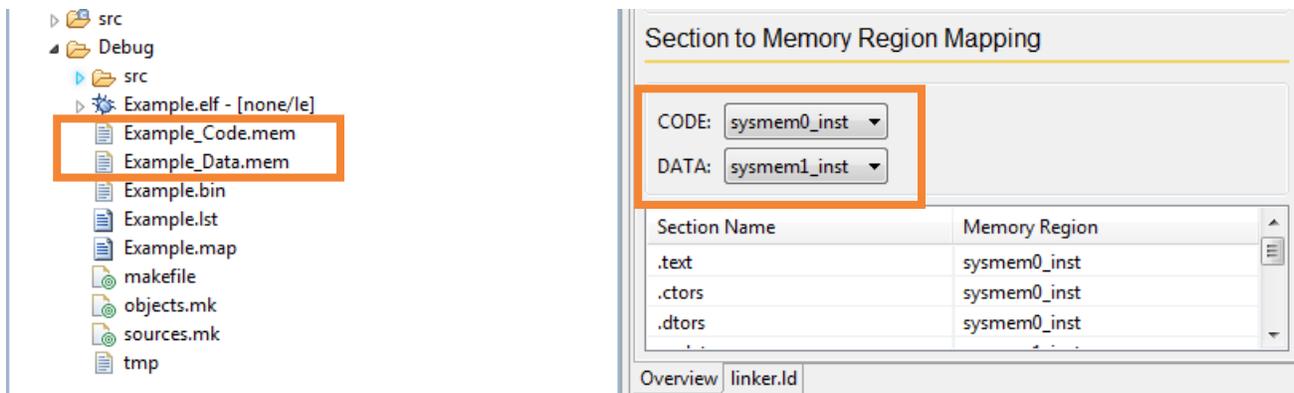


Figure A. 3. Linker Script and Generated Memory Files

If you modify the linker script manually after the Lattice C/C++ project creation, especially change the number of the used memory regions, the number of memory files generated during project building cannot be changed automatically. You can re-configure the generation of memory files in Propel by:

1. In the **Project Explorer** view of Propel, select a C/C++ project.
2. Choose **Project > Properties**. The Properties dialog opens showing the properties of the current project.
3. Select **Settings of C/C++ Build** category from the left pane. Select the **Toolchains** tab (Figure A. 4).
Check **Create memory file**, if you point code and data segments to same memory region. Or, check **Create multiple memory files**, if you point code and data segments to separate memory regions.
4. Click **Apply**.

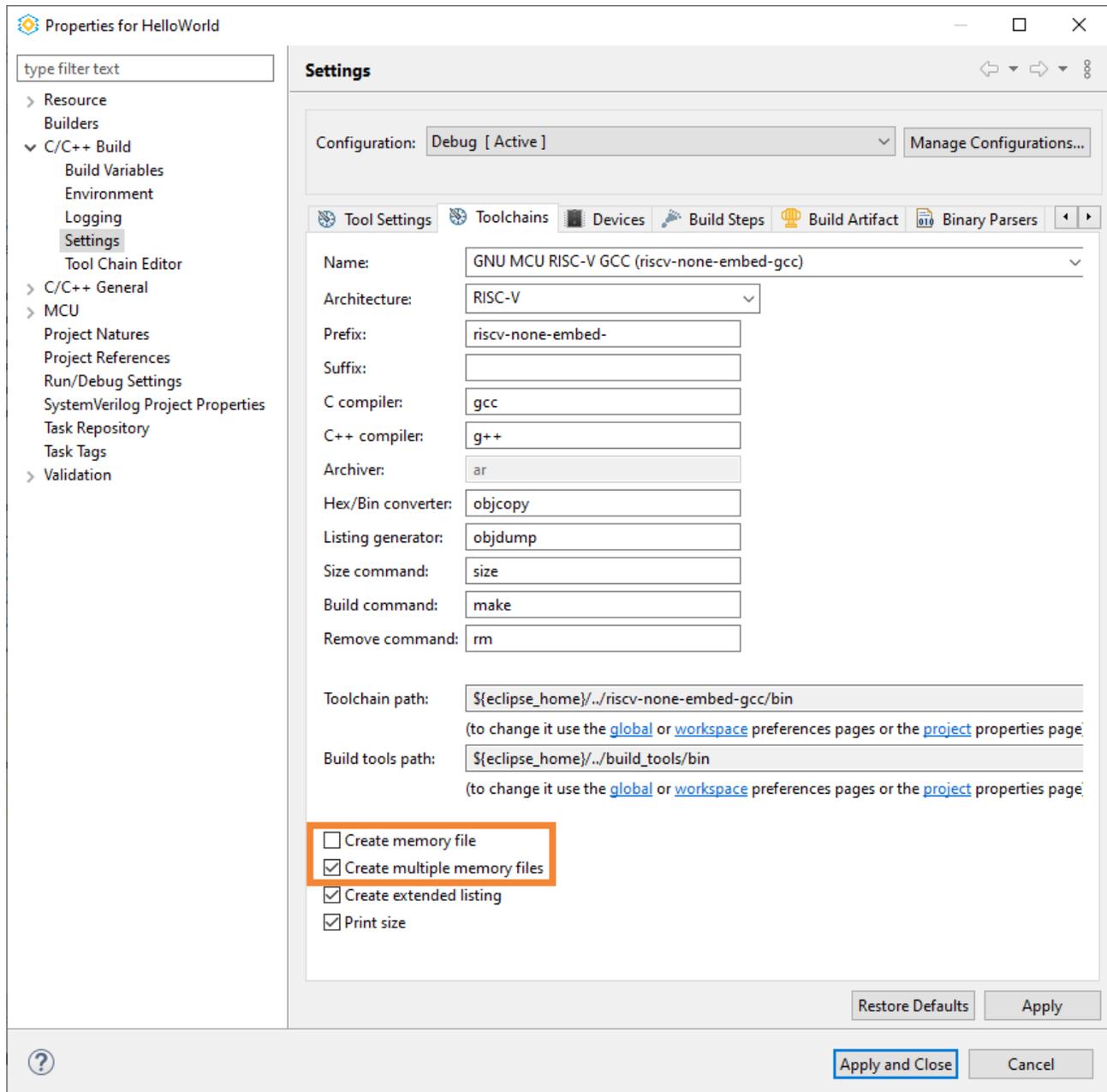


Figure A. 4. Toolchains Tab of C/C++ Build Settings

- Go back to the **Tool Settings** tab. The relevant Lattice memory deployment tools can be found (Figure A. 5). Customize the tool options as needed.
- Click **Apply and Close** to save the change.

Note: Setting for each configuration, **Debug** or **Release**, is independent.

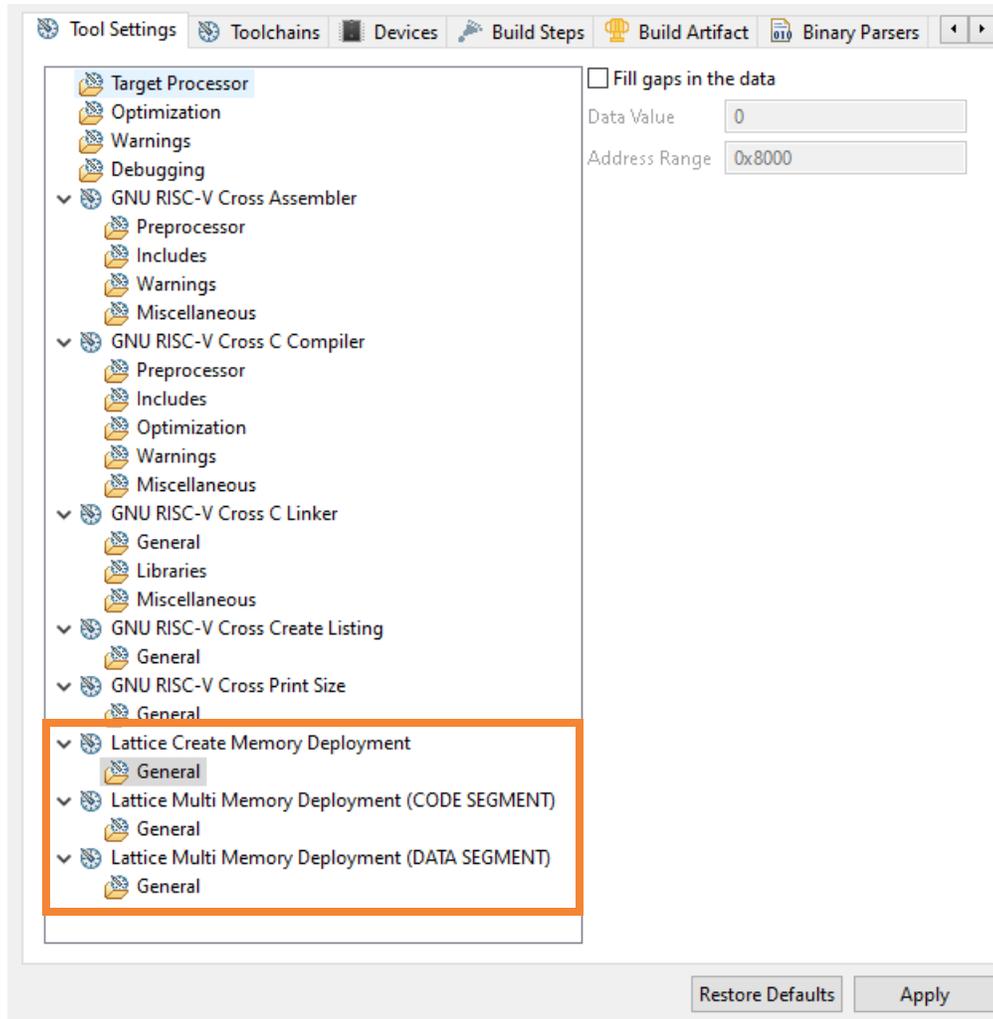


Figure A. 5. Tool Settings Tab of C/C++ Build Settings

Appendix B. Standard C Library Support

Propel SDK bundles Picolibc as the standard library support (<https://keithp.com/picolibc/>). Picolibc is a set of standard C libraries, both libc and libm, designed for smaller embedded systems with limited ROM and RAM. Picolibc includes code from Newlib (<https://sourceware.org/newlib/>) and AVR Libc (<https://www.nongnu.org/avr-libc/>).

Printf and Scanf levels in Propel SDK

Propel SDK provides three levels of printf support with the support of Picolibc, which can be selected when creating a Lattice C/C++ project (Refer to [Figure B. 1](#)), or be modified in the toolchain settings in the project properties after the project is created, noting that the options in both compiler and linker need to be set (Refer to [Figure B. 2](#) and [Figure B. 3](#)).

- Integer only printf. This is the default selection in Propel SDK, which removes the support for all float and double conversions to save code size.
- Float printf. It requires a special macro for float values: `printf_float`. To make it easier to switch between that and other two levels, that macro should also be correctly defined for the other two levels.

Here is a sample program to demonstrate the usage:

```
#include <stdio.h>

void main(void) {
    printf(" 2^61 = %lld, Pi = %.17g\n", 1ll << 61, printf_float(3.141592653589793));
}
```

- Full printf. This offers full printf functionality, including both float and double conversions.

System Library Interfaces used in Propel SDK

Propel SDK provides three system library for stdio support with the help of Picolibc, which can be selected when creating a Lattice C/C++ project (refer to [Figure B. 1](#)), or be modified in the toolchain settings in the project properties after the project is created, noting that only the option in linker needs to be set (refer to [Figure B. 3](#)).

- Default. Use the default system library interface (UART) in BSP, this requires a UART instance inside SoC design.
- Semihosting. “Semihosting” is a mechanism that enables code running on the target to communicate with and use the I/O of the host computer. Propel SDK provides semihosting support in On-Chip-Debugging flow. It allows printing messages to the debugger console without relying on the UART instance.
- Dummyhosting. Dummy stdio hooks. This allows programs to link without requiring any system-dependent functions. This is only used if the program doesn't provide its own version of stdin, stdout, stderr.

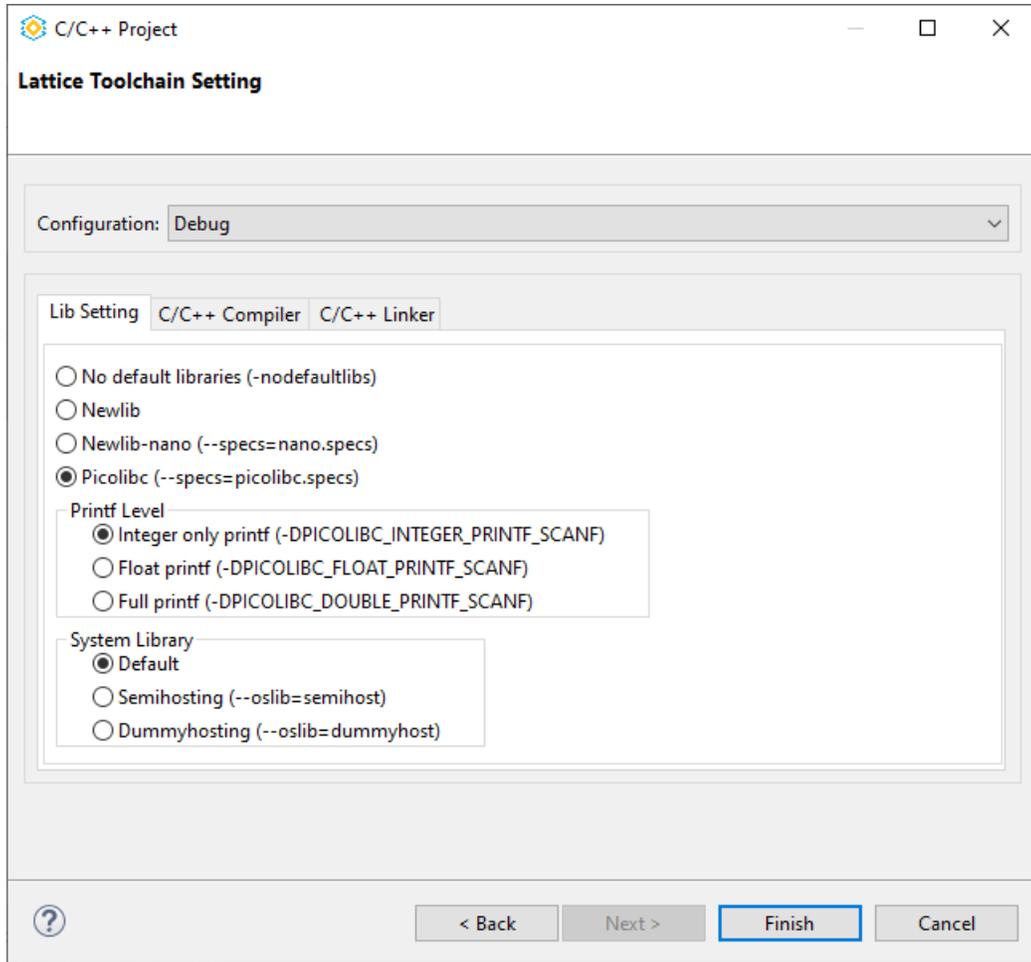


Figure B. 1. Lattice Toolchain Setting Dialog

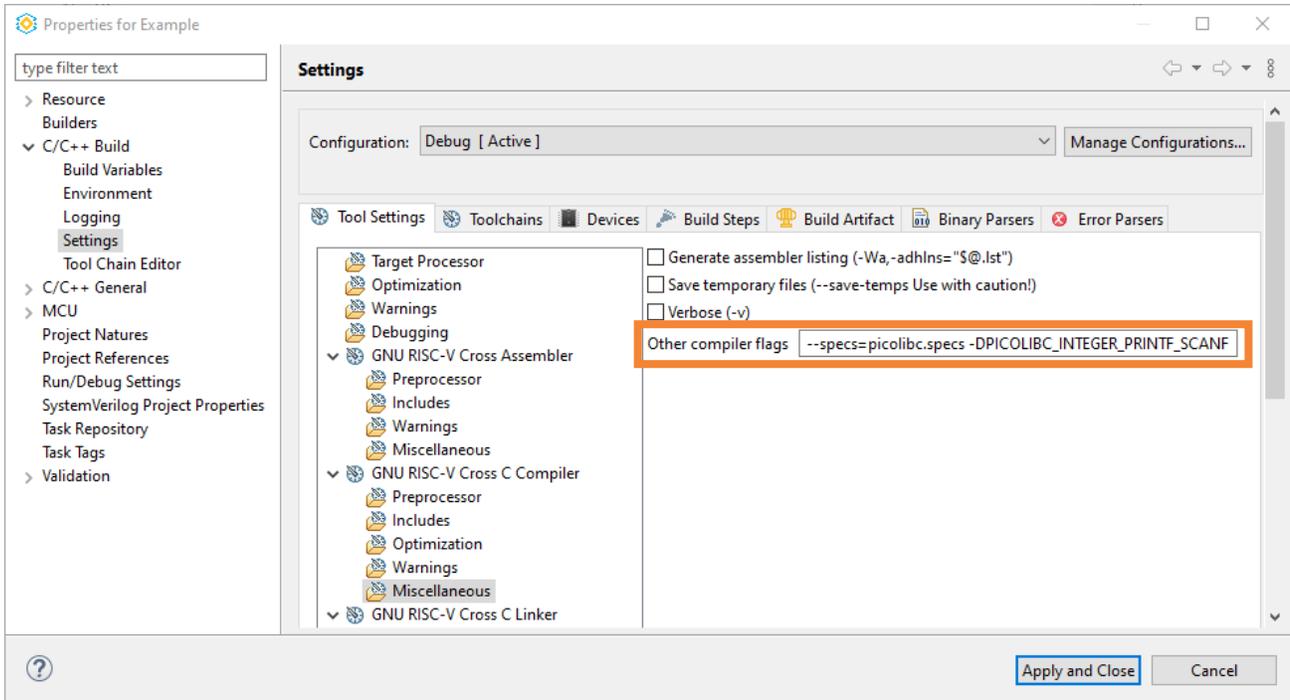


Figure B. 2. Properties of C/C++ Project – Compiler Options

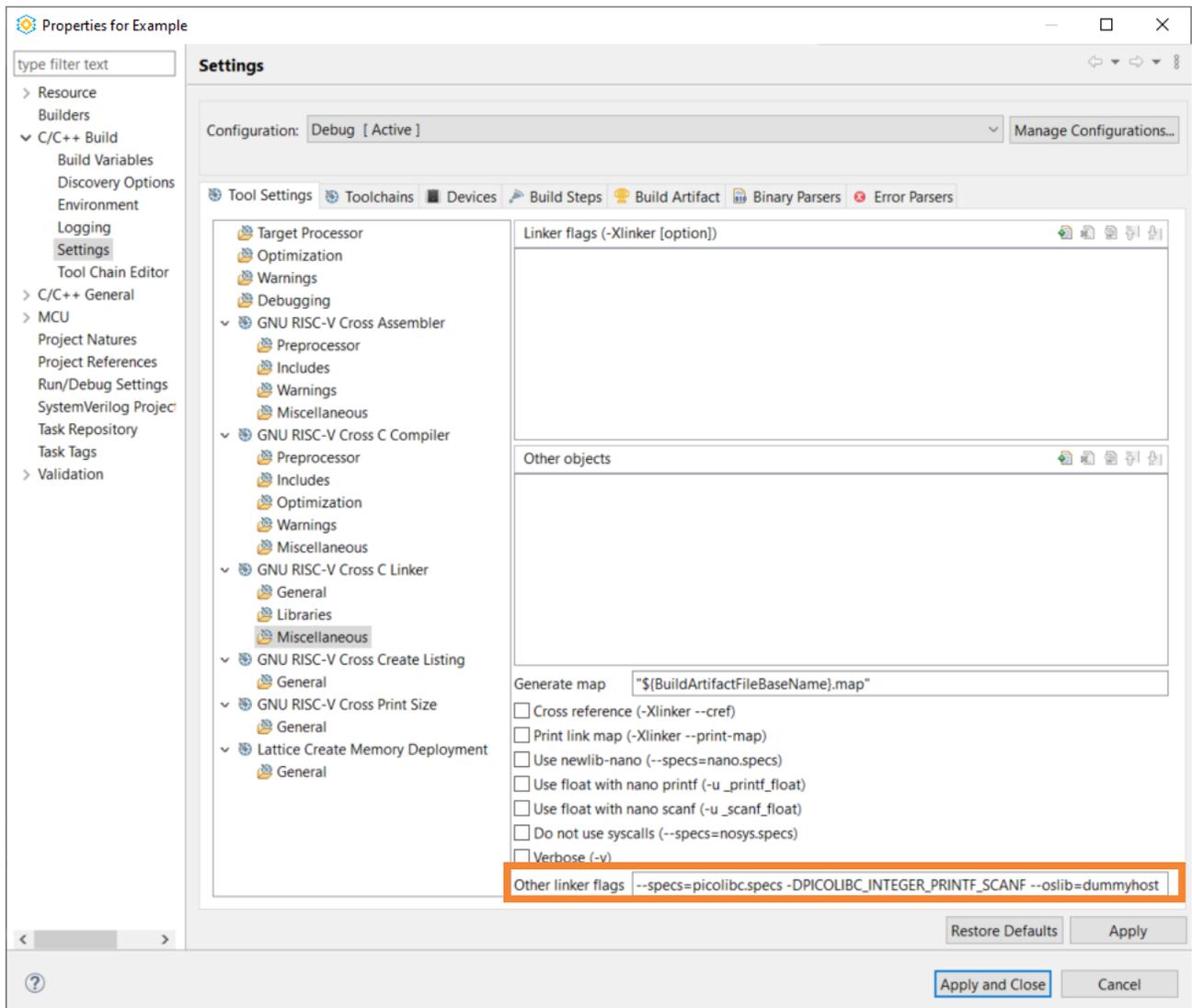


Figure B. 3. Properties of C/C++ Project – Linker Options

Appendix C. Third-party Command-line Tools in Lattice Propel SDK

The Propel SDK integrates with a number of third-party command-line tools, which can be used with Propel User Interface or as stand-alone command-line tools. You can find these command-line tools and their documentation according to the following list.

1. Windows Build tools

Version: 4.2.1-1

Binaries Location: *<Propel Installation Location>*\sdk\build_tools\bin

Documents Location: *<Propel Installation Location>*\sdk\build_tools\share

2. OpenOCD

Version: 0.10.0

Binaries Location: *<Propel Installation Location>*\sdk\openocd\bin

Documents Location: *<Propel Installation Location>*\sdk\openocd\doc

3. GNU RISC-V Embedded GCC

Version: 10.2.0-1.2

Binaries Location: *<Propel Installation Location>*\sdk\riscv-none-embed-gcc\bin

Documents Location: *<Propel Installation Location>*\sdk\riscv-none-embed-gcc\share\doc

4. Picolibc

Version: 1.7.4

Binaries Location: *<Propel Installation Location>*\sdk\riscv-none-embed-gcc\riscv-none-embed\picolibc\riscv-none-embed\lib

Documents Location: *<Propel Installation Location>*\sdk\riscv-none-embed-gcc\doc

5. SRecord

Version: 1.6.4

Binaries Location: *<Propel Installation Location>*\sdk\tools\bin

Documents Location: *<Propel Installation Location>*\sdk\tools\bin

Appendix D. Command-line Environment Setting Script in Lattice Propel SDK

Propel provides a script to set necessary environment variables for running all Propel SDK command line tools. It enables you to fast get up to using command line tools, especially for Lattice specific tools.

To use the script:

1. Run the script `propel_commandline.cmd` (Windows) or `propel_commandline.sh` (Linux) under *<Propel Installation Location>*.

The message "Lattice Propel Commandline" is printed, and let you go to a new command line interface.

2. All command line tools in the Propel SDK can be run from this command line interface without any special configuration.

Here are examples of using the command line tools within this script.

Example A: Build a C project under command line.

```
$ cd <C project Location>/Debug
$ make
```

Example B: Launching openocd under command line.

```
$ cd <C project Location>
$ openocd -c "gdb_port 3333" -c "set target 0" -c "set tck 1" -c "set
port FTUSB-0" -c "set RISC_V_SMALL_YAML src/cpu0.yaml" -f
interface/lattice-cable.cfg -f target/riscv-small.cfg
```

References

- [Lattice Propel 2022.1 Release Notes \(FPGA-AN-02258\)](#)
- [Lattice Propel 2022.1 Installation for Windows User Guide \(FPGA-AN-02056\)](#)
- [Lattice Propel 2022.1 Installation for Linux User Guide \(FPGA-AN-02057\)](#)
- [Lattice Propel Builder 2022.1 Usage Guide \(FPGA-UG-02177\)](#)
- [MachXO3D Family Data Sheet \(FPGA-DS-02026\)](#)
- [MachXO3D Programming and Configuration Usage Guide \(FPGA-TN-02069\)](#)
- [MachXO3D Breakout Board User Guide \(FPGA-UG-02084\)](#)

Technical Support Assistance

Submit a technical support case through www.latticesemi.com/techsupport.

Revision History

Revision 1.0, November 2022

Section	Change Summary
All	Initial release.



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