

DG0802
Demo Guide
PolarFire FPGA PCIe Root Port



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1 Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

1.1 Revision 7.0

The following is a summary of the changes made in this revision.

- Updated the document for Libero SoC v2021.2.
- Added support for PERSTn signal generation.
- Replaced [Figure 1](#), page 3 through [Figure 7](#), page 9.
- Updated [Table 2](#), page 4 and [Table 3](#), page 12.
- Updated section [Design Implementation](#), page 5.
- **AHBtoAXIAPB** subsystem is removed from the MiV subsystem.
- **AXI_Interconnect_0** and **Core_APB_0** were added in the MiV subsystem.
- Enabled AXI master interface and APB master interface on MiV core.
- Updated the reset structure.

1.2 Revision 6.0

The following is a summary of the changes made in this revision.

- Updated the document for Libero SoC v12.6.
- Removed the references to Libero version numbers.

1.3 Revision 5.0

The document was updated for Libero SoC v12.0.

1.4 Revision 4.0

The document was updated for Libero SoC PolarFire v2.3.

1.5 Revision 3.0

The document was updated for Libero SoC PolarFire v2.2.

1.6 Revision 2.0

The document was updated for Libero SoC PolarFire v2.1.

1.7 Revision 1.0

The first publication of this document.

2 PolarFire FPGA PCIe Root Port

Microsemi PolarFire® FPGAs support fully integrated PCIe Endpoint and Root Port subsystems with optimized embedded controller blocks that use the physical layer interface (PHY) of the transceiver. Each PolarFire device includes two embedded PCIe subsystem (PCIESS) blocks that can be configured either separately, or as a pair, using the PF_PCIE IP configurator in the Libero® SoC software.

The PF_PCIE IP core is compliant with the PCI Express Base Specification, Revision 3.0 with Gen1/2. It implements memory-mapped Advanced Microcontroller Bus Architecture (AMBA) advanced extensible interface 4 (AXI4) access to the PCIe space and the PCIe access to the memory-mapped AXI4 space. For more information, see [UG0685: PolarFire FPGA PCI Express User Guide](#).

This document describes the Root Port capabilities of the PolarFire FPGA PCIe controller using Mi-V soft processor. The PCIe Root Port capabilities like the enumeration of an Endpoint device, low-speed and high-speed data transfers are demonstrated using the PCIe Root Port Demo GUI application.

The demo design includes a Mi-V soft processor, which initiates PCIe control and data plane functions. For more information about the PCIe Root Port design implementation, and the necessary blocks and IP cores instantiated in Libero SoC, see [Demo Design](#), page 3.

The demo design can be programmed using any of the following options:

- Using the job file: To program the device using the job file provided along with the design files, see [Setting Up the Demo](#), page 17.
- Using Libero SoC: To program the device using Libero SoC, see [Libero Design Flow](#), page 10. Use this option when the demo design is modified.

To run the demo, perform the following steps:

- The Root Port demo design must be programmed on a PolarFire Evaluation board.
- The Endpoint demo design must be programmed on another PolarFire Evaluation board.
- Both the boards must be connected using a PCIe Adapter card.

For more information about setting up the PCIe Root Port demo, see [Setting Up the Demo](#), page 17.

2.1 Design Requirements

The following table lists the hardware and software requirements for this demo design.

Table 1 • Design Requirements

Requirement	Version
Operating system	64-bit Windows 7 or 10
Hardware	
Two PolarFire Evaluation Kits (MPF300TS-FCG1152I)	Rev D or later
Microsemi PCIe Adapter Card	PCIE-ROOTPORT-AD
Software	
Libero SoC	Note: Refer to the readme.txt file provided in the design files for the software versions used with this reference design.
SoftConsole	
ModelSim	
Synplify Pro	

Note: Libero SmartDesign and configuration screen shots shown in this guide are for illustration purpose only. Open the Libero design to see the latest updates.

2.2 Prerequisites

Before you begin:

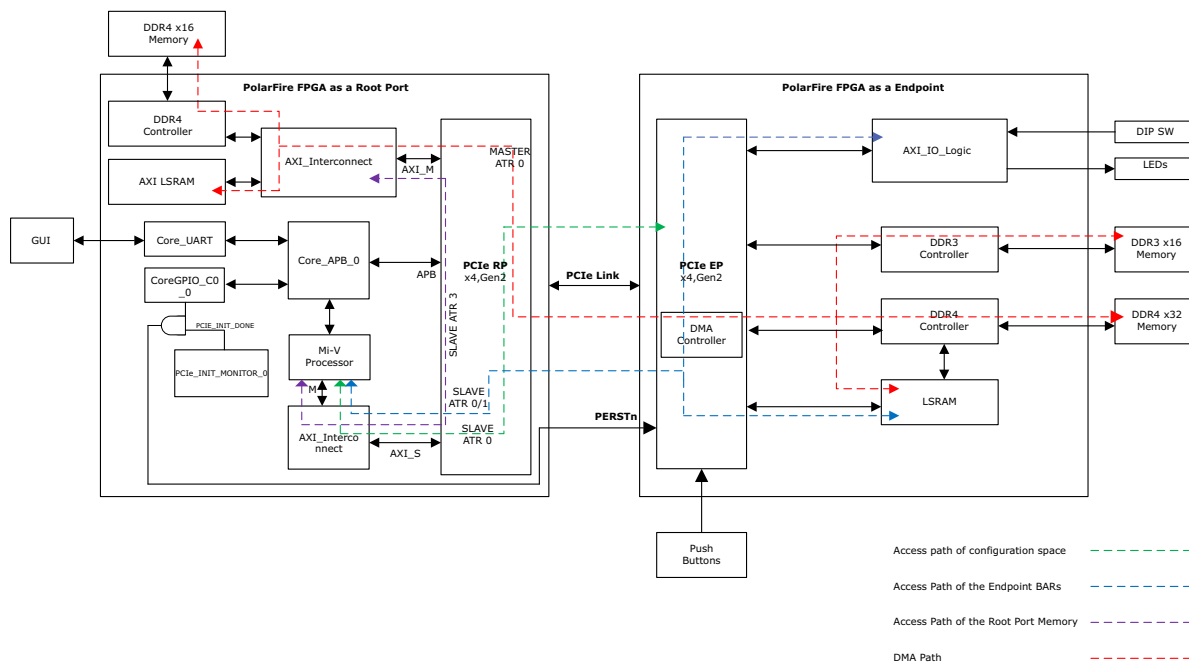
1. For demo design files download link:
http://soc.microsemi.com/download/rsc/?f=mpf_dg0802_df
2. http://soc.microsemi.com/download/rsc/?f=mpf_dg0756_eval_df
3. Download and install Libero SoC (as indicated in the website for this design) on the host PC from the following location:
<https://www.microsemi.com/product-directory/design-resources/1750-libero-soc#downloads>

The latest versions of ModelSim, Synplify Pro, and FTDI drivers are included in the Libero SoC installation package.

2.3 Demo Design

The top-level block diagram of the PCIe Root Port design is shown in the following figure. The PolarFire PCIe Root Port can establish a PCIe link with any PCIe Endpoint or Bridge. The user application enumerates the Endpoint device using the ECAM (enhanced configuration access mechanism) feature. The user application also initiates the AXI transactions from the Root Port. These AXI transactions are converted to PCIe Configuration space or memory transactions (CfgWr/CfgRd/MWr/MRd) to Endpoint.

Figure 1 • Block Diagram



As shown in [Figure 1](#), page 3, the following points describe the data flow in the PCIe Root Port design:

1. The CoreUART block interfaces with the GUI.
2. The Mi-V soft processor reads/writes data to the Core_UART_0 block through the core Core_APB_0.
3. The Mi-V soft processor forwards the corresponding PCIe command to the PF_PCIE_0 block through the PCIe_APB/PCIe_AXI slave interface.
4. The PCIe request and completion TLPs are transmitted and received between the Root Port and the Endpoint through the serial link.
5. Inbound TLPs are reflected as AXI transactions on the AXI_1_Master port of PF_PCIE.
6. The Mi-V soft processor uses the PCIe_AXI bus interface to read the data from AXI_1_SLAVE.
7. The Mi-V soft processor uses the core Core_APB_0 and writes the data to the UART_APB slave interface to forward the data to the GUI.

As shown in [Figure 1](#), page 3, the following points describe the DMA flow from Root Port to Endpoint:

1. The Mi-V soft processor enumerates the Endpoint by accessing the Root Port and the Endpoint configuration space through the SLAVE ATR0 path.

Note: ATRs (address translation registers) perform address translation from PCIe address space to the AXI master. For more information about ATRs, see [UG0685: PolarFire FPGA PCI Express User Guide](#).

2. The Mi-V soft processor accesses the Endpoint BAR 0/2 through the SLAVE ATR 0/1 path.
3. The Mi-V soft processor accesses the Root Port LSRAM memory through the SLAVE ATR 3 path.
4. The DMA is performed according to the user selection on the GUI application.

2.3.1 Memory and Peripheral Address Map

This section lists the memory and peripheral address map of the Root Port demo design.

The address map of the Mi-V peripherals and main memory are:

- APB/AXI MMIO Interface: 0x60000000 to 0x7FFFFFFF
- AHB MEM Interface: 0x80000000 to 0x8FFFFFFF

The address map of the bus interfaces connecting Mi-V to PF_PCIE is listed in the following table.

Table 2 • Mi-V and PF_PCIE Address Maps

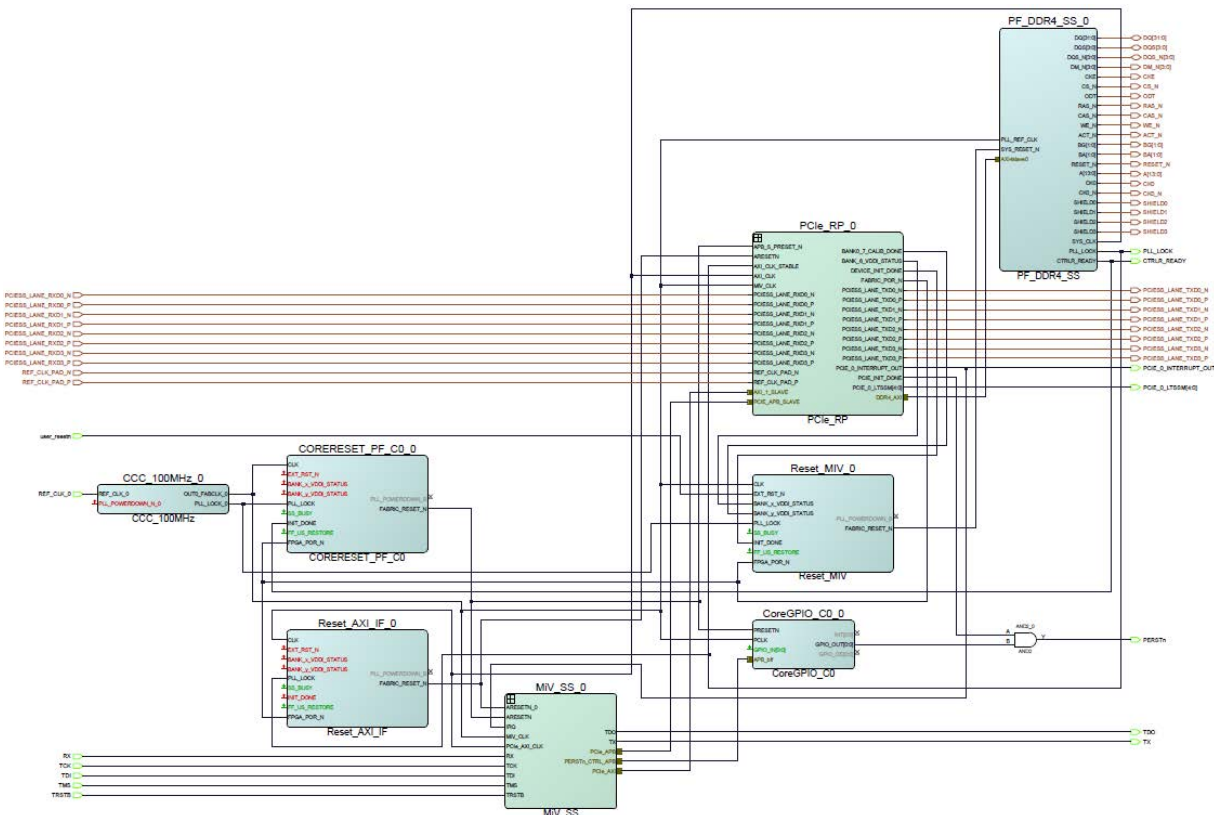
Bus Interface/Component	Description	Memory Map
PCIe_APB	This bus interface is used to access the PCIe register	0x63000000 to 0x63FFFFFF
CoreUARTapb	This block establishes a UART interface to connect the Mi-V processor to the external world	0x64000000 to 0x64FFFFFF
CoreGPIO_C0	This component is used to generate the PERSTn signal for the link partner that is connected to the Root port	0x65000000 to 0x65FFFFFF
PCIe_AXI	This bus interface is the PCIe AXI slave for EP configuration or BAR space access	0x70000000 to 0x7000FFFF – Configuration space (Mi-V configures through PCIe APB) 0x71000000 to 0x7100FFFF – EP BAR0 space 0x72000000 to 0x7200FFFF – EP BAR2 space 0x73000000 to 0x73FFFFFF – RP AXI Master - LSRAM/DDR4 (Mi-V configures through PCIe APB)
TCM	This block is the main memory of the Mi-V processor	0x80000000 to 0x8FFFFFFF

The PF_PCIE block connects to the DDR4 and LSRAM blocks through the AXI_1_MASTER bus interface. The address maps of DDR4 and LSRAM are 0x10000000 to 0x1FFFFFFF and 0x00000000 to 0x00000FFF respectively.

2.3.2 Design Implementation

Figure 2, page 5 shows the Libero SoC software design implementation of the PCIe Root Port demo design.

Figure 2 • PCIe Root Port demo design



The top-level design includes the following SmartDesign components and memory controller subsystems:

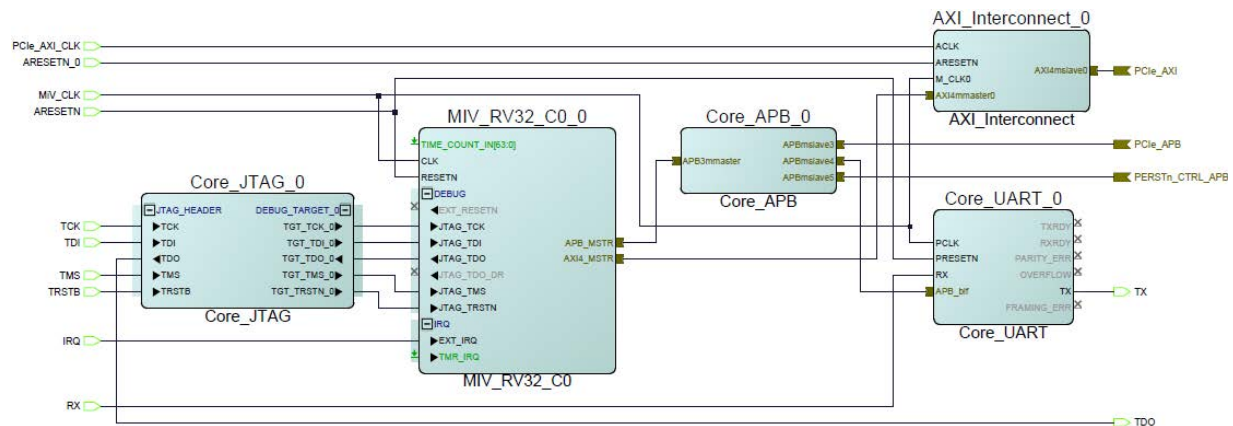
- MIV_SS_0
- PCIe_RP_0
- DDR4
- CoreGPIO_C0_0

Note: PERSTn is a fundamental reset signal defined in both **PCI Express Base Specification** and **PCI Express Card Electromechanical Specification**. It is a reset signal issued by the Root port via PCIe slots to reset the entire PCIe fabric hierarchy. CoreGPIO_C0_0 is used to generate the PERSTn signal for the link partner that is connected to the root port. The Root port firmware running on the MI-V processor can assert the PERSTn signal through CoreGPIO_C0_0. When the host is power cycled, the PERSTn signal is asserted by the PCIe_INIT_MONITOR_0 until the PCIe controller in the Root port is initialized.

2.3.2.1 Mi-V Subsystem

The sub-blocks of MIV_SS_0 are shown in the following figure.

Figure 3 • MIV_SS_0 SmartDesign



2.3.2.1.1 MIV_RV32_C0

The MIV_RV32_C0 (MIV_RV32_C0) is configured with a Reset Vector Address of 0x80000000. After reset, the processor starts executing the instructions from this address. The main memory of the processor address ranges from 0x80000000 to 0x8FFFFFFF.

The AXI_Interconnect_0 and Core_APB_0 block connects the MIV_RV32_C0 block to:

- The PF_PCIE_0 block through PCIe_APB slave interface. The MIV_RV32_C0 block accesses the PCIe control registers through the PCIe_APB slave interface.
- The PF_PCIE_0 block through PCIe_AXI slave interface.
- The Core_UART_0 block through a APB slave interface.
- The CoreGPIO_C0_0 block through the PERSTn_CTRL APB slave interface of CoreGPIO_C0_0.

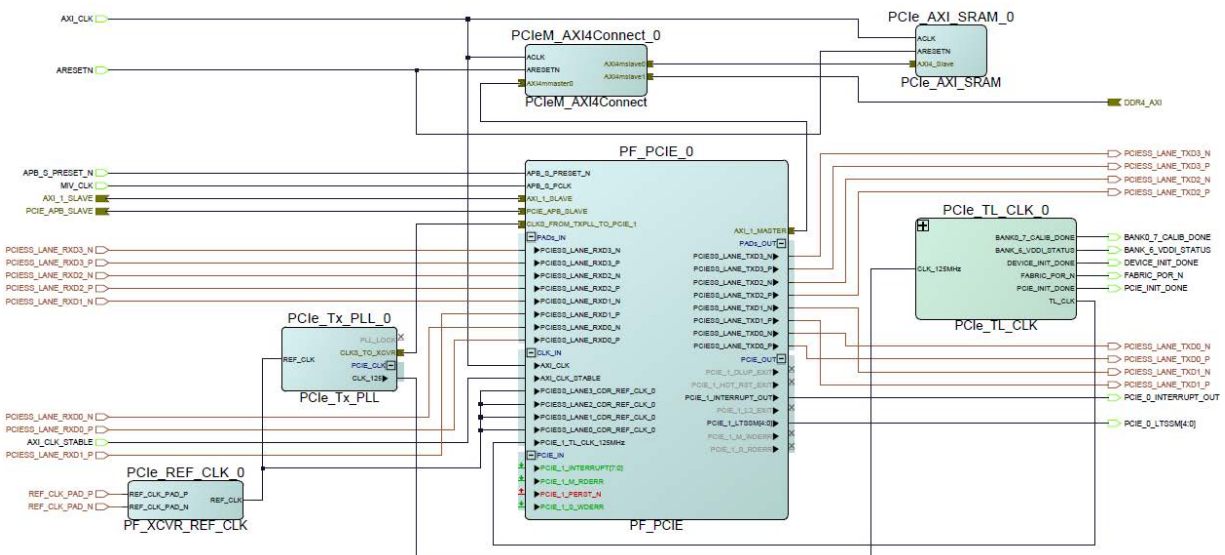
These slaves are connected at the following addresses:

- PCIe_APB slave: 0x63000000
- PCIe_AXI: 0x70000000
- UART_APB slave: 0x64000000
- PERSTn_CTRL_APB slave: 0x65000000

2.3.2.2 PCIe Rootport Subsystem

The sub-blocks of PCIe_RP_0 are shown in the following figure.

Figure 4 • PCIe_RP SmartDesign



2.3.2.2.1 PF_PCIE_0

The PF_PCIE_0 IP block is used to configure the PCIe subsystem (PCIESS) as a Root Port (PCIe 1). PCIESS block is configured for x4 lanes, 5 Gbps data rate, and APB interface for PCIe Controller access.

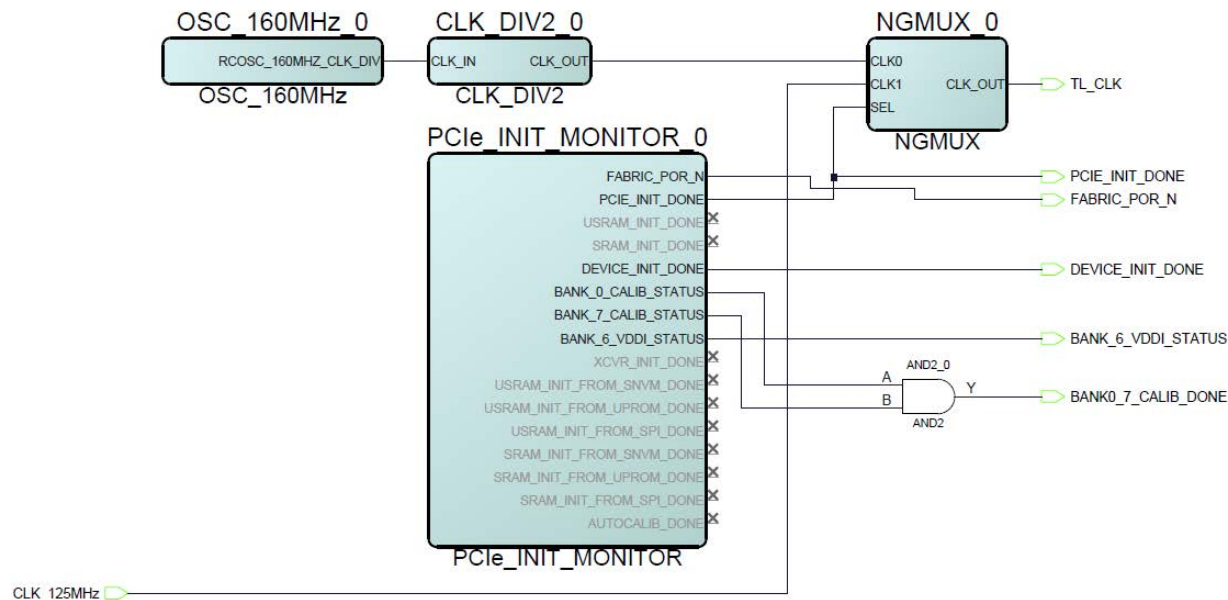
2.3.2.2.2 PCIe_Tx_PLL_0

The PCIe_Tx_PLL_0 (Transmit PLL) is configured for a 100 MHz **Reference Clock** and a 5000 Mbps **Desired Output Bit Clock**.

The PolarFire FPGA transceiver is a half-rate architecture that is the internal high-speed path that uses both edges of the clock to keep the clock rates down. Therefore, the clock can run at half of the data rate, thereby consuming less dynamic power. The transceiver in PCIe mode requires a 2500 MHz bit clock.

2.3.2.2.3 PCIe_TL_CLK_0 SmartDesign

The PCIe_TL_CLK SmartDesign implements PCIe TL CLK for PolarFire devices as shown in the following figure. PCIe TL CLK needs to be connected to CLK_125 MHz of Tx PLL. In PolarFire devices, TL CLK is available only after PCIe initialization. The 80 MHz clock is derived from the on-chip 160 MHz oscillator to drive the TL CLK during PCIe initialization. The NGMUX is used to switch this clock to the required CLK_125 MHz after PCIe initialization.

Figure 5 • PCIe_TL_CLK_0 SmartDesign

2.3.2.2.4 PCIeM_AXI4Connect_0

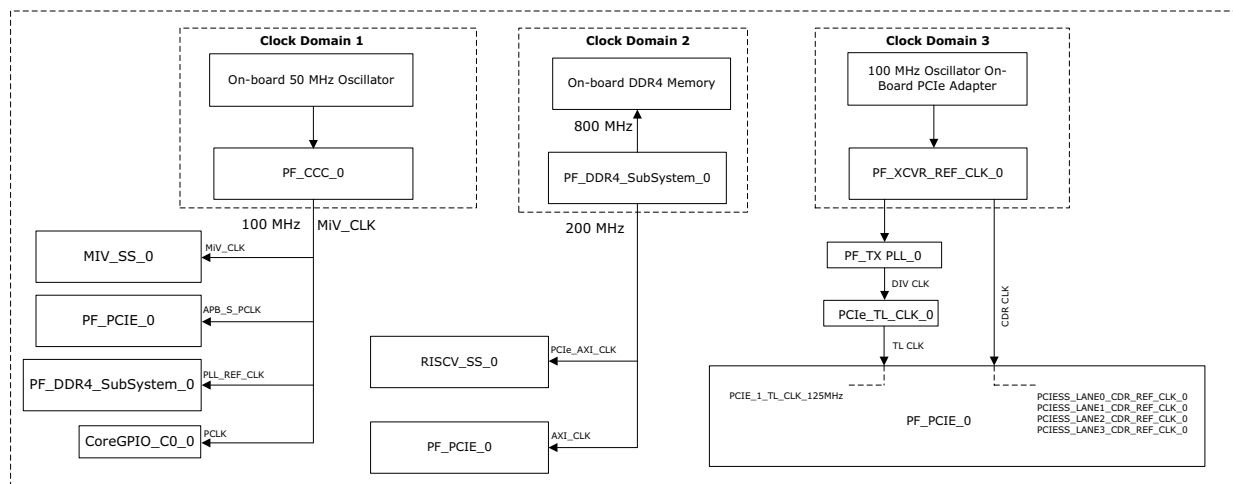
The PCIeM_AXI4Connect_0 (CoreAXI4Interconnect) bus is configured for a single master and two slaves and used to connect the PF_PCIE_0 with PCIe_AXI_SRAM_0 and DDR4 for DMA operations.

2.3.2.3 DDR4 Subsystem

The DDR4 subsystem is configured to access the 32-bit DDR4 memory through an AXI4 64-bit interface. The DDR4 memory initialization and timing parameters are configured as per the DDR4 memory on the PolarFire Evaluation kit.

2.4 Clocking Structure

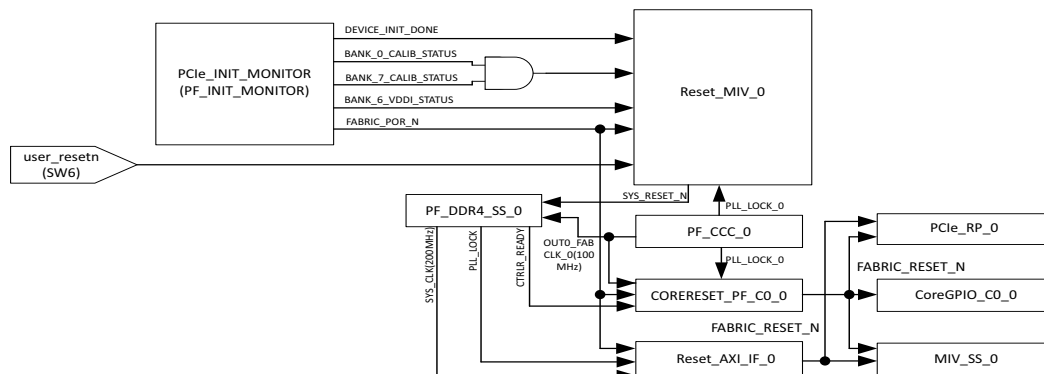
The following figure shows the clocking structure of the demo design.

Figure 6 • Clocking Structure

2.5 Reset Structure

The following figure shows the reset structure of the PCIe Root port demo design.

Figure 7 • Reset Structure



The Reset_AXI_IF_0(CoreReset_PF) block synchronizes "PLL_LOCK" signal of PF_DDR4_SS_0 IP with the DDR4 system clock(200MHz) to generate FABRIC_RESET_N signal, which drives the PCle_RP_0 and MIV_SS_0 blocks.

The Reset_MIV_0(CoreReset_PF) block synchronizes the external user_resetrn (SW6 on the PolarFire Evaluation board) and DEVICE_INIT_DONE(PF_INIT_MONITOR) together with the RISC-V system clock (100 MHz) to generate the SYS_RESET_N, which drives the PF_DDR4_SS block.

The CORERESET_PF_C0_0(CoreReset_PF) block synchronizes "CTRLR_READY" signal of PF_DDR4_SS_0 IP with the RISC-V system clock (100 MHz) to generate FABRIC_RESET_N signal, which drives the PCle_RP_0, MIV_SS_0 and CoreGPIO_C0_0 blocks.

For more information about device initialization, see [UG0725: PolarFire FPGA Device Power-Up and Resets User Guide](#).

For more information on CoreReset_PF IP core, see CoreReset_PF handbook from the Libero catalog.

3 Libero Design Flow

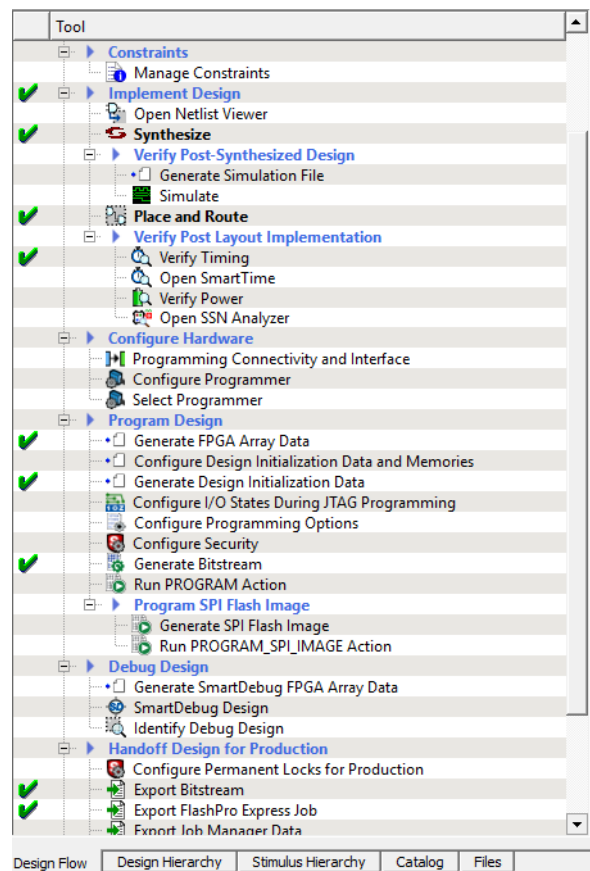
This chapter describes the Libero design flow of the demo design. The Libero design flow involves the following steps:

- Synthesize
- Place and route
- Verify Timing
- Configure Design Initialization Data and Memories
- Generate Bitstream
- Run PROGRAM Action

Note: To initialize the TCM in PolarFire using the system controller, a local parameter `l_cfg_hard_tcm0_en`, in the `miv_rv32_opsrv_cfg_pkg.v` file should be changed to 1'b1 prior to synthesis. See the 2.7 TCM section in the *MIV_RV32 Handbook*.

The following figure shows these options in the Design Flow tab.

Figure 8 • Libero Design Flow Options



3.1 Synthesize

To synthesize the design, perform the following steps:

1. From the **Design Flow** window, double-click **Synthesize**.

When the synthesis is successful, a green tick mark appears as shown in [Figure 8](#), page 10.

2. Right-click **Synthesize** and select **View Report** to view the synthesis report and log files in the Reports tab.

We recommend viewing the `RP_Demo_Top.srr` and the `RP_Demo_Top_compile_netlist.log` files for debugging synthesis and compile errors.

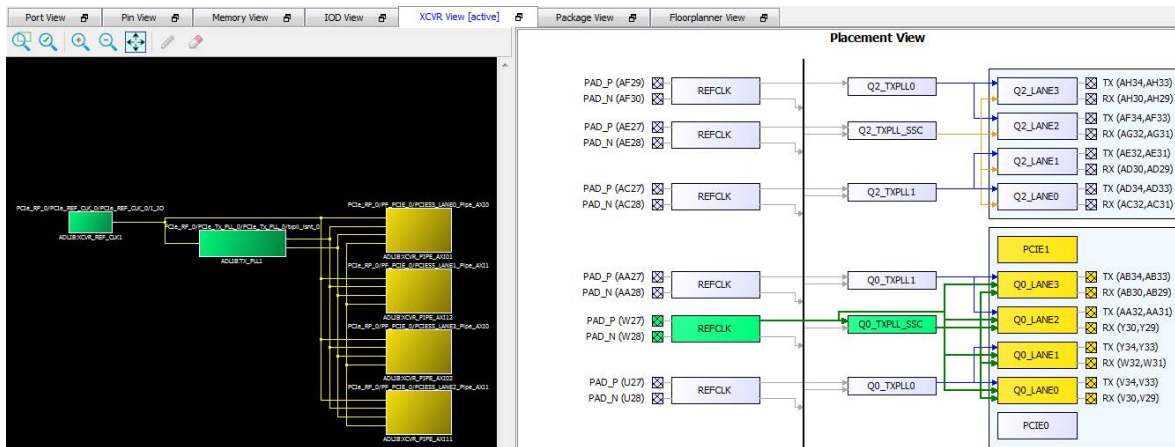
3.2 Place and Route

To place and route the design, the Transmit PLL (TX_PLL), XCVR_REF_CLK, PF_XCVR TX and RX lane, and the PF_DDR4_SS_0 must be placed using the **I/O Editor**.

To place and route the design, perform the following steps:

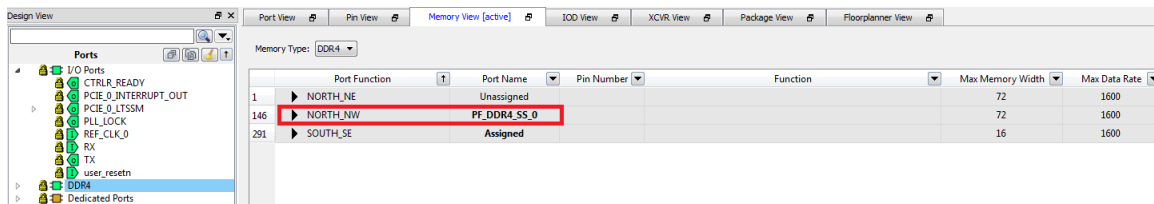
1. From the **Constraints Manager** window, place the Transmit PLL, XCVR_REF_CLK, and PF_XCVR TX and RX lanes using **I/O Editor** as shown in the following figure.

Figure 9 • I/O Editor—XCVR View



2. Place the PF_DDR4_SS_0 at NORTH_NW location as shown in the following figure.

Figure 10 • PF_DDR3_SubSystem_0 Placement



Port Function	Port Name	Pin Number	Function	Max Memory Width	Max Data Rate
NORTH_NE	Unassigned			72	1600
NORTH_NW	PF_DDR4_SS_0	146		72	1600
SOUTH_SE	Assigned	291		16	1600

3. From the **Design Flow** window, double-click **Place and Route**.
When place and route is successful, a green tick mark appears as shown in [Figure 8](#), page 10.
4. Right-click **Place and Route** and select **View Report** to view the place and route report and log files in the Reports tab.

We recommend viewing the `RP_Demo_Top_place_and_route_constraint_coverage.xml` file for place and route constraint coverage.

3.2.1 Resource Utilization

The resource utilization report is written to the `RP_Demo_Top_layout_log.log` file in the **Reports** tab -> `RP_Demo_Top` report -> **Place and Route**. [Table 3](#), page 12 lists the resource utilization of the design after place and route. These values may vary slightly for different Libero runs, settings, and seed values.

Table 3 • Resource Utilization

Type	Used	Total	Percentage
4LUT	30938	299544	10.33
DFF	23206	299544	7.75
I/O Register	0	510	0

3.3 Verify Timing

To verify timing, perform the following steps:

1. From the **Design Flow** window, double-click **Verify Timing**.
2. When the design successfully meets the timing requirements, a green tick mark appears as shown in [Figure 8](#), page 10.
3. Right-click **Verify Timing** and select **View Report** to view the verify timing report and log files in the Reports tab.

3.4 Generate FPGA Array Data

To generate FPGA array data, In the **Design Flow** window, double-click **Generate FPGA Array Data**.

A green tick mark is displayed after the successful generation of the FPGA array data as shown in [Figure 8](#), page 10.

3.5 Configure Design Initialization Data and Memories

The Configure Design Initialization Data and Memories step generates an TCM initialization client and adds it to sNVM, μ PROM, or an external SPI flash, based on the type of non-volatile memory selected. In this tutorial, the TCM is initialized from μ PROM.

This process requires the user application executable file (hex file) as input to initialize the TCM after device power-up. The hex file is provided with the design files.

To select the non-volatile memory and generate the initialization client, perform the following steps:

1. On the **Design Flow** tab, double-click **Configure Design Initialization Data and Memories**. The **Design and Memory Initialization** window opens.
2. Under **Third stage (uPROM/sNVM/SPI-Flash)**, select **μ PROM**, as shown in [Figure 11](#), page 13. In the Third Stage pane, select uPROM as the non-volatile memory, and retain the default start address (0x00000000).

Note: The default start address 0x00000000 is retained because there are no other initialization clients specified in μ PROM.

Figure 11 • Design and Memory Initialization Window

Design Initialization | uPROM | sNVM | SPI Flash | Fabric RAMs

Apply Discard Help

In design initialization, user design blocks such as LSRAM, uSRAM, transceivers, and PCIe can be initialized as an option using data stored in the non-volatile storage memory. The initialization data can be stored in uPROM, sNVM, or an external SPI Flash.

Follow the below steps to program the initialization data:

1. Set up your fabric RAMs initialization data, if any, using the 'Fabric RAMs' tab
2. Define the storage location of the initialization data
3. Generate the initialization clients
4. Generate or export the bitstream
5. Program the device

Design initialization specification

First stage (sNVM)

In the first stage, the initialization sequence de-asserts FABRIC_POR_N.

Second stage (sNVM)

In the second stage, the initialization sequence initializes the PCIe and XCVR blocks present in the design.

Start address for second stage initialization client: 0x 00000000 sNVM start page: 0

Third stage (sNVM/uPROM/SPI-Flash)

In the third stage, the initialization sequence initializes the Fabric RAMs present in the design.

To save the initialization instructions in sNVM/uPROM/SPI-Flash, please use 'Fabric RAMs' tab to make your selection for each RAM client.

☒ Start address for sNVM clients: 0x 00000000 sNVM start page: 0

☐ Start address for uPROM clients: 0x 00000000

☐ Start address for SPI-Flash clients: 0x 00000400

SPI-Flash Binding: SPI-Flash - No-binding Plaintext SPI Clock divider value: 6

Time Out (s): 128

Auto Calibration Time Out (ms): 3000

Custom configuration file:

3. On the **Fabric RAMs** tab, select MIV_SS_0/MIV_RV32_C0_0/MIV_RV32_C0_0/u_opsrv_0/gen_tcm0.u_opsrv_TCM_0/tcm_ram_macro.u_ram_0 from the list of logical instances, and click **Edit**, as shown in Figure 12, page 13. The MIV_SS_0/MIV_RV32_C0_0/MIV_RV32_C0_0/u_opsrv_0/gen_tcm0.u_opsrv_TCM_0/tcm_ram_macro.u_ram_0 instance is the Mi-V processor's main memory. The System Controller initializes this instance with the imported client at power-up.

Figure 12 • Fabric RAMs Tab

Flash Fabric RAMs

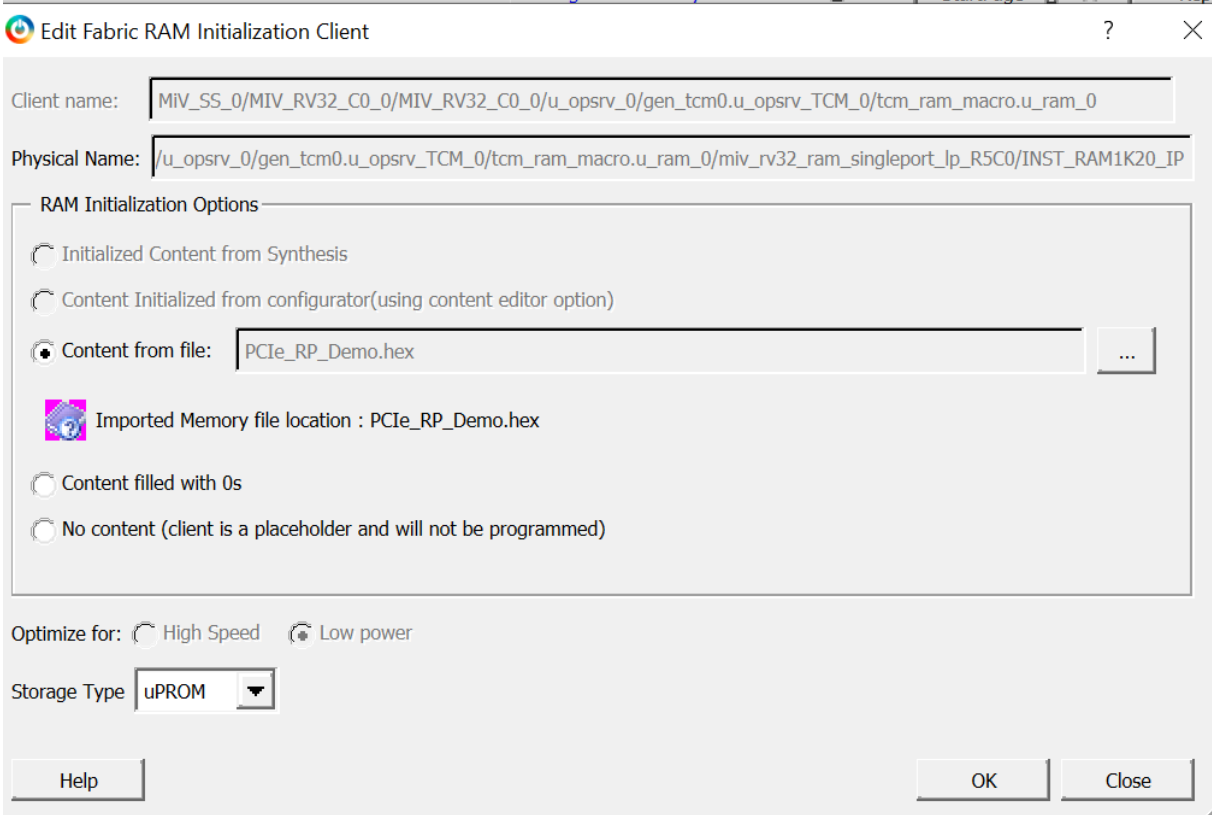
Clients

Load design configuration Edit... Initialize all clients from: Initialize all Clients from sNVM

☒ Filter out Inferred RAMs

	Logical Instance Name	PORTA Depth * Width	PORTB Depth * Width	Memory Content	Storage Type	Memory Source
1	MIV_SS_0/MIV_RV32_C0_0/MIV_RV32_C0_0/u_opsrv_0/gen_tcm0.u_opsrv_TCM_0/tcm_ram_macro.u_ram_0	65536x32	65536x32	PCIe_RP_Demo.hex	sNVM	Configurator
2	PCIe_RP_0/PCIe_AXI_SRAM_0	1024x80	1024x80	No content	sNVM	Configurator

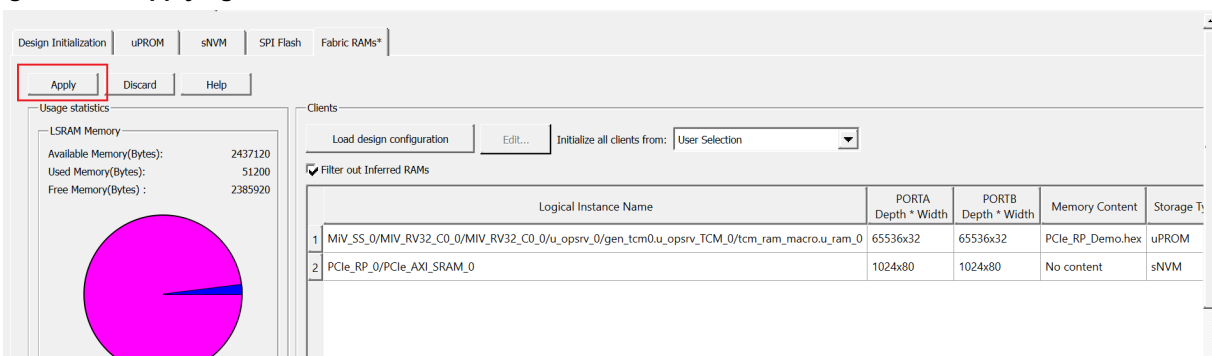
4. In the **Edit Fabric RAM Initialization Client** dialog box, click the **Import** button next to **Content from file**, as shown in the following figure.

Figure 13 • Edit Fabric RAM Initialization Client Dialog Box

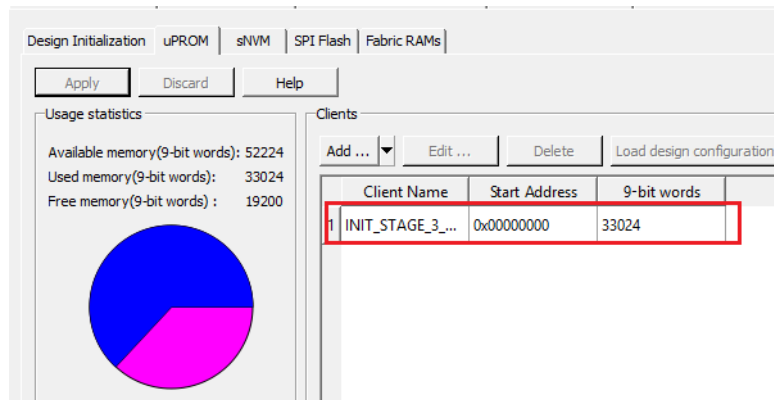
Note: In the following dialog box, browse the `mpf_dg0802_df\Libero_Project\PCIe_RP_Demo.hex` file and double-click it.

Note: If any changes are applied to the Mi-V application code, rebuild the SoftConsole project in the release mode.

5. In the **Edit Fabric RAM Initialization Client** window, click **OK**.
6. On the **Fabric RAMs** tab, click **Apply**, as shown in the following figure.

Figure 14 • Applying Fabric RAM Content

7. The initialization client for `MIV_SS_0/MIV_RV32_C0_0/MIV_RV32_C0_0/u_opsrv_0/gen_tcm0.u_opsrv_TCM_0/tcm_ram_macro.u_ram_0` instance is generated and stored in μ PROM. This step can be verified by viewing the third stage client created in the μ PROM tab as shown in the following figure.

Figure 15 • Third Stage INIT Client

The first and second stage clients are generated and stored in sNVM by default.

3.6 Generate Bitstream

To generate the bitstream, perform the following steps:

1. On the **Design Flow** tab, double-click **Generate Bitstream**.
When the bitstream is successfully generated, a green tick mark appears as shown in [Figure 8](#), page 10.
2. Right-click **Generate Bitstream** and select **View Report** to view the corresponding log file in the **Reports** tab.

3.7 Run PROGRAM Action

After generating the bitstream, the PolarFire device must be programmed. To program the PolarFire device, perform the following steps:

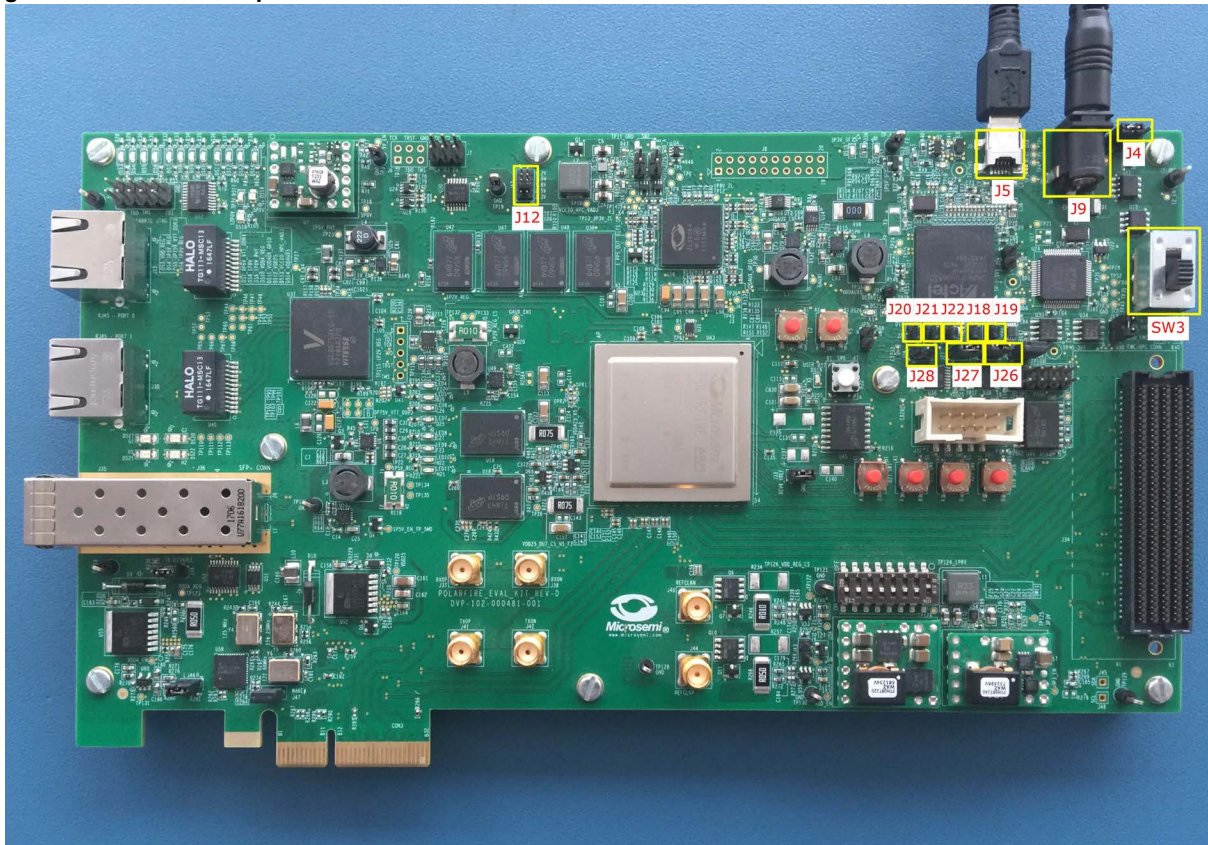
1. Ensure that the following Jumper Settings are set on the board, which will be used as the Root Port device.

Table 4 • Jumper Settings

Jumper	Description	Default
J18, J19, J20, J21, and J22	Short pin 2 and 3 for programming the PolarFire FPGA through FTDI	Closed
J28	Short pin 1 and 2 for programming through the on-board FlashPro5	Open
J26	Short pin 1 and 2 for programming through the FTDI SPI	Closed
J4	Short pin 1 and 2 for manual power switching using SW3	Closed
J12	Short pin 3 and 4 for 2.5 V	Closed

2. Connect the power supply cable to the **J9** connector on the board.
3. Connect the USB cable from the Host PC to **J5** (FTDI port) on the board.
4. Power on the board using the **SW3** slide switch.
5. On the **Libero in the Design Flow** tab, double-click **Run PROGRAM Action**.

When the device is programmed successfully, a green tick mark appears as shown [Figure 8](#), page 10. The device is successfully programmed, see [Setting Up the Demo](#), page 17.

Figure 16 • Board Setup—Evaluation Kit

4 Setting Up the Demo

Setting up the demo involves the following steps:

1. Programming the PolarFire devices on the two evaluation boards
2. Connecting the two PolarFire Evaluation boards through the PCIe Adapter card

Throughout this chapter, the two boards are referred using the following labels for simplicity:

- Board A—board running the Root Port design
- Board B—board running the Endpoint design

4.1 Connecting the Two Boards

This section describes how to connect the two boards through the Microsemi PCIe Adapter Card.

To connect the boards, perform the following steps:

1. Ensure that the pins 1 and 2 of the J1 jumper on the PCIe adapter card are closed.
2. Ensure that the pins 1 and 3 of the J2 jumper on the PCIe adapter card are open.
3. Connect CON1 of the adapter card to CON3 (PCIe slot) of Board A.
4. Connect CON2 of the adapter card to CON3 (PCIe slot) of Board B.
5. Connect the USB cable from the Host PC to J5 (FTDI port) on Board A.
6. Connect the USB cable from the Host PC to J5 (FTDI port) on Board B.
7. Connect the power supply cable to the J3 connector of the PCIe adapter card.
8. Power on Board A and B using the SW3 slide switch.
9. Power-up the PCIe adapter card using the SW1 slide switch.

Board A and Board B power-up using the PCIe adapter card. After successfully connecting the two boards, the demo setup looks like the following figure:

Figure 17 • Demo Setup



5 Running the Demo

This chapter describes how to install and use the GUI to run the PCIe Root Port demo. This chapter is divided into the following sections:

- Installing the GUI
- Viewing the Enumeration Data
- Running the Control Plane Commands
- Running the Data Plane Commands

5.1 Installing the GUI

To install the GUI, perform the following steps:

1. Extract the contents of the `mpf_dg0802_df.rar` file. From the `mpf_dg0802_df\GUI_Installer` folder, double-click the `setup.exe` file.
2. Follow the instructions displayed on the installation wizard.

After successful installation, `PCIe_Root_Port_GUI` appears on the Start menu of the host PC desktop.

5.2 Viewing the Enumeration Data

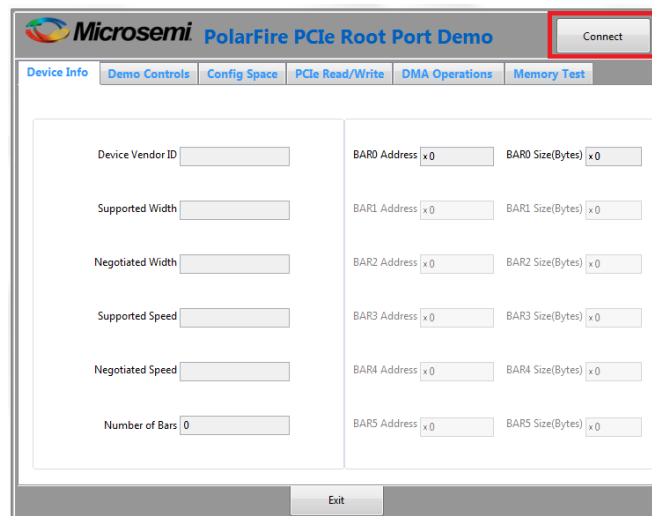
Before you begin, ensure that:

1. The PolarFire FPGA on one board is programmed with the PCIe Root Port design and the PolarFire FPGA on the other board is programmed with the PCIe Endpoint design
2. The two boards are connected through a Microsemi PCIe adapter card and powered-up.
3. LED 9, 10, and 11 are glowing on the Root Port board. This indicates that the PCIe link is up. Otherwise, power-cycle the boards again.

To start the GUI and view the enumeration data, perform the following steps:

1. From the task bar, click the Start button and select `PCIe_Root_Port_GUI`.
2. Click **Connect** to connect the GUI to the Root Port board as shown in the following figure.

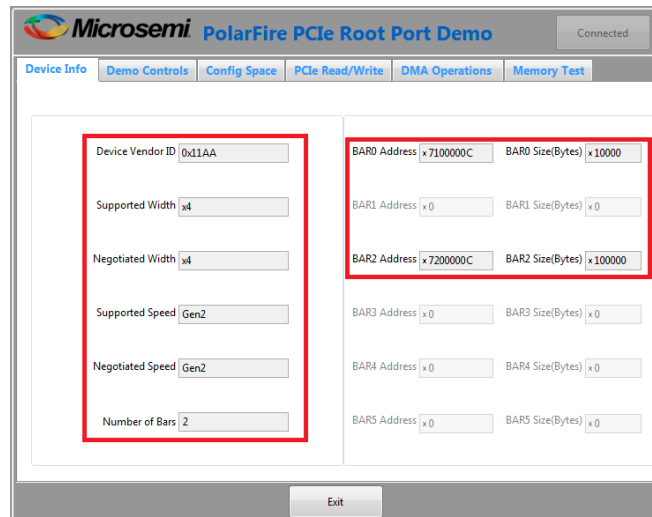
Figure 18 • PCIe Root Port GUI



The GUI starts detecting the UART COM Port of the Root Port device.

- After successfully connecting to the COM port, the Mi-V soft processor enumerates the PCIe EP device and sends the configuration space data to the GUI.
- Click **Device Info** tab to view the Endpoint device information as shown in the following figure.

Figure 19 • Endpoint Device Information



Microsemi PolarFire PCIe Root Port Demo

Connected

Device Info | Demo Controls | Config Space | PCIe Read/Write | DMA Operations | Memory Test

Device Vendor ID: 0x11AA

Supported Width: x4

Negotiated Width: x4

Supported Speed: Gen2

Negotiated Speed: Gen2

Number of Bars: 2

BAR0 Address: x7100000C, BAR0 Size(Bytes): x10000

BAR1 Address: x0, BAR1 Size(Bytes): x0

BAR2 Address: x7200000C, BAR2 Size(Bytes): x10000

BAR3 Address: x0, BAR3 Size(Bytes): x0

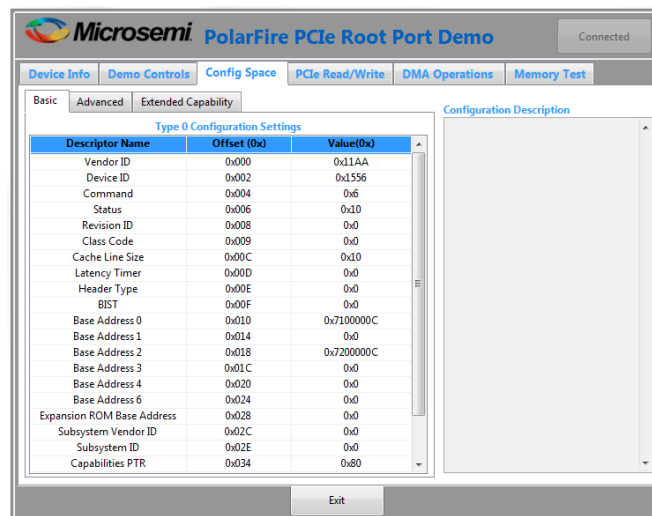
BAR4 Address: x0, BAR4 Size(Bytes): x0

BAR5 Address: x0, BAR5 Size(Bytes): x0

Exit

- Click **Config Space** tab to view the basic Type 0 Configuration Settings of the Endpoint as shown in the following figure.

Figure 20 • Endpoint Config Space-Basic



Microsemi PolarFire PCIe Root Port Demo

Connected

Device Info | Demo Controls | Config Space | PCIe Read/Write | DMA Operations | Memory Test

Basic | Advanced | Extended Capability

Type 0 Configuration Settings

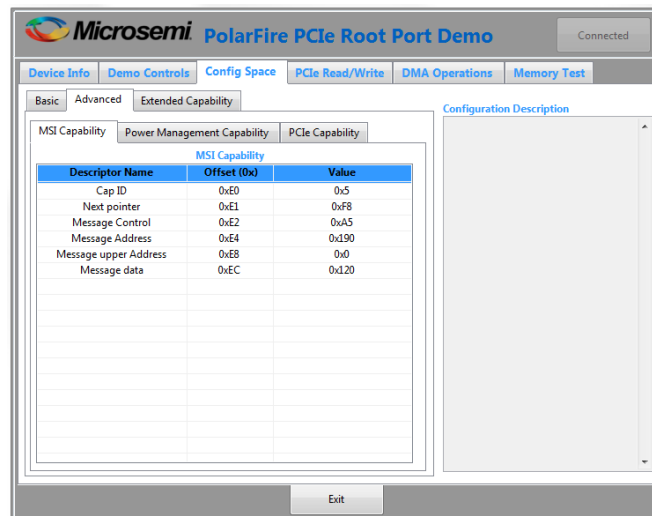
Descriptor Name	Offset (0x)	Value(0x)
Vendor ID	0x000	0x11AA
Device ID	0x002	0x1556
Command	0x004	0x6
Status	0x006	0x10
Revision ID	0x008	0x0
Class Code	0x009	0x0
Cache Line Size	0x00C	0x10
Latency Timer	0x00D	0x0
Header Type	0x00E	0x0
BIST	0x00F	0x0
Base Address 0	0x010	0x7100000C
Base Address 1	0x014	0x0
Base Address 2	0x018	0x7200000C
Base Address 3	0x01C	0x0
Base Address 4	0x020	0x0
Base Address 6	0x024	0x0
Expansion ROM Base Address	0x028	0x0
Subsystem Vendor ID	0x02C	0x0
Subsystem ID	0x02E	0x0
Capabilities PTR	0x034	0x80

Configuration Description

Exit

6. Click **Advanced** tab to view the MSI Capabilities of the Endpoint as shown in the following figure.

Figure 21 • Endpoint Config Space-Advanced



7. Similarly, click **Power Management Capability** and **PCIe Capability** tabs to view the relevant data.

5.3 Running the Control Plane Commands

In this demo, the Root Port initiates the following control plane operations:

- Control Endpoint LEDs
- Read DIP SW Status
- Read MSI count values
- BAR2 Memory read/write commands

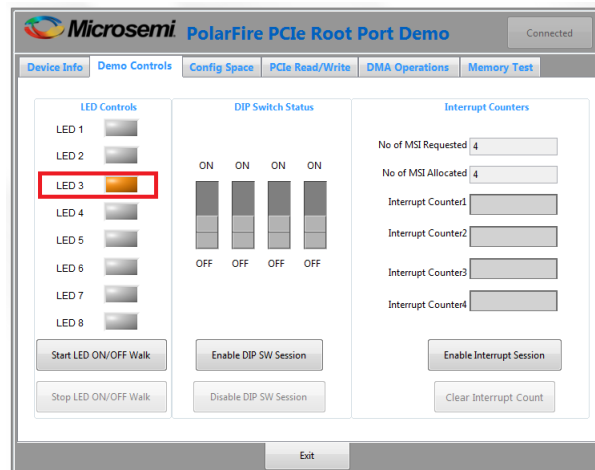
5.3.1 Controlling Endpoint LEDs

Root Port can initiate the Endpoint LED glowing and walk through.

To issue LED Commands, perform the following steps:

1. Click **Demo Controls** tab.
2. Select any single LED. For example, select LED3 as shown in the following figure.

Figure 22 • Single LED Control

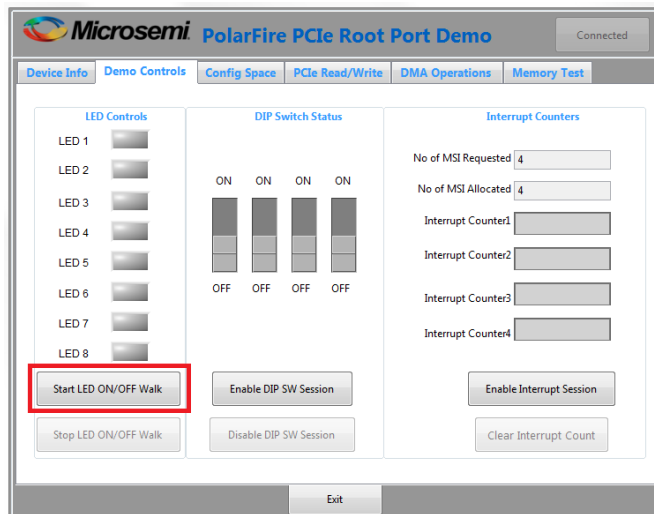


The GUI initiates the LED glow request to the RISC-V processor, which passes this request to the PF_PCIE_0 block. PF_PCIE_0 sends the BAR2 MWr packet to the Endpoint.

As a result, LED6 on the Endpoint board glows.

- Click **Start LED ON/OFF Walk** button as shown in Figure 23, page 21.

Figure 23 • LED ON/OFF Walk



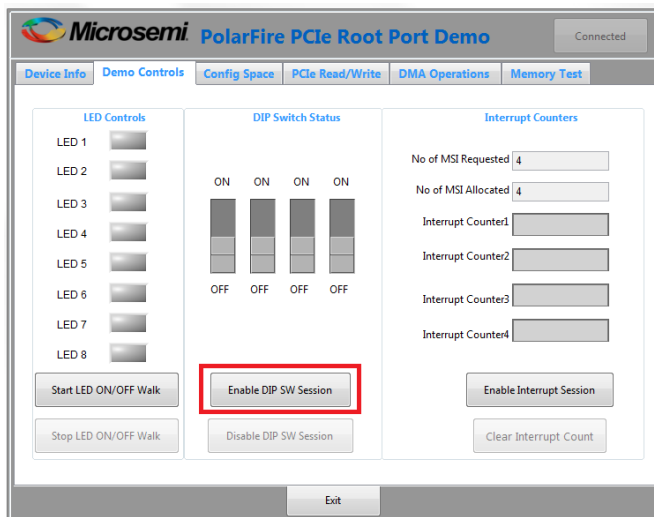
The GUI initiates the LED ON/OFF walk request. As a result, LED ON/OFF is executed from the first to the last LED and in the reverse order.

5.3.2 Reading Endpoint DIP SW Status

To read the DIP SW Status, perform the following steps:

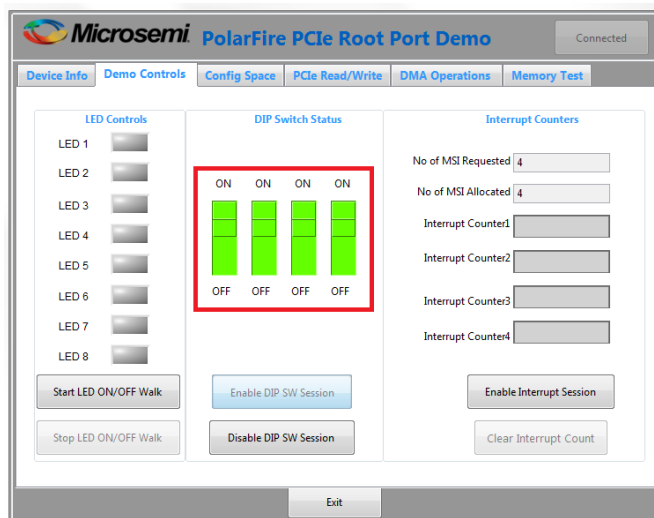
- Click **Enable DIP SW Session** button as shown in the following figure.

Figure 24 • DIP SW Status Option



The GUI initiates the DIP switch status read request. As a result, the DIP SW status on the Endpoint board is displayed as shown in Figure 25, page 22. Change the DIP SW positions on the Endpoint board and observe the same in GUI.

Figure 25 • Endpoint DIP SW Status



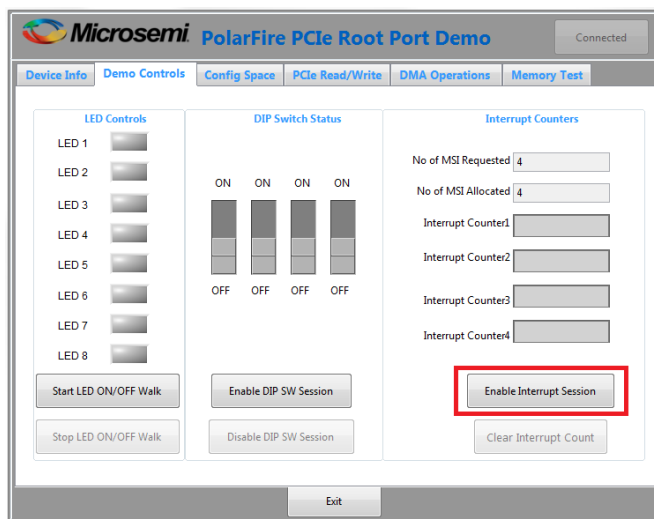
5.3.3 Reading MSI Count Values

In the demo, Root Port can read the MSI count values for push-button interrupts on the Endpoint board.

To read the MSI count values:

1. Click **Enable Interrupt Session** button as shown in Figure 26, page 22.

Figure 26 • Enable Interrupt Session Option



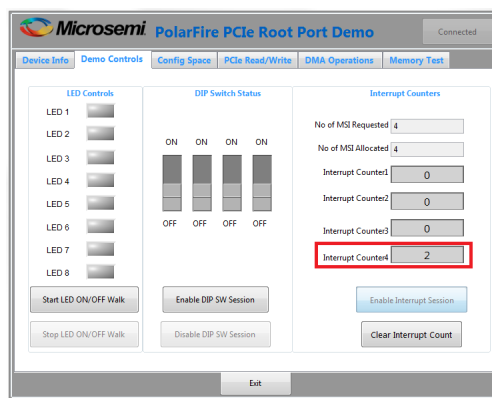
When the Interrupt session is enabled, the GUI sends the Enable Interrupt session request to the RISC-V processor. PF_PCIE_0 receives the number of MSI requested by the Endpoint. In the reference design, the Root Port allocates 4 types of MSI as shown in the following table.

Table 5 • Allocated MSIs

MSI Number	Interrupt Type on the Endpoint Board	Mapped Interrupt Counter on the GUI
1	SW10	Interrupt Counter1
2	SW9	Interrupt Counter2
3	SW8	Interrupt Counter3
4	SW7	Interrupt Counter4

- Press switch and observe interrupt count.

Figure 27 • Interrupt Counter4



- Click **Clear Interrupt Count** button to clear all of the Interrupt counters on the GUI.

5.3.4 Running BAR2 Memory Read/Write Commands

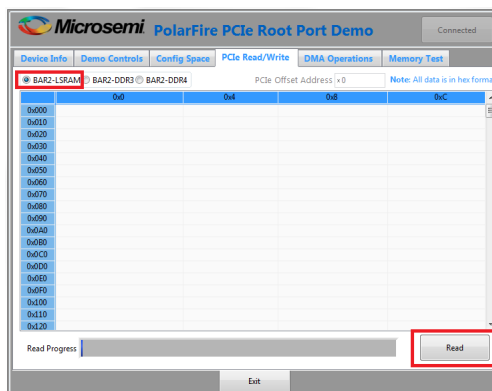
In the demo, the Root port can initiate BAR2 memory read/write commands for reading/writing to Endpoint LSRAM/DDR3/DDR4.

The **PCIe Read/Write** tab on the GUI is used to initiate these commands. The Endpoint LSRAM/DDR3/DDR4 memory is first read, and then a value can be entered in a specific location to initiate the write command.

To run BAR2 read/write, perform the following steps:

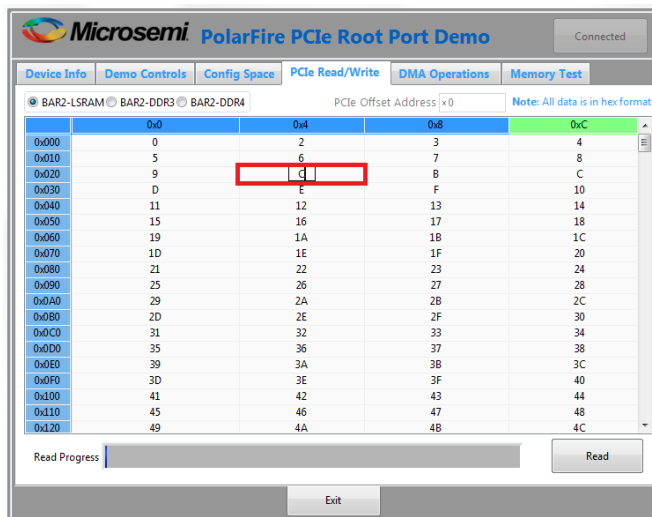
- Select **BAR2-LSRAM** option and click **Read** button as shown in the following figure.

Figure 28 • BAR2-LSRAM Read Option



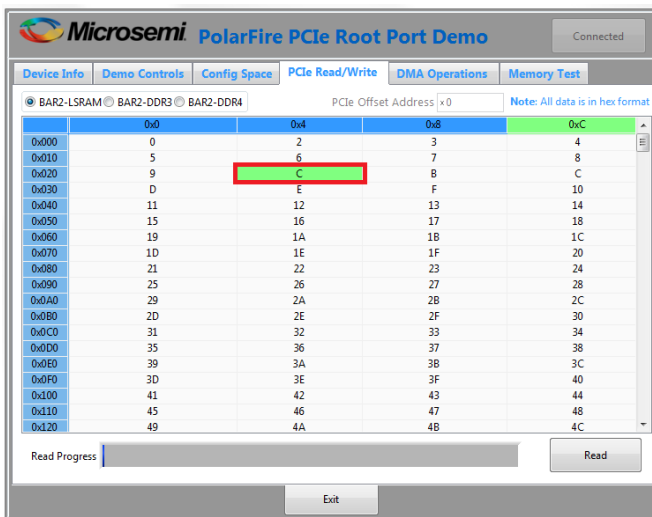
2. Select any memory location and edit the value of that location. For example: See the following figure.

Figure 29 • BAR2-LSRAM Write



3. The edited memory location turns green and the value entered is written to the Endpoint LSRAM memory location as shown in Figure 30, page 24.

Figure 30 • BAR2-LSRAM Write Successful



4. Similarly change any other memory location also.
5. Click **Read** button to check whether the memory locations contain the latest values or not.
6. Similarly, run the BAR2-DDR3 and BAR2-DDR4 memory read/write.

5.4 Running the Data Plane Commands

In the demo, the Root port initiates the Endpoint DMA engines to perform the following data plane commands:

- Running DMA operations
- Running memory test

5.4.1 Running DMA Operations

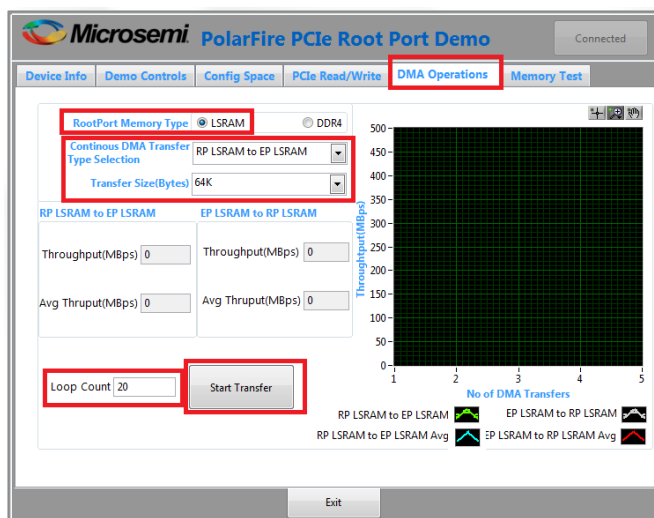
When the Root Port initiates the DMA operation, the Mi-V soft processor activates the Endpoint DMA registers through BAR0. The Endpoint DMA engines can perform the following DMA operations:

- Root Port LSRAM/DDR4 to Endpoint LSRAM/DDR3/DDR4
- Endpoint LSRAM/DDR3/DDR4 to Root Port LSRAM/DDR4

To run the DMA operations, perform the following steps:

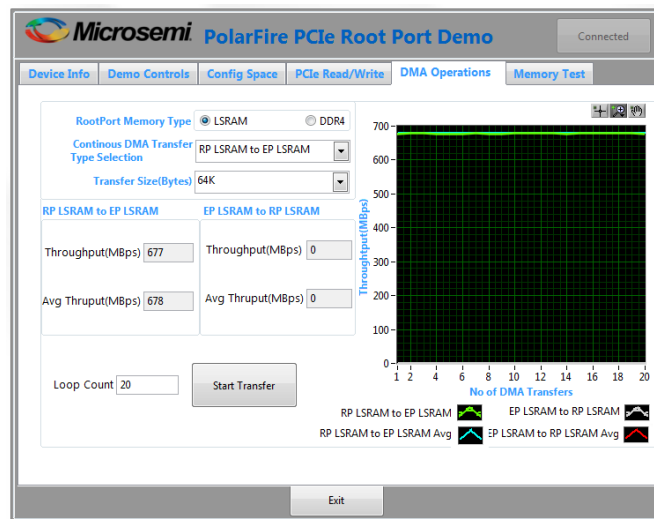
1. Click **DMA Operations** tab as shown in Figure 31, page 25.
2. Do the following:
 - Select the **RP LSRAM -> EP LSRAM** from the drop-down list.
 - Select 64K from the Transfer Size (Bytes) drop-down.
 - Set the **Loop Count** to 20
 - Click **Start transfer**.

Figure 31 • Initiating RP LSRAM to EP LSRAM DMA



The GUI displays the corresponding throughput details and graph as shown in the following figure.

Figure 32 • RP LSRAM to EP LSRAM Throughput



3. Do the following to initiate another DMA transaction:
 - Select **Both RP LSRAM <-> EP LSRAM** from the drop-down list.
 - Select 64K from the **Transfer Size (Bytes)** drop-down.
 - Set the **Loop Count** to 20.
 - Click **Start Transfer**.
4. Similarly, select the RP LSRAM to EP DDR3 and RP LSRAM to EP DDR4 from the drop-down and observe the throughputs.
5. Select DDR4 as the Root Port Memory Type and perform DMA operations by selecting the Endpoint destination memory type.

5.4.2 Running Memory Test

The **Memory Test** tab provides the memory test feature, which is also a DMA operation. The **Memory Test** tab enables DMA transactions between Root Port and Endpoint memory type (LSRAM, DDR3, and DDR4). This feature provides data pattern options with which the Root Port memory is initialized and then DMA operation is performed.

In memory testing, the user application performs the following sequence of operations:

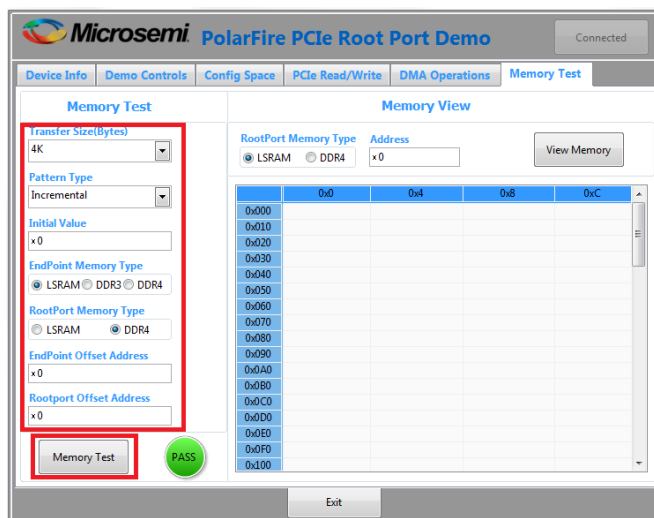
1. Initializes the Root Port memory with the specified data pattern
2. Performs the DMA from Root Port memory to Endpoint memory
3. Erases the data pattern in the Root Port memory
4. Performs the DMA from Endpoint memory to Root Port memory
5. Compares the data in Root Port memory with the selected data pattern

To run the memory test, perform the following steps:

1. Select the DMA parameters like Transfer Size(Bytes), Pattern Type, Endpoint Memory Type, RootPort Memory Type, EndPoint Offset Address, and RootPort Offset Address as shown in the following figure.

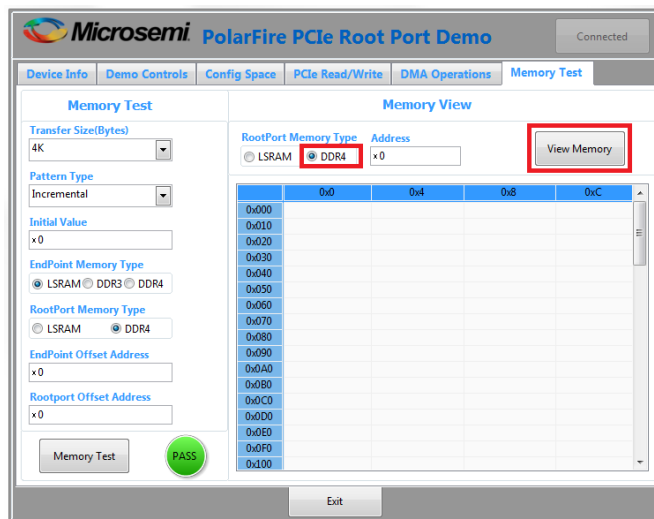
Note: The Root Port slave ATR3 is configured for 1 MB. Hence, the maximum Endpoint offset address is F80000 and the maximum Root Port address is 0x80000.

Figure 33 • Memory Test Feature



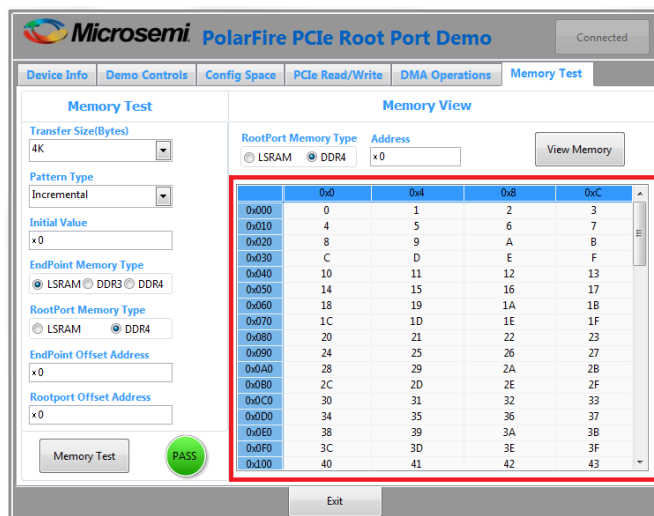
2. Click **Memory Test**.
3. Select option **DDR4** from the Root Port memory type and click **View Memory** as shown in the following figure to read the Root Port DDR4.

Figure 34 • The View Memory Option



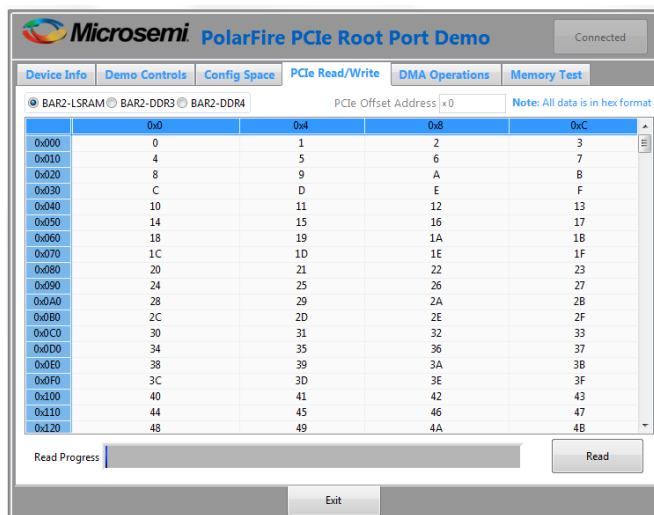
4. The GUI displays the data pattern written to the Root port DDR4 as shown in Figure 35, page 28.

Figure 35 • Root port DDR4 Memory Content



5. Select the **PCIe Read/Write** tab and click **Read** to view the data pattern written to the Endpoint LSRAM.

Figure 36 • Endpoint LSRAM Memory Content



5.5 PolarFire DMA Throughput Summary

The following table lists the throughput values observed during the continuous DMA mode.

Table 6 • Throughput Summary

DMA Transfer Type	DMA Size	Throughput (MBps)	Throughput Average (MBps)
RP LSRAM to EP LSRAM	512 K	1022	1022
EP LSRAM to RP LSRAM	512 K	779	779
RP LSRAM to EP DDR3	512 K	773	773
EP DDR3 to RP LSRAM	512 K	328	328
RP LSRAM to EP DDR4	512 K	998	998
EP DDR4 to RP LSRAM	512 K	391	391
RP DDR4 to EP LSRAM	512 K	540	540
EP LSRAM to RP DDR4	512 K	779	779
RP DDR4 to EP DDR3	512 K	540	540
EP DDR3 to RP DDR4	512 K	328	328
RP DDR4 to EP DDR4	512 K	540	540
EP DDR4 to RP DDR4	512 K	391	391

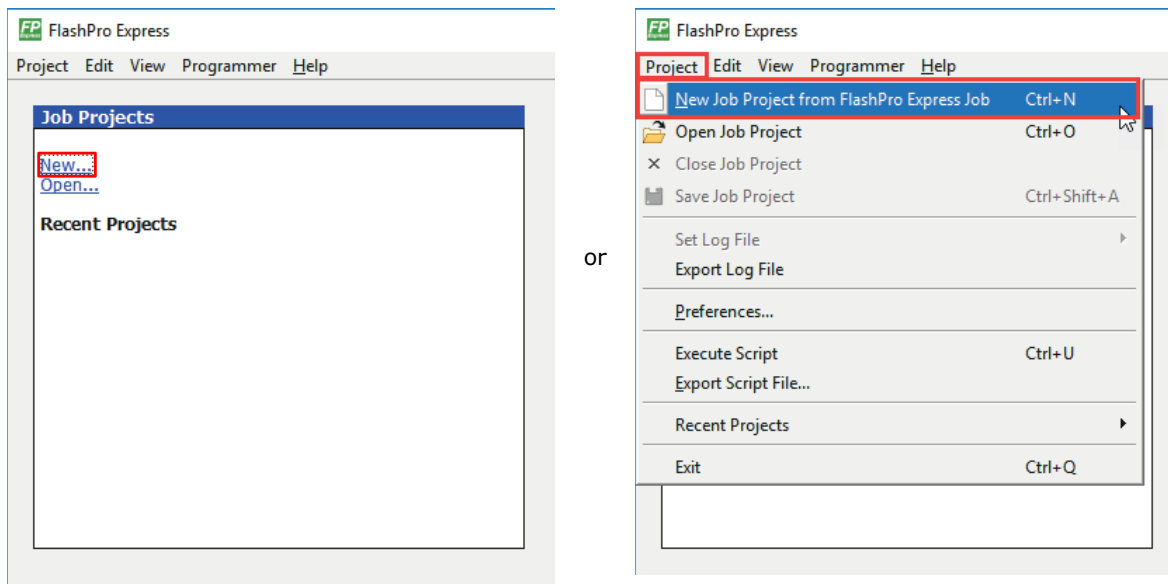
6 Appendix 1: Programming the Devices Using FlashPro Express

The Root Port design must be programmed on Board A and the Endpoint design must be programmed on Board B.

To program, perform the following steps:

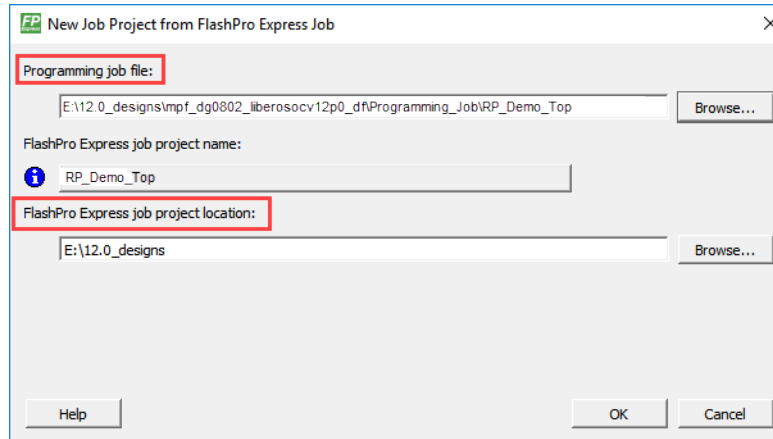
1. Take Board A and ensure that the Jumper Settings are set as listed in [Table 4](#), page 15.
2. Connect the power supply cable to the J9 connector on Board A.
3. Connect the USB cable from the Host PC to J5 (FTDI port) on Board A.
4. Power-up Board A using the SW3 slide switch.
5. On the host PC, launch the **FlashPro Express** software.
6. To create a new job, click **New** or
 in the **Project** menu, select **New Job Project from FlashPro Express Job** as shown in the following figure.

Figure 37 • FlashPro Express Job Project



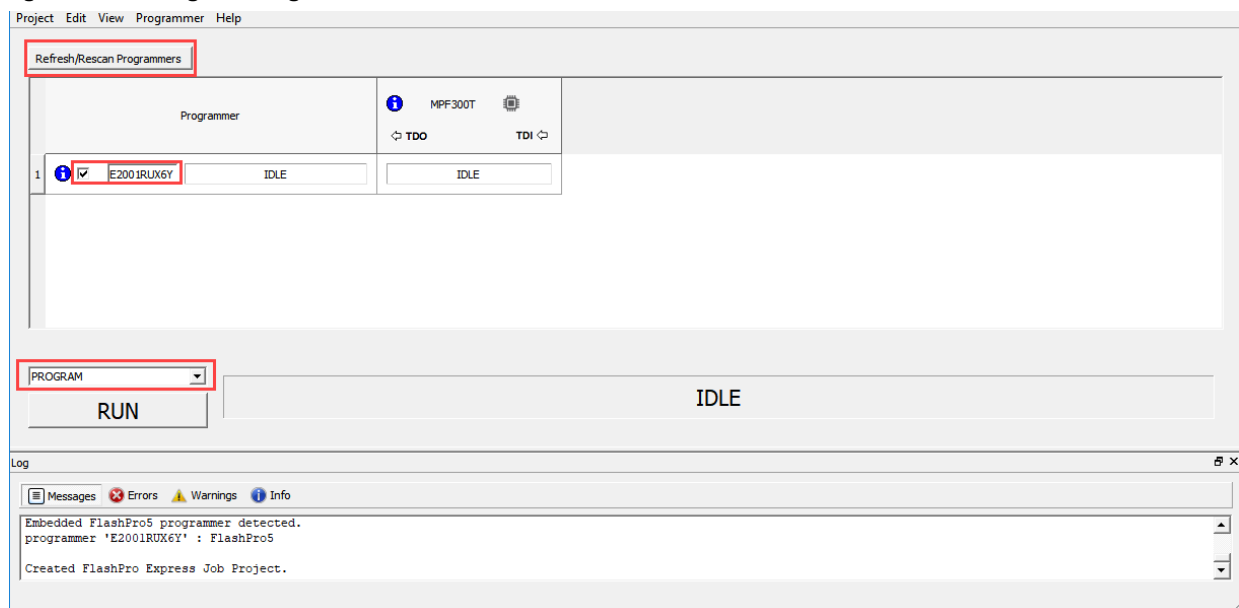
7. Enter the following in the **New Job Project from FlashPro Express Job** dialog box:
 - **Programming job file:** Click **Browse**, and navigate to the location where the .job file is located and select the file. The default location is:
`<download_folder>\mpf_dg0802_df\Programming_Job.`
 - **FlashPro Express job project location:** Click **Browse** and navigate to the location where you want to save the project.

Figure 38 • New Job Project from FlashPro Express Job



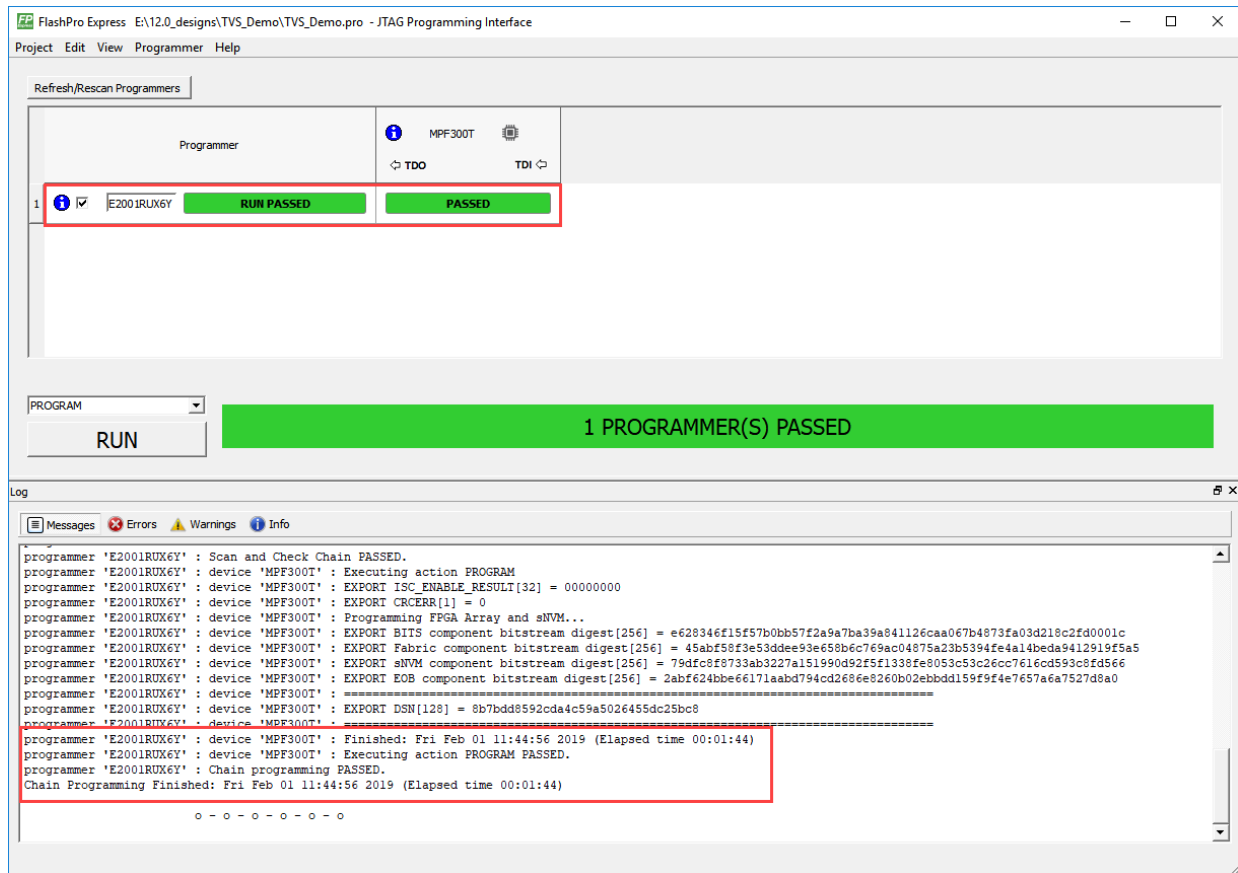
8. Click **OK**. The required programming file is selected and ready to be programmed in the device.
9. The FlashPro Express window appears as shown in the following figure. Confirm that a programmer number appears in the Programmer field. If it does not, confirm the board connections and click **Refresh/Rescan Programm**ers.

Figure 39 • Programming the Device



10. Click **RUN**. When the device is programmed successfully, a **RUN PASSED** status is displayed as shown in the following figure. See [Running the Demo](#), page 18 to run the PCIe Root Port demo.

Figure 40 • FlashPro Express—RUN PASSED

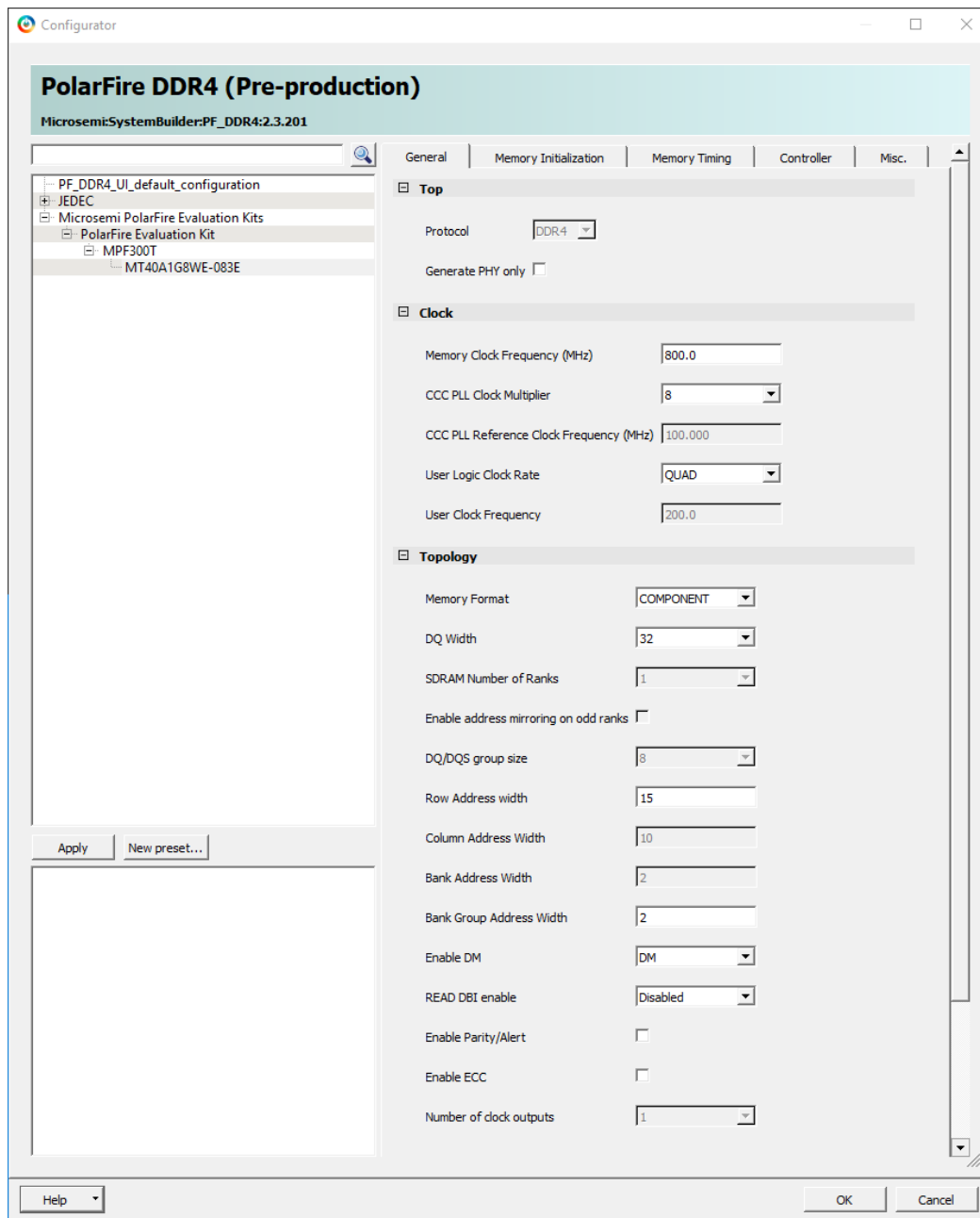


11. Close **FlashPro Express** or in the **Project** tab, click **Exit**.
Root port design is successfully programmed on Board A.
12. Similarly, program Board B with the Endpoint design. Browse `PCIe_EP_Demo_EvalKit.job` file from `mpf_dg0756_df\Programming_Job` location.

7 Appendix 2: DDR4 Configuration

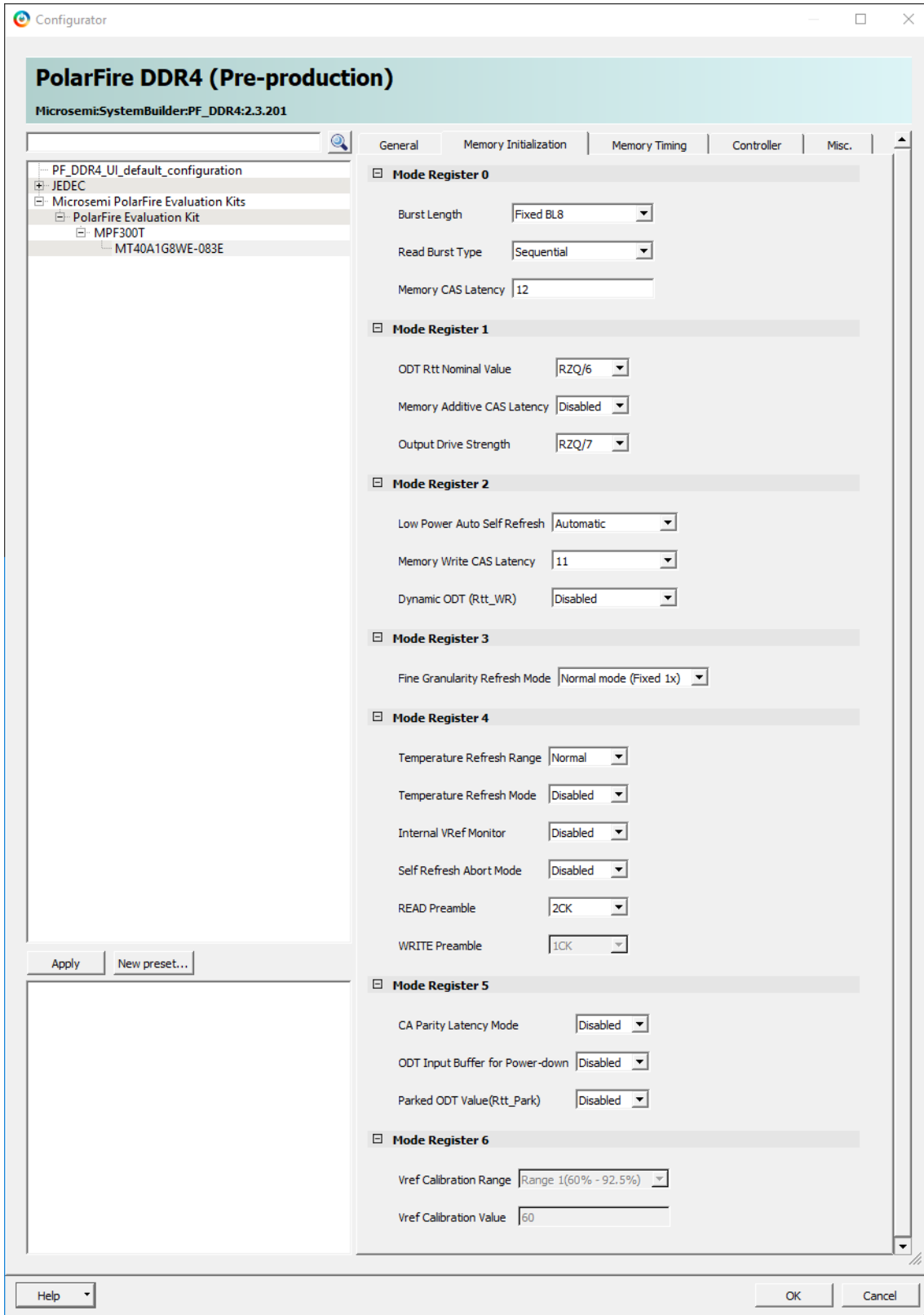
The DDR4 subsystem is configured to access the 32-bit DDR4 memory through an AXI4 64-bit interface. The DDR4 memory initialization and timing parameters are configured as per the DDR4 memory on the PolarFire Evaluation kit. The following figure shows the general configuration settings for the DDR4 memory.

Figure 41 • PF_DDR4 Configurator—General



The following figure shows the initialization configuration settings for the DDR4 memory.

Figure 42 • PF_DDR4 Configurator—Memory Initialization



PolarFire DDR4 (Pre-production)
Microsemi:SystemBuilder:PF_DDR4:2.3.201

General | **Memory Initialization** | Memory Timing | Controller | Misc.

PF_DDR4_UL_default_configuration
 JEDEC
 Microsemi PolarFire Evaluation Kits
 PolarFire Evaluation Kit
 MPF300T
 MT40A1G8WE-083E

Mode Register 0

Burst Length: Fixed BL8
 Read Burst Type: Sequential
 Memory CAS Latency: 12

Mode Register 1

ODT Rtt Nominal Value: RZQ/6
 Memory Additive CAS Latency: Disabled
 Output Drive Strength: RZQ/7

Mode Register 2

Low Power Auto Self Refresh: Automatic
 Memory Write CAS Latency: 11
 Dynamic ODT (Rtt_WR): Disabled

Mode Register 3

Fine Granularity Refresh Mode: Normal mode (Fixed 1x)

Mode Register 4

Temperature Refresh Range: Normal
 Temperature Refresh Mode: Disabled
 Internal VRef Monitor: Disabled
 Self Refresh Abort Mode: Disabled
 READ Preamble: 2CK
 WRITE Preamble: 1CK

Mode Register 5

CA Parity Latency Mode: Disabled
 ODT Input Buffer for Power-down: Disabled
 Parked ODT Value(Rtt_Park): Disabled

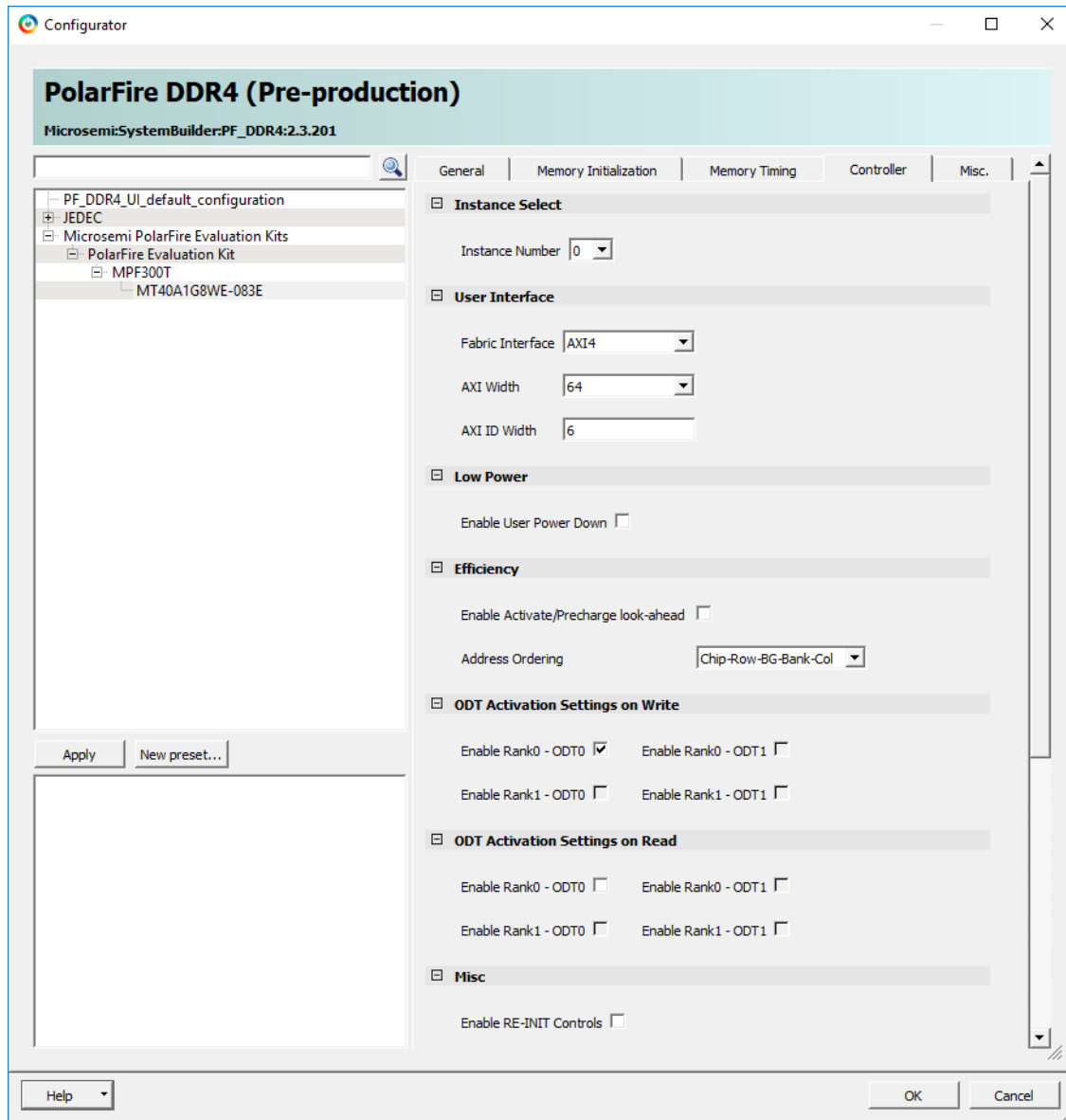
Mode Register 6

Vref Calibration Range: Range 1(60% - 92.5%)
 Vref Calibration Value: 60

Apply | New preset... | Help | OK | Cancel

The following figure shows the controller configuration settings for the DDR4 memory.

Figure 43 • PF_DDR4 Configurator—Controller



8 Appendix 3: Running the TCL Script

TCL scripts are provided in the design files folder under directory TCL_Scripts. If required, the design flow can be reproduced from Design Implementation till generation of job file.

To run the TCL, follow the steps below:

1. Launch the Libero software
2. Select **Project > Execute Script....**
3. Click Browse and select `script.tcl` from the downloaded TCL_Scripts directory.
4. Click **Run**.

After successful execution of TCL script, Libero project is created within TCL_Scripts directory.

For more information about TCL scripts, refer to `\\mpf_dg0802_df\TCL_Scripts\readme.txt`.

Refer to [Libero® SoC TCL Command Reference Guide](#) for more details on TCL commands. Contact Technical Support for any queries encountered when running the TCL script.

9 Appendix 4: References

This section lists documents that provide more information about the PCIe Endpoint and IP cores used in the reference design.

- For more information about PolarFire transceiver blocks, PF_TX_PLL, and PF_XCVR_REF_CLK, see [UG0677: PolarFire FPGA Transceiver User Guide](#).
- For more information about PF_PCIE, see [UG0685: PolarFire FPGA PCI Express User Guide](#).
- For more information about PF_CCC, see [UG0684: PolarFire FPGA Clocking Resources User Guide](#).
- For more information about DDR3 memory, see [UG0676: PolarFire FPGA DDR Memory Controller User Guide](#).
- For more information about Libero, ModelSim, and Synplify, see the [Microsemi Libero SoC PolarFire](#) web page.
- For more information about PolarFire FPGA Evaluation Kit, see [UG0747: PolarFire FPGA Evaluation Kit User Guide](#).
- For more information about CoreAHBLite, see [CoreAHBLite Handbook](#).
- For more information about CoreAHBtoAPB3, see [CoreAHBtoAPB3 Handbook](#).
- For more information about CoreUART, see [CoreUART Handbook](#).