

# TR10a-LPQ

## User Manual



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# Chapter 1

## Overview

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**T**his chapter provides an overview of the TR10a-LPQ Development Board and installation guide.

### 1.1 General Description

The Terasic TR10a-LPQ Arria 10 GX FPGA Development Kit provides the ideal hardware solution for designs that demand high capacity and bandwidth memory interfacing, ultra-low latency communication, and power efficiency. With a Low-Profile form-factor package, the TR10a-LPQ is designed for the most demanding high-end applications, empowered with the top-of-the-line Altera Arria 10 GX, delivering the best system-level integration and flexibility in the industry.

The Arria® 10 GX FPGA features integrated transceivers that transfer at a maximum of 12.5 Gbps, allowing the TR10a-LPQ to be fully compliant with version 3.0 of the PCI Express standard, as well as allowing an ultra low-latency, straight connections to two external 40G QSFP+ modules. Not relying on an external PHY will accelerate mainstream development of network applications enabling customers to deploy designs for a broad range of high-speed connectivity applications. For designs that demand high capacity and high speed for memory and storage, the TR10a-LPQ delivers with five independent banks of QDRII+ SRAM, high-speed parallel flash memory. The feature-set of the TR10a-LPQ fully supports all high-intensity applications such as low-latency trading, cloud computing, high-performance computing, data acquisition, network processing, and signal processing.

## 1.2 Key Features

The following hardware is implemented on the TR10a-LPQ board:

### ■ **FPGA**

- Altera Arria® 10 GX FPGA (10AX115N2F45E1SG)

### ■ **FPGA Configuration**

- On-Board USB Blaster II for FPGA programming
- Fast passive parallel (FPPx16) configuration via MAX II CPLD and flash memory

### ■ **General user input/output**

- 4 LEDs
- 2 push-buttons
- 2 dip switches

### ■ **Clock System**

- 50MHz Oscillator
- Programmable clock generators Si5340A and Si53306

### ■ **Memory**

- QDRII+ SRAM
- FLASH

### ■ **Communication Ports**

- Two QSFP+ connectors
- Dual PCI Express (PCIe) x8 edge connector
- One 2x5 GPIO timing expansion header

### ■ **System Monitor and Control**

- Temperature sensor
- Fan control
- Power monitor
- UART to USB for board management

## ■ Power

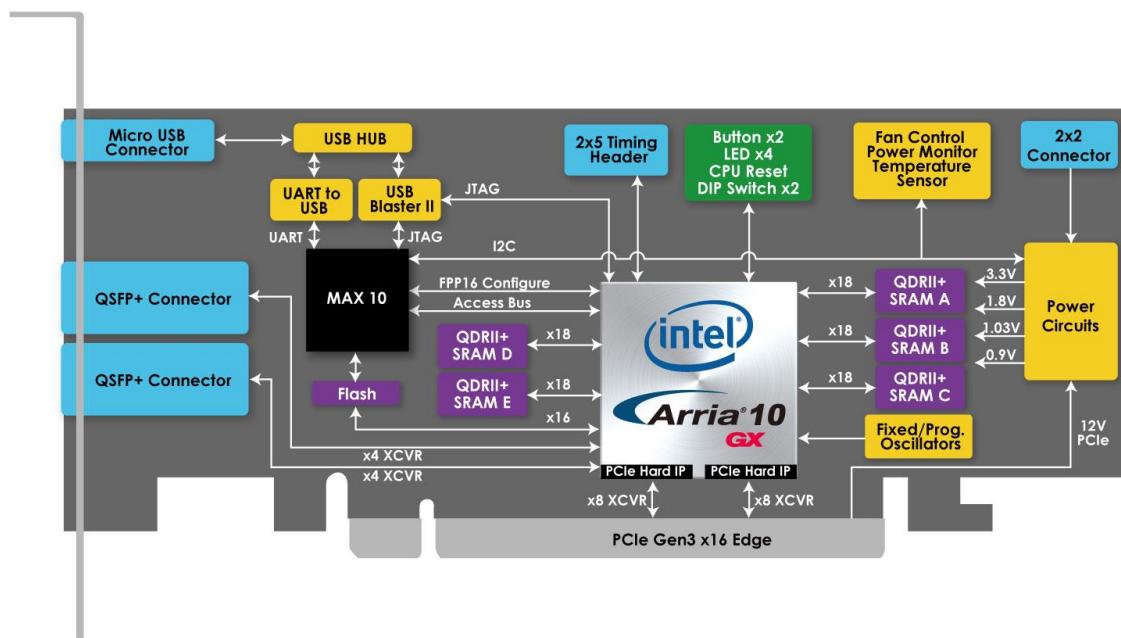
- PCI Express 4-pin power connector, 12V DC Input
- PCI Express edge connector power

## ■ Mechanical Specification

- PCI Express Low-Profile x16

## 1.3 Block Diagram

**Figure 1-1** shows the block diagram of the TR10a-LPQ board. To provide maximum flexibility for the users, all key components are connected to the Arria 10 GX FPGA device. Thus, users can configure the FPGA to implement any system design.



**Figure 1-1 Block diagram of the TR10a-LPQ board**

Below is more detailed information regarding the blocks in **Figure 1-1**.

## ■ Arria 10 GX FPGA

- 10AX115N2F45E1SG
- 1,150K logic elements (LEs)

- 67-Mbits embedded memory
- 48 transceivers (12.5Gbps)
- 3,036 18-bit x 19-bit multipliers
- 1,518 Variable-precision DSP blocks
- 4 PCI Express hard IP blocks
- 768 user I/Os
- 384 LVDS channels
- 32 phase locked loops (PLLs)

## ■ **FPGA Configuration**

- On-board USB Blaster II for use with the Quartus Prime Programmer
- MAX 10 CPLD System Controller and Fast Passive Parallel (FPP x16) configuration

## ■ **Memory devices**

- 40MB QDRII+ SRAM
- 128MB FLASH

## ■ **General user I/O**

- 4 user controllable LEDs
- 2 user push buttons
- 2 user dip switches

## ■ **On-Board Clock**

- 50MHz oscillator
- Programming PLL providing clock for 40G QSFP+ transceiver
- Programming PLL providing clock for PCIe transceiver
- Programming PLL providing clocks for QDRII+ SRAM

## ■ **Four QSFP+ ports**

- Two QSFP+ connector (40 Gbps+)

## ■ **Dual PCIe x8 edge connector**

- Support for Dual PCIe x8 Gen1/2/3
- Edge connector for PC motherboard with x16 PCIe slot

## ■ System Monitor and Control

- Temperature sensor
- Fan control
- Power monitor
- UART to USB for board management

## ■ Power Source

- PCI Express 4-pin DC 12V power
- PCI Express edge connector power

## Chapter 2

# Board Components

**T**his chapter introduces all the important components on the TR10a-LPQ.

## 2.1 Board Overview

**Figure 2-1** and **Figure 2-2** are the top and bottom view of the TR10a-LPQ development board. It depicts the layout of the board and indicates the location of the connectors and key components. Users can refer to this figure for relative location of the connectors and key components.

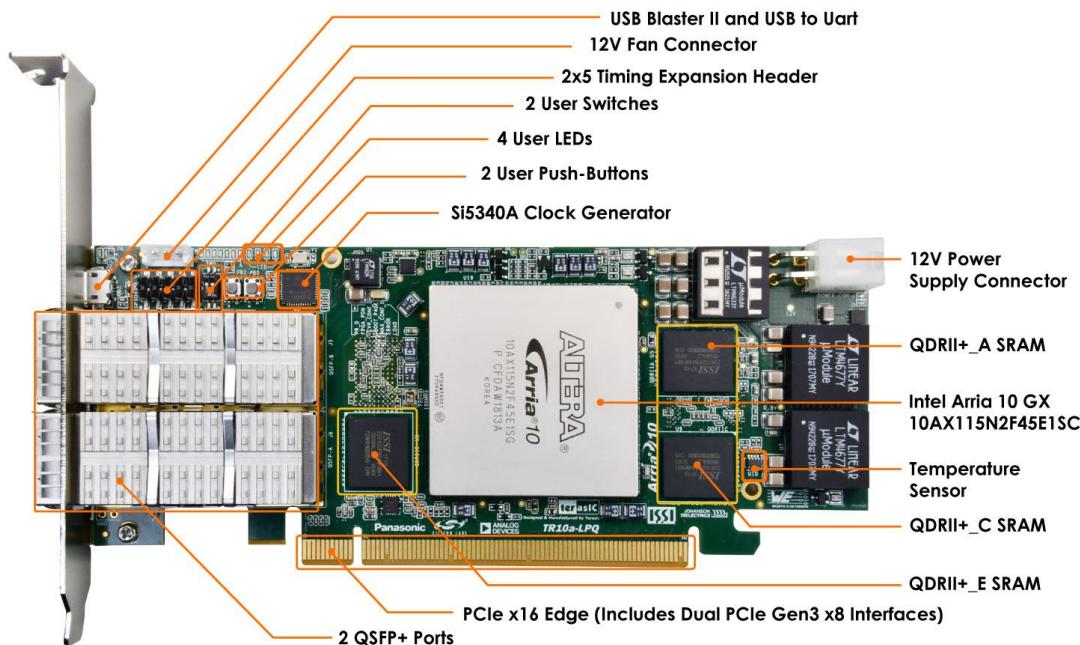


Figure 2-1 FPGA Board (Top)

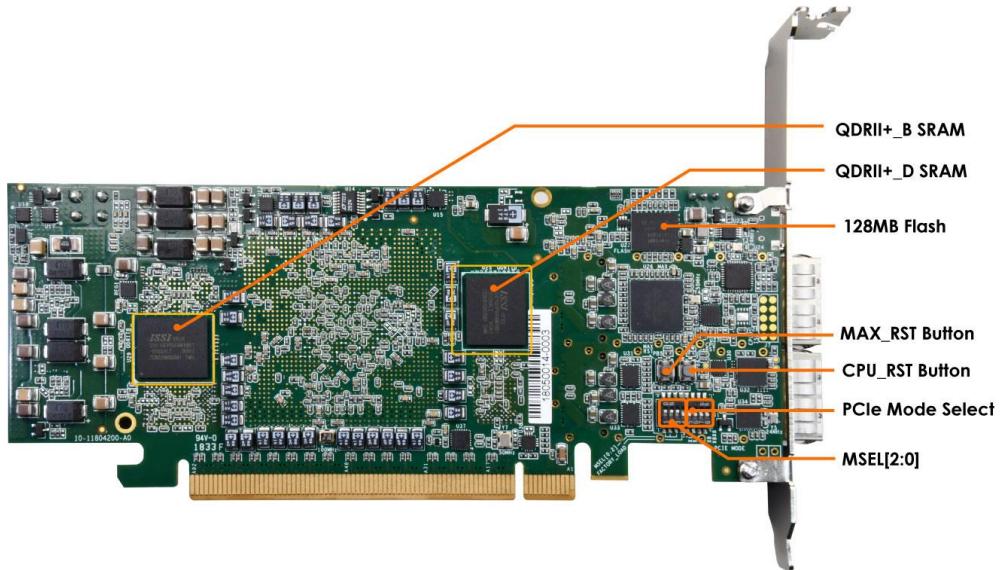


Figure 2-2 FPGA Board (Bottom)

## 2.2 Configuration, Status and Setup

### ■ Configure

The FPGA board supports two configuration methods for the Arria 10 FPGA:

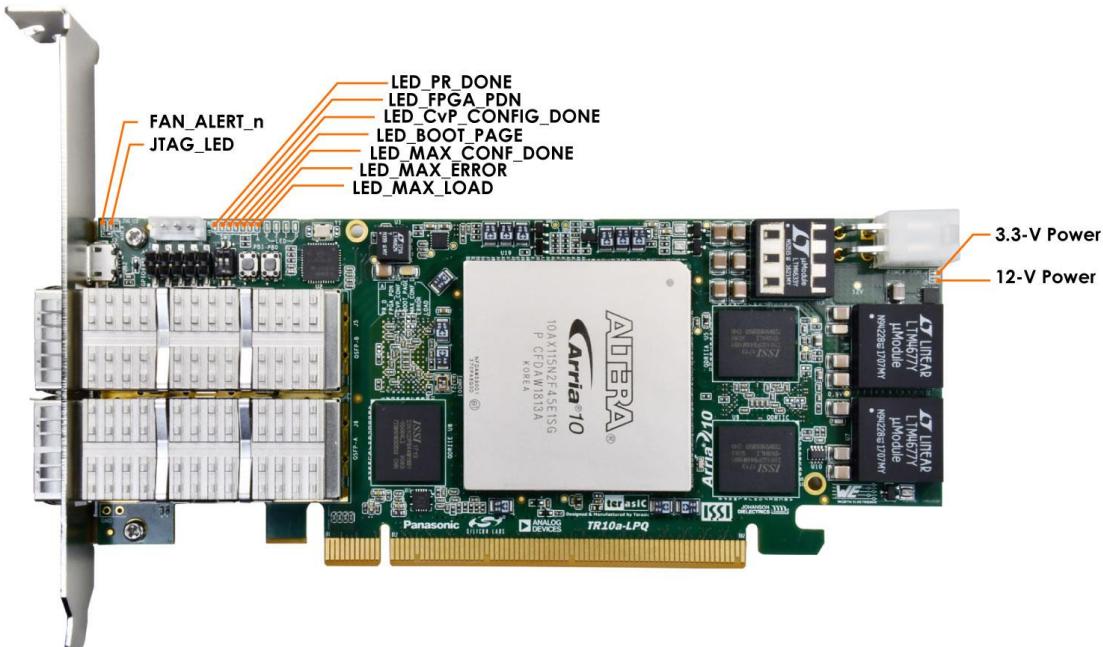
- Configure the FPGA using the on-board USB-Blaster II.
- Flash memory configuration of the FPGA using stored images from the flash memory on power-up.

For programming by on-board USB-Blaster II, the following procedures show how to download a configuration bit stream into the Arria 10 GX FPGA:

- Make sure that power is provided to the FPGA board
- Connect your PC to the FPGA board using a micro-USB cable and make sure the USB-Blaster II driver is installed on PC.
- Launch Quartus Prime programmer and make sure the USB-Blaster II is detected.
- In Quartus Prime Programmer, add the configuration bit stream file (.sof), check the associated “Program/Configure” item, and click “Start” to start FPGA programming.

## ■ Status LED

The FPGA Board development board includes board-specific status LEDs to indicate board status as shown in **Figure 2-3**. Please refer to **Table 2-1** for the description of the LED indicator.



**Figure 2-3 Status LED on the TR10a-LPQ**

**Table 2-1 Status LED**

Board Reference	LED Name	Description
D10	12-V Power	Illuminates when 12-V power is active.
D9	3.3-V Power	Illuminates when 3.3-V power is active.
D6	LED_MAX_CONF_DONE	Illuminates when the FPGA is successfully configured. Driven by the MAX 10 CPLD System Controller.
D8	LED_MAX_LOAD	Illuminates when the MAX 10 CPLD System Controller is actively configuring the FPGA. Driven by the MAX 10 CPLD System Controller with the Embedded Blaster CPLD.
D7	LED_MAX_ERROR	Illuminates when the MAX 10 CPLD System Controller fails to configure the FPGA. Driven

		by the MAX 10 CPLD System Controller.
D5	LED_BOOT_PAGE	Illuminates when FPGA is configured by the factory configuration bit stream.
D3	LED_PR_DONE	Illuminates when FPGA partial reconfiguration is done
D4	LED_CvP_CONFIG_DONE	Illuminates when FPGA Configuration via Protocol (CvP) is done
LED6	LED_FPGA_PDN	Illuminates when the temperature of the FPGA is too high and exceeds the set value, the FPGA power is automatically turned off.
D1	JTAG_LED	Indicates transmit or receive activity of the JTAG chain. The LED flickers if the link is in use and active.
D2	FAN_ALERT_n	Illuminates when the temperature of the FPGA exceeds the set value.

## ■ Setup PCI Express Control DIP switch

The PCI Express Control DIP switch (S1) is provided to enable or disable different configurations of the PCIe Connector. **Table 2-2** lists the switch controls and description.

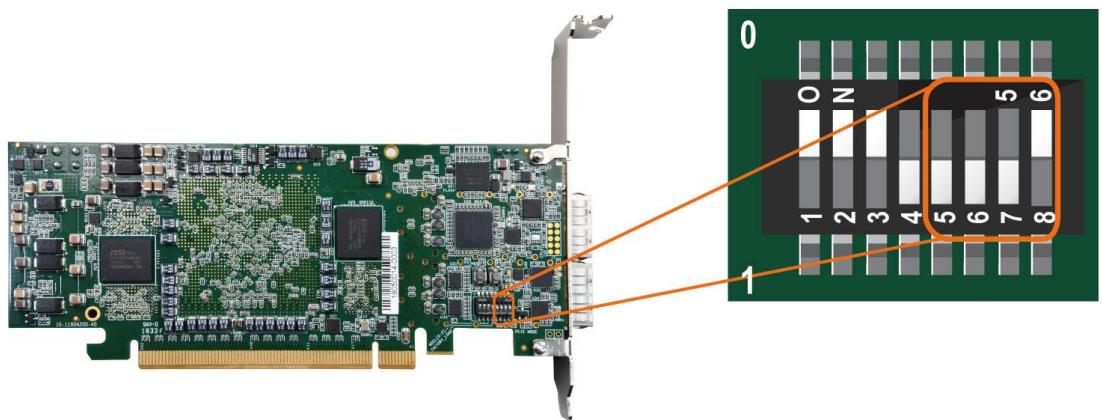


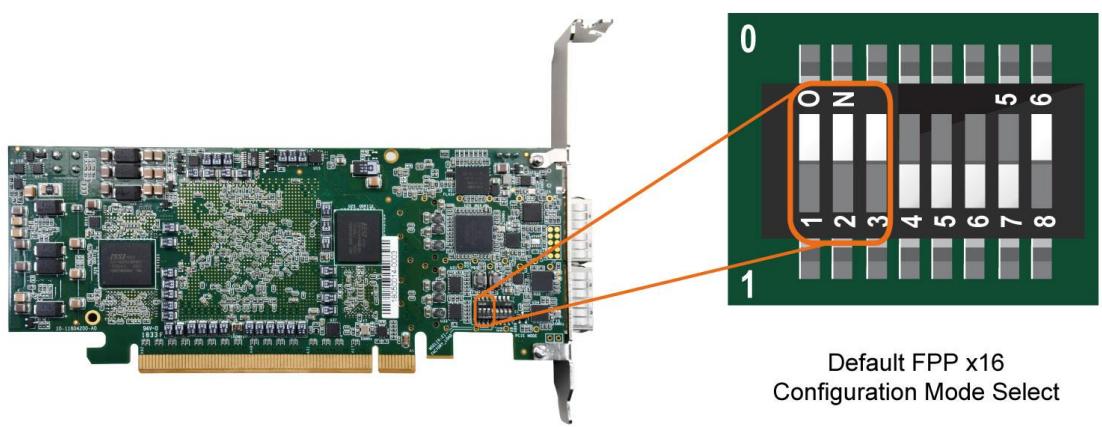
Figure 2-4 Setup PCI Express Control DIP switch

**Table 2-2 S1 PCIe Control DIP Switch**

Board Reference	Signal Name	Description	Default
S1.5	PCIE_PRSNT2n_x1	On : Enable x1 presence detect Off: Disable x1 presence detect	Off
S1.6	PCIE_PRSNT2n_x4	On : Enable x4 presence detect Off: Disable x4 presence detect	Off
S1.7	PCIE_PRSNT2n_x8	On : Enable x8 presence detect Off: Disable x8 presence detect	Off
S1.8	PCIE_PRSNT2n_x16	On: Enable dual x8 presence detect Off: Disable dual x8 presence detect	On

## ■ Setup Configure Mode

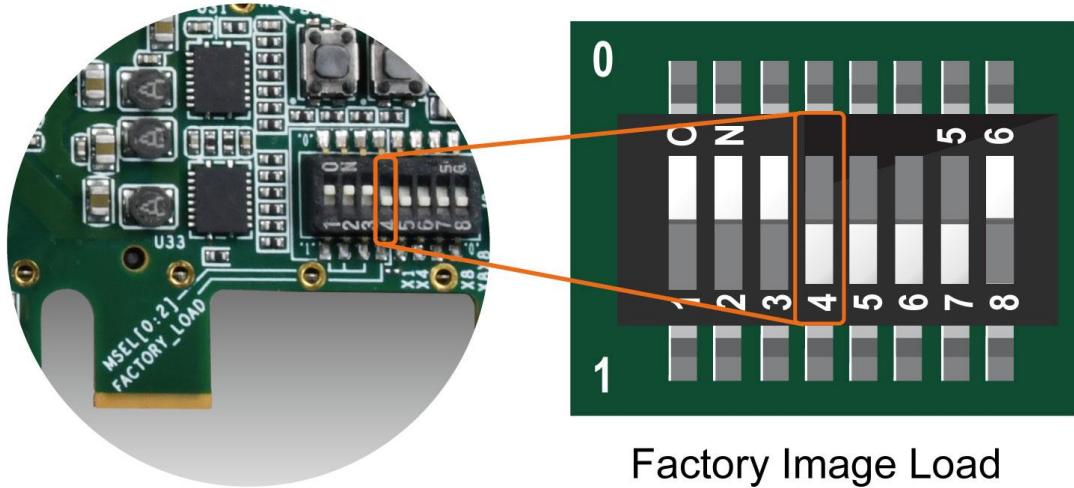
The position 1~3 of DIP switch S1 are used to specify the configuration mode of the FPGA. As currently only one mode is supported, please set all positions as shown in **Figure 2-5**.



**Figure 2-5 Position of DIP switch S1 for Configure Mode**

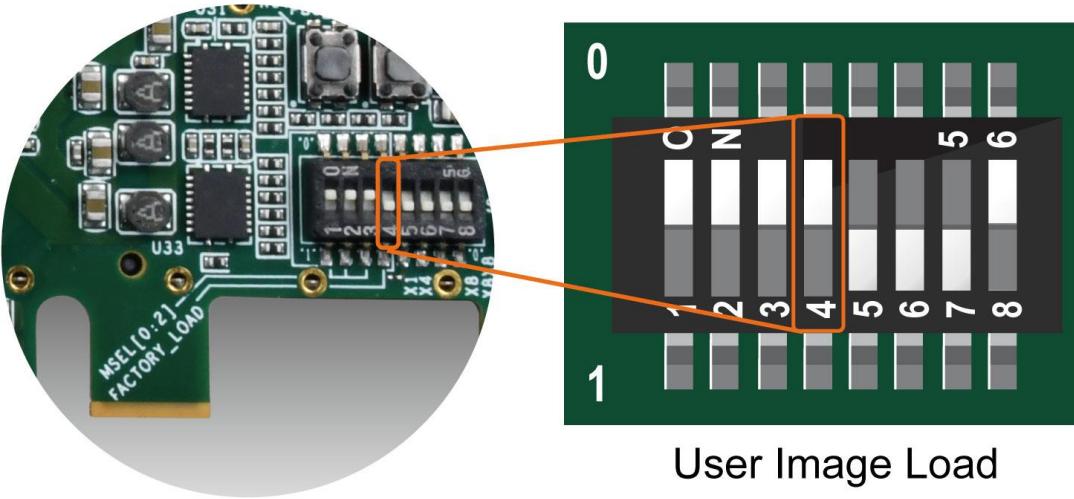
## ■ Select Flash Image for Configuration

The position 4 of DIP switch S1 is used to specify the image for configuration of the FPGA. Setting Position 4 of S1 to “1” (down position) specifies the default factory image to be loaded, as shown in **Figure 2-6**. Setting Position 4 of S1 to “0” (up position) specifies the TR10a-LPQ to load a user-defined image, as shown in **Figure 2-7**.



Factory Image Load

Figure 2-6 Position of DIP switch S1 for Image Select – Factory Image Load



User Image Load

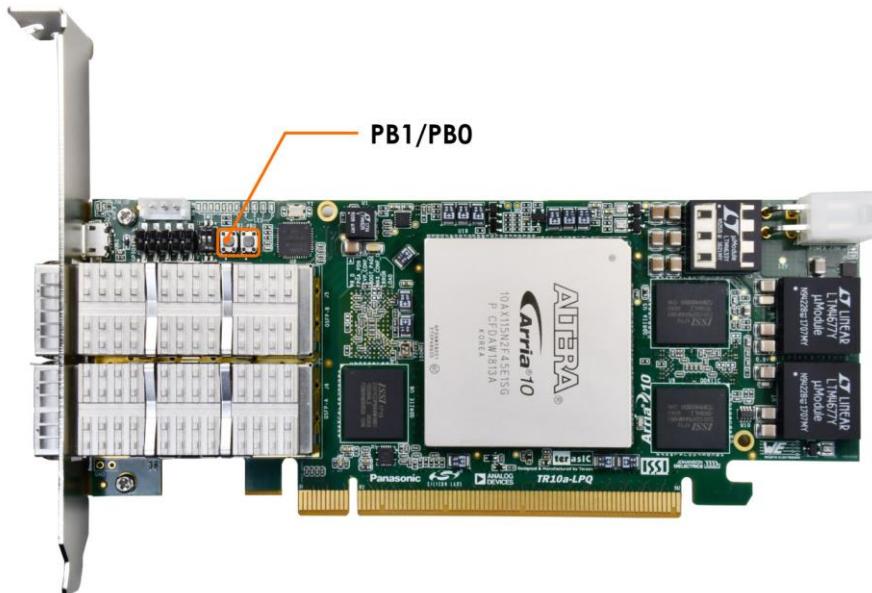
Figure 2-7 Position of DIP switch S1 for Image Select – User Image Load

## 2.3 General User Input/Output

This section describes the user I/O interface to the FPGA.

### ■ User Defined Push-buttons

The FPGA board includes four user defined push-buttons that allow users to interact with the Arria 10 GX device. Each push-button provides a high logic level or a low logic level when it is not pressed or pressed, respectively. **Table 2-3** lists the board references, signal names and their corresponding Arria 10 GX device pin numbers.



**Figure 2-8 User Defined Buttons**

**Table 2-3 Push-button Pin Assignments, Schematic Signal Names, and Functions**

Board Reference	Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
PB0	BUTTON0	High Logic Level when the button is not pressed	1.8-V	PIN_AR6
PB1	BUTTON1	High Logic Level when the button is not pressed	1.8-V	PIN_AP6
PB4	CPU_RESET_n		1.8-V	AP24

## ■ User-Defined Dip Switch

There are two dip switches on the FPGA board to provide additional FPGA input control. When a dip switch is in the DOWN position or the UPPER position, it provides a high logic level or a low logic level to the Arria 10 GX FPGA, respectively, as shown in [Figure 2-9](#).

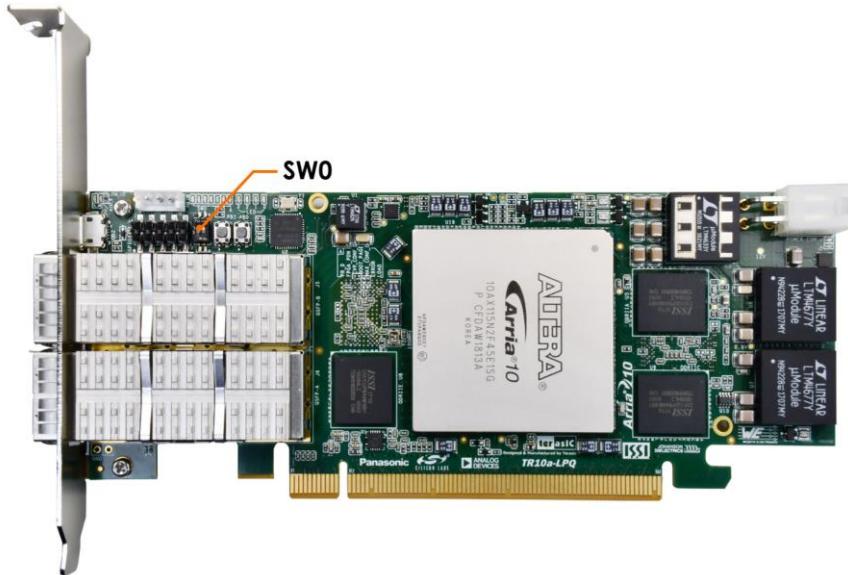


Figure 2-9 2 Dip switches

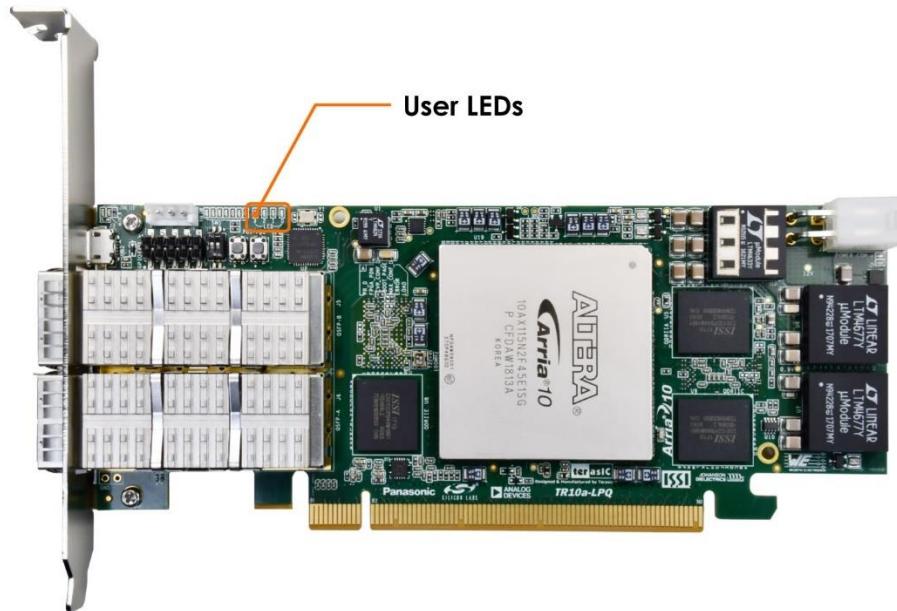
**Table 2-4** lists the signal names and their corresponding Arria 10 GX device pin numbers.

Table 2-4 Dip Switch Pin Assignments, Schematic Signal Names, and Functions

Board Reference	Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
SW0	SW0	High logic level when SW in the UPPER position.	1.8-V	PIN_AU35
	SW1		1.8-V	PIN_AH33

## ■ User-Defined LEDs

The FPGA board consists of 4 user-controllable LEDs to allow status and debugging signals to be driven to the LEDs from the designs loaded into the Arria 10 GX device. Each LED is driven directly by the Arria 10 GX FPGA. The LED is turned on or off when the associated pins are driven to a low or high logic level, respectively, as shown in **Figure 2-10**. A list of the pin names on the FPGA that are connected to the LEDs is given in **Table 2-5**.



**Figure 2-10 Four User LEDs**

**Table 2-5 User LEDs Pin Assignments, Schematic Signal Names, and Functions**

Board Reference	Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
LED0	LED0	Driving a logic 0 on the I/O port	1.8-V	PIN_Y13
LED1	LED1	turns the LED ON.	1.8-V	PIN_Y14
LED2	LED2	Driving a logic 1 on the I/O port	1.8-V	PIN_W11
LED3	LED3	turns the LED OFF.	1.8-V	PIN_V10

## 2.4 Temperature Sensor and Fan Control

The TR10a-LPQ has an automatic management system for the temperature of the FPGA, the fan speed, and the power supply of the FPGA. As shown in [Figure 2-11](#). The MAX10 FPGA is the main control device on the board.

The temperature of the Arria 10 FPGA is obtained through the TMP441 temperature sensor and the MAX10 FPGA can read it from TMP441 via I2C bus. The MAX10 FPGA will adjust the fan speed automatically according to the temperature of the Arria 10 FPGA.

When the board power is on, the fan speed is preset to 3000 rpm. As the temperature

of the Arria10 FPGA rises, the MAX10 will increase the fan speed to decrease the temperature of the FPGA.

In order to avoid the failure of the fan on the FPGA and stop the rotation and cause the FPGA temperature to rise rapidly. When the FPGA temperature reaches 95 degrees (The setting threshold value), the MAX10 will cut off the power supply to the Arria10 FPGA to avoid damage caused by excessive FPGA temperature.

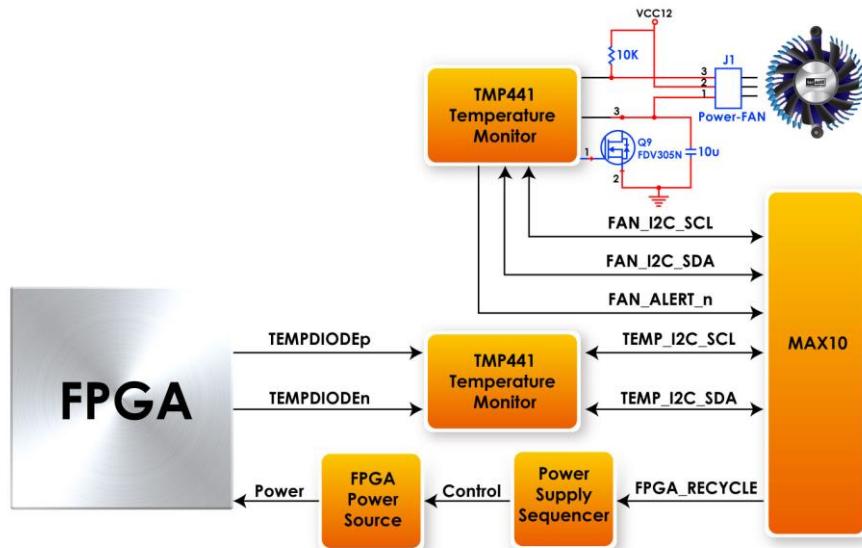
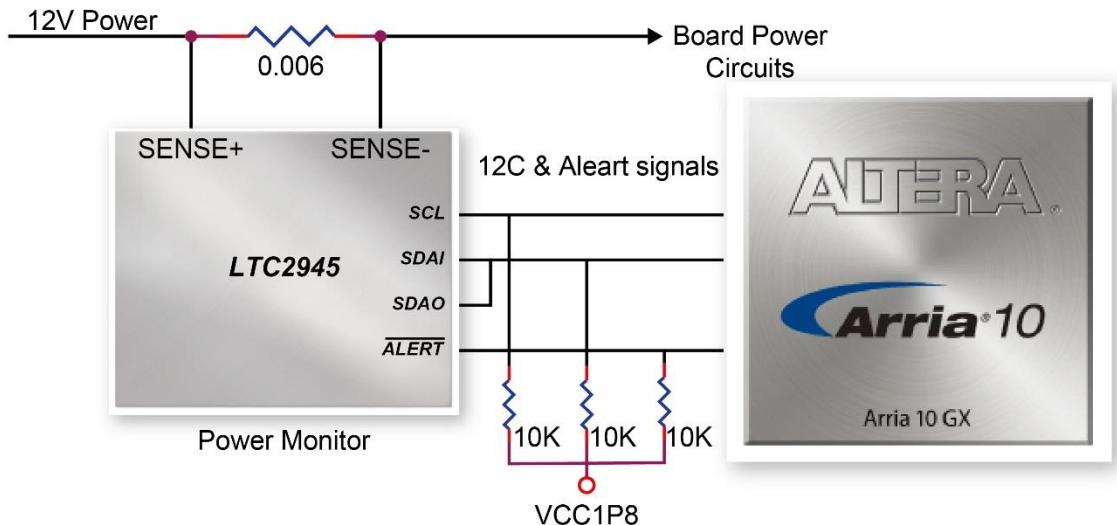


Figure 2-11 The Temperature, Fan Speed and FPGA power control system

## 2.5 Power Monitor

The TR10a-LPQ has implemented a power monitor chip to monitor the board input power voltage and current. **Figure 2-12** shows the connection between the power monitor chip and the Arria 10 GX FPGA. The power monitor chip monitors both shunt voltage drops and board input power voltage allows user to monitor the total board power consumption. Programmable calibration value, conversion times, and averaging, combined with an internal multiplier, enable direct readouts of current in amperes and power in watts. **Table 2-6** shows the pin assignment of power monitor I2C bus.



**Figure 2-12 Connections between the Power Monitor chip and the Arria 10 GX FPGA**

**Table 2-6 Pin Assignment of Power Monitor I2C bus**

Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
POWER_MONITOR_I2C_SCL	Power Monitor SCL	1.8V	PIN_AT26
POWER_MONITOR_I2C_SDA	Power Monitor SDA	1.8V	PIN_AP25
POWER_MONITOR_ALERT_N	Power Monitor ALERT	1.8V	PIN_BD23

## 2.6 Clock Circuit

The development board includes four 50 MHz oscillators and two programmable clock generators. **Figure 2-13** shows the default frequencies of on-board all external clocks going to the Arria 10 GX FPGA.

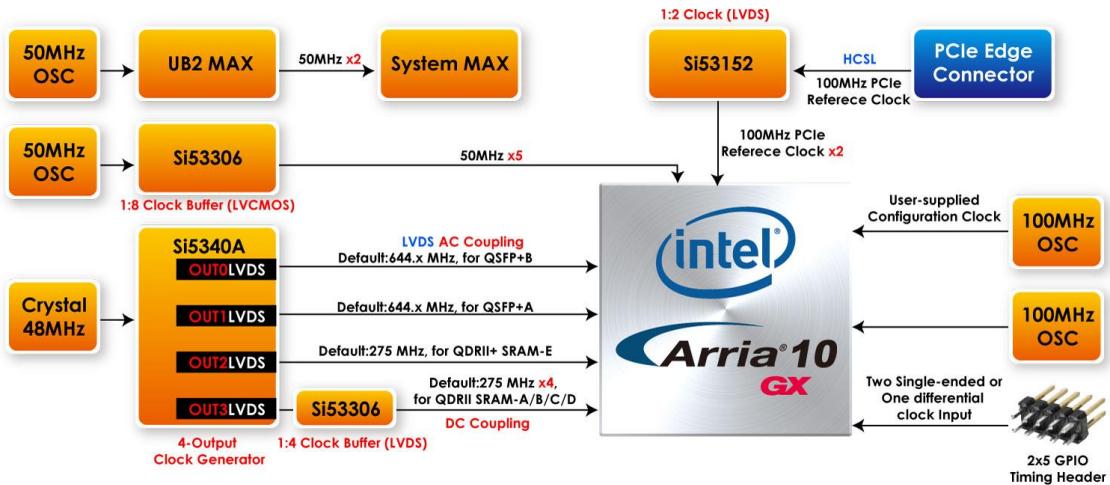


Figure 2-13 Clock circuit of the FPGA Board

A clock buffer is used to duplicate the 50 MHz oscillator, so there are six 50MHz clocks fed into different five FPGA banks. The two programming clock generators are low-jitter oscillators which are used to provide special and high quality clock signals for high-speed transceivers and high bandwidth memory. Through I2C serial interface, the clock generator controllers in the Arria 10 GX FPGA can be used to program the Si5340A and Si5340B to generate 40G Ethernet QSFP+ and high bandwidth memory reference clocks respectively.

**Table 2-7** lists the clock source, signal names, default frequency and their corresponding Arria 10 GX device pin numbers.

Table 2-7 Clock Source, Signal Name, Default Frequency, Pin Assignments and Functions

Source	Schematic Signal Name	Default Frequency	I/O Standard	Arria 10 GX Pin Number	Application
U38	CLK_50_B2H	50.0 MHz	1.8V	PIN_AP34	User Application
	CLK_50_B2I		1.8V	PIN_C30	User Application
	CLK_50_B2J		1.8V	PIN_W36	User Application
	CLK_50_B3C		1.8V	PIN_AK12	User Application
	CLK_50_B3D		1.8V	PIN_AJ11	User Application
Y6	CLK_100_B2J	100.0MHz	1.8V	PIN_AC32	User Application
Y2	OSC_100_CLKUSR	100.0MHz	1.8V	PIN_AV26	User-supplied

					configuration clock
U2 (Si5340A)	QSFP_A_REFCLK_p	644.53125 MHz	LVDS	PIN_AH5	40G QSFP+ A port
	QSFP_B_REFCLK_p	644.53125 MHz	LVDS	PIN_AD5	40G QSFP+ B port
	QDRII_E_REFCLK_p	275 MHz	LVDS	PIN_AT27	QDRII+ reference clock for E port
U13	QDRII_A_REFCLK_p	275 MHz	LVDS	PIN_L9	QDRII+ reference clock for A port
	QDRII_B_REFCLK_p	275 MHz	LVDS	PIN_N18	QDRII+ reference clock for B port
	QDRII_C_REFCLK_p	275 MHz	LVDS	PIN_M34	QDRII+ reference clock for C port
	QDRII_D_REFCLK_p	275 MHz	LVDS	PIN_BB18	QDRII+ reference clock for D port

**Table 2-8** lists the programmable oscillator control pins, signal names, I/O standard and their corresponding Arria 10 GX device pin numbers.

**Table 2-8 Programmable oscillator control pin, Signal Name, I/O standard, Pin Assignments and Descriptions**

Programmable Oscillator	Schematic Signal Name	I/O Standard	Arria 10 GX Pin Number	Description
Si5340A (U2)	Si5340A_I2C_SCL	1.8-V	PIN_F24	I2C bus, connected with Si5340A
	Si5340A_I2C_SDA	1.8-V	PIN_G24	
	Si5340A_RST	1.8-V	PIN_C27	Si5340A reset signal
	Si5340A_INTR	1.8-V	PIN_C28	Si5340A interrupt signal
	Si5340A_OE_n	1.8-V	PIN_AP39	Si5340A output enable signal

## 2.7 FLASH Memory

The development board has one 1Gb CFI-compatible synchronous flash device for non-volatile storage of FPGA configuration data, user application data, and user code space. Each interface has a 16-bit data bus and the device combined allow for FPP x16 configuration. This device is part of the shared flash and MAX (FM) bus, which connects to the flash memory and MAX V CPLD System Controller. **Figure 2-14** shows the connections between the Flash, MAX and Arria 10 GX FPGA.

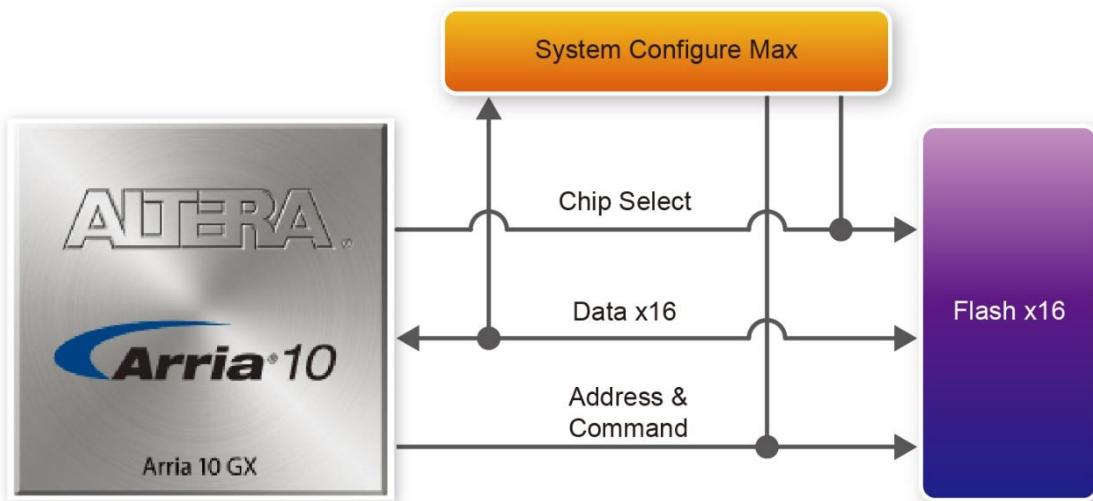


Figure 2-14 Connection between the Flash, Max and Arria 10 GX FPGA

**Table 2-9** lists the flash pin assignments, signal names, and functions.

**Table 2-9 Flash Memory Pin Assignments, Schematic Signal Names, and Functions**

Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
FLASH_A1	Address bus	1.8-V	PIN_AE14
FLASH_A2	Address bus	1.8-V	PIN_AT7
FLASH_A3	Address bus	1.8-V	PIN_AC11
FLASH_A4	Address bus	1.8-V	PIN_AC13
FLASH_A5	Address bus	1.8-V	PIN_AC12
FLASH_A6	Address bus	1.8-V	PIN_AF14
FLASH_A7	Address bus	1.8-V	PIN_AD13

FLASH_A8	Address bus	1.8-V	PIN_AG14
FLASH_A9	Address bus	1.8-V	PIN_AJ13
FLASH_A10	Address bus	1.8-V	PIN_AE13
FLASH_A11	Address bus	1.8-V	PIN_AB14
FLASH_A12	Address bus	1.8-V	PIN_AH12
FLASH_A13	Address bus	1.8-V	PIN_AK13
FLASH_A14	Address bus	1.8-V	PIN_AL12
FLASH_A15	Address bus	1.8-V	PIN_AV7
FLASH_A16	Address bus	1.8-V	PIN_AJ10
FLASH_A17	Address bus	1.8-V	PIN_AH13
FLASH_A18	Address bus	1.8-V	PIN_AN12
FLASH_A19	Address bus	1.8-V	PIN_AU9
FLASH_A20	Address bus	1.8-V	PIN_AV6
FLASH_A21	Address bus	1.8-V	PIN_AT6
FLASH_A22	Address bus	1.8-V	PIN_AR9
FLASH_A23	Address bus	1.8-V	PIN_AB13
FLASH_A24	Address bus	1.8-V	PIN_AF12
FLASH_A25	Address bus	1.8-V	PIN_AT9
FLASH_A26	Address bus	1.8-V	PIN_AV8
FLASH_A27	Address bus (Reserve)	1.8-V	PIN_AB12
FLASH_D0	Data bus	1.8-V	PIN_AN11
FLASH_D1	Data bus	1.8-V	PIN_AT12
FLASH_D2	Data bus	1.8-V	PIN_AP8
FLASH_D3	Data bus	1.8-V	PIN_AT11
FLASH_D4	Data bus	1.8-V	PIN_AR11
FLASH_D5	Data bus	1.8-V	PIN_AR7
FLASH_D6	Data bus	1.8-V	PIN_AU8
FLASH_D7	Data bus	1.8-V	PIN_AR8
FLASH_D8	Data bus	1.8-V	PIN_AN10
FLASH_D9	Data bus	1.8-V	PIN_AR12
FLASH_D10	Data bus	1.8-V	PIN_AP10
FLASH_D11	Data bus	1.8-V	PIN_AP11
FLASH_D12	Data bus	1.8-V	PIN_AT10
FLASH_D13	Data bus	1.8-V	PIN_AP9
FLASH_D14	Data bus	1.8-V	PIN_AU7

FLASH_D15	Data bus	1.8-V	PIN_AU10
FLASH_CLK	Clock	1.8-V	PIN_AM12
FLASH_RESET_n	Reset	1.8-V	PIN_AE12
FLASH_CE_n	Chip enable of flash	1.8-V	PIN_AL11
FLASH_OE_n	Output enable	1.8-V	PIN_AH10
FLASH_WE_n	Write enable	1.8-V	PIN_AG12
FLASH_ADV_n	Address valid	1.8-V	PIN_AD14
FLASH_RDY_BS Y_n	Ready of flash	1.8-V	PIN_AG13

## 2.8 QDRII+ SRAM

The development board supports five independent QDRII+ SRAM memory devices for very-high speed and low-latency memory access. Each of QDRII+ has a x18 interface, providing addressing to a device of up to a 8MB (not including parity bits). The QDRII+ has separate read and write data ports with DDR signaling at up to 550 MHz.

**Table 2-10, Table 2-11, Table 2-12, Table 2-13** and

**Table 2-14** lists the QDRII+ SRAM Bank A, B, C, D and E pin assignments, signal names relative to the Arria 10 GX device, in respectively.

**Table 2-10 QDRII+ SRAM A Pin Assignments, Schematic Signal Names, and Functions**

Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
QDRIIA_A0	Address bus[0]	1.8-V HSTL Class I	PIN_V12
QDRIIA_A1	Address bus[1]	1.8-V HSTL Class I	PIN_V13
QDRIIA_A2	Address bus[2]	1.8-V HSTL Class I	PIN_N10
QDRIIA_A3	Address bus[3]	1.8-V HSTL Class I	PIN_M10
QDRIIA_A4	Address bus[4]	1.8-V HSTL Class I	PIN_P11
QDRIIA_A5	Address bus[5]	1.8-V HSTL Class I	PIN_N11
QDRIIA_A6	Address bus[6]	1.8-V HSTL Class I	PIN_M9
QDRIIA_A7	Address bus[7]	1.8-V HSTL Class I	PIN_M8
QDRIIA_A8	Address bus[8]	1.8-V HSTL Class I	PIN_N7

QDRIIA_A9	Address bus[9]	1.8-V HSTL Class I	PIN_N8
QDRIIA_A10	Address bus[10]	1.8-V HSTL Class I	PIN_P10
QDRIIA_A11	Address bus[11]	1.8-V HSTL Class I	PIN_P9
QDRIIA_A12	Address bus[12]	1.8-V HSTL Class I	PIN_N6
QDRIIA_A13	Address bus[13]	1.8-V HSTL Class I	PIN_M7
QDRIIA_A14	Address bus[14]	1.8-V HSTL Class I	PIN_L10
QDRIIA_A15	Address bus[15]	1.8-V HSTL Class I	PIN_L7
QDRIIA_A16	Address bus[16]	1.8-V HSTL Class I	PIN_K7
QDRIIA_A17	Address bus[17]	1.8-V HSTL Class I	PIN_K8
QDRIIA_A18	Address bus[18]	1.8-V HSTL Class I	PIN_J9
QDRIIA_A19	Address bus[19]	1.8-V HSTL Class I	PIN_L6
QDRIIA_A20	Address bus[20]	1.8-V HSTL Class I	PIN_K6
QDRIIA_A21	Address bus[21]	1.8-V HSTL Class I	PIN_J6
QDRIIA_D0	Write data bus[0]	1.8-V HSTL Class I	PIN_C13
QDRIIA_D1	Write data bus[1]	1.8-V HSTL Class I	PIN_D13
QDRIIA_D2	Write data bus[2]	1.8-V HSTL Class I	PIN_E13
QDRIIA_D3	Write data bus[3]	1.8-V HSTL Class I	PIN_B13
QDRIIA_D4	Write data bus[4]	1.8-V HSTL Class I	PIN_E11
QDRIIA_D5	Write data bus[5]	1.8-V HSTL Class I	PIN_C12
QDRIIA_D6	Write data bus[6]	1.8-V HSTL Class I	PIN_B12
QDRIIA_D7	Write data bus[7]	1.8-V HSTL Class I	PIN_A12
QDRIIA_D8	Write data bus[8]	1.8-V HSTL Class I	PIN_D11
QDRIIA_D9	Write data bus[9]	1.8-V HSTL Class I	PIN_E9
QDRIIA_D10	Write data bus[10]	1.8-V HSTL Class I	PIN_C8
QDRIIA_D11	Write data bus[11]	1.8-V HSTL Class I	PIN_D8
QDRIIA_D12	Write data bus[12]	1.8-V HSTL Class I	PIN_D9
QDRIIA_D13	Write data bus[13]	1.8-V HSTL Class I	PIN_D10
QDRIIA_D14	Write data bus[14]	1.8-V HSTL Class I	PIN_B10
QDRIIA_D15	Write data bus[15]	1.8-V HSTL Class I	PIN_A10
QDRIIA_D16	Write data bus[16]	1.8-V HSTL Class I	PIN_A11
QDRIIA_D17	Write data bus[17]	1.8-V HSTL Class I	PIN_C11
QDRIIA_Q0	Read Data bus[0]	1.8-V HSTL Class I	PIN_H12
QDRIIA_Q1	Read Data bus[1]	1.8-V HSTL Class I	PIN_K12
QDRIIA_Q2	Read Data bus[2]	1.8-V HSTL Class I	PIN_J14
QDRIIA_Q3	Read Data bus[3]	1.8-V HSTL Class I	PIN_H11

QDRIIA_Q4	Read Data bus[4]	1.8-V HSTL Class I	PIN_K13
QDRIIA_Q5	Read Data bus[5]	1.8-V HSTL Class I	PIN_G10
QDRIIA_Q6	Read Data bus[6]	1.8-V HSTL Class I	PIN_L12
QDRIIA_Q7	Read Data bus[7]	1.8-V HSTL Class I	PIN_P13
QDRIIA_Q8	Read Data bus[8]	1.8-V HSTL Class I	PIN_M13
QDRIIA_Q9	Read Data bus[9]	1.8-V HSTL Class I	PIN_T14
QDRIIA_Q10	Read Data bus[10]	1.8-V HSTL Class I	PIN_R13
QDRIIA_Q11	Read Data bus[11]	1.8-V HSTL Class I	PIN_R12
QDRIIA_Q12	Read Data bus[12]	1.8-V HSTL Class I	PIN_R14
QDRIIA_Q13	Read Data bus[13]	1.8-V HSTL Class I	PIN_N13
QDRIIA_Q14	Read Data bus[14]	1.8-V HSTL Class I	PIN_M14
QDRIIA_Q15	Read Data bus[15]	1.8-V HSTL Class I	PIN_N12
QDRIIA_Q16	Read Data bus[16]	1.8-V HSTL Class I	PIN_L14
QDRIIA_Q17	Read Data bus[17]	1.8-V HSTL Class I	PIN_M12
QDRIIA_BWS_n0	Byte Write select[0]	1.8-V HSTL Class I	PIN_C10
QDRIIA_BWS_n1	Byte Write select[1]	1.8-V HSTL Class I	PIN_E8
QDRIIA_K_P	Clock P	Differential 1.8-V HSTL Class I	PIN_F12
QDRIIA_K_N	Clock N	Differential 1.8-V HSTL Class I	PIN_E12
QDRIIA_CQ_P	Echo clock P	1.8-V HSTL Class I	PIN_J13
QDRIIA_CQ_N	Echo clock N	1.8-V HSTL Class I	PIN_H13
QDRIIA_RPS_n	Report Select	1.8-V HSTL Class I	PIN_U9
QDRIIA_WPS_n	Write Port Select	1.8-V HSTL Class I	PIN_U8
QDRIIA_DOFF_n	DLL enable	1.8-V HSTL Class I	PIN_R9
QDRIIA_ODT	On-Die Termination Input	1.8-V HSTL Class I	PIN_T10
QDRIIA_QVLD	Valid Output	1.8-V HSTL Class I	PIN_K14

**Table 2-11 QDRII+ SRAM B Pin Assignments, Schematic Signal Names, and Functions**

Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
QDRIIB_A0	Address bus[0]	1.8-V HSTL Class I	PIN_L16
QDRIIB_A1	Address bus[1]	1.8-V HSTL Class I	PIN_L15

QDRIIB_A2	Address bus[2]	1.8-V HSTL Class I	PIN_E14
QDRIIB_A3	Address bus[3]	1.8-V HSTL Class I	PIN_D14
QDRIIB_A4	Address bus[4]	1.8-V HSTL Class I	PIN_G14
QDRIIB_A5	Address bus[5]	1.8-V HSTL Class I	PIN_F14
QDRIIB_A6	Address bus[6]	1.8-V HSTL Class I	PIN_D15
QDRIIB_A7	Address bus[7]	1.8-V HSTL Class I	PIN_C15
QDRIIB_A8	Address bus[8]	1.8-V HSTL Class I	PIN_F15
QDRIIB_A9	Address bus[9]	1.8-V HSTL Class I	PIN_F16
QDRIIB_A10	Address bus[10]	1.8-V HSTL Class I	PIN_H15
QDRIIB_A11	Address bus[11]	1.8-V HSTL Class I	PIN_G15
QDRIIB_A12	Address bus[12]	1.8-V HSTL Class I	PIN_E16
QDRIIB_A13	Address bus[13]	1.8-V HSTL Class I	PIN_D16
QDRIIB_A14	Address bus[14]	1.8-V HSTL Class I	PIN_E17
QDRIIB_A15	Address bus[15]	1.8-V HSTL Class I	PIN_G17
QDRIIB_A16	Address bus[16]	1.8-V HSTL Class I	PIN_G18
QDRIIB_A17	Address bus[17]	1.8-V HSTL Class I	PIN_L17
QDRIIB_A18	Address bus[18]	1.8-V HSTL Class I	PIN_K17
QDRIIB_A19	Address bus[19]	1.8-V HSTL Class I	PIN_H17
QDRIIB_A20	Address bus[20]	1.8-V HSTL Class I	PIN_H18
QDRIIB_A21	Address bus[21]	1.8-V HSTL Class I	PIN_K18
QDRIIB_D0	Write data bus[0]	1.8-V HSTL Class I	PIN_C18
QDRIIB_D1	Write data bus[1]	1.8-V HSTL Class I	PIN_G19
QDRIIB_D2	Write data bus[2]	1.8-V HSTL Class I	PIN_J19
QDRIIB_D3	Write data bus[3]	1.8-V HSTL Class I	PIN_D19
QDRIIB_D4	Write data bus[4]	1.8-V HSTL Class I	PIN_K19
QDRIIB_D5	Write data bus[5]	1.8-V HSTL Class I	PIN_L19
QDRIIB_D6	Write data bus[6]	1.8-V HSTL Class I	PIN_B20
QDRIIB_D7	Write data bus[7]	1.8-V HSTL Class I	PIN_M19
QDRIIB_D8	Write data bus[8]	1.8-V HSTL Class I	PIN_B19
QDRIIB_D9	Write data bus[9]	1.8-V HSTL Class I	PIN_N20
QDRIIB_D10	Write data bus[10]	1.8-V HSTL Class I	PIN_M20
QDRIIB_D11	Write data bus[11]	1.8-V HSTL Class I	PIN_L21
QDRIIB_D12	Write data bus[12]	1.8-V HSTL Class I	PIN_L20
QDRIIB_D13	Write data bus[13]	1.8-V HSTL Class I	PIN_F20
QDRIIB_D14	Write data bus[14]	1.8-V HSTL Class I	PIN_F19

QDRIIB_D15	Write data bus[15]	1.8-V HSTL Class I	PIN_H20
QDRIIB_D16	Write data bus[16]	1.8-V HSTL Class I	PIN_J20
QDRIIB_D17	Write data bus[17]	1.8-V HSTL Class I	PIN_G20
QDRIIB_Q0	Read Data bus[0]	1.8-V HSTL Class I	PIN_G23
QDRIIB_Q1	Read Data bus[1]	1.8-V HSTL Class I	PIN_F21
QDRIIB_Q2	Read Data bus[2]	1.8-V HSTL Class I	PIN_G22
QDRIIB_Q3	Read Data bus[3]	1.8-V HSTL Class I	PIN_H23
QDRIIB_Q4	Read Data bus[4]	1.8-V HSTL Class I	PIN_H21
QDRIIB_Q5	Read Data bus[5]	1.8-V HSTL Class I	PIN_H22
QDRIIB_Q6	Read Data bus[6]	1.8-V HSTL Class I	PIN_J23
QDRIIB_Q7	Read Data bus[7]	1.8-V HSTL Class I	PIN_K22
QDRIIB_Q8	Read Data bus[8]	1.8-V HSTL Class I	PIN_L22
QDRIIB_Q9	Read Data bus[9]	1.8-V HSTL Class I	PIN_B23
QDRIIB_Q10	Read Data bus[10]	1.8-V HSTL Class I	PIN_A21
QDRIIB_Q11	Read Data bus[11]	1.8-V HSTL Class I	PIN_F22
QDRIIB_Q12	Read Data bus[12]	1.8-V HSTL Class I	PIN_E22
QDRIIB_Q13	Read Data bus[13]	1.8-V HSTL Class I	PIN_C21
QDRIIB_Q14	Read Data bus[14]	1.8-V HSTL Class I	PIN_A22
QDRIIB_Q15	Read Data bus[15]	1.8-V HSTL Class I	PIN_E23
QDRIIB_Q16	Read Data bus[16]	1.8-V HSTL Class I	PIN_B22
QDRIIB_Q17	Read Data bus[17]	1.8-V HSTL Class I	PIN_C22
QDRIIB_BWS_n0	Byte Write select[0]	1.8-V HSTL Class I	PIN_C20
QDRIIB_BWS_n1	Byte Write select[1]	1.8-V HSTL Class I	PIN_E19
QDRIIB_K_p	Clock P	Differential 1.8-V HSTL Class I	PIN_K21
QDRIIB_K_n	Clock N	Differential 1.8-V HSTL Class I	PIN_J21
QDRIIB_CQ_p	Echo clock P	1.8-V HSTL Class I	PIN_D23
QDRIIB_CQ_n	Echo clock N	1.8-V HSTL Class I	PIN_C23
QDRIIB_RPS_n	Report Select	1.8-V HSTL Class I	PIN_J16
QDRIIB_WPS_n	Write Port Select	1.8-V HSTL Class I	PIN_K16
QDRIIB_DOFF_n	PLL Turn Off	1.8-V HSTL Class I	PIN_H16
QDRIIB_ODT	On-Die Termination Input	1.8-V HSTL Class I	PIN_M17
QDRIIB_QVLD	Valid Output	1.8-V HSTL Class I	PIN_K23

	Indicator		
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**Table 2-12 QDRII+ SRAM C Pin Assignments, Schematic Signal Names, and Functions**

Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
QDRIIC_A0	Address bus[0]	1.8-V HSTL Class I	PIN_Y32
QDRIIC_A1	Address bus[1]	1.8-V HSTL Class I	PIN_W33
QDRIIC_A2	Address bus[2]	1.8-V HSTL Class I	PIN_P34
QDRIIC_A3	Address bus[3]	1.8-V HSTL Class I	PIN_P33
QDRIIC_A4	Address bus[4]	1.8-V HSTL Class I	PIN_L32
QDRIIC_A5	Address bus[5]	1.8-V HSTL Class I	PIN_K32
QDRIIC_A6	Address bus[6]	1.8-V HSTL Class I	PIN_R34
QDRIIC_A7	Address bus[7]	1.8-V HSTL Class I	PIN_R33
QDRIIC_A8	Address bus[8]	1.8-V HSTL Class I	PIN_T32
QDRIIC_A9	Address bus[9]	1.8-V HSTL Class I	PIN_R32
QDRIIC_A10	Address bus[10]	1.8-V HSTL Class I	PIN_N32
QDRIIC_A11	Address bus[11]	1.8-V HSTL Class I	PIN_M32
QDRIIC_A12	Address bus[12]	1.8-V HSTL Class I	PIN_T31
QDRIIC_A13	Address bus[13]	1.8-V HSTL Class I	PIN_R31
QDRIIC_A14	Address bus[14]	1.8-V HSTL Class I	PIN_K38
QDRIIC_A15	Address bus[15]	1.8-V HSTL Class I	PIN_L37
QDRIIC_A16	Address bus[16]	1.8-V HSTL Class I	PIN_K36
QDRIIC_A17	Address bus[17]	1.8-V HSTL Class I	PIN_N33
QDRIIC_A18	Address bus[18]	1.8-V HSTL Class I	PIN_M33
QDRIIC_A19	Address bus[19]	1.8-V HSTL Class I	PIN_L39
QDRIIC_A20	Address bus[20]	1.8-V HSTL Class I	PIN_K39
QDRIIC_A21	Address bus[21]	1.8-V HSTL Class I	PIN_L35
QDRIIC_D0	Write data bus[0]	1.8-V HSTL Class I	PIN_E34
QDRIIC_D1	Write data bus[1]	1.8-V HSTL Class I	PIN_D36
QDRIIC_D2	Write data bus[2]	1.8-V HSTL Class I	PIN_E36
QDRIIC_D3	Write data bus[3]	1.8-V HSTL Class I	PIN_D35
QDRIIC_D4	Write data bus[4]	1.8-V HSTL Class I	PIN_E37
QDRIIC_D5	Write data bus[5]	1.8-V HSTL Class I	PIN_F39
QDRIIC_D6	Write data bus[6]	1.8-V HSTL Class I	PIN_F37

QDRIIC_D7	Write data bus[7]	1.8-V HSTL Class I	PIN_G39
QDRIIC_D8	Write data bus[8]	1.8-V HSTL Class I	PIN_F36
QDRIIC_D9	Write data bus[9]	1.8-V HSTL Class I	PIN_G30
QDRIIC_D10	Write data bus[10]	1.8-V HSTL Class I	PIN_D33
QDRIIC_D11	Write data bus[11]	1.8-V HSTL Class I	PIN_H30
QDRIIC_D12	Write data bus[12]	1.8-V HSTL Class I	PIN_D34
QDRIIC_D13	Write data bus[13]	1.8-V HSTL Class I	PIN_G29
QDRIIC_D14	Write data bus[14]	1.8-V HSTL Class I	PIN_E33
QDRIIC_D15	Write data bus[15]	1.8-V HSTL Class I	PIN_E31
QDRIIC_D16	Write data bus[16]	1.8-V HSTL Class I	PIN_F31
QDRIIC_D17	Write data bus[17]	1.8-V HSTL Class I	PIN_F30
QDRIIC_Q0	Read Data bus[0]	1.8-V HSTL Class I	PIN_P31
QDRIIC_Q1	Read Data bus[1]	1.8-V HSTL Class I	PIN_N31
QDRIIC_Q2	Read Data bus[2]	1.8-V HSTL Class I	PIN_G33
QDRIIC_Q3	Read Data bus[3]	1.8-V HSTL Class I	PIN_G32
QDRIIC_Q4	Read Data bus[4]	1.8-V HSTL Class I	PIN_J31
QDRIIC_Q5	Read Data bus[5]	1.8-V HSTL Class I	PIN_G34
QDRIIC_Q6	Read Data bus[6]	1.8-V HSTL Class I	PIN_L31
QDRIIC_Q7	Read Data bus[7]	1.8-V HSTL Class I	PIN_L30
QDRIIC_Q8	Read Data bus[8]	1.8-V HSTL Class I	PIN_J30
QDRIIC_Q9	Read Data bus[9]	1.8-V HSTL Class I	PIN_P28
QDRIIC_Q10	Read Data bus[10]	1.8-V HSTL Class I	PIN_N28
QDRIIC_Q11	Read Data bus[11]	1.8-V HSTL Class I	PIN_M28
QDRIIC_Q12	Read Data bus[12]	1.8-V HSTL Class I	PIN_M29
QDRIIC_Q13	Read Data bus[13]	1.8-V HSTL Class I	PIN_N30
QDRIIC_Q14	Read Data bus[14]	1.8-V HSTL Class I	PIN_M30
QDRIIC_Q15	Read Data bus[15]	1.8-V HSTL Class I	PIN_L29
QDRIIC_Q16	Read Data bus[16]	1.8-V HSTL Class I	PIN_K29
QDRIIC_Q17	Read Data bus[17]	1.8-V HSTL Class I	PIN_J29
QDRIIC_BWS_n0	Byte Write select[0]	1.8-V HSTL Class I	PIN_F34
QDRIIC_BWS_n1	Byte Write select[1]	1.8-V HSTL Class I	PIN_C37
QDRIIC_K_p	Clock P	Differential 1.8-V HSTL Class I	PIN_F32
QDRIIC_K_n	Clock N	Differential 1.8-V HSTL Class I	PIN_E32

QDRIIC_CQ_p	Echo clock P	1.8-V HSTL Class I	PIN_G35
QDRIIC_CQ_n	Echo clock N	1.8-V HSTL Class I	PIN_F35
QDRIIC_RPS_n	Report Select	1.8-V HSTL Class I	PIN_E26
QDRIIC_WPS_n	Write Port Select	1.8-V HSTL Class I	PIN_V33
QDRIIC_DOFF_n	PLL Turn Off	1.8-V HSTL Class I	PIN_W31
QDRIIC_ODT	On-Die Termination Input	1.8-V HSTL Class I	PIN_Y33
QDRIIC_QVLD	Valid Output Indicator	1.8-V HSTL Class I	PIN_K31

**Table 2-13 QDRII+ SRAM D Pin Assignments, Schematic Signal Names, and Functions**

Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
QDRIID_A0	Address bus[0]	1.8-V HSTL Class I	PIN_AT17
QDRIID_A1	Address bus[1]	1.8-V HSTL Class I	PIN_AU17
QDRIID_A2	Address bus[2]	1.8-V HSTL Class I	PIN_AV16
QDRIID_A3	Address bus[3]	1.8-V HSTL Class I	PIN_AV17
QDRIID_A4	Address bus[4]	1.8-V HSTL Class I	PIN_AU15
QDRIID_A5	Address bus[5]	1.8-V HSTL Class I	PIN_AV15
QDRIID_A6	Address bus[6]	1.8-V HSTL Class I	PIN_BA15
QDRIID_A7	Address bus[7]	1.8-V HSTL Class I	PIN_BA16
QDRIID_A8	Address bus[8]	1.8-V HSTL Class I	PIN_AY17
QDRIID_A9	Address bus[9]	1.8-V HSTL Class I	PIN_BA17
QDRIID_A10	Address bus[10]	1.8-V HSTL Class I	PIN_AW16
QDRIID_A11	Address bus[11]	1.8-V HSTL Class I	PIN_AY16
QDRIID_A12	Address bus[12]	1.8-V HSTL Class I	PIN_AW18
QDRIID_A13	Address bus[13]	1.8-V HSTL Class I	PIN_AY18
QDRIID_A14	Address bus[14]	1.8-V HSTL Class I	PIN_BC15
QDRIID_A15	Address bus[15]	1.8-V HSTL Class I	PIN_BD13
QDRIID_A16	Address bus[16]	1.8-V HSTL Class I	PIN_BD14
QDRIID_A17	Address bus[17]	1.8-V HSTL Class I	PIN_BC18
QDRIID_A18	Address bus[18]	1.8-V HSTL Class I	PIN_BD18
QDRIID_A19	Address bus[19]	1.8-V HSTL Class I	PIN_BD15
QDRIID_A20	Address bus[20]	1.8-V HSTL Class I	PIN_BD16
QDRIID_A21	Address bus[21]	1.8-V HSTL Class I	PIN_BC16

QDRIID_D0	Write data bus[0]	1.8-V HSTL Class I	PIN_AL14
QDRIID_D1	Write data bus[1]	1.8-V HSTL Class I	PIN_AM13
QDRIID_D2	Write data bus[2]	1.8-V HSTL Class I	PIN_AT14
QDRIID_D3	Write data bus[3]	1.8-V HSTL Class I	PIN_AN13
QDRIID_D4	Write data bus[4]	1.8-V HSTL Class I	PIN_AU14
QDRIID_D5	Write data bus[5]	1.8-V HSTL Class I	PIN_AU12
QDRIID_D6	Write data bus[6]	1.8-V HSTL Class I	PIN_BA9
QDRIID_D7	Write data bus[7]	1.8-V HSTL Class I	PIN_AY8
QDRIID_D8	Write data bus[8]	1.8-V HSTL Class I	PIN_AW8
QDRIID_D9	Write data bus[9]	1.8-V HSTL Class I	PIN_AW9
QDRIID_D10	Write data bus[10]	1.8-V HSTL Class I	PIN_AW10
QDRIID_D11	Write data bus[11]	1.8-V HSTL Class I	PIN_AV11
QDRIID_D12	Write data bus[12]	1.8-V HSTL Class I	PIN_AV12
QDRIID_D13	Write data bus[13]	1.8-V HSTL Class I	PIN_AR13
QDRIID_D14	Write data bus[14]	1.8-V HSTL Class I	PIN_AP13
QDRIID_D15	Write data bus[15]	1.8-V HSTL Class I	PIN_AM14
QDRIID_D16	Write data bus[16]	1.8-V HSTL Class I	PIN_AJ14
QDRIID_D17	Write data bus[17]	1.8-V HSTL Class I	PIN_AK14
QDRIID_Q0	Read Data bus[0]	1.8-V HSTL Class I	PIN_BA14
QDRIID_Q1	Read Data bus[1]	1.8-V HSTL Class I	PIN_BB13
QDRIID_Q2	Read Data bus[2]	1.8-V HSTL Class I	PIN_BC13
QDRIID_Q3	Read Data bus[3]	1.8-V HSTL Class I	PIN_BC10
QDRIID_Q4	Read Data bus[4]	1.8-V HSTL Class I	PIN_BC11
QDRIID_Q5	Read Data bus[5]	1.8-V HSTL Class I	PIN_BA10
QDRIID_Q6	Read Data bus[6]	1.8-V HSTL Class I	PIN_BD10
QDRIID_Q7	Read Data bus[7]	1.8-V HSTL Class I	PIN_BB8
QDRIID_Q8	Read Data bus[8]	1.8-V HSTL Class I	PIN_BB9
QDRIID_Q9	Read Data bus[9]	1.8-V HSTL Class I	PIN_BD11
QDRIID_Q10	Read Data bus[10]	1.8-V HSTL Class I	PIN_BC12
QDRIID_Q11	Read Data bus[11]	1.8-V HSTL Class I	PIN_BB10
QDRIID_Q12	Read Data bus[12]	1.8-V HSTL Class I	PIN_BA12
QDRIID_Q13	Read Data bus[13]	1.8-V HSTL Class I	PIN_BB14
QDRIID_Q14	Read Data bus[14]	1.8-V HSTL Class I	PIN_AY14
QDRIID_Q15	Read Data bus[15]	1.8-V HSTL Class I	PIN_AU13
QDRIID_Q16	Read Data bus[16]	1.8-V HSTL Class I	PIN_AW13

QDRIID_Q17	Read Data bus[17]	1.8-V HSTL Class I	PIN_AY13
QDRIID_BWS_n0	Byte Write select[0]	1.8-V HSTL Class I	PIN_AV10
QDRIID_BWS_n1	Byte Write select[1]	1.8-V HSTL Class I	PIN_AY9
QDRIID_K_p	Clock P	Differential 1.8-V HSTL Class I	PIN_AW11
QDRIID_K_n	Clock N	Differential 1.8-V HSTL Class I	PIN_AY12
QDRIID_CQ_p	Echo clock P	1.8-V HSTL Class I	PIN_AW15
QDRIID_CQ_n	Echo clock N	1.8-V HSTL Class I	PIN_AW14
QDRIID_RPS_n	Report Select	1.8-V HSTL Class I	PIN_AM15
QDRIID_WPS_n	Write Port Select	1.8-V HSTL Class I	PIN_AN15
QDRIID_DOFF_n	PLL Turn Off	1.8-V HSTL Class I	PIN_AT16
QDRIID_ODT	On-Die Termination Input	1.8-V HSTL Class I	PIN_AP15
QDRIID_QVLD	ValidOutput Indicator	1.8-V HSTL Class I	PIN_AV13

**Table 2-14 QDRII+ SRAM E Pin Assignments, Schematic Signal Names, and Functions**

Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
QDRIIE_A0	Address bus[0]	1.8-V HSTL Class I	PIN_BD30
QDRIIE_A1	Address bus[1]	1.8-V HSTL Class I	PIN_BD31
QDRIIE_A2	Address bus[2]	1.8-V HSTL Class I	PIN_AY28
QDRIIE_A3	Address bus[3]	1.8-V HSTL Class I	PIN_AY29
QDRIIE_A4	Address bus[4]	1.8-V HSTL Class I	PIN_BB30
QDRIIE_A5	Address bus[5]	1.8-V HSTL Class I	PIN_BC31
QDRIIE_A6	Address bus[6]	1.8-V HSTL Class I	PIN_BA29
QDRIIE_A7	Address bus[7]	1.8-V HSTL Class I	PIN_BA30
QDRIIE_A8	Address bus[8]	1.8-V HSTL Class I	PIN_AW28
QDRIIE_A9	Address bus[9]	1.8-V HSTL Class I	PIN_AW29
QDRIIE_A10	Address bus[10]	1.8-V HSTL Class I	PIN_BA32
QDRIIE_A11	Address bus[11]	1.8-V HSTL Class I	PIN_BB32
QDRIIE_A12	Address bus[12]	1.8-V HSTL Class I	PIN_AY31
QDRIIE_A13	Address bus[13]	1.8-V HSTL Class I	PIN_BA31
QDRIIE_A14	Address bus[14]	1.8-V HSTL Class I	PIN_AV28

QDRIIE_A15	Address bus[15]	1.8-V HSTL Class I	PIN_AV30
QDRIIE_A16	Address bus[16]	1.8-V HSTL Class I	PIN_AW30
QDRIIE_A17	Address bus[17]	1.8-V HSTL Class I	PIN_AR28
QDRIIE_A18	Address bus[18]	1.8-V HSTL Class I	PIN_AR27
QDRIIE_A19	Address bus[19]	1.8-V HSTL Class I	PIN_AT29
QDRIIE_A20	Address bus[20]	1.8-V HSTL Class I	PIN_AU29
QDRIIE_A21	Address bus[21]	1.8-V HSTL Class I	PIN_AT30
QDRIIE_D0	Write data bus[0]	1.8-V HSTL Class I	PIN_AK33
QDRIIE_D1	Write data bus[1]	1.8-V HSTL Class I	PIN_AJ33
QDRIIE_D2	Write data bus[2]	1.8-V HSTL Class I	PIN_AK32
QDRIIE_D3	Write data bus[3]	1.8-V HSTL Class I	PIN_AM33
QDRIIE_D4	Write data bus[4]	1.8-V HSTL Class I	PIN_AN33
QDRIIE_D5	Write data bus[5]	1.8-V HSTL Class I	PIN_AT32
QDRIIE_D6	Write data bus[6]	1.8-V HSTL Class I	PIN_AR32
QDRIIE_D7	Write data bus[7]	1.8-V HSTL Class I	PIN_AN32
QDRIIE_D8	Write data bus[8]	1.8-V HSTL Class I	PIN_AM32
QDRIIE_D9	Write data bus[9]	1.8-V HSTL Class I	PIN_AP31
QDRIIE_D10	Write data bus[10]	1.8-V HSTL Class I	PIN_AR31
QDRIIE_D11	Write data bus[11]	1.8-V HSTL Class I	PIN_AT31
QDRIIE_D12	Write data bus[12]	1.8-V HSTL Class I	PIN_AV32
QDRIIE_D13	Write data bus[13]	1.8-V HSTL Class I	PIN_AU32
QDRIIE_D14	Write data bus[14]	1.8-V HSTL Class I	PIN_AU33
QDRIIE_D15	Write data bus[15]	1.8-V HSTL Class I	PIN_AR33
QDRIIE_D16	Write data bus[16]	1.8-V HSTL Class I	PIN_AP33
QDRIIE_D17	Write data bus[17]	1.8-V HSTL Class I	PIN_AU34
QDRIIE_Q0	Read Data bus[0]	1.8-V HSTL Class I	PIN_BB37
QDRIIE_Q1	Read Data bus[1]	1.8-V HSTL Class I	PIN_BA35
QDRIIE_Q2	Read Data bus[2]	1.8-V HSTL Class I	PIN_BB35
QDRIIE_Q3	Read Data bus[3]	1.8-V HSTL Class I	PIN_BC35
QDRIIE_Q4	Read Data bus[4]	1.8-V HSTL Class I	PIN_BB34
QDRIIE_Q5	Read Data bus[5]	1.8-V HSTL Class I	PIN_BB33
QDRIIE_Q6	Read Data bus[6]	1.8-V HSTL Class I	PIN_BC33
QDRIIE_Q7	Read Data bus[7]	1.8-V HSTL Class I	PIN_AY33
QDRIIE_Q8	Read Data bus[8]	1.8-V HSTL Class I	PIN_AY32
QDRIIE_Q9	Read Data bus[9]	1.8-V HSTL Class I	PIN_AV31

QDRIIE_Q10	Read Data bus[10]	1.8-V HSTL Class I	PIN_AW31
QDRIIE_Q11	Read Data bus[11]	1.8-V HSTL Class I	PIN_BC32
QDRIIE_Q12	Read Data bus[12]	1.8-V HSTL Class I	PIN_BD33
QDRIIE_Q13	Read Data bus[13]	1.8-V HSTL Class I	PIN_BD34
QDRIIE_Q14	Read Data bus[14]	1.8-V HSTL Class I	PIN_BD35
QDRIIE_Q15	Read Data bus[15]	1.8-V HSTL Class I	PIN_BA34
QDRIIE_Q16	Read Data bus[16]	1.8-V HSTL Class I	PIN_BA37
QDRIIE_Q17	Read Data bus[17]	1.8-V HSTL Class I	PIN_AY36
QDRIIE_BWS_n0	Byte Write select[0]	1.8-V HSTL Class I	PIN_AN31
QDRIIE_BWS_n1	Byte Write select[1]	1.8-V HSTL Class I	PIN_AK31
QDRIIE_K_p	Clock P	Differential 1.8-V HSTL Class I	PIN_AL32
QDRIIE_K_n	Clock N	Differential 1.8-V HSTL Class I	PIN_AL31
QDRIIE_CQ_p	Echo clock P	1.8-V HSTL Class I	PIN_AL32
QDRIIE_CQ_n	Echo clock N	1.8-V HSTL Class I	PIN_AL31
QDRIIE_RPS_n	Report Select	1.8-V HSTL Class I	PIN_BC27
QDRIIE_WPS_n	Write Port Select	1.8-V HSTL Class I	PIN_BB27
QDRIIE_DOFF_n	PLL Turn Off	1.8-V HSTL Class I	PIN_BA27
QDRIIE_ODT	On-Die Termination Input	1.8-V HSTL Class I	PIN_BD28
QDRIIE_QVLD	Valid Output Indicator	1.8-V HSTL Class I	PIN_BA36

## 2.9 QSFP+ Ports

The development board has two independent 40G QSFP+ connectors that use one transceiver channel each from the Arria 10 GX FPGA device. These modules take in serial data from the Arria 10 GX FPGA device and transform them to optical signals. The board includes cage assemblies for the QSFP+ connectors. **Figure 2-15** shows the connections between the QSFP+ and Arria 10 GX FPGA.

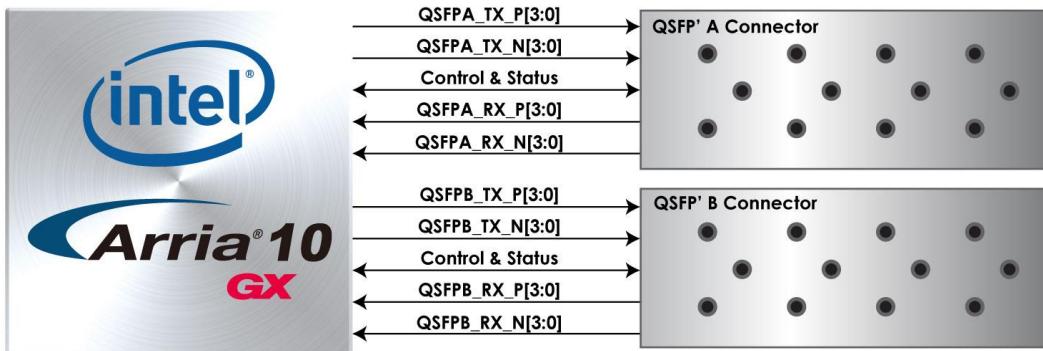


Figure 2-15 Connection between the QSFP+ and Arria GX FPGA

**Table 2-15** and **Table 2-16** list the QSFP+ A and B pin assignments and signal names relative to the Arria 10 GX device.

Table 2-15 QSFP+ A Pin Assignments, Schematic Signal Names, and Functions

Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
QSFP_A_TX_P0	Transmitter data of channel 0	1.4-V PCML	PIN_BD5
QSFP_A_RX_P0	Receiver data of channel 0	1.4-V PCML	PIN_BB5
QSFP_A_TX_P1	Transmitter data of channel 1	1.4-V PCML	PIN_BC3
QSFP_A_RX_P1	Receiver data of channel 1	1.4-V PCML	PIN_AY5
QSFP_A_TX_P2	Transmitter data of channel 2	1.4-V PCML	PIN_BB1
QSFP_A_RX_P2	Receiver data of channel 2	1.4-V PCML	PIN_BA3
QSFP_A_TX_P3	Transmitter data of channel 3	1.4-V PCML	PIN_AY1
QSFP_A_RX_P3	Receiver data of channel 3	1.4-V PCML	PIN_AW3
QSFP_A_MOD_SEL_n	Module Select	1.8V	PIN_AL36
QSFP_A_RST_n	Module Reset	1.8V	PIN_AN37
QSFP_A_SCL	2-wire serial interface clock	1.8V	PIN_AV37
QSFP_A_SDA	2-wire serial interface data	1.8V	PIN_AV38
QSFP_A_LP_MODE	Low Power Mode	1.8V	PIN_AU37
QSFP_A_INTERRUPT_n	Interrupt	1.8V	PIN_AU39
QSFP_A_MOD_PRS_n	Module Present	1.8V	PIN_AT37

Table 2-16 QSFP+ B Pin Assignments, Schematic Signal Names, and Functions

Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
QSFP_B_TX_P0	Transmitter data of channel 0	1.4-V PCML	PIN_AP1

QSFPB_RX_P0	Receiver data of channel 0	1.4-V PCML	PIN_AN3
QSFPB_TX_P1	Transmitter data of channel 1	1.4-V PCML	PIN_AM1
QSFPB_RX_P1	Receiver data of channel 1	1.4-V PCML	PIN_AL3
QSFPB_TX_P2	Transmitter data of channel 2	1.4-V PCML	PIN_AK1
QSFPB_RX_P2	Receiver data of channel 2	1.4-V PCML	PIN_AJ3
QSFPB_TX_P3	Transmitter data of channel 3	1.4-V PCML	PIN_AH1
QSFPB_RX_P3	Receiver data of channel 3	1.4-V PCML	PIN_AG3
QSFPB_MOD_SEL_n	Module Select	1.8V	PIN_AH36
QSFPB_RST_n	Module Reset	1.8V	PIN_AK36
QSFPB_SCL	2-wire serial interface clock	1.8V	PIN_AL34
QSFPB_SDA	2-wire serial interface data	1.8V	PIN_AM34
QSFPB_LP_MODE	Low Power Mode	1.8V	PIN_AL35
QSFPB_INTERRUPT_n	Interrupt	1.8V	PIN_AR34
QSFPB_MOD_PRS_n	Module Present	1.8V	PIN_AT34

## 2.10 PCI Express

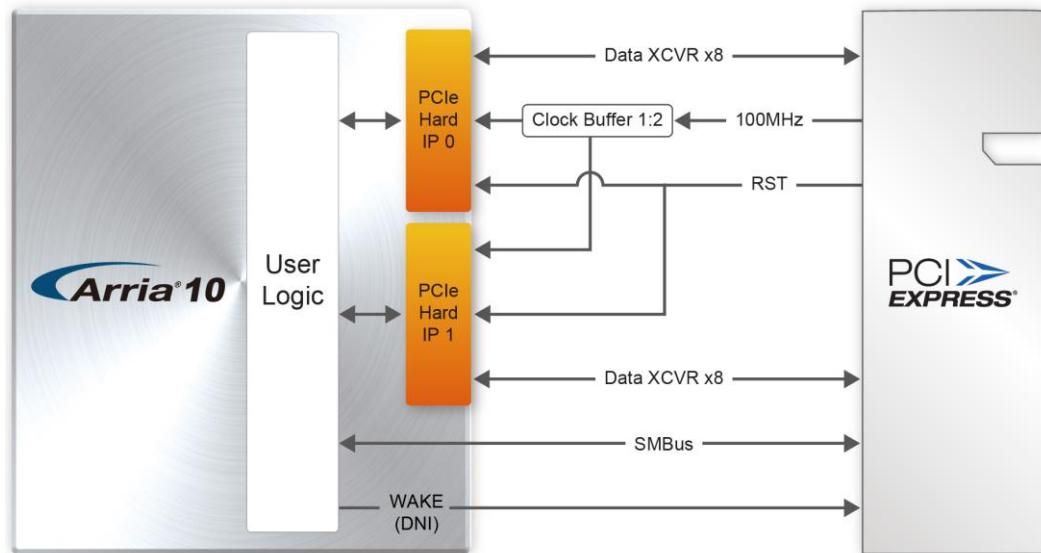
The FPGA development board is designed to fit entirely into a PC motherboard with x8 or x16 PCI Express slot. Utilizing built-in transceivers on the Arria 10 GX device, it is able to provide a fully integrated PCI Express-compliant solution for multi-lane (x1, x4, and x8) applications. With the PCI Express hard IP block incorporated in the Arria 10 GX device, it will allow users to implement simple and fast protocol, as well as saving logic resources for logic application. **Figure 2-16** presents the pin connection established between the Arria 10 GX and PCI Express.

The Dual PCI Express interface supports complete PCI Express Gen1 at 2.5Gbps/lane, Gen2 at 5.0Gbps/lane, and Gen3 at 8.0Gbps/lane protocol stack solution compliant to PCI Express base specification 3.0 that includes PHY-MAC, Data Link, and transaction layer circuitry embedded in PCI Express hard IP blocks.

Please note that it is a requirement that you connect the PCIe external power connector to 4-pin 12V DC power connector in the FPGA to avoid FPGA damage due to insufficient power. The PCIE\_REFCLK\_p signal is a differential input that is driven from the PC motherboard on this board through the PCIe edge connector. A DIP switch (S1) is connected to the PCI Express to allow different configurations to enable a x1, x4, or x8

PCIe.

**Table 2-17** summarizes the Dual PCI Express pin assignments of the signal names relative to the Arria 10 GX FPGA.



**Figure 2-16 PCI Express pin connection**

**Table 2-17 PCI Express Pin Assignments, Schematic Signal Names, and Functions**

Schematic Signal Name	Description	I/O Standard	Arria 10 GX Pin Number
PCIE_TX_p0	Add-in card transmit bus	1.4-V PCML	PIN_AV44
PCIE_TX_p1	Add-in card transmit bus	1.4-V PCML	PIN_AT44
PCIE_TX_p2	Add-in card transmit bus	1.4-V PCML	PIN_AP44
PCIE_TX_p3	Add-in card transmit bus	1.4-V PCML	PIN_AM44
PCIE_TX_p4	Add-in card transmit bus	1.4-V PCML	PIN_AK44
PCIE_TX_p5	Add-in card transmit bus	1.4-V PCML	PIN_AH44
PCIE_TX_p6	Add-in card transmit bus	1.4-V PCML	PIN_AF44
PCIE_TX_p7	Add-in card transmit bus	1.4-V PCML	PIN_AD44
PCIE_RX_p0	Add-in card receive bus	1.4-V PCML	PIN_AU42
PCIE_RX_p1	Add-in card receive bus	1.4-V PCML	PIN_AR42
PCIE_RX_p2	Add-in card receive bus	1.4-V PCML	PIN_AN42
PCIE_RX_p3	Add-in card receive bus	1.4-V PCML	PIN_AL42
PCIE_RX_p4	Add-in card receive bus	1.4-V PCML	PIN_AJ42
PCIE_RX_p5	Add-in card receive bus	1.4-V PCML	PIN_AG42

PCIE_RX_p6	Add-in card receive bus	1.4-V PCML	PIN_AE42
PCIE_RX_p7	Add-in card receive bus	1.4-V PCML	PIN_AC42
PCIE_REFCLK_p	Motherboard reference clock	HCSL	PIN_AH40
PCIE_PERST_n	Reset	1.8-V	PIN_AT25
PCIE_SMBCLK	SMB clock	1.8-V	PIN_AM25
PCIE_SMBDAT	SMB data	1.8-V	PIN_BD24
PCIE_WAKE_n	Wake signal	1.8-V	PIN_AN26
PCIE_PRSNT1n	Hot plug detect	-	-
PCIE_PRSNT2n_x1	Hot plug detect x1 PCIe slot enabled using SW5 dip switch	-	-
PCIE_PRSNT2n_x4	Hot plug detect x4 PCIe slot enabled using SW5 dip switch	-	-
PCIE_PRSNT2n_x8	Hot plug detect x8 PCIe slot enabled using SW5 dip switch	-	-
PCIE2_TX_p0	Add-in card transmit bus	1.4-V PCML	PIN_P44
PCIE2_TX_p1	Add-in card transmit bus	1.4-V PCML	PIN_M44
PCIE2_TX_p2	Add-in card transmit bus	1.4-V PCML	PIN_K44
PCIE2_TX_p3	Add-in card transmit bus	1.4-V PCML	PIN_H44
PCIE2_TX_p4	Add-in card transmit bus	1.4-V PCML	PIN_F44
PCIE2_TX_p5	Add-in card transmit bus	1.4-V PCML	PIN_D44
PCIE2_TX_p6	Add-in card transmit bus	1.4-V PCML	PIN_B44
PCIE2_TX_p7	Add-in card transmit bus	1.4-V PCML	PIN_A42
PCIE2_RX_p0	Add-in card receive bus	1.4-V PCML	PIN_N42
PCIE2_RX_p1	Add-in card receive bus	1.4-V PCML	PIN_L42
PCIE2_RX_p2	Add-in card receive bus	1.4-V PCML	PIN_J42
PCIE2_RX_p3	Add-in card receive bus	1.4-V PCML	PIN_G42
PCIE2_RX_p4	Add-in card receive bus	1.4-V PCML	PIN_E42
PCIE2_RX_p5	Add-in card receive bus	1.4-V PCML	PIN_D40
PCIE2_RX_p6	Add-in card receive bus	1.4-V PCML	PIN_C42
PCIE2_RX_p7	Add-in card receive bus	1.4-V PCML	PIN_B40
PCIE2_REFCLK_p	Motherboard reference clock	HCSL	PIN_Y40
PCIE2_PERST_n	Reset	1.8-V	PIN_AR24

## 2.11 2x5 Timing Header

The FPGA board has one 2x5 GPIO header J5 for expansion function. The pin-out of J5 is shown in **Figure 2-17**. GPIO\_P0 ~ GPIO\_P3 are bi-direction 1.8V GPIO. GPIO\_CLK0 and GPIO\_CLK1 are connected to FPGA dedicated clock input and can be configured as two single-ended clock signals or one differential clock signal. Users can use Terasic defined RS422-RJ45 board and TUB (Timing and UART Board) for RS422 and external clock inputs/UART applications.

**Table 2-18** shows the mapping of the FPGA pin assignments to the 2x5 GPIO header.

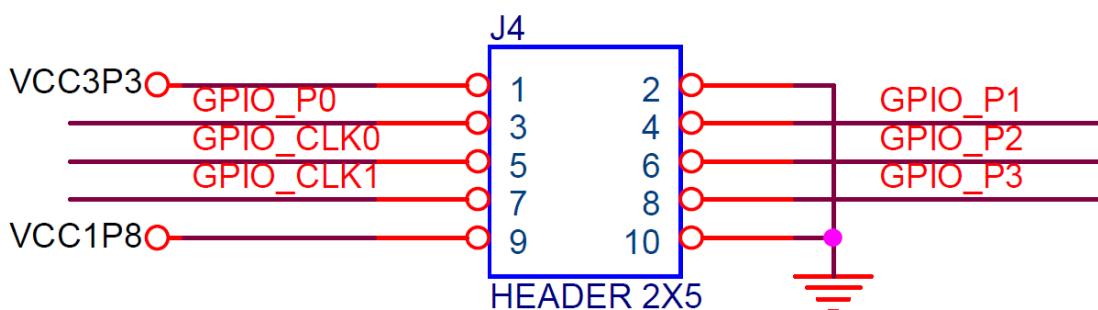


Figure 2-17 Pin-out of Timing Expansion Header

**Table 2-18 Timing Expansion Header Pin Assignments, Schematic Signal Names, and Functions**

Schematic Signal Name	Description	I/O Standard	Stratix 10 GX/SX Pin Number
GPIO_P0	Bi-direction 1.8V GPIO	1.8-V	PIN_W13
GPIO_P1	Bi-direction 1.8V GPIO	1.8-V	PIN_W9
GPIO_P2	Bi-direction 1.8V GPIO	1.8-V	PIN_W10
GPIO_P3	Bi-direction 1.8V GPIO	1.8-V	PIN_W14
GPIO_CLK0	FPGA dedicated clock input or Bi-direction 1.8V GPIO	1.8-V	PIN_AN7
GPIO_CLK1	FPGA dedicated clock input or Bi-direction 1.8V GPIO	1.8-V	PIN_AN8

## Chapter 3

# Flash Programming

**A**s you develop your own project using the Altera tools, you can program the flash memory device so that your own design loads from CFI flash memory into the FPGA on power up. This chapter will describe how to use Altera Quartus Prime Programmer Tool to program the common flash interface (CFI) flash memory device on the FPGA board.

The Arria 10 GX FPGA development board ships with the CFI flash device preprogrammed with two FPGA configurations. The two configuration images are called: **factory** image and **user** image, respectively.

### 3.1 FPGA Configure Operation

Below shows the procedure to enable the FPGA configuration from Flash. Users can select one boot image between factory image and user image.

1. Make sure the two default FPGA configurations data has been stored in the CFI flash.
2. Set the FPGA configuration mode to FPPx16 mode by setting S1 MSEL[2:0] as **000** as shown in **Figure 3-1**.
3. Specify the configuration of the FPGA using the default Factory Configuration Image or User Configuration Image by setting S1.4 according to **Figure 3-2**. When the switch is in position “1”, the factory image is used when the system boots. When the switch is in position “0”, user image is used when the system boots.
4. Power on the FPGA board or press the MAX\_RST button if board is already powered on,
5. When the configuration is completed, the green Configure Done LED will light. If there is an error, the red Configure Error LED will light.

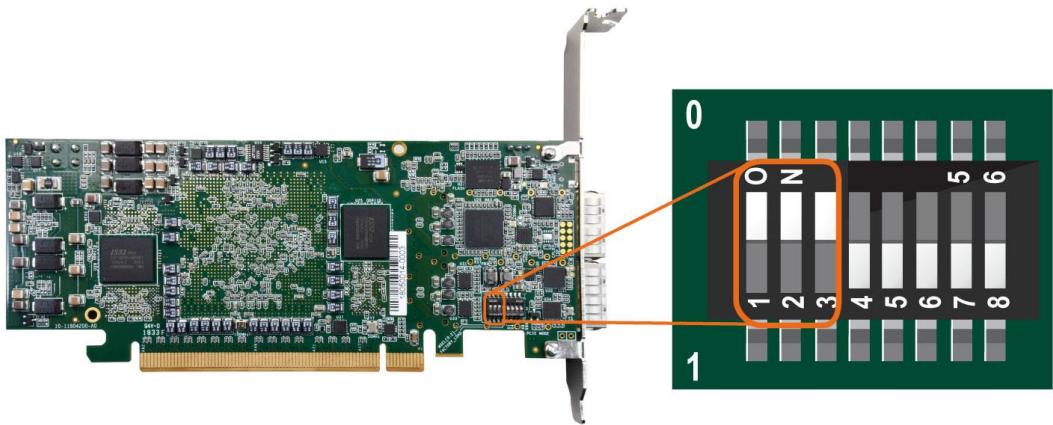


Figure 3-1 MSEL[2:0]=000

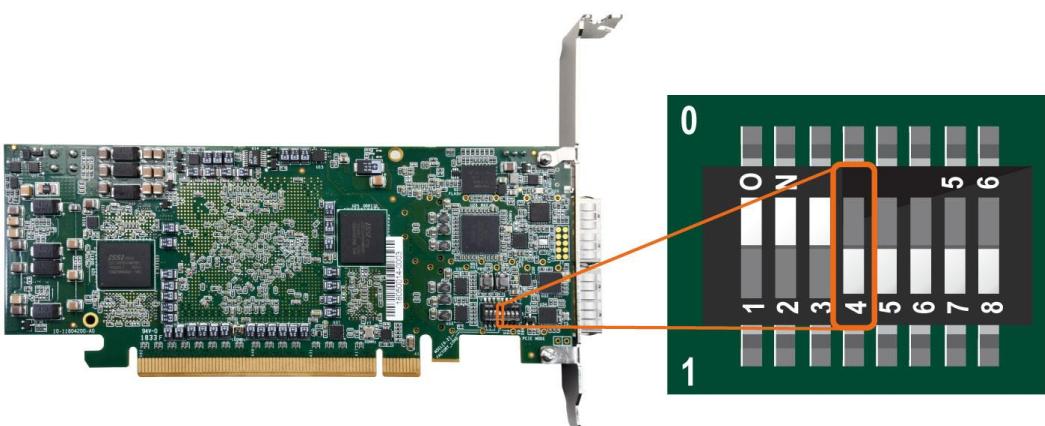


Figure 3-2 Configuration Image Selection

## 3.2 CFI Flash Memory Map

The TR10a-LPQ has one 1-Gbit, 16-bit data width, CFI compatible synchronous flash device for non-volatile storage of the FPGA configuration data, user Nios II code, and user data. Both MAX V CPLD and Stratix 10 GX FPGA can access this Flash device.

MAXV CPLD accesses flash for FPP x16 configuration of the FPGA at power-on and board reset events. It uses the PFL-II Mega function. Arria10 10 GX FPGA access to the flash memory's user space is done by Nios II.

**Table 3-1** shows the memory map for the on-board flash. This memory provides non-volatile storage for two FPGA bit-streams and Nios II Program, users data, as well as FPL option bits for PFL II configuration bits and board information. For the factory default

code to run correctly and update designs in the user memory, this memory map address must not be altered.

**Table 3-1 Flash Memory Map (Byte Address)**

Block Description	Size(KB)	Address Range
Factory Board Information	128	0x00010000 – 0x0002FFFF
PFL option bits	64	0x00030000 – 0x0003FFFF
Factory hardware	44,032	0x00040000 – 0x02B3FFFF
User hardware	44,032	0x02B40000 – 0x0563FFFF
Factory software	8,192	0x05640000 – 0x05E3FFFF
User software and data	34,560	0x05E40000 – 0x07FFFFFF

The **Factory Board Information** stores the Manufacture Serial Number of the FPGA board. The Serial Number is a 13 digital number with format mmmmmmmmm-nnnn. Users can find the number on the serial number sticker on the FPGA board.

The **PFL option bits** contains the image location of the **Factory hardware** and **User hardware**, so the PLF II IP in the MAX V CPLD can know where to find the FPGA configuration data. If developers erase all flash content, [please ensure that the PFL option is reprogrammed with the FPGA configuration data.](#)

For user's application, the **User hardware** must be stored with start address **0x02B40000**, and the user's software is suggested to be stored with start address **0x05E40000**. Users also can overwrite the Factory hardware and Factory software based on their application. **Factory hardware** must be stored with start address **0x00040000**, and the Factory software should be stored with start address **0x05640000**. We strongly recommend users to use the batch file in the **Flash\_Restore** folder to write the hardware and software data into the CFI-Flash.

### 3.3 Flash Example Designs

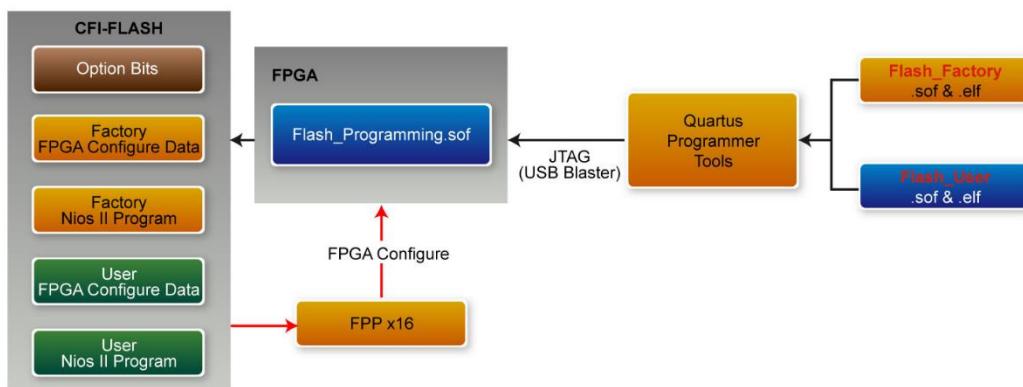
There are four flash example designs and one programming batch folder in the Demonstration folder under the System CD as shown in **Table 3-2**.

**Table 3-2 Flash Example Design**

Example Folder	Description
Flash_Programming	This is the flash programming design. It is used to write data into FLASH by a Quartus Programmer.

Flash_Factory	A simple example design. Its FPGA configure data and Nios II codes are stored in the Factory Image Area.
Flash_User	A simple example design. Its FPGA configure data and Nios II codes are stored in the User Image Area.
Flash_Tool	A Nios II program shows how to access flash content.
Flash_Restore	A batch file used for programming Flash_Factory and the Flash_User project into CFI Flash.

**Figure 3-3** shows the relationship between the three examples – **Flash\_Programming**, **Flash\_Factory** and **Flash\_User**. The **Flash\_Programming** example is used to write data into the CFI Flash on the FPGA Board. The **Flash\_Factory** and **Flash\_User** are simple designs with Nios II processor. These two designed are written into CFI-Flash so they are selected to configure the FPGA when the FPGA is powered on.



**Figure 3-3 Relationship between three flash examples**

The **Flash\_Tool** is designed to show how to access flash via the Nios II processor. The design shows how to erase flash and read flash content.

## 3.4 Flash\_Programming Example

The **Flash\_Programming** project is designed to program CFI flash by a Quartus Programmer. In the project, Intel Parallel Flash Loader II IP is used to program the CFI-Flash. **Figure 3-4** shows the Generic Setting in the IP. “Flash Programming” operation mode is used, and “CFI Parallel Flash” is selected. **Figure 3-5** shows the Flash Interface Setting. “CFI 1 Gbit” is selected. The **Flash\_Programming.sof** generated by this program is used in the flash programming batch files located in the **Flash\_Restore** folder.

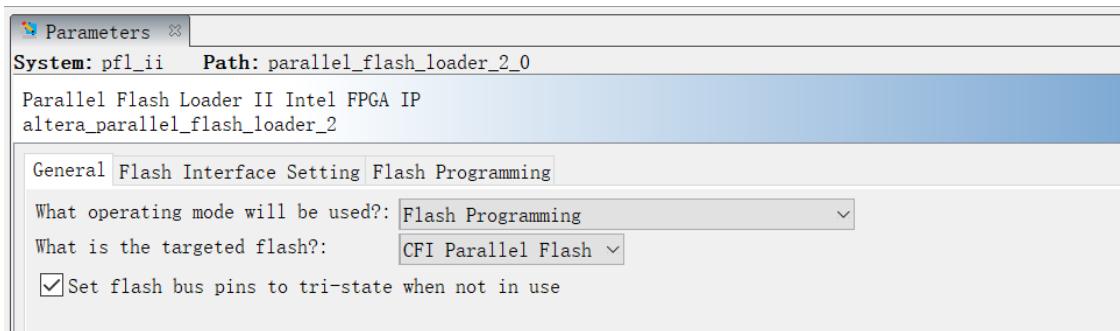


Figure 3-4 General Setting in PFL II IP

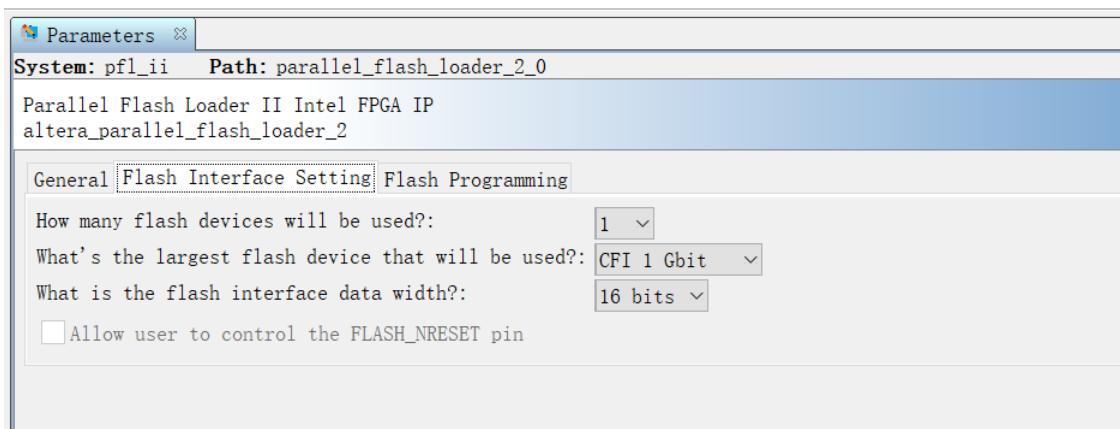


Figure 3-5 Flash Interface Setting in PFL II IP

## 3.5 Flash\_Factory Example

The **Flash\_Factory** is designed to show how to create a Nios II code which is booted from the Factory Software location in the CFI Flash when the board is powered on. This project's FPGA configuration data and Nios II code are stored in the Factory Hard area and Factory Software area of the CFI Flash when the FPGA board is shipped.

To develop this kind of boot code, first, developers need to include the Tri-State Conduit Bridge and the Generic Tri-State Controller in the **Platform Designer** (formerly Qsys) to implement the flash controller function, and connect the Nios II processor's data bus and instruction bus to the flash controller as shown in **Figure 3-6**. Then, specify the Factory Software Location **0x05640000** as Reset Vector in the Nios II Processor component as shown in **Figure 3-7**. Finally, developers need to uncheck the **allow\_code\_at\_reset** and **enable\_alt\_load** options in the BSP editor under of Nios II IDE tool (Nios II Software Builder Tools for Eclipse) as shown in **Figure 3-8**.

System Contents Address Map Interconnect Requirements

System: system Path: clk\_50

Use Connections	Name	Description	Export	Clock	Base
<input checked="" type="checkbox"/>	jtag_uart	JTAG UART Intel FPGA IP	Double-click	clk_50	0x0804_1048
<input checked="" type="checkbox"/>	led	PIO (Parallel I/O) Intel FPGA IP	Double-click	clk_50	0x0804_1030
<input checked="" type="checkbox"/>	led_bracket	PIO (Parallel I/O) Intel FPGA IP	Double-click	clk_50	0x0804_1020
<input checked="" type="checkbox"/>	ext_flash	Generic Tri-State Controller	Double-click	clk_50	0x0000_0000
<input checked="" type="checkbox"/>	cfi_flash...	Tri-State Conduit Bridge	Double-click	clk_50	

Figure 3-6 Flash Controller Settings in Platform Designer (formerly Qsys)

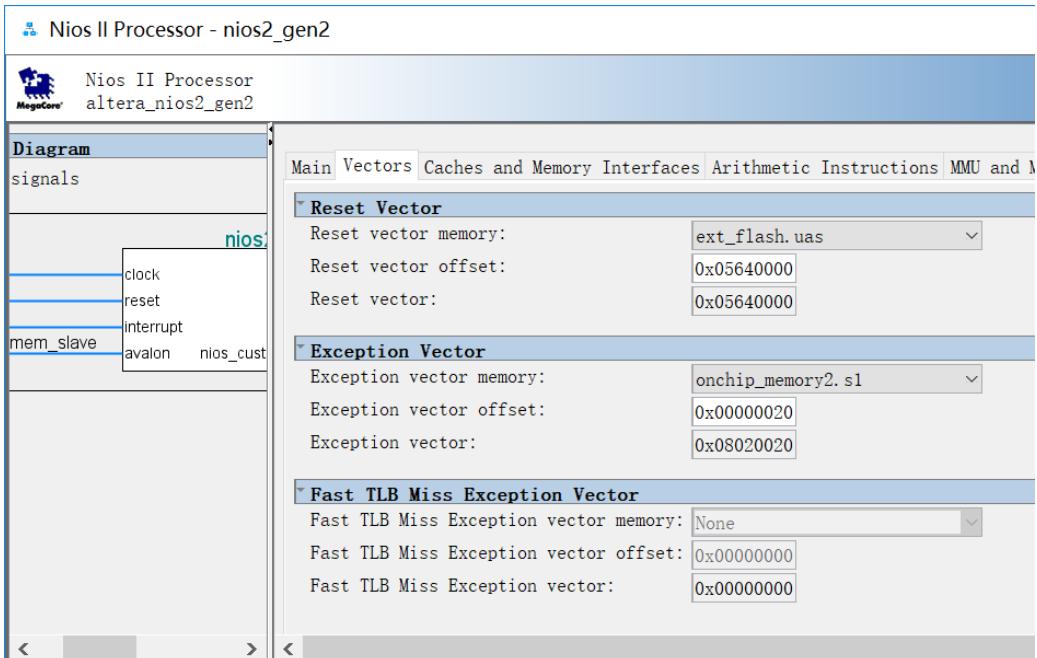


Figure 3-7 Factory Software Reset Vector Settings for NIOS II Processor

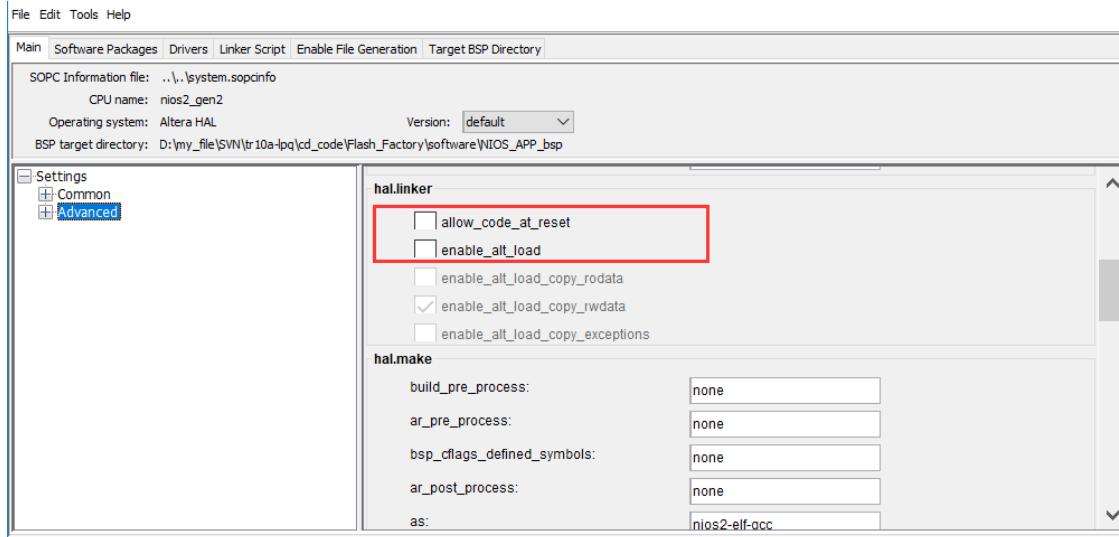


Figure 3-8 BSP Editor in Nios II IDE

## 3.6 Flash\_User Example

The **Flash\_User** project is similar with the above **Flash\_Factory** example code. This project's FPGA configuration data and Nios II code are stored in the User Hard area and User Software area when the FPGA board is shipped.

The major difference between the **Flash\_User** and **Flash\_Factory** is the Reset Vector address in the Nios II processor component and the LED control code in Nios II program. The User Software Location **0x05E40000** is used as Reset Vector as shown in **Figure 3-9**.

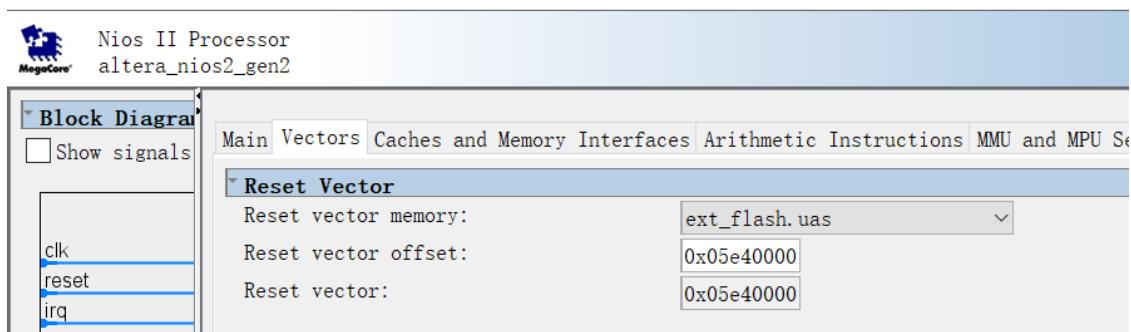
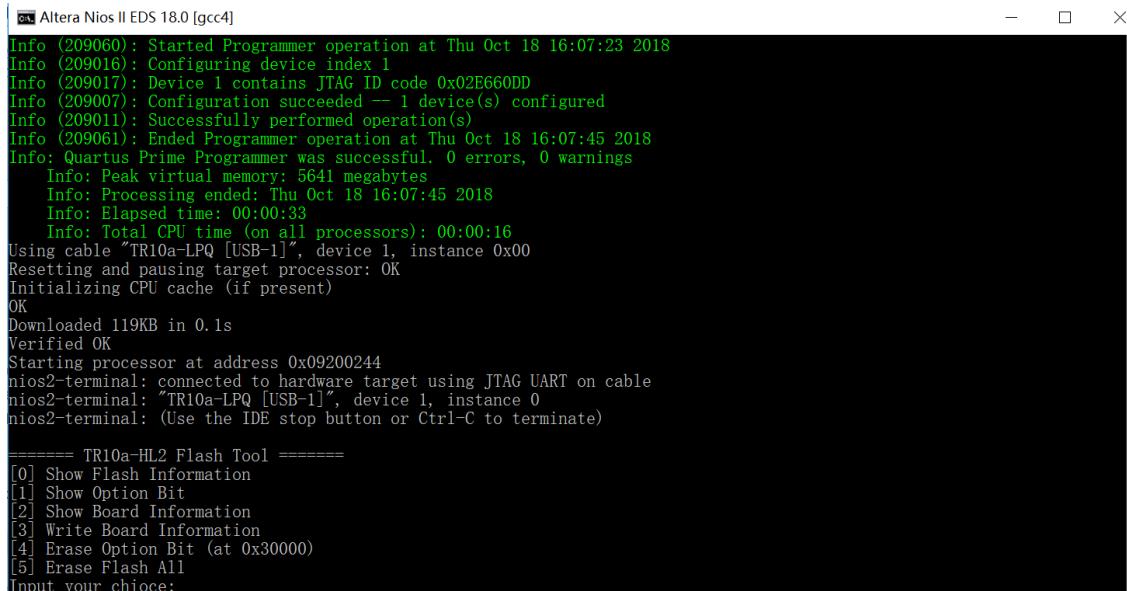


Figure 3-9 User Software Reset Vector Settings for NIOS II Processor

## 3.7 Flash\_Tool Example

This example shows how the Nios II program accesses the FLASH. **Figure 3-10** shows a screenshot of the Flash\_Tool menu shown under Nios II terminal.



The screenshot shows a terminal window titled "Altera Nios II EDS 18.0 [gcc4]". The window displays a log of programmer operations and then presents a menu for the TR10a-HL2 Flash Tool. The menu options are:

```
Info (209060): Started Programmer operation at Thu Oct 18 16:07:23 2018
Info (209016): Configuring device index 1
Info (209017): Device 1 contains JTAG ID code 0x02E660DD
Info (209007): Configuration succeeded — 1 device(s) configured
Info (209011): Successfully performed operation(s)
Info (209061): Ended Programmer operation at Thu Oct 18 16:07:45 2018
Info: Quartus Prime Programmer was successful. 0 errors, 0 warnings
  Info: Peak virtual memory: 5641 megabytes
  Info: Processing ended: Thu Oct 18 16:07:45 2018
  Info: Elapsed time: 00:00:33
  Info: Total CPU time (on all processors): 00:00:16
Using cable "TR10a-LPQ [USB-1]", device 1, instance 0x00
Resetting and pausing target processor: OK
Initializing CPU cache (if present)
OK
Downloaded 119KB in 0.1s
Verified OK
Starting processor at address 0x09200244
nios2-terminal: connected to hardware target using JTAG UART on cable
nios2-terminal: "TR10a-LPQ [USB-1]", device 1, instance 0
nios2-terminal: (Use the IDE stop button or Ctrl-C to terminate)

===== TR10a-HL2 Flash Tool =====
[0] Show Flash Information
[1] Show Option Bit
[2] Show Board Information
[3] Write Board Information
[4] Erase Option Bit (at 0x30000)
[5] Erase Flash All
Input your choice:
```

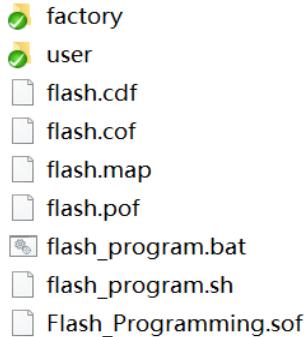
**Figure 3-10 Screenshot of Flash\_Tool menu**

The tools provide the following functions:

- Show CFI Flash Size
- Show Option bits used by FPP x16 Configuration
- Read Serial Number from the CFI Flash
- Erase Serial Number to the CFI flash
- Erase option bits used by FPP x16
- Erase whole flash

## 3.8 Programming Batch File

The **Flash\_Restore** folder includes batch files to program the Factory image and User image into the CFI flash. **Figure 3-11** shows the contents of the **Flash\_Restore** folder. The **factory** subfolder includes the .sof & .elf files generated by the **Flash\_Factory** project. The **user** subfolder includes the .sof & .elf files generated by the **Flash\_User** project. Flash\_Programming.sof is generated by the **Flash\_Programming** project.



**Figure 3-11 Flash\_Restore folder content**

The **flash\_program.bat** is the top batch file for flash programming. The batch file will configure the FPGA with **Flash\_Programming.sof** (Parallel Flash Loader II IP) and launch **flash\_program.sh** Nios II command batch file to perform the following tasks:

1. Use Nios II utilities **elf2flash** and **nios2-elf-objcopy** to convert **Factory** Nios II code and **User** Nios II code to **factory\_sw.hex** and **user\_sw.hex**, respectively.
2. Use **quartus\_cpf** utility according to a given configuration file **flash.cof** to merger all files (**factory\_sw.hex**, **user\_sw.hex**, **factory .sof** file, **user .sof** file, and option bit) into a single file **flash.pof**.
3. Use **jtagconfig** utility to adjust jtag speed.
4. Use **quartus\_pgm** utility to program flash with **flash.pof**.

Developers can copy their **.sof** & **.elf** files into the **factory** folder or the **user** folder, and launch the **flash\_program.bat** to program their code into the CFI-Flash.

## 3.9 Restore Factory Settings

This section describes how to restore the original **Factory** image and **User** image into the flash memory device on the FPGA development board. A programming batch file located in the **Flash\_Restore** folder is used to restore the flash content. Performing the following instructions can restore the flash content:

1. Make sure the Nios II EDS and USB-Blaster II driver are installed.
2. Make sure the FPGA board and PC are connected with an USB Cable.
3. Power on the FPGA board.
4. Copy the “Demonstrations/Flash\_Restore” folder under the CD to your PC’s

local drive.

5. Execute the batch file flash\_program.bat to start flash programming.

After restoring the flash, perform the following procedures to test the restored boot code.

1. Power off the FPGA Board.
2. Set FPGA configuration mode as FPPx16 Mode by setting S1 MSEL[2:0] to **000**.
3. Specify configuration of the FPGA to Factory Hardware by setting the FACTORY\_LOAD dip in S1.4 to the '1' position.
4. Power on the FPGA Board, and the Configure Done LED D4 should light up.

The batch file converts the **Factory** and **User** .sof/.elf and PFL option bit into a flash.pof file and use Quartus Programmer to program the CFI-Flash with the generated flash.pof. The **factory** subfolder includes Flash\_Programming.sof and NIOS\_APP.elf files generated by **Flash\_Factory** project, and the **user** subfolder includes Flash\_Programming.sof and NIOS\_APP.elf files generated by **Flash\_User** project. The Flash\_Programming.sof under the **Flash\_Restore** folder is used to program flash by Quartus Programmer.

# Peripheral Reference Design

This chapter introduces TR10a-LPQ peripheral interface reference designs. It mainly introduces Si5340 chip which is a programmable clock generator. We provide two ways (Pure RTL IP and NIOS/Qsys System) respectively to show how to control Si5340 to output desired frequencies, as well as how to control the fan speed. The source codes and tool of these examples are all available on the System CD.

## 4.1 Configure Si5340A in RTL

There is a Silicon Labs Si5340A clock generators on TR10a-LPQ FPGA board can provide adjustable frequency reference clock (See **Figure 4-1**) for QSFP+ connectors and memory modules (QDR-II+). The Si5340A clock generator can output four differential frequencies from 100Hz ~ 712.5Mhz though I2C interface configuration. This chapter will show you how to use FPGA RTL IP to configure each Si5340A PLL and generate users desired output frequency to each peripheral.

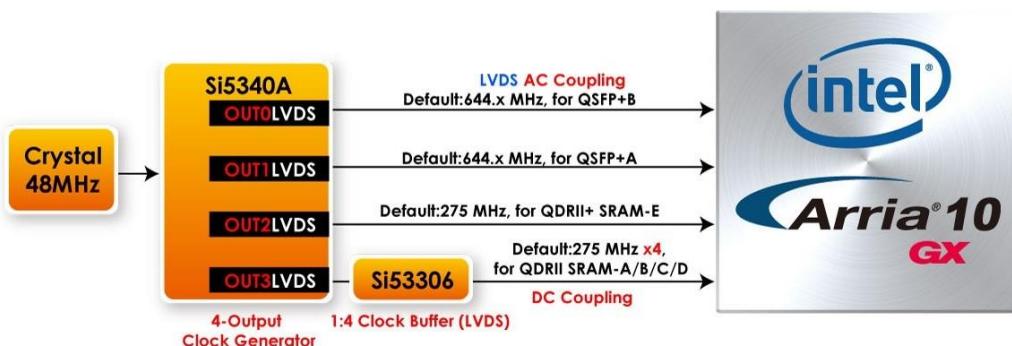


Figure 4-1 The clock tree of the TR10a-LPQ

### ■ Creating Si5340A Control IP

The Si5340A control IP is located in the folder: "\Demonstrations\si5340\_controller" in the System CD. Developers can use the IP directly in their Quartus top. Developers can

refer to the example in Demonstrations/Clock\_Controller folder. This example shows how to instantiate the IP in Quartus top project (See **Figure 4-2**).

```

//=====
// Configure Si5340A
//=====

`define XCVR_REF_644M53125      4'h0
`define XCVR_REF_322M265625     4'h1
`define XCVR_REF_250M           4'h2
`define XCVR_REF_125M           4'h3
`define XCVR_REF_100M           4'h4

`define MEM_REF_275M            4'h6
`define MEM_REF_250M            4'h2

//=====
// REG/WIRE declarations
//=====

//--Si5340
wire    si5340a_controller_start;
wire    si5340a_config_done;

//=====
// Structural coding
//=====

assign si5340a_controller_start = ~BUTTON[0]  ;

//--Configure Si5340A0
TR10ALPQ_SI5340A_CONFIG si5340a_controller(
    .iCLK    (CLK_50_B2H),
    .iRST_n  (CPU_RESET_n),
    .iStart  (si5340a_controller_start),
    .iXCVR0_REFCLK(`XCVR_REF_644M53125),//`XCVR_REF_644M53125),//QSFP-B
    .iXCVR1_REFCLK(`XCVR_REF_322M265625),//`XCVR_REF_644M53125),//QSFP-A
    .iMEM_REFCLK(`MEM_REF_250M),//`MEM_REF_275M),//QDRIIA/B/C/D/E
    .I2C_CLK    (SI5340A_I2C_SCL),
    .I2C_DATA   (SI5340A_I2C_SDA),
    .oPLL_REG_CONFIG_DONE(si5340a_config_done)
);

assign SI5340A_OE_n  = 1'b0;
assign SI5340A_RST_n = CPU_RESET_n;

```

**Figure 4-2 The controller IP of the Si5340A**

## ■ Using Si5340A control IP

**Table 4-1** lists the instruction ports of Si5340A Controller IP.

**Table 4-1 Si5340A Controller Instruction Ports**

Port	Direction	Description
iCLK	input	System Clock (50Mhz)
iRST_n	input	Synchronous Reset (0: Module Reset, 1: Normal)
iStart	input	Start to Configure (positive edge)

		trigger )
iXCVR0_REFCLK iXCVR1_REFCLK iMEM_REFCLK	input	Setting Si5340A Output Channel Frequency Value
oPLL_REG_CONFIG_DONE	output	Si5340 Configuration status (0: Configuration in Progress, 1: Configuration Complete)
I2C_DATA	inout	I2C Serial Data to/from Si5340A
I2C_CLK	output	I2C Serial Clock to Si5340A

As shown in **Table 4-2** and **Table 4-3**, Si5340A control IP have preset several output frequency parameters, if users want to change frequency, users can fill in the input ports " iXCVR0\_REF\_CLK", " iXCVR1\_REF\_CLK" and " iMEM0\_REF\_CLK" with desired frequency values and recompile the project. For example, in the components Si5340A, change

```
.iXCVR0_REFCLK(`XCVR_REF_644M53125),  
to  
.iXCVR0_REFCLK(`XCVR_REF_322M265625),
```

Recompile project, the Si5340A OUT0 channel (for QSFP+) output frequency will change from 644.53125Mhz to 322.26562Mhz.

**Table 4-2 Si5340A Controller Reference Clock Frequency Setting for QSFP+**

iXCVR0_REFCLK iXCVR1_REFCLK Input Setting	Si5340A Channel Clock Frequency (MHz)
4'h0	644.53125
4'h1	322.265625
4'h2	250
4'h3	125
4'h4	100

**Table 4-3 Si5340A Controller Reference Clock Frequency Setting for Memory**

iMEM_REFCLK Input Setting	Si5340A Channel Clock Frequency (MHz)
------------------------------	---------------------------------------

4'h2	250
4'h6	275

Users can also dynamically modify the input parameters, and input a positive edge trigger for “iStart”, then, Si5340A output frequency can be modified.

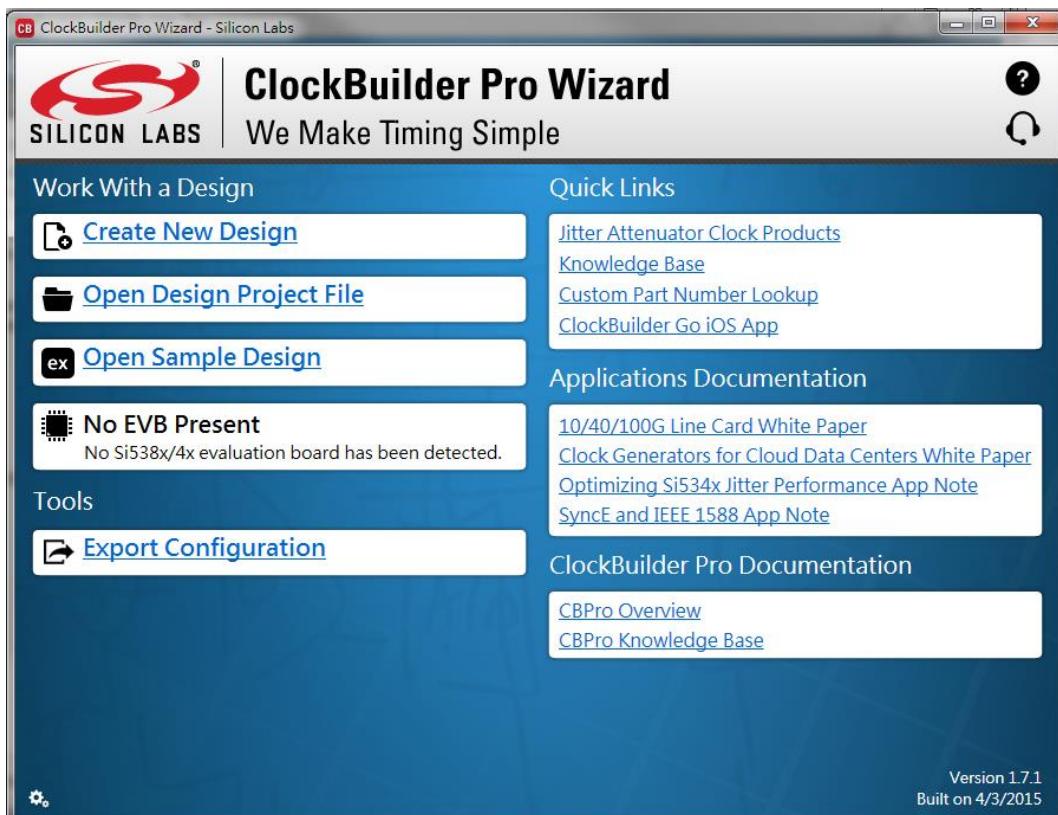
After the manually modifying, please remember to modify the corresponding frequency value in SDC file.

## ■ Modify Clock Parameter for Your Own Frequency

If the Si5340A control IP built-in frequencies are not users' desired, users can refer to the below steps to the modify control IP register parameter settings to modify the IP to output a desired frequency.

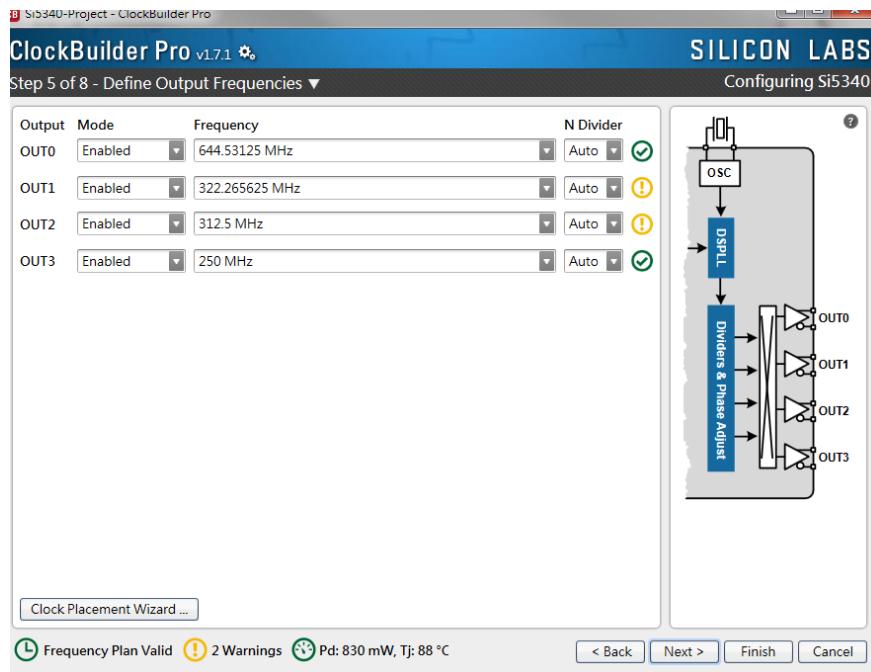
1. Firstly, download ClockBuilder Pro Software (See **Figure 4-3**), which is provided by Silicon Labs. This tool can help users to set the Si5340A's output frequency of each channel through the GUI interface, and it will automatically calculate the Register parameters required for each frequency. The tool download link:

<http://www.silabs.com/products/clocksoscillators/pages/timing-software-development-tools.aspx>



**Figure 4-3 ClockBuilder Pro Wizard**

2. After the installation, select Si5340, and configure the input frequency and output frequency as shown in **Figure 4-4**.



**Figure 4-4 Define Output Clock Frequencies on ClockBuilder Pro Wizard**

3. After the setting is completed, ClockBuilder Pro Wizard generates a Design Report(text), which contains users setting frequency corresponding register value (See **Figure 4-5**).

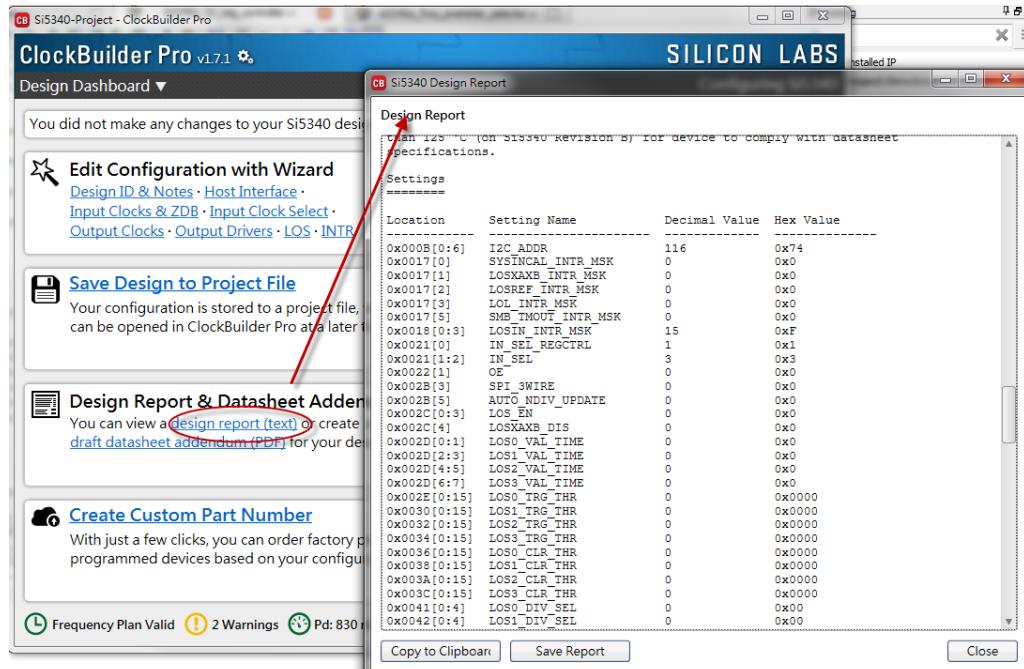


Figure 4-5 Open Design Report on ClockBuilder Pro Wizard

4. Open Si5340A control IP sub-module “si5340a\_i2c\_reg\_controller.v” as shown in **Figure 4-6**, refer Design Report parameter to modify sub-module corresponding register value (See **Figure 4-7**).

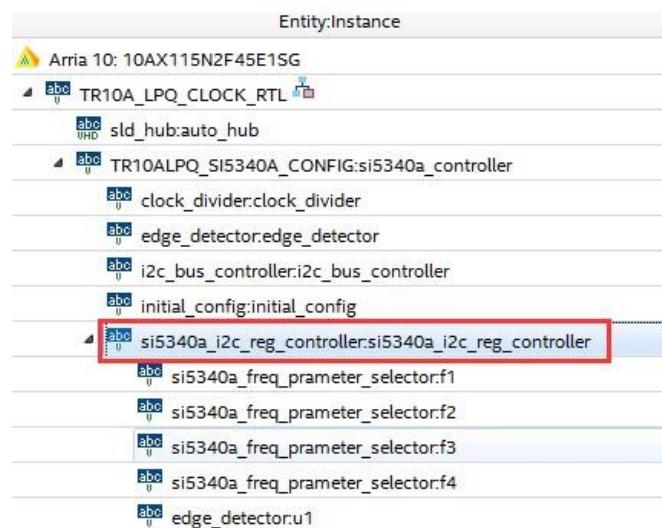


Figure 4-6 Sub-Module file "si5340a\_i2c\_reg\_controller.v"

Design Report			
Location	Setting Name	Decimal Value	Hex Value
0x000B[0:6]	I2C_ADDR	116	0x74
0x0017[0]	SYSTCAL_INTR_MSK	0	0x0
0x0017[1]	LOSSXAXB_INTR_MSK	0	0x0
0x0017[2]	LOSREF_INTR_MSK	0	0x0
0x0017[3]	LOL_INTR_MSK	0	0x0
0x0017[5]	SMB_TMOUT_INTR_MSK	0	0x0
0x0018[0:3]	LOSIN_INTR_MSK	15	0xF
0x0021[0]	IN_SEL_REGCTRL	1	0x1
0x0021[1:2]	IN_SEL	3	0x3
0x0022[1]	OE	0	0x0
0x0022[3]	SPI_3WIRE	0	0x0
0x002B[5]	AUTO_NDIV_UPDATE	0	0x0
0x002C[0:3]	LOS_EN	0	0x0
0x002C[4]	LOSSXAXB_DIS	0	0x0
0x002D[0:1]	LOSS0_VAL_TIME	0	0x0
0x002D[2:3]	LOSS1_VAL_TIME	0	0x0

Figure 4-7 Modify Si5340 Control IP Base on Design Report

After modifying and compiling, Si5340A can output new frequencies according to the users' setting.

Note:

1. No need to modify all Design Report parameters in `si5340a_i2c_reg_controller.v`, users can ignore parameters which have nothing to do with the frequency setting
2. After the manually modifying, please remember to modify clock constrain setting in .SDC file

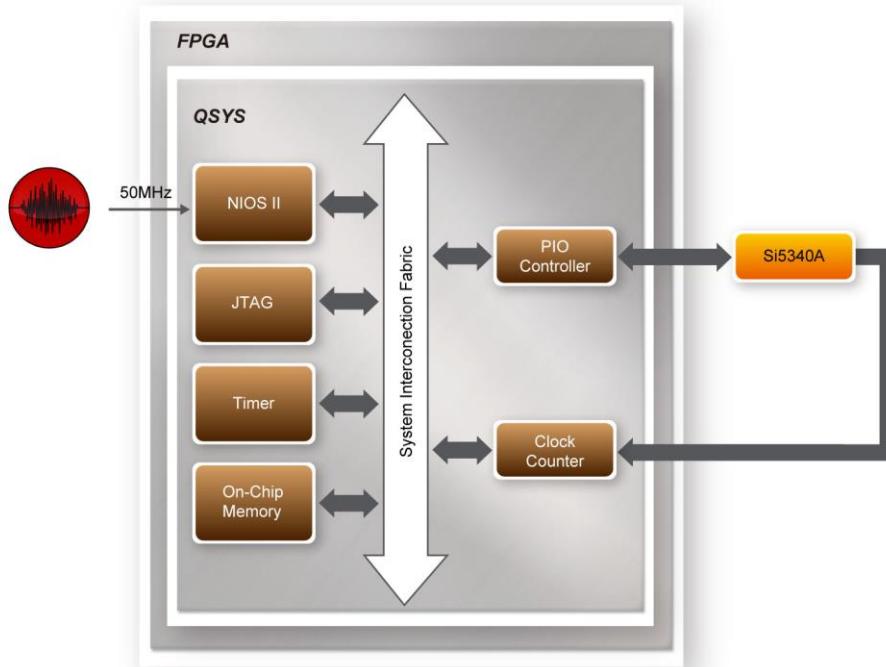
## 4.2 Nios II control for SI5340

This demonstration shows how to use the Nios II processor to program the programmable oscillators (Si5340A) on the FPGA board

### ■ System Block Diagram

**Figure 4-8** shows the system block diagram of this demonstration. The system requires a 50 MHz clock provided from the board. Si5340A is controlled by Nios II through the PIO controller, and programmed through I2C protocol which is implemented in the C code. The I2C pins from chip are connected to Qsys System Interconnect Fabric through PIO controllers. The Nios II program toggles the PIO controller to implement

the I2C protocol. The Nios II program is running in the on-chip memory.



**Figure 4-8 Block diagram of the Nios II Basic Demonstration**

The program provides a menu in nios-terminal, as shown in **Figure 4-9** to provide an interactive interface. With the menu, users can perform the test for Si5340A. Note, pressing 'ENTER' should be followed with the choice number.



**Figure 4-9 Menu of Demo Program**

In the external PLL(Si5340A) programming test, the program will program the PLL first, and subsequently will use TERASIC QSYS custom CLOCK\_COUNTER IP to count the clock count in a specified period to check whether the output frequency is changed as configured. To avoid a Quartus Prime compilation error, dummy transceiver controllers are created to receive the clock from the external PLL. Users can ignore the functionality of the transceiver controller in the demonstration. For Si5340A programming, please

note the device I2C address are 0xEE. The program can control the Si5340A to configure the output frequency of QSFP/A/B, QDRIIA/B/C/D/E REFCLK.

## ■ Demonstration File Locations

- Hardware project directory: NIOS\_BASIC\_DEMO
- Bitstream used: NIOS\_BASIC\_DEMO.sof
- Software project directory: NIOS\_BASIC\_DEMO \software
- Demo batch file: NIOS\_BASIC\_DEMO\demo\_batch\test.bat, test.sh

## ■ Demonstration Setup and Instructions

- Make sure Quartus Prime 18.0 and Nios II EDS are installed on your PC.
- Power on the TR10a-LPQ board.
- Use the USB Cable to connect your PC and the FPGA board and install USB Blaster II driver if necessary.
- Execute the demo batch file “test.bat” under the batch file folder, NIOS\_BASIC\_DEMO\demo\_batch.
- After the Nios II program is downloaded and executed successfully, a prompt message will be displayed in nios2-terminal.
- For programmable PLL Si5340A test, please input key “0” and press “Enter” in the nios-terminal first, then select the desired output frequency of QSFP/A/B/C/D REFCLK, as shown in **Figure 4-10**.

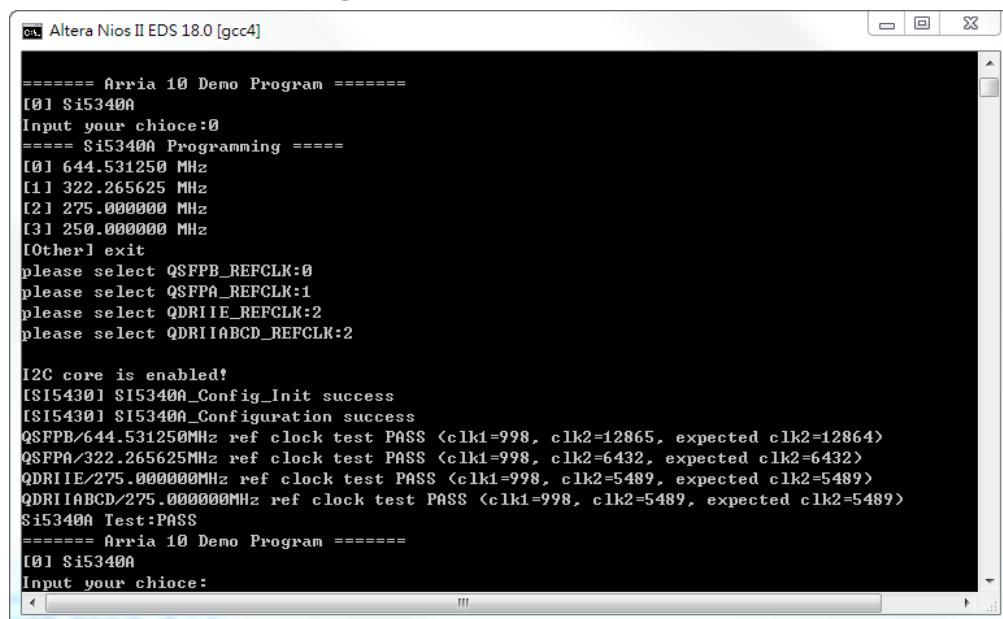


Figure 4-10 Si5340A Demo

## Chapter 5

# Memory Reference Design

This chapter will show two examples which use the Altera Memory IP to perform memory test functions. The source codes of these examples are all available on the FPGA System CD. These three examples are:

- QDRII+ SRAM Test: Full test of the five banks of QDRII+ SRAM
- QDRII+ SRAM Test by Nios II: Full test of five banks of QDRII+ SRAM with Nios II

Note. 64-Bit Quartus Prime Standard 18.0 or later is strongly recommended for compiling these projects.

## 5.1 QDRII+ SRAM Test

QDR II/QDR II+ SRAM devices enable you to maximize memory bandwidth with separate read and write ports. The memory architecture features separate read and write ports operating twice per clock cycle to deliver a total of four data transfers per cycle. The resulting performance increase is particularly valuable in bandwidth-intensive and low-latency applications.

This demonstration utilizes five QDRII+ SRAMs on the FPGA board. It describes how to use Altera's "Arria 10 External Memory Interfaces" (Arria 10 EMIF) IP to implement a memory test function.

### ■ Function Block Diagram

**Figure 5-1** shows the function block diagram of the demonstration. The five QDRII+ SRAM controllers are configured as a 72Mb controller. The QDRII+ SRAM IP generates a 550MHz clock as memory clock and a half-rate system clock, 275MHz, for the

controllers.

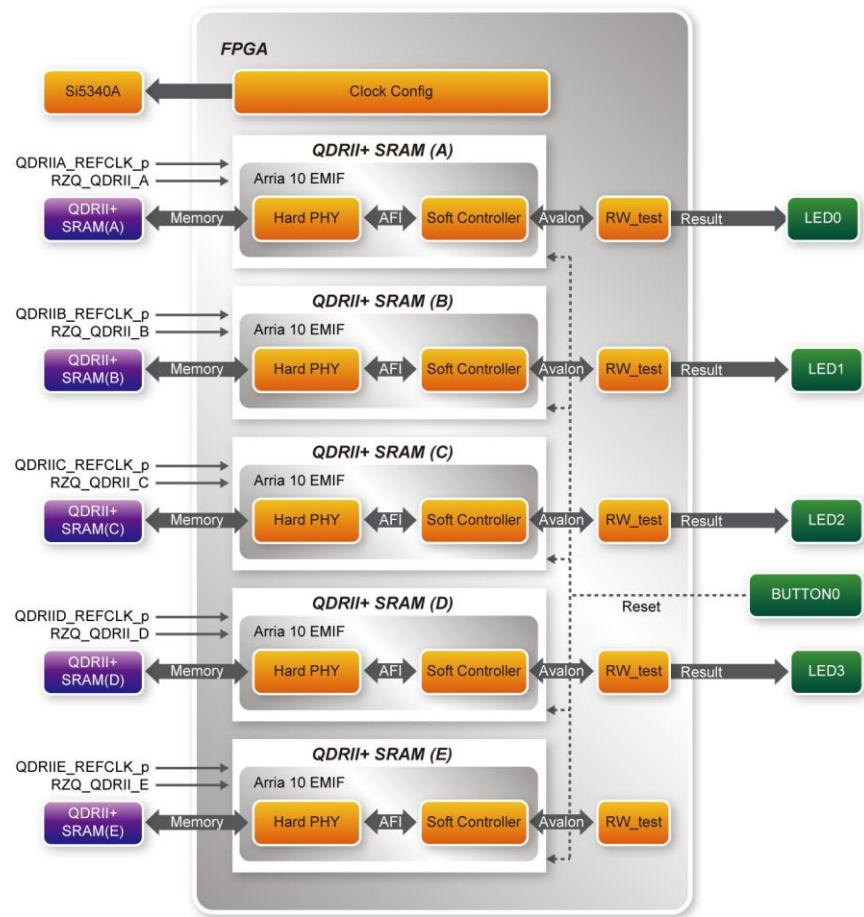


Figure 5-1 Function Block Diagram of the QDRII+ SRAM x4 Demonstration

The QDRIIA/B/C/D/E\_REFCLK is generated from Si5340A which configured 275MHz for QDRII+ 550MHz by Clock Config module. QDRIIA/B/C/D/E\_REFCLK has no default frequency output so that they must be configured first.

In this demonstration, each QDRII+ SRAM has its own PLL, DLL and OCT resources. The Arria 10 EMIF QDRII IP uses a Hard PHY and a soft Controller. The Hard PHY is capable of performing key memory interface functionality such as read/write leveling, FIFO buffering to lower latency and improve margin, timing calibration, and on-chip termination.

The Avalon bus read/write test (RW\_test) modules read and write the entire memory space of each QDRII+ SRAM through the Avalon interface of each controller. In this project, the RW test module will first write the entire memory and then compare the

read back data with the regenerated data (the same sequence as the write data). Test control signals for five QDRII+ SRAMs will generate from CPU\_RESET\_n and four LEDs will indicate the test results of the first four QDRII+ SRAMs.

## ■ Altera QDRII and QDRII+ SRAM Controller with UniPHY

To use Altera QDRII+ SRAM controller, users need to perform the following steps in order:

1. Create correct pin assignments for QDRII+.
2. Setup correct parameters in QDRII+ SRAM controller dialog.

## ■ Design Tools

- Quartus Prime Standard 18.0

## ■ Demonstration Source Code

- Project directory: QDRII\_x5\_Test\_550MHz
- Bit stream used: QDRII\_x5\_Test\_550MHz.sof

## ■ Demonstration Batch File

Demo Batch File Folder: QDRII\_x5\_Test\_550MHz\demo\_batch

The demo batch files include the followings:

- Batch file for USB-Blaster II: test.bat,
- FPGA configuration file: QDRII\_x5\_Test\_550MHz.sof

## ■ Demonstration Setup

- Make sure Quartus Prime Standard 18.0 and Nios II EDS are installed on your PC.
- Connect the USB cable to the FPGA board and host PC. Install the USB-Blaster II driver if necessary.
- Power on the FPGA Board.
- Execute the demo batch file “test.bat” under the batch file folder, QDRII\_x5\_Test\_550MHz \demo\_batch.
- Press CPU\_RESET\_n of the FPGA board to start the verification process. When CPU\_RESET\_n is held down, all the LEDs will be turned off. All LEDs should turn back on to indicate test passes upon the release of CPU\_RESET\_n.
- If any LED is not lit up after releasing CPU\_RESET\_n, it indicates the

corresponding QDRII+ SRAM test has failed. **Table 5-1** lists the matchup for the four LEDs.

- Press CPU\_RESET\_n again to regenerate the test control signals for a repeat test.

**Table 5-1 LED Indicators**

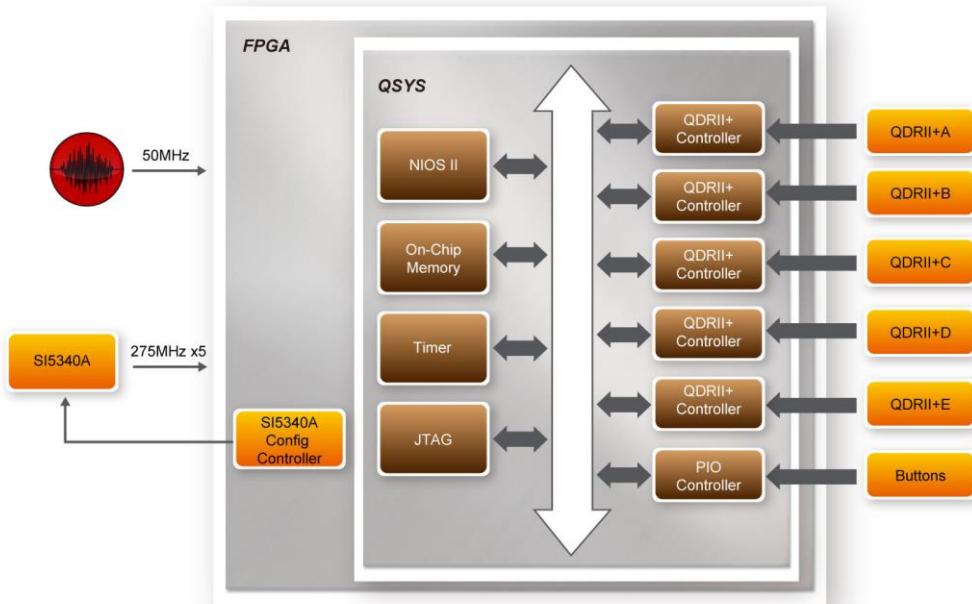
NAME	Description
LED0	QDRII+ SRAM(A) test result
LED1	QDRII+ SRAM(B) test result
LED2	QDRII+ SRAM(C) test result
LED3	QDRII+ SRAM(D) test result

## 5.2 QDRII+ SRAM Test by Nios II

This demonstration hardware and software designs are provided to illustrate how to perform QDRII+ SRAM memory access in QSYS. We describe how the Altera’s “Arria 10 External Memory Interfaces” IP is used to access the five QDRII+ SRAM on the FPGA board, and how the Nios II processor is used to read and write the SRAM for hardware verification. The QDRII+ SRAM controller handles the complex aspects of using QDRII+ SRAM by initializing the memory devices, managing SRAM banks, and keeping the devices refreshed at appropriate intervals.

### ■ System Block Diagram

**Figure 5-2** shows the system block diagram of this demonstration. The QSYS system requires one 50 MHz and five 550MHz clock source. The five 550MHz clock source is provided by Si5340A clock generator on the board. Si5340A Config Controller is used to configure the Si5340A to generate the required clock. The five 550MHz clock are used as reference clocks for the QDRII+ controllers. There are five QDRII+ Controllers are used in the demonstrations. Each controller is responsible for one QDRII+ SRAM. Each QDRII+ controller is configured as a 8 MB QDRII+ controller. Nios II processor is used to perform memory test. The Nios II program is running in the On-Chip Memory. A PIO Controller is used to monitor buttons status which is used to trigger starting memory testing.



**Figure 5-2 Block diagram of the QDRII+ Demonstration**

The system flow is controlled by a Nios II program. First, the Nios II program writes test patterns into the whole 8 MB of SRAM. Then, it calls Nios II system function, `alt_dcache_flush_all()`, to make sure all data has been written to SRAM. Finally, it reads data from SRAM for data verification. The program will show progress in JTAG-Terminal when writing/reading data to/from the SRAM. When verification process is completed, the result is displayed in the JTAG-Terminal.

## ■ Design Tools

- Quartus Prime Standard 18.0.
- Nios II Eclipse 18.0

## ■ Demonstration Source Code

- Quartus Project directory: NIOS\_QDRII\_x5\_550
- Nios II Eclipse: NIOS\_QDRII\_x5\_550\software
- Nios II Project Compilation

## ■ Nios II Project Compilation

Before you attempt to compile the reference design under Nios II Eclipse, make sure the project is cleaned first by clicking 'Clean' from the 'Project' menu of Nios II Eclipse.

## ■ Demonstration Batch File

Demo Batch File Folder: NIOS\_QDRII\_x5\_550\demo\_batch

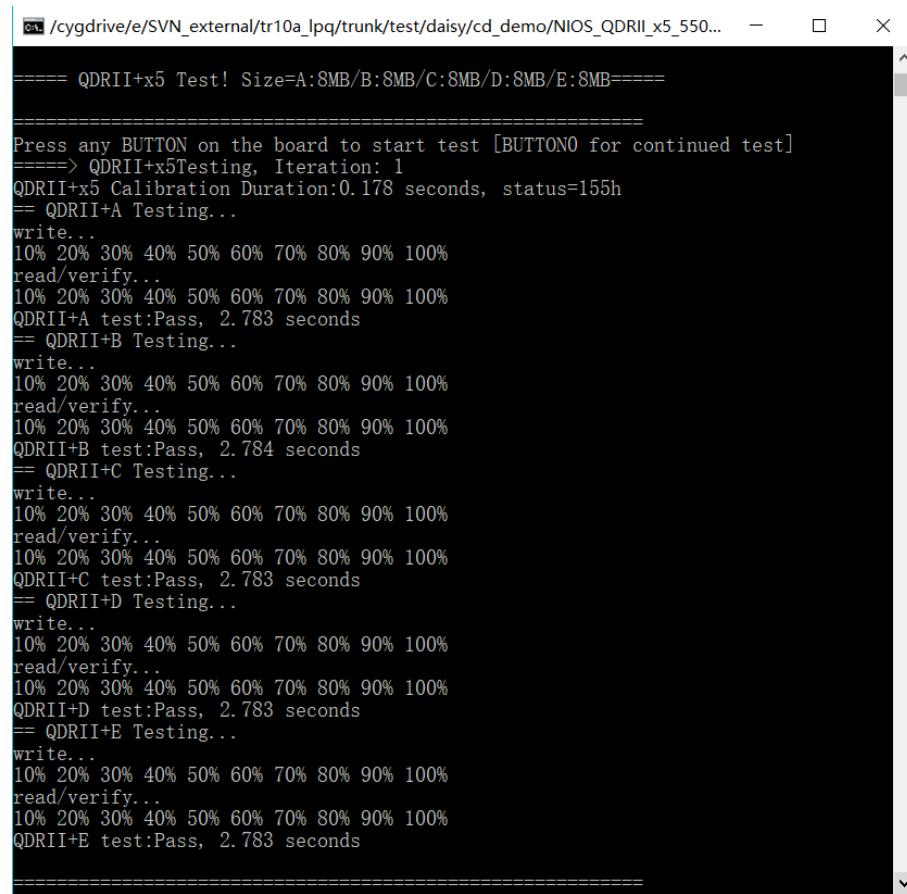
The demo batch file includes following files:

- Batch File for USB-Blaster II: test.bat, test.sh
- FPGA Configure File: NIOS\_QDRII\_x5\_550.sof
- Nios II Program: TEST\_QDRII.elf

## ■ Demonstration Setup

Please follow below procedures to setup the demonstrations.

- Make sure Quartus Prime Standard 18.0 and Nios II 18.0 are installed on your PC.
- Make sure both QDRII+ SRAMs are installed on the FPGA board.
- Power on the FPGA board.
- Use USB Cable to connect PC and the FPGA board and install USB Blaster II driver if necessary.
- Execute the demo batch file “test.bat” under the folder “NIOS\_QDRII\_x5\_550\demo\_batch”.
- After Nios II program is downloaded and executed successfully, a prompt message will be displayed in nios2-terminal.
- Press Button1~Button0 of the FPGA board to start SRAM verify process. Press Button0 for continued test.
- The program will display progressing and result information, as shown in **Figure 5-3**.



```
==== QDRII+x5 Test! Size=A:8MB/B:8MB/C:8MB/D:8MB/E:8MB====  
=====  
Press any BUTTON on the board to start test [BUTTON0 for continued test]  
=====> QDRII+x5Testing, Iteration: 1  
QDRII+x5 Calibration Duration:0.178 seconds, status=155h  
== QDRII+A Testing...  
write...  
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%  
read/verify...  
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%  
QDRII+A test:Pass, 2.783 seconds  
== QDRII+B Testing...  
write...  
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%  
read/verify...  
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%  
QDRII+B test:Pass, 2.784 seconds  
== QDRII+C Testing...  
write...  
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%  
read/verify...  
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%  
QDRII+C test:Pass, 2.783 seconds  
== QDRII+D Testing...  
write...  
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%  
read/verify...  
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%  
QDRII+D test:Pass, 2.783 seconds  
== QDRII+E Testing...  
write...  
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%  
read/verify...  
10% 20% 30% 40% 50% 60% 70% 80% 90% 100%  
QDRII+E test:Pass, 2.783 seconds  
=====
```

Figure 5-3 Progress and Result Information for the QDRII+ Demonstration

## ***PCI Express Reference Design***

---

**P**CI Express is commonly used in consumer, server, and industrial applications, to link motherboard-mounted peripherals. From this demonstration, it will show how the PC and FPGA communicate with each other through the PCI Express interface. Arria 10 Hard IP for PCI Express with Avalon-MM DMA IP is used in this demonstration. For detail about this IP, please refer to Altera document [ug\\_a10\\_pcie\\_avmm\\_dma.pdf](#).

### **6.1 PCI Express System Infrastructure**

**Figure 6-1** shows the infrastructure of the PCI Express System in this demonstration. It consists of two primary components: FPGA System and PC System. The FPGA System is developed based on Arria 10 Hard IP for PCI Express with Avalon-MM DMA. The application software on the PC side is developed by Terasic based on Altera's PCIe kernel mode driver.

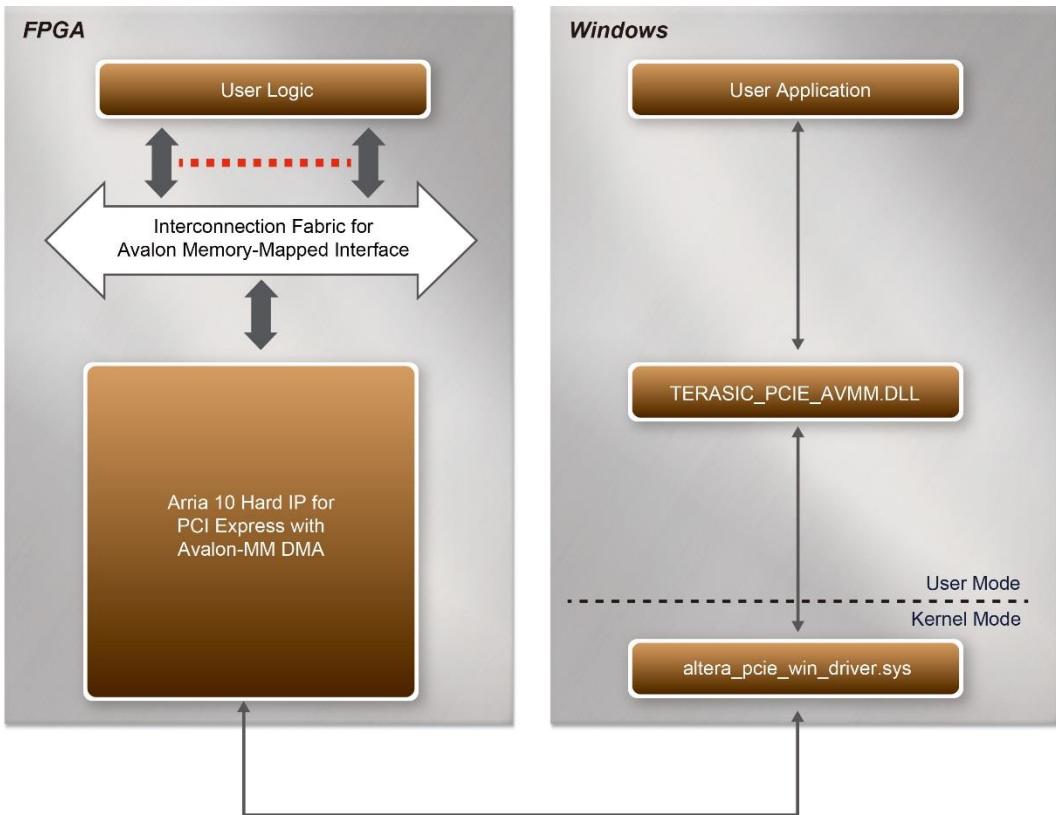


Figure 6-1 Infrastructure of PCI Express System

## 6.2 PC PCI Express Software SDK

The FPGA System CD contains a PC Windows based SDK to allow users to develop their 64-bit software application on Windows 7/Window XP 64-bit. The SDK is located in the "CDROM \demonstrations\PCIe\_SW\_KIT" folder which includes:

- PCI Express Driver
- PCI Express Library
- PCI Express Examples

The kernel mode driver assumes the PCIe vendor ID (VID) is 0x1172 and the device ID (DID) is 0xE003. If different VID and DID are used in the design, users need to modify the PCIe vendor ID (VID) and device ID (DID) in the driver INF file accordingly.

The PCI Express Library is implemented as a single DLL named "TERASIC\_PCIE\_AVMM.DLL".

This file is a 64-bit DLL. With the DLL is exported to the software API, users can easily

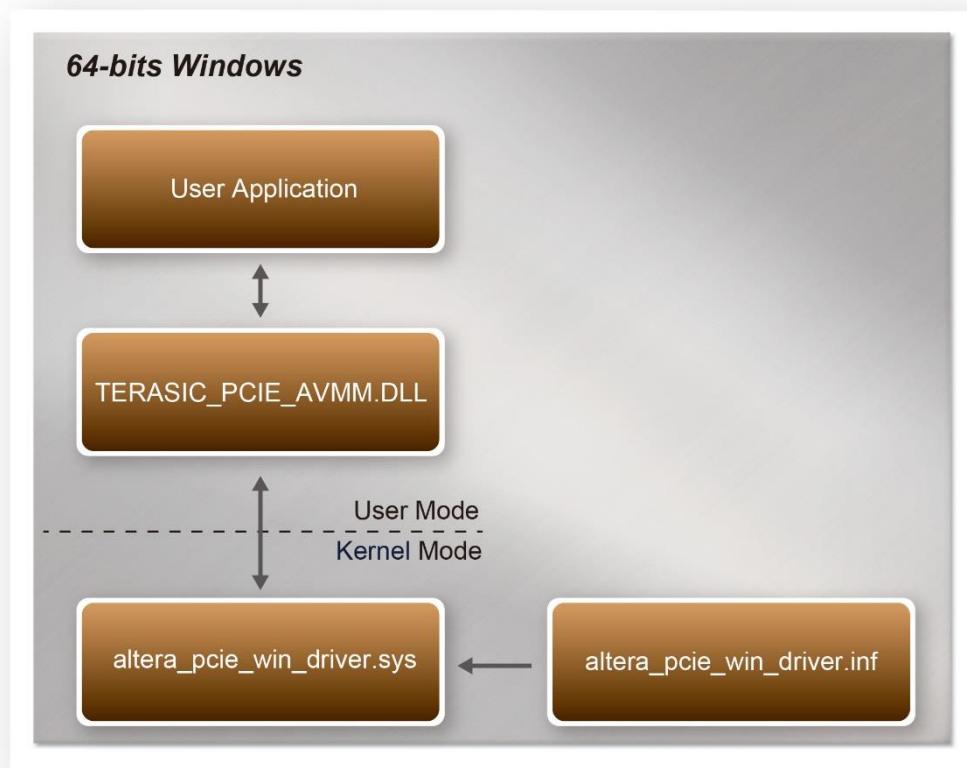
communicate with the FPGA. The library provides the following functions:

- Basic data read and write
- Data read and write by DMA

For high performance data transmission, Altera AVMM DMA is required as the read and write operations are specified under the hardware design on the FPGA.

## 6.3 PCI Express Software Stack

**Figure 6-2** shows the software stack for the PCI Express application software on 64-bit Windows. The PCI Express driver incorporated in the DLL library is called "TERASIC\_PCIE\_AVMM.dll". Users can develop their applications based on this DLL. The "altera\_pcie\_win\_driver.sys" kernel driver is provided by Altera.



**Figure 6-2 PCI Express Software Stack**

## ■ Install PCI Express Driver on Windows

The PCIe driver is located in the folder:

CDROM\Demonstrations\PCIe\_SW\_KIT\Windows\PCIe\_Driver

The folder includes the following four files:

- Altera\_pcie\_win\_driver.cat
- Altera\_pcie\_win\_driver.inf
- Altera\_pcie\_win\_driver.sys
- WdfCoInstaller01011.dll

To install the PCI Express driver, please execute the steps below:

1. Install the TR10a-LPQ on the PCIe slot of the host PC
2. Make sure Altera Programmer and USB-Blaster II driver are installed
3. Execute test.bat in "CDROM\Demonstrations\PCIe\_Fundamental\demo\_batch" to configure the FPGA
4. Restart windows operation system
5. Click Control Panel menu from Windows Start menu. Click Hardware and Sound item before clicking the Device Manager to launch the Device Manager dialog. There will be a PCI Device item in the dialog, as shown in **Figure 6-3**. Move the mouse cursor to the PCI Device item and right click it to select the Update Driver Software... item.

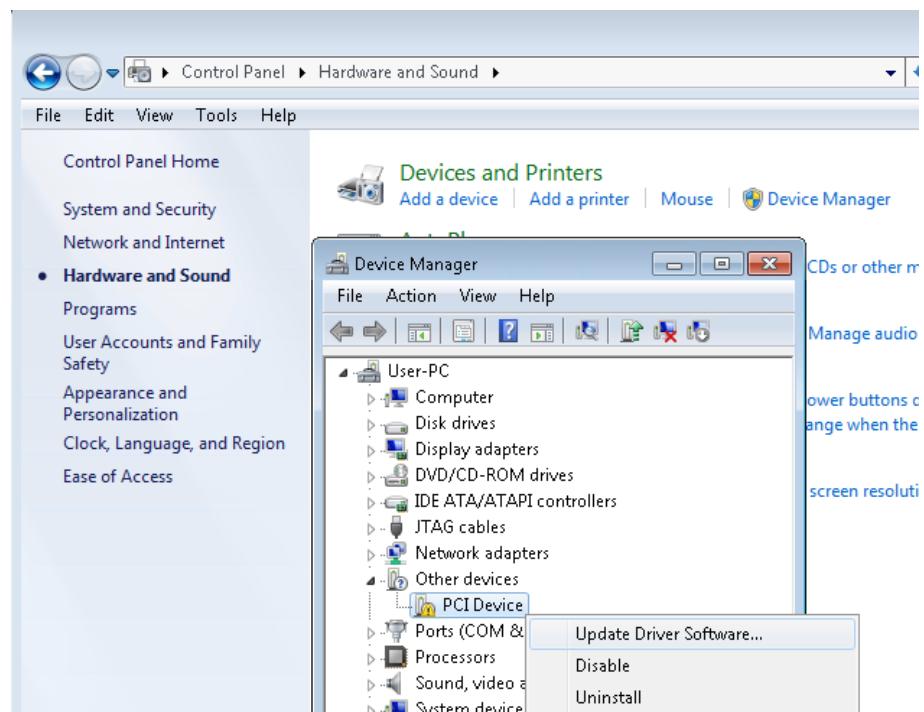


Figure 6-3 Screenshot of launching Update Driver Software... dialog

6. In the **How do you want to search for driver software** dialog, click **Browse my computer for driver software** item, as shown in [Figure 6-4](#).

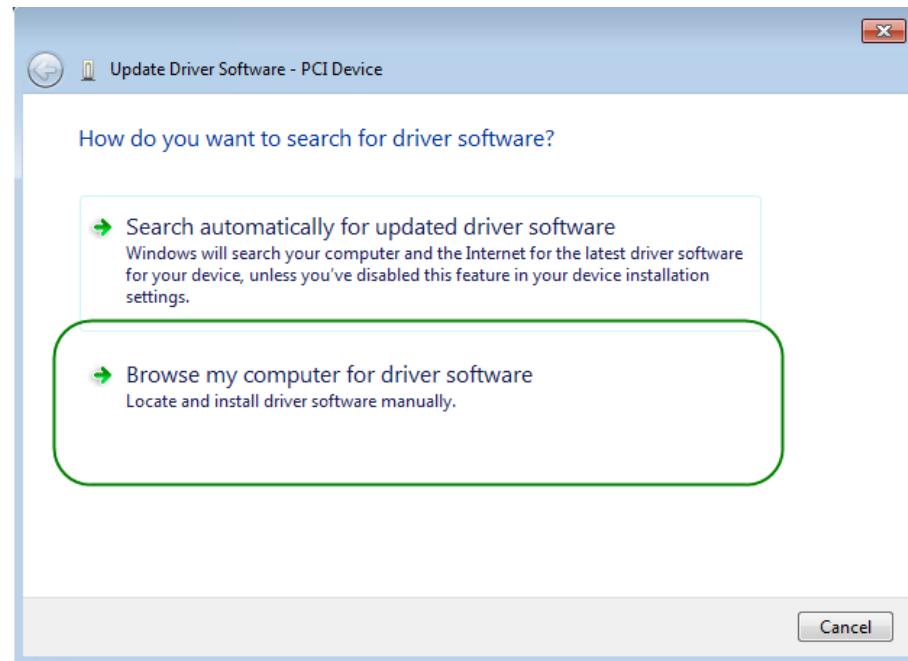
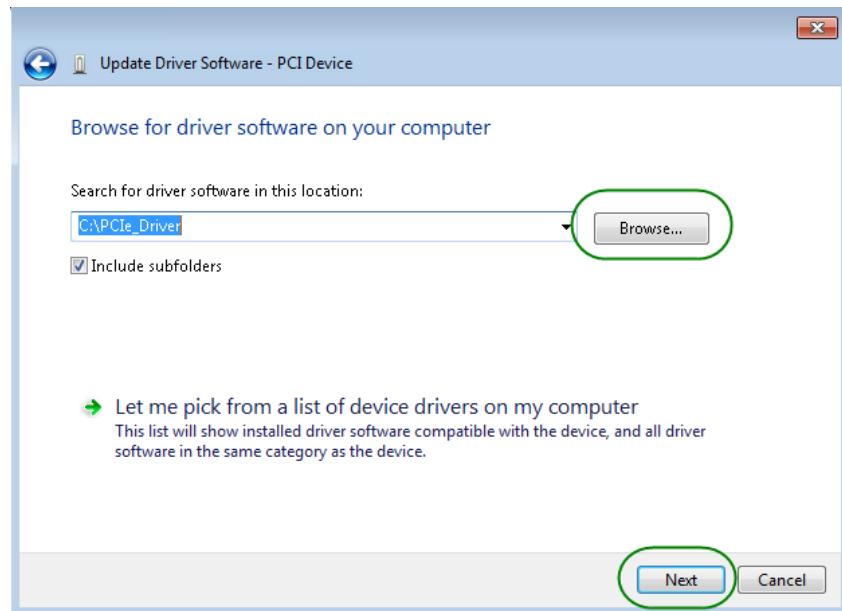


Figure 6-4 Dialog of Browse my computer for driver software

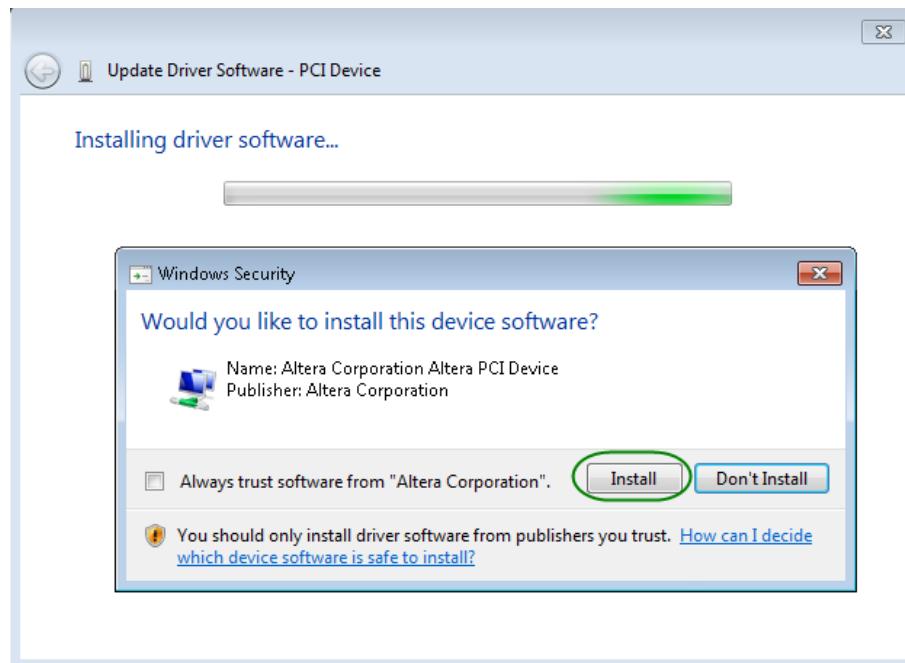
7. In the **Browse for driver software on your computer** dialog, click the **Browse**

button to specify the folder where `altera_pcie_din_driver.inf` is located, as shown in **Figure 6-5**. Click the **Next** button.



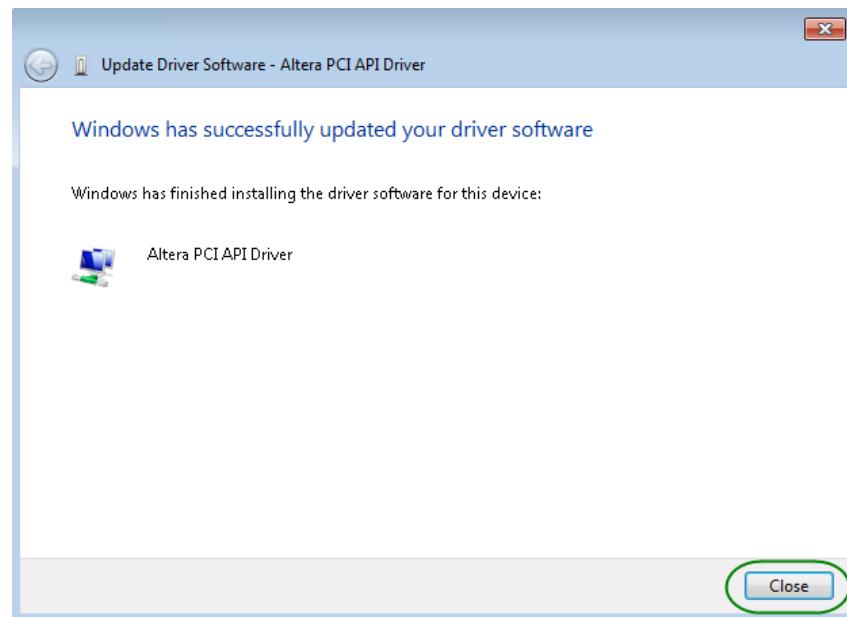
**Figure 6-5** Browse for driver software on your computer

8. When the **Windows Security** dialog appears, as shown **Figure 6-6**, click the **Install** button.



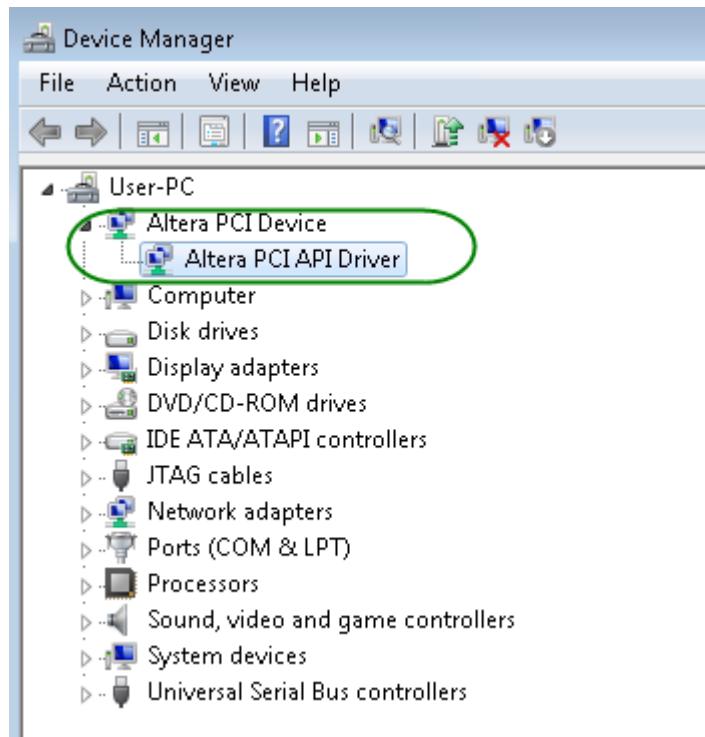
**Figure 6-6** Click **Install** in the dialog of **Windows Security**

- When the driver is installed successfully, the successfully dialog will appear, as shown in **Figure 6-7**. Click the **Close** button.



**Figure 6-7 Click Close when the installation of Altera PCI API Driver is complete**

Once the driver is successfully installed, users can see the **Altera PCI API Driver** under the device manager window, as shown in **Figure 6-8**.



**Figure 6-8 Altera PCI API Driver in Device Manager**

## ■ Create a Software Application

All the files needed to create a PCIe software application are located in the directory CDROM\demonstration\PCIe\_SW\_KIT\PCIe\_Library. It includes the following files:

- TERASIC\_PCIE\_AVMM.h
- TERASIC\_PCIE\_AVMM.DLL (64-bit DLL)

Below lists the procedures to use the SDK files in users' C/C++ project :

1. Create a 64-bit C/C++ project.
2. Include "TERASIC\_PCIE\_AVMM.h" in the C/C++ project.
3. Copy "TERASIC\_PCIE\_AVMM.DLL" to the folder where the project.exe is located.
4. Dynamically load "TERASIC\_PCIE\_AVMM.DLL" in C/C++ program. To load the DLL, please refer to the PCIe fundamental example below.
5. Call the SDK API to implement the desired application.

Users can easily communicate with the FPGA through the PCIe bus through the "TERASIC\_PCIE\_AVMM.DLL" API. The details of API are described below:

## ■ PCIE\_Open

### Function:

Open a specified PCIe card with vendor ID, device ID, and matched card index.

### Prototype:

```
PCIE_HANDLE PCIE_Open(  
    WORD wVendorID,  
    WORD wDeviceID,  
    WORD wCardIndex);
```

### Parameters:

wVendorID:

Specify the desired vendor ID. A zero value means to ignore the vendor ID.

wDeviceID:

Specify the desired device ID. A zero value means to ignore the device ID.

wCardIndex:

Specify the matched card index, a zero based index, based on the matched vendor ID and device ID.

### Return Value:

Return a handle to presents specified PCIe card. A positive value is return if the PCIe card is opened successfully. A value zero means failed to connect the target PCIe card.

This handle value is used as a parameter for other functions, e.g. PCIE\_Read32.

Users need to call PCIE\_Close to release handle once the handle is no more used.

## ■ PCIE\_Close

### Function:

Close a handle associated to the PCIe card.

### Prototype:

```
void PCIE_Close(  
    PCIE_HANDLE hPCIE);
```

### Parameters:

hPCIE:

A PCIe handle return by PCIE\_Open function.

### Return Value:

None.

## ■ PCIE\_Read32

### Function:



Read a 32-bit data from the FPGA board.

**Prototype:**

```
bool PCIE_Read32(  
    PCIE_HANDLE hPCIE,  
    PCIE_BAR PcieBar,  
    PCIE_ADDRESS PcieAddress,  
    DWORD * pdwData);
```

**Parameters:**

hPCIE:

A PCIe handle return by PCIE\_Open function.

PcieBar:

Specify the target BAR.

PcieAddress:

Specify the target address in FPGA.

pdwData:

A buffer to retrieve the 32-bit data.

**Return Value:**

Return TRUE if read data is successful; otherwise FALSE is returned.

## ■ PCIE\_Write32

**Function:**

Write a 32-bit data to the FPGA Board.

Maximal write size is (4GB-1) bytes.

**Prototype:**

```
bool PCIE_Write32(  
    PCIE_HANDLE hPCIE,  
    PCIE_BAR PcieBar,  
    PCIE_ADDRESS PcieAddress,  
    DWORD dwData);
```

**Parameters:**

hPCIE:

A PCIe handle return by PCIE\_Open function.

PcieBar:

Specify the target BAR.

PcieAddress:

Specify the target address in FPGA.

dwData:

Specify a 32-bit data which will be written to FPGA board.

**Return Value:**

Return TRUE if write data is successful; otherwise FALSE is returned.

## ■ PCIE\_DmaRead

**Function:**

Read data from the memory-mapped memory of FPGA board in DMA.

Maximal read size is (4GB-1) bytes.

**Prototype:**

```
bool PCIE_DmaRead(  
    PCIE_HANDLE hPCIE,  
    PCIE_LOCAL_ADDRESS LocalAddress,  
    void *pBuffer,  
    DWORD dwBufSize  
)
```

**Parameters:**

hPCIE:

A PCIe handle return by PCIE\_Open function.

LocalAddress:

Specify the target memory-mapped address in FPGA.

pBuffer:

A pointer to a memory buffer to retrieved the data from FPGA. The size of buffer should be equal or larger the dwBufSize.

dwBufSize:

Specify the byte number of data retrieved from FPGA.

**Return Value:**

Return TRUE if read data is successful; otherwise FALSE is returned.

## ■ PCIE\_DmaWrite

**Function:**

Write data to the memory-mapped memory of FPGA board in DMA.

**Prototype:**

```
bool PCIE_DmaWrite(  
    PCIE_HANDLE hPCIE,  
    PCIE_LOCAL_ADDRESS LocalAddress,  
    void *pData,  
    DWORD dwDataSize  
)
```

**Parameters:**

hPCIE:

A PCIe handle return by PCIE\_Open function.

LocalAddress:

Specify the target memory mapped address in FPGA.

pData:

A pointer to a memory buffer to store the data which will be written to FPGA.

dwDataSize:

Specify the byte number of data which will be written to FPGA.

**Return Value:**

Return TRUE if write data is successful; otherwise FALSE is returned.

## ■ PCIE\_ConfigRead32

**Function:**

Read PCIe Configuration Table. Read a 32-bit data by given a byte offset.

**Prototype:**

```
bool PCIE_ConfigRead32 (  
    PCIE_HANDLE hPCIE,  
    DWORD Offset,  
    DWORD *pdwData  
)
```

**Parameters:**

hPCIE:

A PCIe handle return by PCIE\_Open function.

Offset:

Specify the target byte of offset in PCIe configuration table.

pdwData:

A 4-bytes buffer to retrieve the 32-bit data.

**Return Value:**

Return TRUE if read data is successful; otherwise FALSE is returned.

## 6.4 PCIe Design - Fundamental

The application reference design shows how to implement fundamental control and data transfer in DMA. In the design, basic I/O is used to control the BUTTON and LED on the FPGA board. High-speed data transfer is performed by DMA.

### ■ Demonstration Files Location

The demo file is located in the batch folder:

CDROM\demonstrations\PCIe\_fundamental\demo\_batch

The folder includes following files:

- FPGA Configuration File: PCIe\_Fundamental.sof
- Download Batch file: test.bat
- Windows Application Software folder : windows\_app, includes
  - ◊ PCIE\_FUNDAMENTAL.exe
  - ◊ TERASIC\_PCIE\_AVMM.dll

### ■ Demonstration Setup

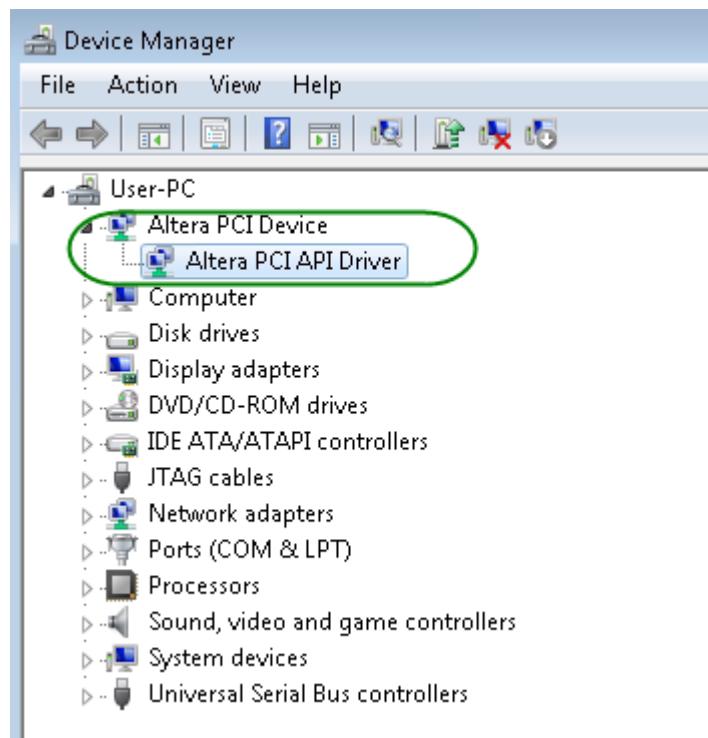
1. Install the FPGA board on your PC as shown in **Figure 6-9**.



**Figure 6-9** FPGA board installation on PC

2. Configure FPGA with PCIe\_Fundamental.sof by executing the test.bat.
3. Install PCIe driver if necessary. The driver is located in the folder:

4. Restart Windows
5. Make sure the Windows has detected the FPGA Board by checking the Windows Control panel as shown in **Figure 6-10**.



**Figure 6-10 Screenshot for PCIe Driver**

6. Goto windows\_app folder, execute PCIE\_FUNDMENTAL.exe. A menu will appear as shown in **Figure 6-11**.

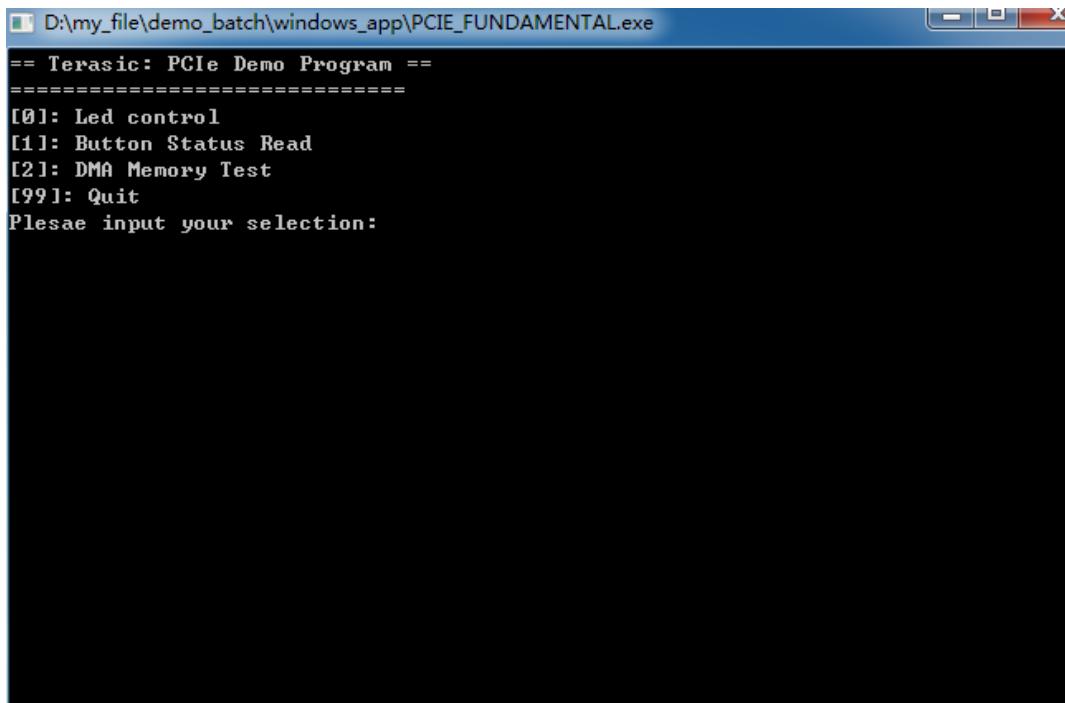


Figure 6-11 Screenshot of Program Menu

7. Type 0 followed by a ENTERY key to select Led Control item, then input 15 (hex 0x0f) will make all led on as shown in **Figure 6-12**. If input 0(hex 0x00), all led will be turn off.

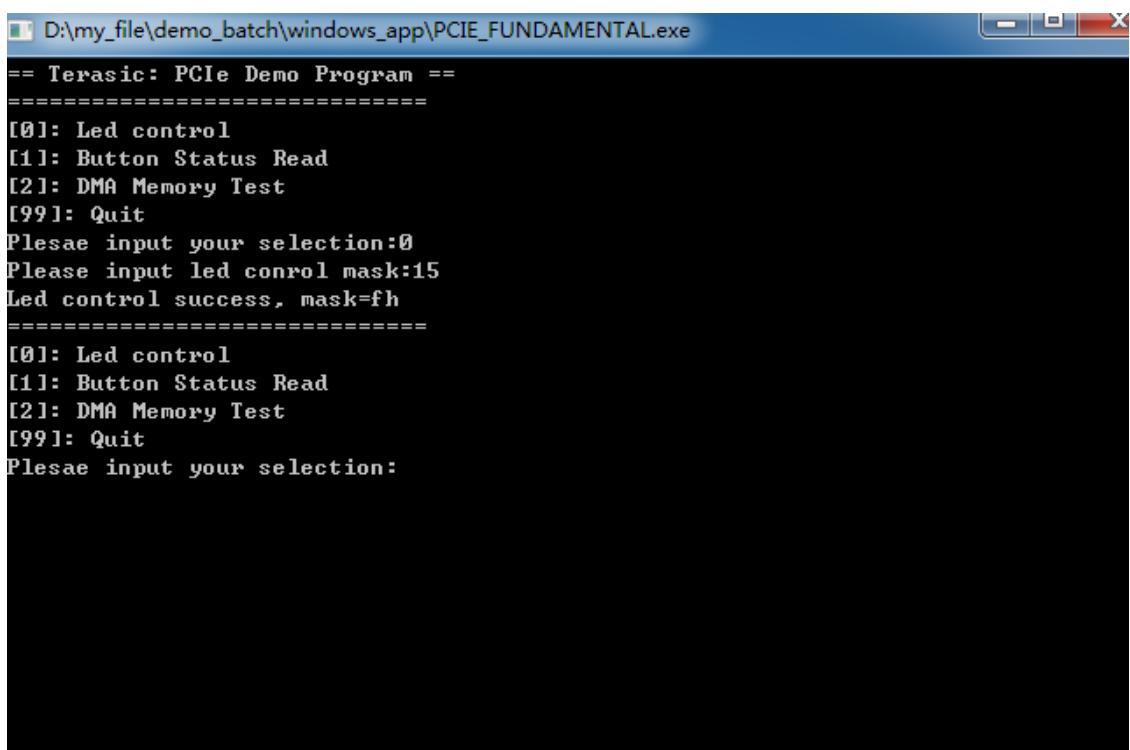
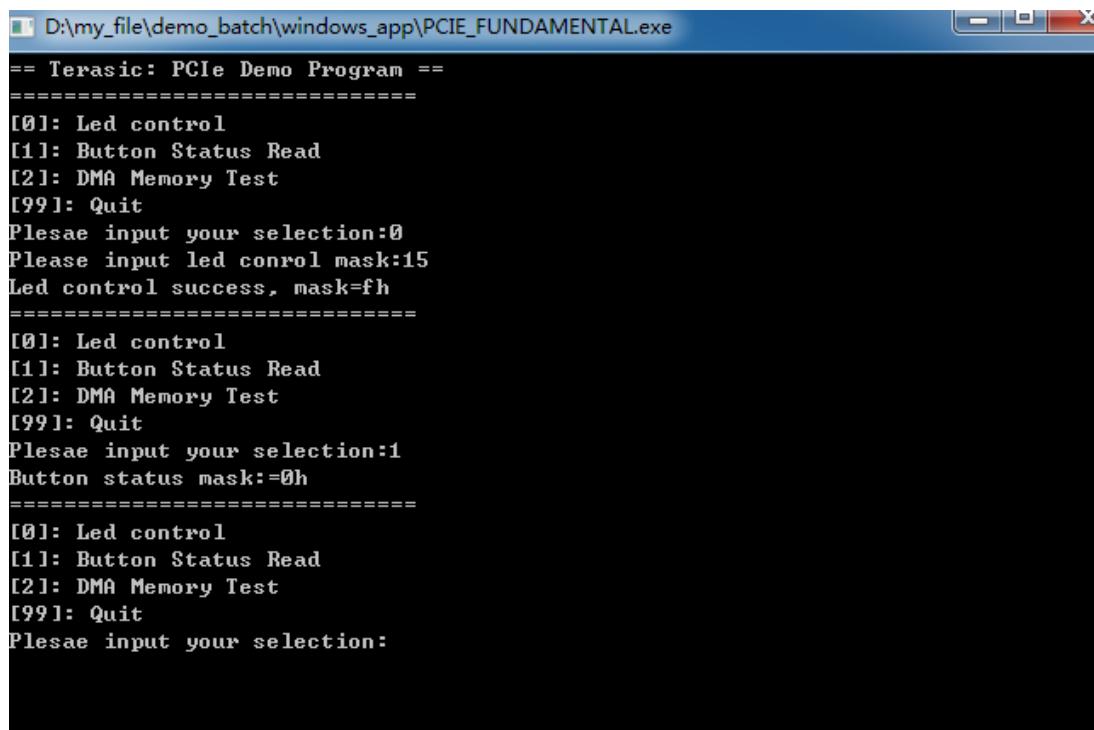


Figure 6-12 Screenshot of LED Control

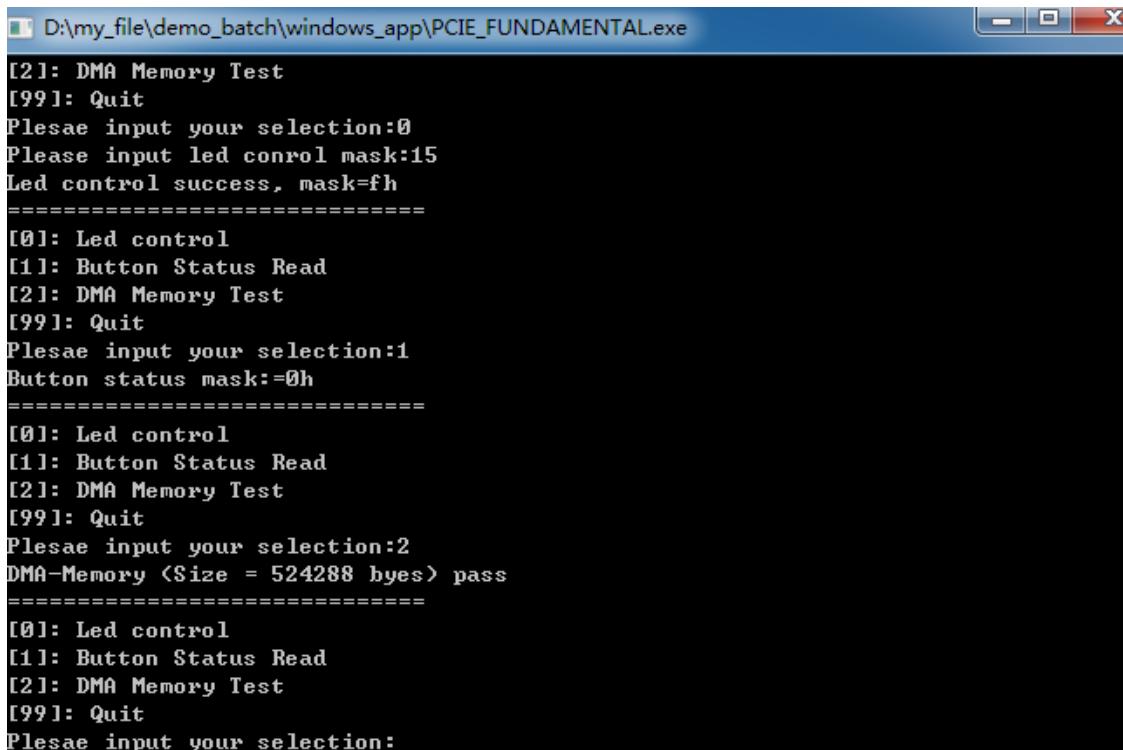
8. Type 1 followed by an ENTRY key to select Button Status Read item. The button status will be report as shown in **Figure 6-13**.



```
D:\my_file\demo_batch\windows_app\PCIE_FUNDAMENTAL.exe
== Terasic: PCIe Demo Program ==
=====
[0]: Led control
[1]: Button Status Read
[2]: DMA Memory Test
[99]: Quit
Please input your selection:0
Please input led control mask:15
Led control success, mask=fh
=====
[0]: Led control
[1]: Button Status Read
[2]: DMA Memory Test
[99]: Quit
Please input your selection:1
Button status mask:=0h
=====
[0]: Led control
[1]: Button Status Read
[2]: DMA Memory Test
[99]: Quit
Please input your selection:
```

Figure 6-13 Screenshot of Button Status Report

9. Type 2 followed by an ENTRY key to select DMA Testing item. The DMA test result will be report as shown in **Figure 6-14**.



```

D:\my_file\demo_batch\windows_app\PCIE_FUNDAMENTAL.exe

[2]: DMA Memory Test
[99]: Quit
Plesae input your selection:0
Please input led conrol mask:15
Led control success, mask=fh
=====
[0]: Led control
[1]: Button Status Read
[2]: DMA Memory Test
[99]: Quit
Plesae input your selection:1
Button status mask:=0h
=====
[0]: Led control
[1]: Button Status Read
[2]: DMA Memory Test
[99]: Quit
Plesae input your selection:2
DMA-Memory <Size = 524288 byes> pass
=====
[0]: Led control
[1]: Button Status Read
[2]: DMA Memory Test
[99]: Quit
Plesae input your selection:

```

Figure 6-14 Screenshot of DMA Memory Test Result

10. Type 99 followed by an ENTRY key to exit this test program

## ■ Development Tools

- Quartus Prime Standard 18.0
- Visual C++ 2012

## ■ Demonstration Source Code Location

- Quartus Project: Demonstrations\PCIe\_Fundamental
- Visual C++ Project: Demonstrations\PCIe\_SW\_KIT\PCIE\_FUNDAMENTAL

## ■ FPGA Application Design

**Figure 6-15** shows the system block diagram in the FPGA system. In the Qsys, Altera PIO controller is used to control the LED and monitor the Button Status, and the On-Chip memory is used for performing DMA testing. The PIO controllers and the On-Chip memory are connected to the PCI Express Hard IP controller through the Memory-Mapped Interface.

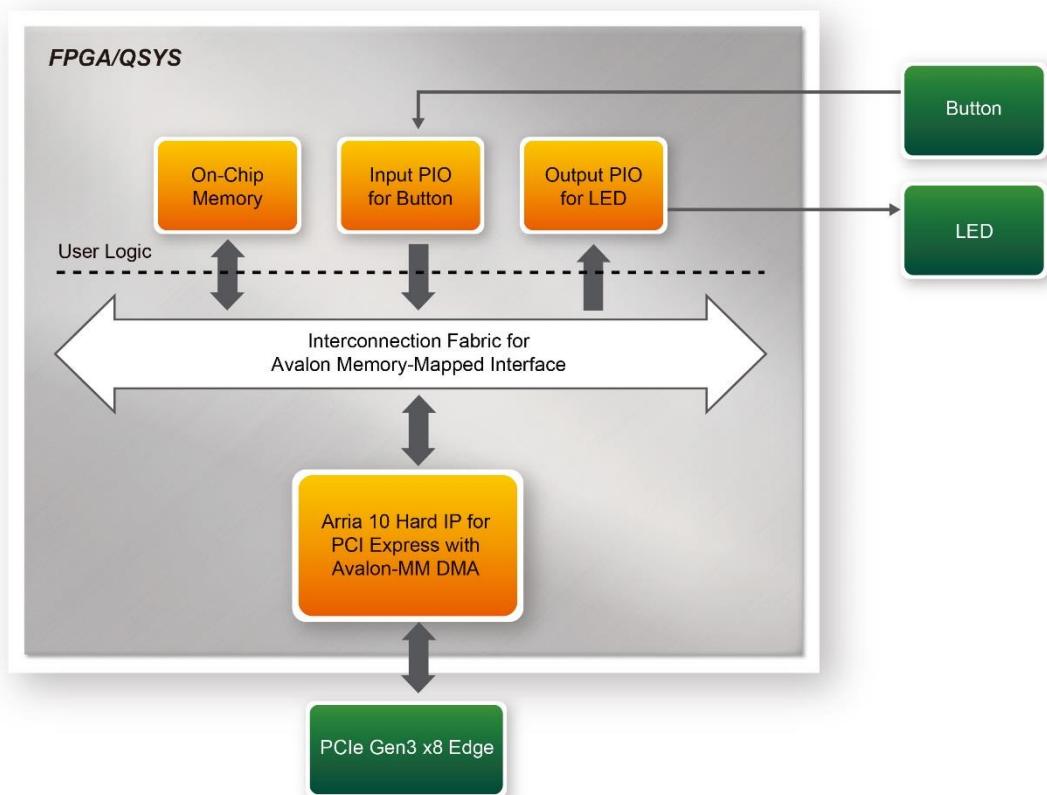


Figure 6-15 Hardware block diagram of the PCIe reference design

## ■ Windows Based Application Software Design

The application software project is built by Visual C++ 2012. The project includes the following major files:

Name	Description
PCIE_FUNDAMENTAL.cpp	Main program
PCIE.c	Implement dynamically load for
PCIE.h	TERASIC_PCIE_AVMM.DLL
TERASIC_PCIE_AVMM.h	SDK library file, defines constant and data structure

The main program PCIE\_FUNDAMENTAL.cpp includes the header file "PCIE.h" and defines the controller address according to the FPGA design.

```

#include "PCIE.h"

#define DEMO_PCIE_USER_BAR      PCIE_BAR4
#define DEMO_PCIE_IO_LED_ADDR  0x4000010
#define DEMO_PCIE_IO_BUTTON_ADDR 0x4000020
#define DEMO_PCIE_MEM_ADDR     0x00000000

#define MEM_SIZE      (512*1024) //512KB

```

The base address of BUTTON and LED controllers are 0x4000010 and 0x4000020 based on PCIE\_BAR4, in respectively. The on-chip memory base address is 0x00000000 relative to the DMA controller.

Before accessing the FPGA through PCI Express, the application first calls PCIE\_Load to dynamically load the TERASIC\_PCIE\_AVMM.DLL. Then, it call PCIE\_Open to open the PCI Express driver. The constant DEFAULT\_PCIE\_VID and DEFAULT\_PCIE\_DID used in PCIE\_Open are defined in TERASIC\_PCIE\_AVMM.h. If developer change the Vender ID and Device ID and PCI Express IP, they also need to change the ID value define in TERASIC\_PCIE\_AVMM.h. If the return value of PCIE\_Open is zero, it means the driver cannot be accessed successfully. In this case, please make sure:

- The FPGA is configured with the associated bit-stream file and the host is rebooted.
- The PCI express driver is loaded successfully.

The LED control is implemented by calling PCIE\_Write32 API, as shown below:

```
bPass = PCIE_Write32(hPCIE, DEMO_PCIE_USER_BAR, DEMO_PCIE_IO_LED_ADDR, (DWORD)Mask);
```

The button status query is implemented by calling the **PCIE\_Read32** API, as shown below:

```
PCIE_Read32(hPCIE, DEMO_PCIE_USER_BAR, DEMO_PCIE_IO_BUTTON_ADDR, &Status);
```

The memory-mapped memory read and write test is implemented by **PCIE\_DmaWrite** and **PCIE\_DmaRead** API, as shown below:

```
PCIE_DmaWrite(hPCIE, LocalAddr, pWrite, nTestSize);
PCIE_DmaRead(hPCIE, LocalAddr, pRead, nTestSize);
```

## 6.5 PCIe Design – QDRII+

The application reference design shows how to add QDRII+ Memory Controllers for five QDRII+ SRAMs into the PCIe Quartus project based on the PCI\_Fundamental Quartus project and perform 8MB data DMA for five SRAMs. Also, this demo shows how to call "PCIE\_ConfigRead32" API to check PCIe link status.

### ■ Demonstration Files Location

The demo file is located in the batch folder:

CDROM\demonstrations\PCIe\_QDR\demo\_batch

The folder includes following files:

- FPGA Configuration File: PCIe\_QDR.sof
- Download Batch file: test.bat
- Windows Application Software folder : windows\_app, includes
  - ✧ PCIE\_QDR.exe
  - ✧ TERASIC\_PCIE\_AVMM.dll

### ■ Demonstration Setup

1. Install the FPGA board on your PC.
2. Configure FPGA with PCIe\_QDR.sof by executing the test.bat.
3. Install PCIe driver if necessary.
4. Restart Windows
5. Make sure the Windows has detected the FPGA Board by checking the Windows Control panel.
6. Goto windows\_app folder, execute PCIE\_QDR.exe. A menu will appear as shown in **Figure 6-16**.

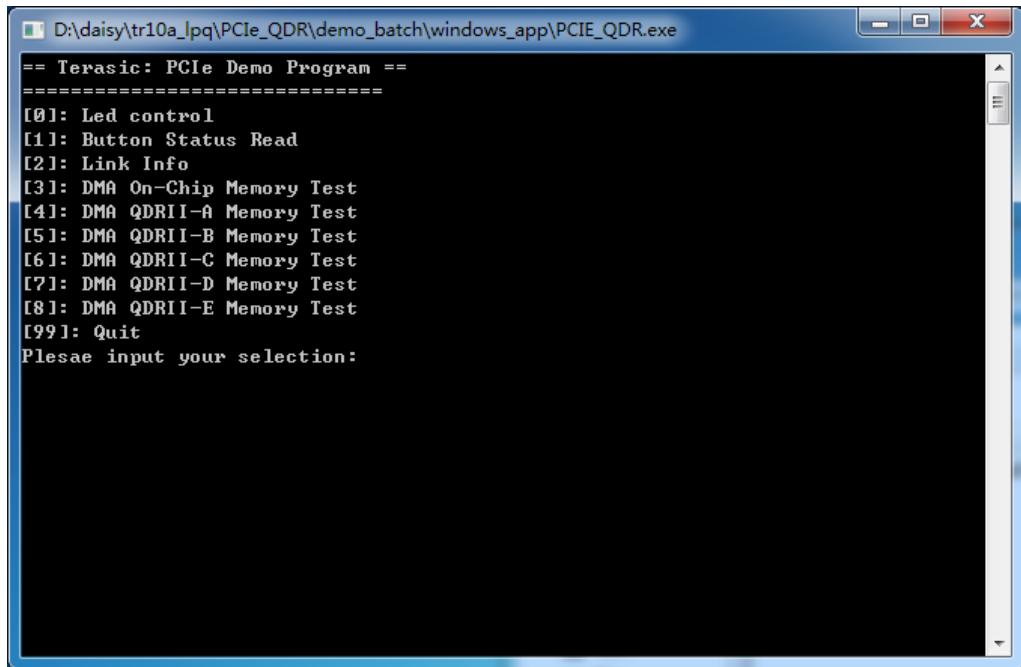


Figure 6-16 Screenshot of Program Menu

7. Type 2 followed by a ENTERY key to select Link Info item. The PICe link information will be shown as in **Figure 6-17**. Gen3 link speed and x8 link width are expected.

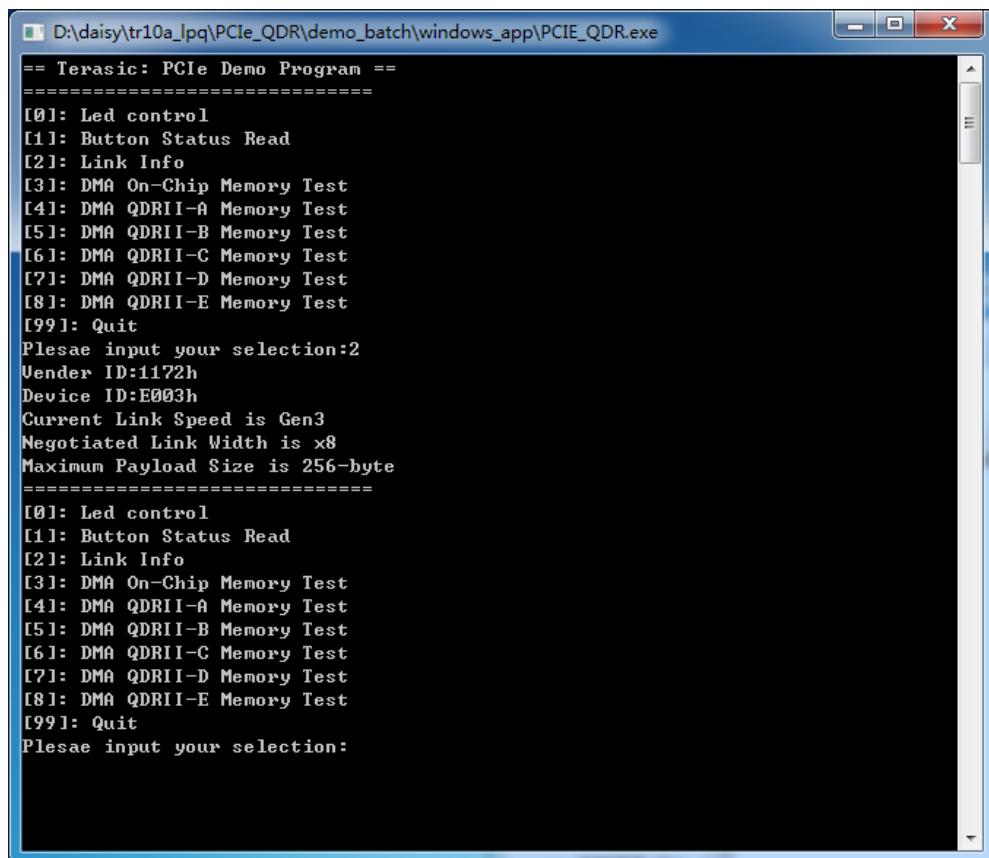
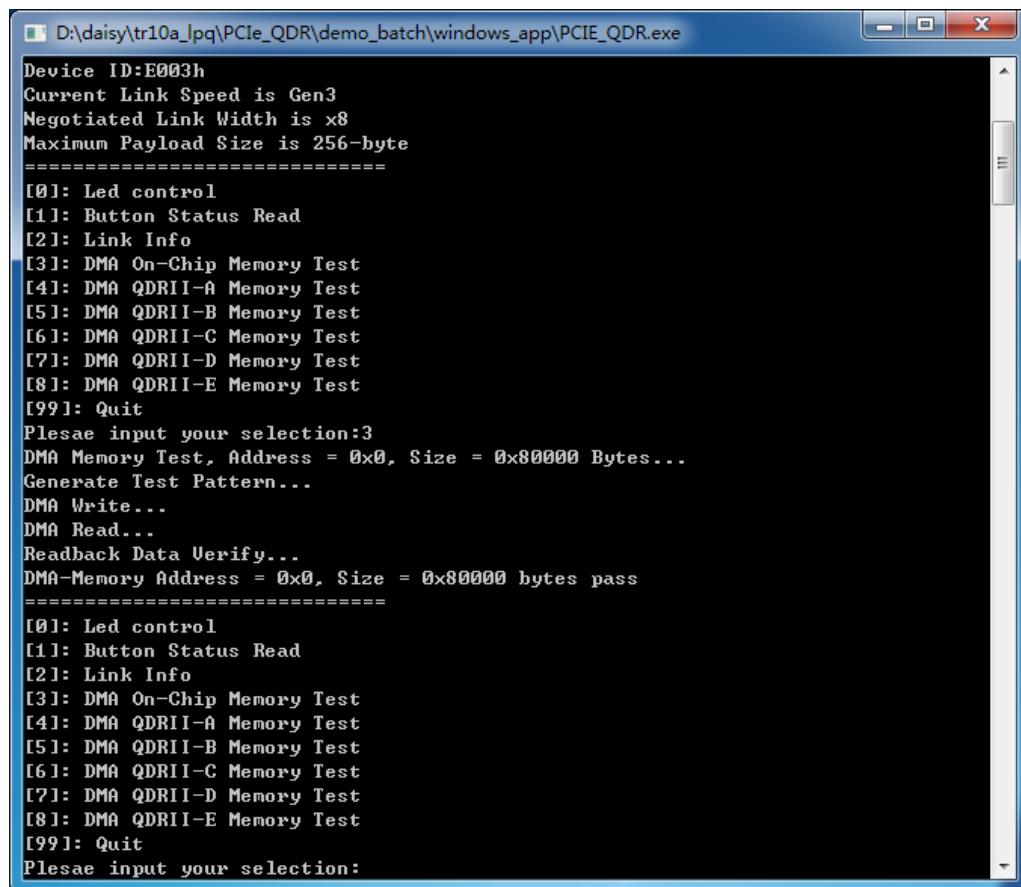


Figure 6-17 Screenshot of Link Info

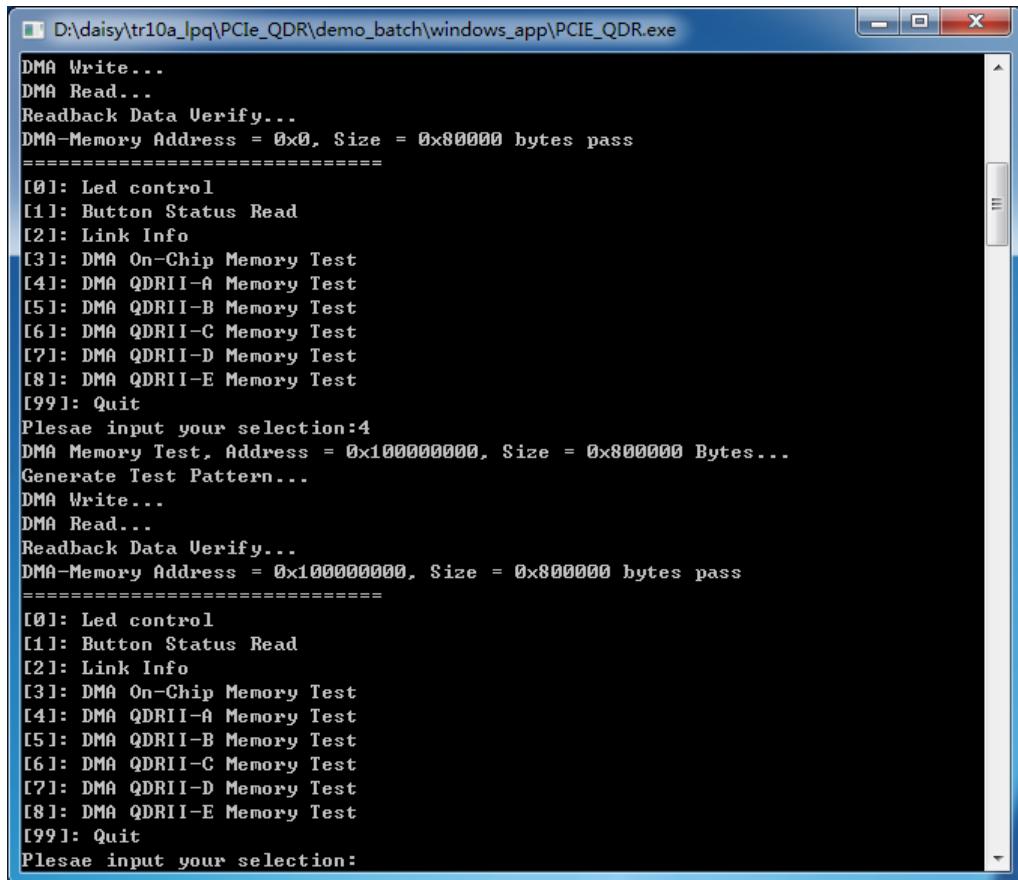
8. Type 3 followed by an ENTRY key to select DMA On-Chip Memory Test item. The DMA write and read test result will be report as shown in **Figure 6-18**.



```
Device ID:E003h
Current Link Speed is Gen3
Negotiated Link Width is x8
Maximum Payload Size is 256-byte
=====
[0]: Led control
[1]: Button Status Read
[2]: Link Info
[3]: DMA On-Chip Memory Test
[4]: DMA QDRII-A Memory Test
[5]: DMA QDRII-B Memory Test
[6]: DMA QDRII-C Memory Test
[7]: DMA QDRII-D Memory Test
[8]: DMA QDRII-E Memory Test
[99]: Quit
Plesae input your selection:3
DMA Memory Test, Address = 0x0, Size = 0x80000 Bytes...
Generate Test Pattern...
DMA Write...
DMA Read...
Readback Data Verify...
DMA-Memory Address = 0x0, Size = 0x80000 bytes pass
=====
[0]: Led control
[1]: Button Status Read
[2]: Link Info
[3]: DMA On-Chip Memory Test
[4]: DMA QDRII-A Memory Test
[5]: DMA QDRII-B Memory Test
[6]: DMA QDRII-C Memory Test
[7]: DMA QDRII-D Memory Test
[8]: DMA QDRII-E Memory Test
[99]: Quit
Plesae input your selection:
```

**Figure 6-18 Screenshot of On-Chip Memory DMA Test Result**

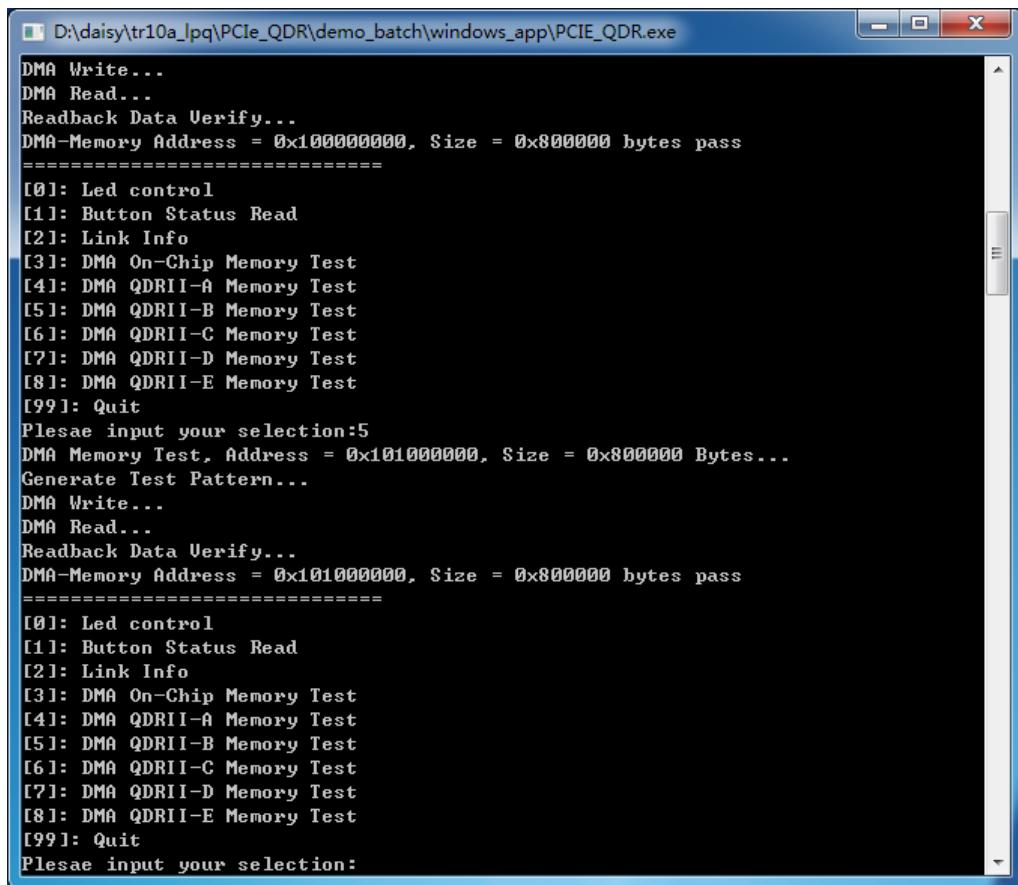
9. Type 4 followed by an ENTRY key to select DMA QDRII-A Memory Test item. The DMA write and read test result will be report as shown in **Figure 6-19**.



```
D:\daisy\tr10a_lpq\PCIe_QDR\demo_batch\windows_app\PCIE_QDR.exe
DMA Write...
DMA Read...
Readback Data Verify...
DMA-Memory Address = 0x0, Size = 0x80000 bytes pass
=====
[0]: Led control
[1]: Button Status Read
[2]: Link Info
[3]: DMA On-Chip Memory Test
[4]: DMA QDRII-A Memory Test
[5]: DMA QDRII-B Memory Test
[6]: DMA QDRII-C Memory Test
[7]: DMA QDRII-D Memory Test
[8]: DMA QDRII-E Memory Test
[99]: Quit
Plesae input your selection:
DMA Memory Test, Address = 0x100000000, Size = 0x800000 Bytes...
Generate Test Pattern...
DMA Write...
DMA Read...
Readback Data Verify...
DMA-Memory Address = 0x100000000, Size = 0x800000 bytes pass
=====
[0]: Led control
[1]: Button Status Read
[2]: Link Info
[3]: DMA On-Chip Memory Test
[4]: DMA QDRII-A Memory Test
[5]: DMA QDRII-B Memory Test
[6]: DMA QDRII-C Memory Test
[7]: DMA QDRII-D Memory Test
[8]: DMA QDRII-E Memory Test
[99]: Quit
Plesae input your selection:
```

Figure 6-19 Screenshot of QDRII-A Memory DAM Test Result

10. Type 5 followed by an ENTERY key to select DMA QDRII-B Memory Test item. The DMA write and read test result will be report as shown in **Figure 6-20**.



```
D:\daisy\tr10a_lpq\PCIe_QDR\demo_batch\windows_app\PCIE_QDR.exe
DMA Write...
DMA Read...
Readback Data Verify...
DMA-Memory Address = 0x100000000, Size = 0x800000 bytes pass
=====
[0]: Led control
[1]: Button Status Read
[2]: Link Info
[3]: DMA On-Chip Memory Test
[4]: DMA QDRII-A Memory Test
[5]: DMA QDRII-B Memory Test
[6]: DMA QDRII-C Memory Test
[7]: DMA QDRII-D Memory Test
[8]: DMA QDRII-E Memory Test
[99]: Quit
Plesae input your selection:5
DMA Memory Test, Address = 0x101000000, Size = 0x800000 Bytes...
Generate Test Pattern...
DMA Write...
DMA Read...
Readback Data Verify...
DMA-Memory Address = 0x101000000, Size = 0x800000 bytes pass
=====
[0]: Led control
[1]: Button Status Read
[2]: Link Info
[3]: DMA On-Chip Memory Test
[4]: DMA QDRII-A Memory Test
[5]: DMA QDRII-B Memory Test
[6]: DMA QDRII-C Memory Test
[7]: DMA QDRII-D Memory Test
[8]: DMA QDRII-E Memory Test
[99]: Quit
Plesae input your selection:
```

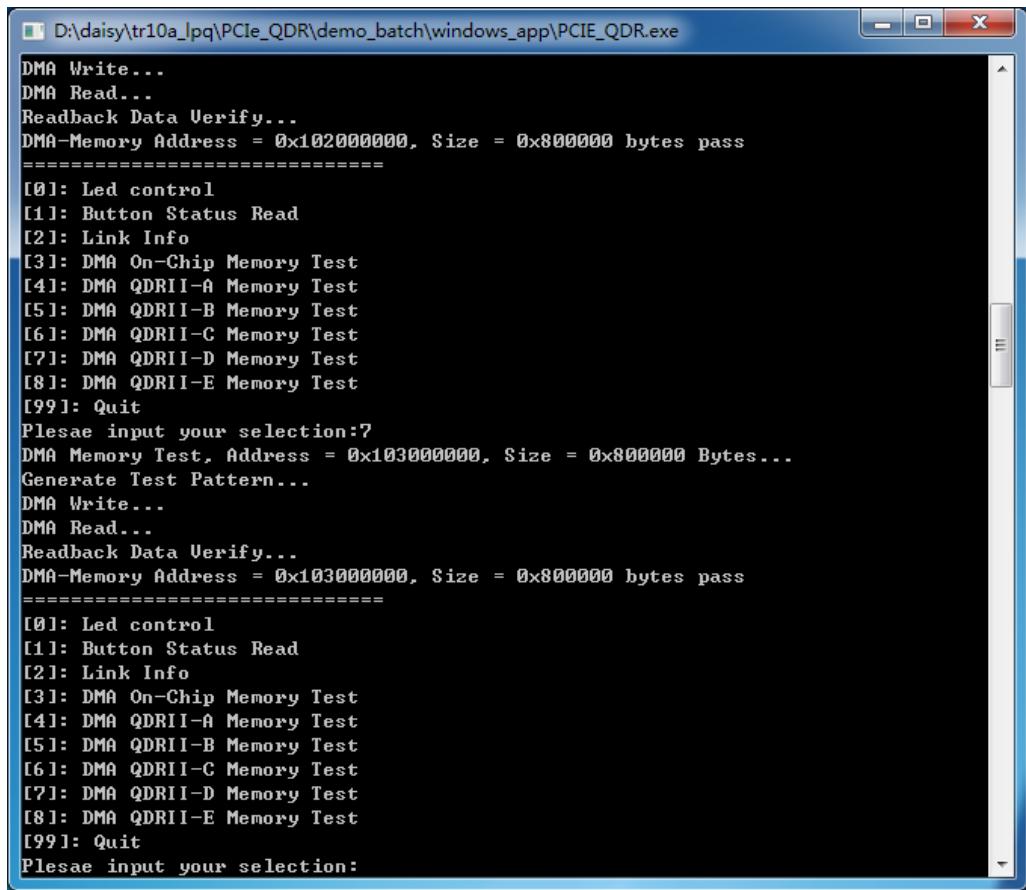
**Figure 6-20 Screenshot of QDRII-B Memory DAM Test Result**

11. Type 6 followed by an ENTERY key to select DMA QDRII-C Memory Test item. The DMA write and read test result will be report as shown in **Figure 6-21**.

```
D:\daisy\tr10a_lpq\PCIe_QDR\demo_batch\windows_app\PCIE_QDR.exe
DMA Write...
DMA Read...
Readback Data Verify...
DMA-Memory Address = 0x101000000, Size = 0x800000 bytes pass
=====
[0]: Led control
[1]: Button Status Read
[2]: Link Info
[3]: DMA On-Chip Memory Test
[4]: DMA QDRII-A Memory Test
[5]: DMA QDRII-B Memory Test
[6]: DMA QDRII-C Memory Test
[7]: DMA QDRII-D Memory Test
[8]: DMA QDRII-E Memory Test
[99]: Quit
Plesae input your selection:
DMA Memory Test, Address = 0x102000000, Size = 0x800000 Bytes...
Generate Test Pattern...
DMA Write...
DMA Read...
Readback Data Verify...
DMA-Memory Address = 0x102000000, Size = 0x800000 bytes pass
=====
[0]: Led control
[1]: Button Status Read
[2]: Link Info
[3]: DMA On-Chip Memory Test
[4]: DMA QDRII-A Memory Test
[5]: DMA QDRII-B Memory Test
[6]: DMA QDRII-C Memory Test
[7]: DMA QDRII-D Memory Test
[8]: DMA QDRII-E Memory Test
[99]: Quit
Plesae input your selection:
```

Figure 6-21 Screenshot of QDRII-C Memory DAM Test Result

12. Type 7 followed by an ENTRY key to select DMA QDRII-D Memory Test item. The DMA write and read test result will be report as shown in **Figure 6-22**.



```
D:\daisy\tr10a_lpq\PCIe_QDR\demo_batch\windows_app\PCIE_QDR.exe
DMA Write...
DMA Read...
Readback Data Verify...
DMA-Memory Address = 0x1020000000, Size = 0x800000 bytes pass
=====
[0]: Led control
[1]: Button Status Read
[2]: Link Info
[3]: DMA On-Chip Memory Test
[4]: DMA QDRII-A Memory Test
[5]: DMA QDRII-B Memory Test
[6]: DMA QDRII-C Memory Test
[7]: DMA QDRII-D Memory Test
[8]: DMA QDRII-E Memory Test
[99]: Quit
Plesae input your selection:?
DMA Memory Test, Address = 0x1030000000, Size = 0x800000 Bytes...
Generate Test Pattern...
DMA Write...
DMA Read...
Readback Data Verify...
DMA-Memory Address = 0x1030000000, Size = 0x800000 bytes pass
=====
[0]: Led control
[1]: Button Status Read
[2]: Link Info
[3]: DMA On-Chip Memory Test
[4]: DMA QDRII-A Memory Test
[5]: DMA QDRII-B Memory Test
[6]: DMA QDRII-C Memory Test
[7]: DMA QDRII-D Memory Test
[8]: DMA QDRII-E Memory Test
[99]: Quit
Plesae input your selection:
```

**Figure 6-22 Screenshot of QDRII-D Memory DAM Test Result**

13. Type 8 followed by an ENTRY key to select DMA QDRII-E Memory Test item. The DMA write and read test result will be report as shown in **Figure 6-23**.

```

D:\daisy\tr10a_lpq\PCIe_QDR\demo_batch\windows_app\PCIE_QDR.exe
DMA Write...
DMA Read...
Readback Data Verify...
DMA-Memory Address = 0x103000000, Size = 0x800000 bytes pass
=====
[0]: Led control
[1]: Button Status Read
[2]: Link Info
[3]: DMA On-Chip Memory Test
[4]: DMA QDRII-A Memory Test
[5]: DMA QDRII-B Memory Test
[6]: DMA QDRII-C Memory Test
[7]: DMA QDRII-D Memory Test
[8]: DMA QDRII-E Memory Test
[99]: Quit
Please input your selection:8
DMA Memory Test, Address = 0x104000000, Size = 0x800000 Bytes...
Generate Test Pattern...
DMA Write...
DMA Read...
Readback Data Verify...
DMA-Memory Address = 0x104000000, Size = 0x800000 bytes pass
=====
[0]: Led control
[1]: Button Status Read
[2]: Link Info
[3]: DMA On-Chip Memory Test
[4]: DMA QDRII-A Memory Test
[5]: DMA QDRII-B Memory Test
[6]: DMA QDRII-C Memory Test
[7]: DMA QDRII-D Memory Test
[8]: DMA QDRII-E Memory Test
[99]: Quit
Please input your selection:

```

Figure 6-23 Screenshot of QDRII-E Memory DAM Test Result

14. Type 99 followed by an ENTERY key to exit this test program.

## ■ Development Tools

- Quartus Prime Standard 18.0
- Visual C++ 2012

## ■ Demonstration Source Code Location

- Quartus Project: Demonstrations\PCIE\_QDR
- Visual C++ Project: Demonstrations\PCIe\_SW\_KIT\PCIE\_QDR

## ■ FPGA Application Design

**Figure 6-24** shows the system block diagram in the FPGA system. In the Qsys, Altera PIO controller is used to control the LED and monitor the Button Status, and the On-Chip memory is used for performing DMA testing. The PIO controllers and the On-Chip memory are connected to the PCI Express Hard IP controller through the Memory-Mapped Interface.

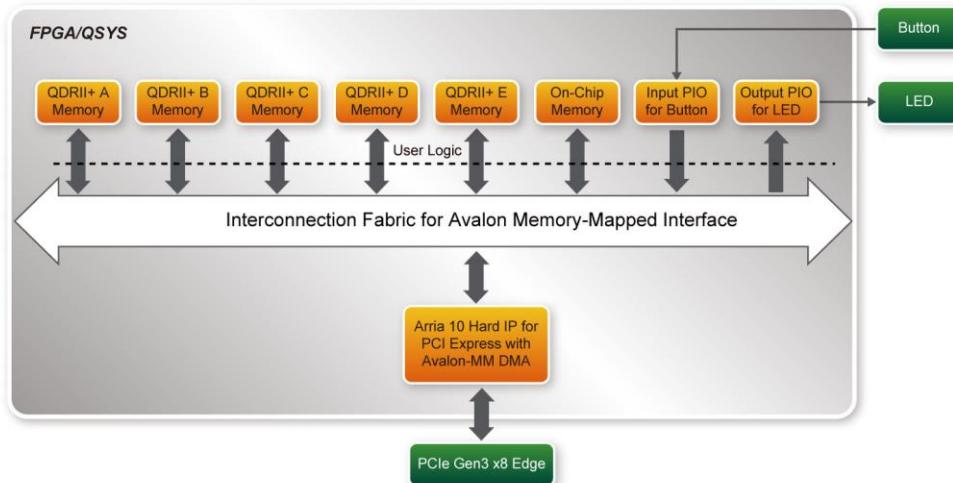


Figure 6-24 Hardware block diagram of the PCIe QDRII+ reference design

## ■ Windows Based Application Software Design

The application software project is built by Visual C++ 2012. The project includes the following major files:

Name	Description
PCIE_QDR.cpp	Main program
PCIE.c	Implement dynamically load for
PCIE.h	TERASIC_PCIE_AVMM.DLL
TERASIC_PCIE_AVMM.h	SDK library file, defines constant and data structure

The main program PCIE\_QDR.cpp includes the header file "PCIE.h" and defines the controller address according to the FPGA design.

```

#define DEMO_PCIE_USER_BAR          PCIE_BAR4
#define DEMO_PCIE_IO_LED_ADDR       0x4000010
#define DEMO_PCIE_IO_BUTTON_ADDR    0x4000020
#define DEMO_PCIE_ONCHIP_MEM_ADDR   0x00000000
#define DEMO_PCIE_QDRIIA_MEM_ADDR   0x10000000
#define DEMO_PCIE_QDRIIB_MEM_ADDR   0x10100000
#define DEMO_PCIE_QDRIIC_MEM_ADDR   0x10200000
#define DEMO_PCIE_QDRIID_MEM_ADDR   0x10300000
#define DEMO_PCIE_QDRIIE_MEM_ADDR   0x10400000
#define DEMO_PCIE_QDRIIF_MEM_ADDR   0x10500000

#define ONCHIP_MEM_TEST_SIZE        (512*1024) //512KB
#define QDRIIA_MEM_TEST_SIZE        (8*1024*1024) //8MB
#define QDRIIB_MEM_TEST_SIZE        (8*1024*1024) //8MB
#define QDRIIC_MEM_TEST_SIZE        (8*1024*1024) //8MB
#define QDRIID_MEM_TEST_SIZE        (8*1024*1024) //8MB
#define QDRIIE_MEM_TEST_SIZE        (8*1024*1024) //8MB
#define QDRIIF_MEM_TEST_SIZE        (8*1024*1024) //8MB

```

The base address of BUTTON and LED controllers are 0x4000010 and 0x4000020 based on PCIE\_BAR4, in respectively. The on-chip memory base address is 0x00000000 relative to the DMA controller. The above definition is the same as those in PCIe Fundamental demo.

Before accessing the FPGA through PCI Express, the application first calls PCIE\_Load to dynamically load the TERASIC\_PCIE\_AVMM.DLL. Then, it call PCIE\_Open to open the PCI Express driver. The constant DEFAULT\_PCIE\_VID and DEFAULT\_PCIE\_DID used in PCIE\_Open are defined in TERASIC\_PCIE\_AVMM.h. If developer change the Vender ID and Device ID and PCI Express IP, they also need to change the ID value define in TERASIC\_PCIE\_AVMM.h. If the return value of PCIE\_Open is zero, it means the driver cannot be accessed successfully. In this case, please make sure:

- The FPGA is configured with the associated bit-stream file and the host is rebooted.
- The PCI express driver is loaded successfully.

The LED control is implemented by calling PCIE\_Write32 API, as shown below:

```
bPass = PCIE_Write32(hPCIE, DEMO_PCIE_USER_BAR, DEMO_PCIE_IO_LED_ADDR, (DWORD)Mask);
```

The button status query is implemented by calling the **PCIE\_Read32** API, as shown below:

```
PCIE_Read32(hPCIE, DEMO_PCIE_USER_BAR, DEMO_PCIE_IO_BUTTON_ADDR, &Status);
```



The memory-mapped memory read and write test is implemented by **PCIE\_DmaWrite** and **PCIE\_DmaRead** API, as shown below:

```
PCIE_DmaWrite(hPCIe, LocalAddr, pWrite, nTestSize);
PCIE_DmaRead(hPCIe, LocalAddr, pRead, nTestSize);
```

The pcie link information is implemented by PCIE\_ConfigRead32 API, as shown below:

```
// read config - link status
if (PCIE_ConfigRead32(hPCIe, 0x90, &Data32)){
    switch((Data32 >> 16) & 0x0F){
        case 1:
            printf("Current Link Speed is Gen1\r\n");
            break;
        case 2:
            printf("Current Link Speed is Gen2\r\n");
            break;
        case 3:
            printf("Current Link Speed is Gen3\r\n");
            break;
        default:
            printf("Current Link Speed is Unknown\r\n");
            break;
    }
    switch((Data32 >> 20) & 0x3F){
        case 1:
            printf("Negotiated Link Width is x1\r\n");
            break;
        case 2:
            printf("Negotiated Link Width is x2\r\n");
            break;
        case 4:
            printf("Negotiated Link Width is x4\r\n");
            break;
        case 8:
            printf("Negotiated Link Width is x8\r\n");
            break;
        case 16:
            printf("Negotiated Link Width is x16\r\n");
            break;
        default:
            printf("Negotiated Link Width is Unknown\r\n");
            break;
    }
} else{
    bPass = false;
}
```

## 6.6 PCIe Design: PCIe\_Fundamental\_x2

The application reference design shows how to utilize the dual PCIe Gen3 x8 edge connector on this board. The two PCIe Gen3 x8 Link are directly connected to two Arria 10 PCIe Hard IP individually. There two IP are call **PCIe0** and **PCIe1** in this design. The Host PC can communicate with the two Hard IP independently, so the throughput between Host PC and FPGA is double than the single PCIe Gen3 x8 link. In the design, basic I/O is used to control the BUTTON and LED on the FPGA board. **PCIe0** controls the **User LED** and **PCIe1** controls the **Bracket LED**. High-speed data transfer is performed by DMA.

Note, this demonstration requires the Host PC to support **PCIe Bifurcation**.

### ■ Demonstration Files Location

The demo file is located in the batch folder:

CDROM\demonstrations\PCIe\_fundamental\_x2\demo\_batch

The folder includes following files:

- FPGA Configuration File: PCIe\_Fundamental\_x2.sof
- Download Batch file: test.bat
- Windows Application Software folder : windows\_app, includes
  - ❖ PCIE\_FUNDAMENTAL.exe
  - ❖ TERASIC\_PCIE\_AVMM.dll

### ■ Demonstration Setup

1. Make sure your Host PC supports PCIe bifurcation and is enabled in BIOS.
2. Install the FPGA board on the bifurcation PCIe slot of your PC.
3. Configure FPGA with PCIe\_Fundamental\_x2.sof by executing the test.bat.
4. Install PCIe driver if necessary. The driver is located in the folder:  
CDROM\Demonstration\PCIe\_SW\_KIT\PCIe\_Driver
5. Restart Windows
6. Make sure there are two Altera PCI API drivers are enumerated by checking the Windows Control panel as shown in **Figure 6-25**.
7. Goto windows\_app folder, execute PCIE\_FUNDMENTAL.exe. A menu will appear as shown in **Figure 6-26**.

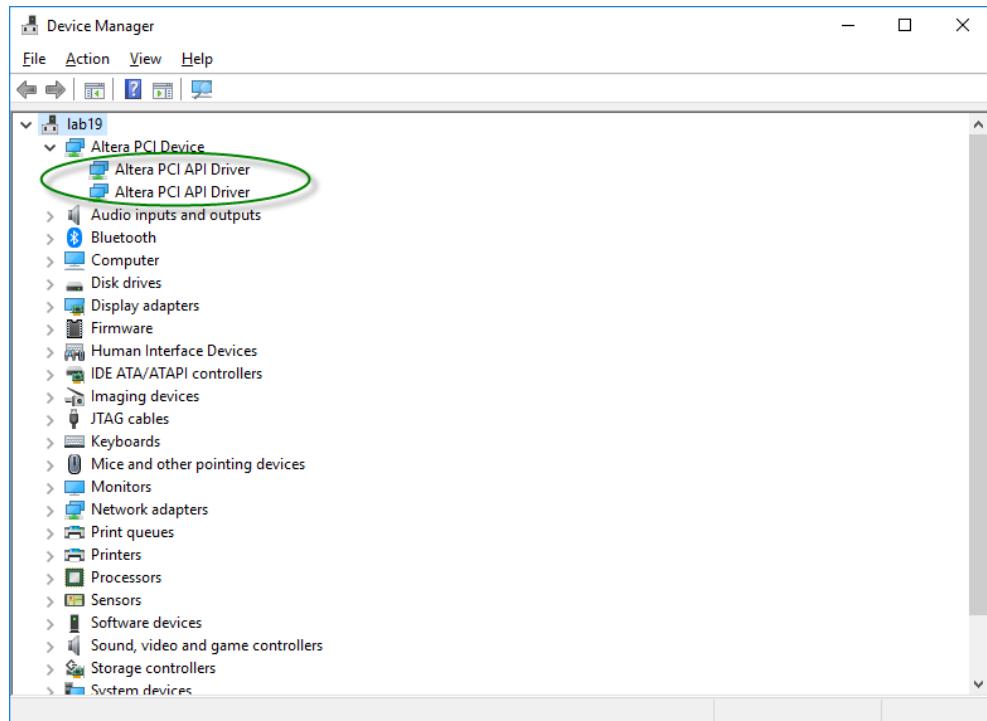


Figure 6-25 Screenshot of two FPGA PCIe devices are detected

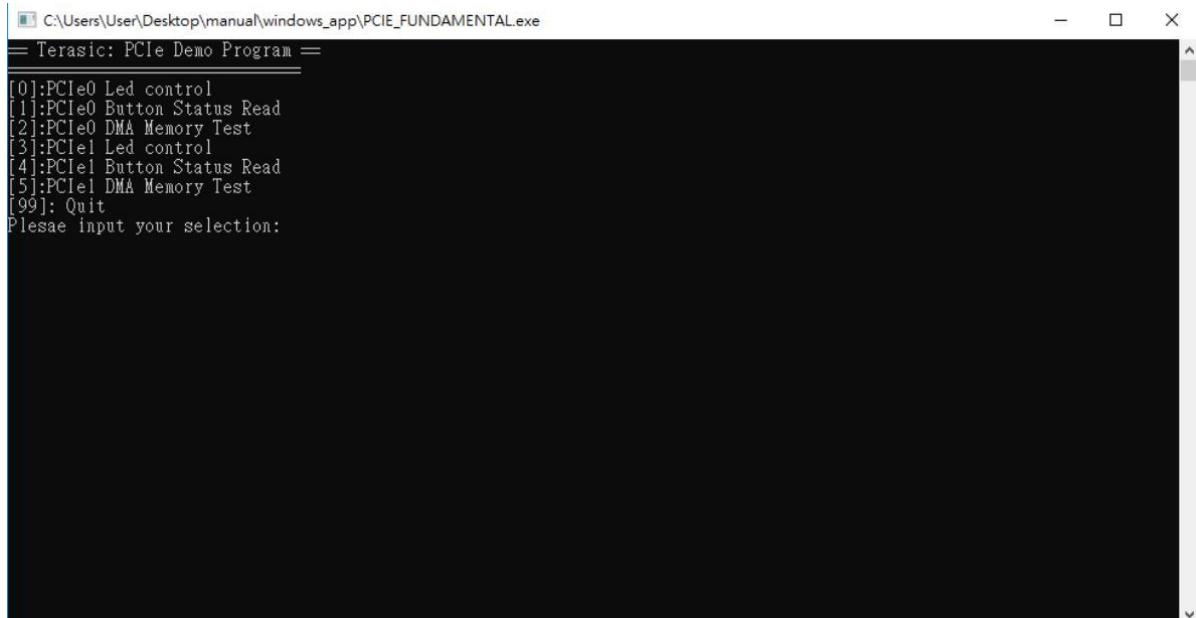
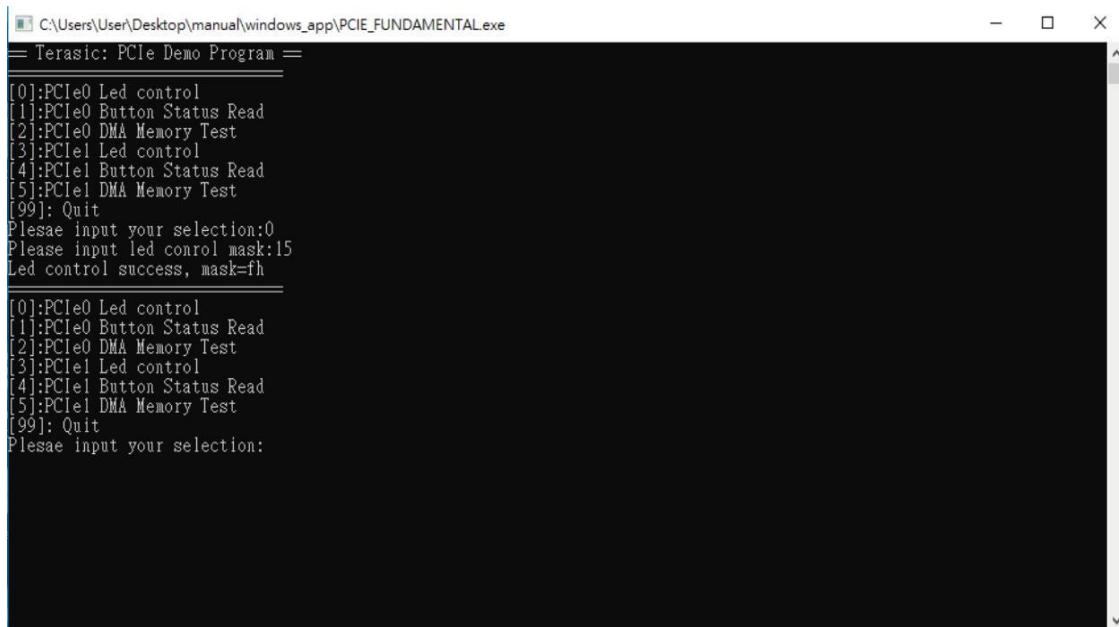


Figure 6-26 Screenshot of Program Menu

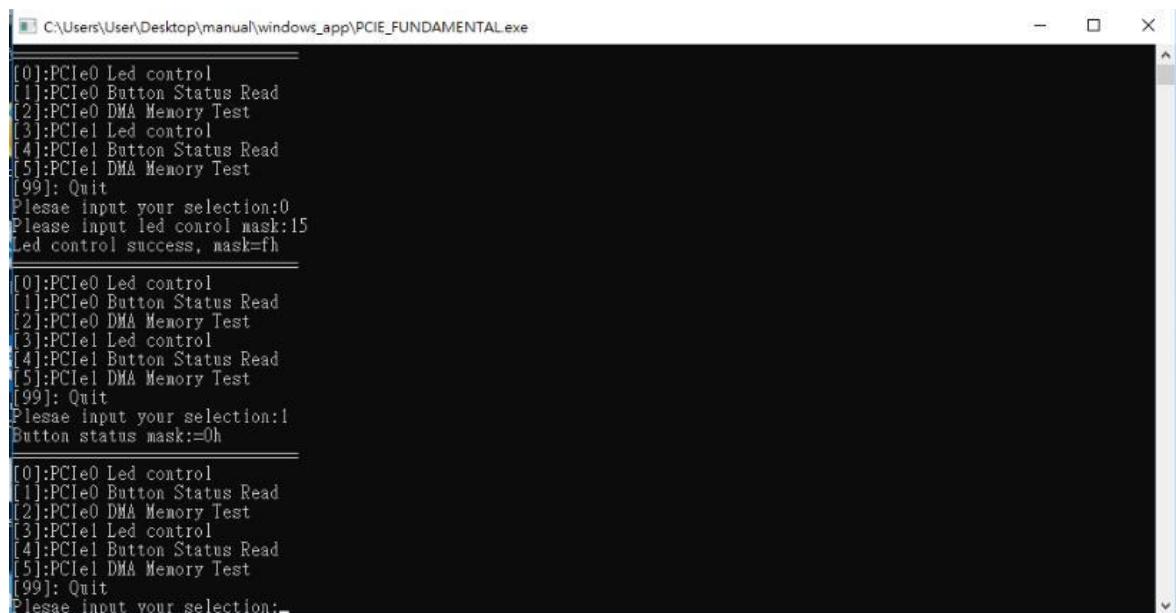
8. Type 0 followed by a ENTRY key to select **PCIe0** Led Control item, then input 15 (hex 0x0f) will make all **User LED** lighten as shown in **Figure 6-27**. If input 0(hex 0x00), all **User LED** will be turn off.



```
C:\Users\User\Desktop\manual\windows_app\PCIE_FUNDAMENTAL.exe
= Terasic: PCIe Demo Program =
[0]:PCIe0 Led control
[1]:PCIe0 Button Status Read
[2]:PCIe0 DMA Memory Test
[3]:PCIe1 Led control
[4]:PCIe1 Button Status Read
[5]:PCIe1 DMA Memory Test
[99]: Quit
Plesae input your selection:0
Please input led conrol mask:15
Led control success, mask=fh
[0]:PCIe0 Led control
[1]:PCIe0 Button Status Read
[2]:PCIe0 DMA Memory Test
[3]:PCIe1 Led control
[4]:PCIe1 Button Status Read
[5]:PCIe1 DMA Memory Test
[99]: Quit
Plesae input your selection:
```

Figure 6-27 Screenshot of PCIe0 LED Control

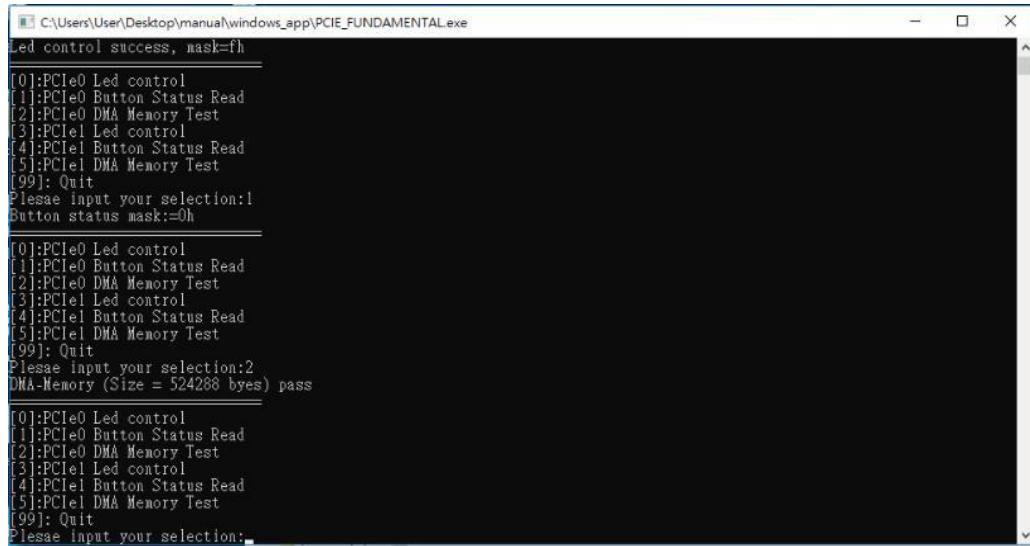
9. Type 1 followed by an ENTRY key to select **PCIe0** Button Status Read item. The button status will be report as shown in [Figure 6-28](#).



```
C:\Users\User\Desktop\manual\windows_app\PCIE_FUNDAMENTAL.exe
[0]:PCIe0 Led control
[1]:PCIe0 Button Status Read
[2]:PCIe0 DMA Memory Test
[3]:PCIe1 Led control
[4]:PCIe1 Button Status Read
[5]:PCIe1 DMA Memory Test
[99]: Quit
Plesae input your selection:0
Please input led conrol mask:15
Led control success, mask=fh
[0]:PCIe0 Led control
[1]:PCIe0 Button Status Read
[2]:PCIe0 DMA Memory Test
[3]:PCIe1 Led control
[4]:PCIe1 Button Status Read
[5]:PCIe1 DMA Memory Test
[99]: Quit
Plesae input your selection:1
Button status mask:=0h
[0]:PCIe0 Led control
[1]:PCIe0 Button Status Read
[2]:PCIe0 DMA Memory Test
[3]:PCIe1 Led control
[4]:PCIe1 Button Status Read
[5]:PCIe1 DMA Memory Test
[99]: Quit
Plesae input your selection:
```

Figure 6-28 Screenshot of PCIe0 Button Status Report

10. Type 2 followed by an ENTRY key to select **PCIe0** DMA Testing item. The DMA test result will be report as shown in [Figure 6-29](#).



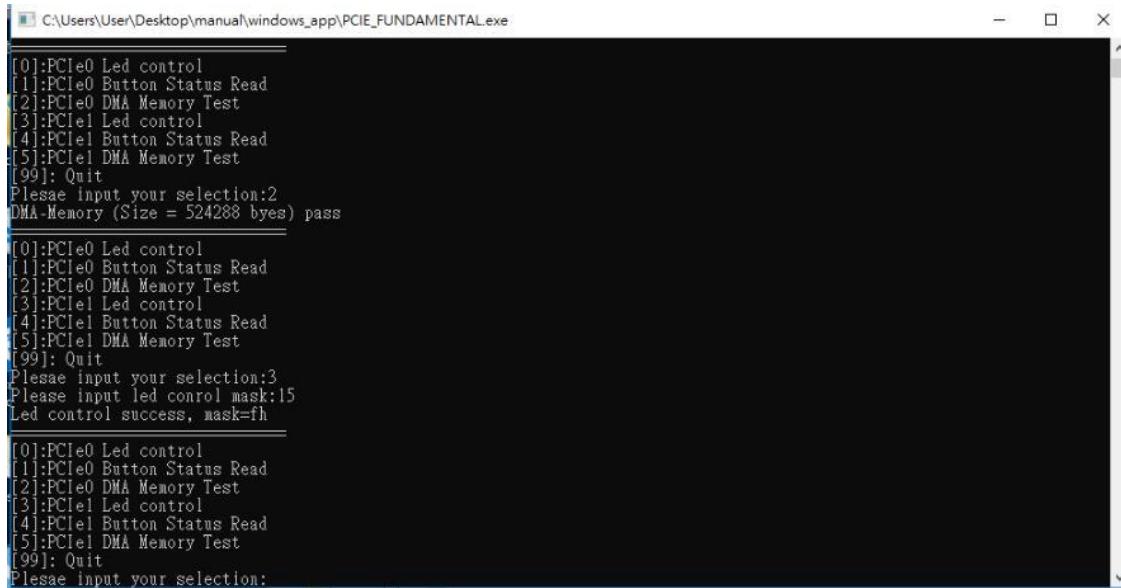
```

C:\Users\User\Desktop\manual\windows_app\PCIE_FUNDAMENTAL.exe
Led control success, mask=fh
[0]:PCle0 Led control
[1]:PCle0 Button Status Read
[2]:PCle0 DMA Memory Test
[3]:PCle1 Led control
[4]:PCle1 Button Status Read
[5]:PCle1 DMA Memory Test
[99]: Quit
Please input your selection:1
Button status mask:=0h
[0]:PCle0 Led control
[1]:PCle0 Button Status Read
[2]:PCle0 DMA Memory Test
[3]:PCle1 Led control
[4]:PCle1 Button Status Read
[5]:PCle1 DMA Memory Test
[99]: Quit
Please input your selection:2
DMA-Memory (Size = 524288 bytes) pass
[0]:PCle0 Led control
[1]:PCle0 Button Status Read
[2]:PCle0 DMA Memory Test
[3]:PCle1 Led control
[4]:PCle1 Button Status Read
[5]:PCle1 DMA Memory Test
[99]: Quit
Please input your selection:_

```

**Figure 6-29 Screenshot of PCIe0 DMA Memory Test Result**

11. Type 3 followed by a ENTERY key to select **PCle1** Led Control item, then input 15 (hex 0x0f) will make all **Bracket LED** on as shown in **Figure 6-30**. If input 0(hex 0x00), all **Bracket LED** will be turn off.



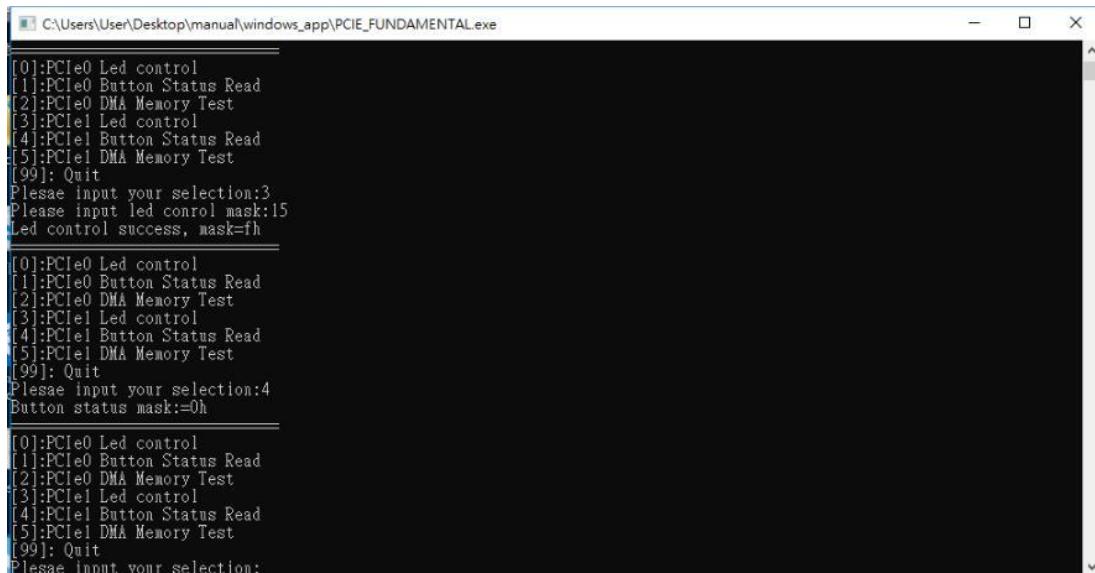
```

C:\Users\User\Desktop\manual\windows_app\PCIE_FUNDAMENTAL.exe
[0]:PCle0 Led control
[1]:PCle0 Button Status Read
[2]:PCle0 DMA Memory Test
[3]:PCle1 Led control
[4]:PCle1 Button Status Read
[5]:PCle1 DMA Memory Test
[99]: Quit
Please input your selection:2
DMA-Memory (Size = 524288 bytes) pass
[0]:PCle0 Led control
[1]:PCle0 Button Status Read
[2]:PCle0 DMA Memory Test
[3]:PCle1 Led control
[4]:PCle1 Button Status Read
[5]:PCle1 DMA Memory Test
[99]: Quit
Please input your selection:3
Please input led control mask:15
Led control success, mask=fh
[0]:PCle0 Led control
[1]:PCle0 Button Status Read
[2]:PCle0 DMA Memory Test
[3]:PCle1 Led control
[4]:PCle1 Button Status Read
[5]:PCle1 DMA Memory Test
[99]: Quit
Please input your selection:_

```

**Figure 6-30 Screenshot of PCIe1 LED Control**

12. Type 4 followed by an ENTERY key to select **PCle1** Button Status Read item. The button status will be report as shown in **Figure 6-31**.



```

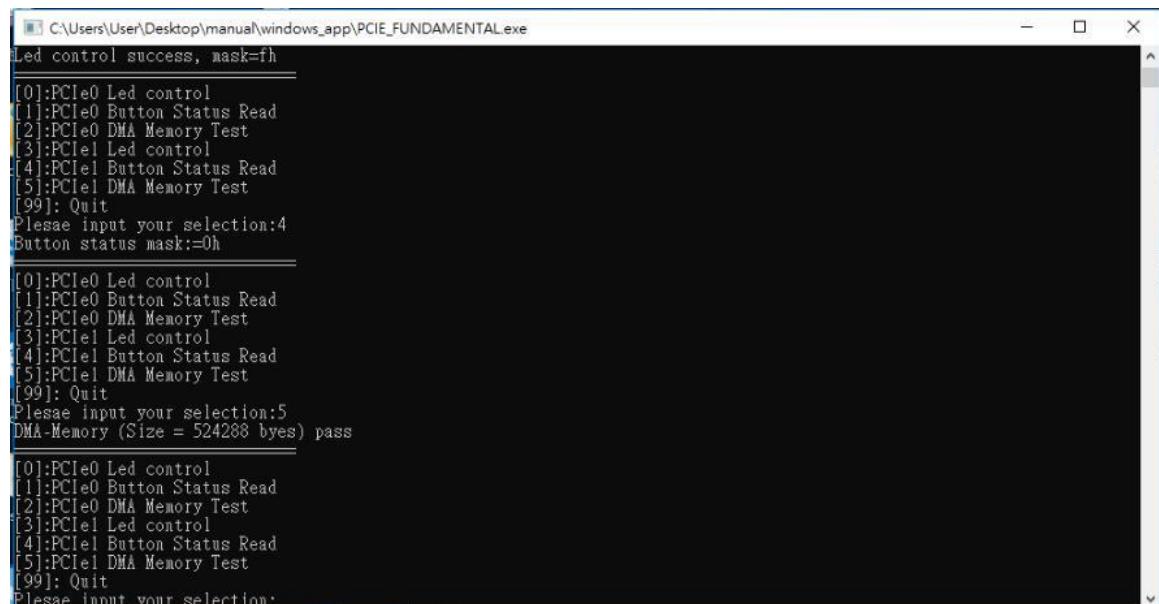
C:\Users\User\Desktop\manual\windows_app\PCIE_FUNDAMENTAL.exe

[0]:PCIe0 Led control
[1]:PCIe0 Button Status Read
[2]:PCIe0 DMA Memory Test
[3]:PCIe1 Led control
[4]:PCIe1 Button Status Read
[5]:PCIe1 DMA Memory Test
[99]: Quit
Please input your selection:3
Please input led control mask:15
Led control success, mask=fh
[0]:PCIe0 Led control
[1]:PCIe0 Button Status Read
[2]:PCIe0 DMA Memory Test
[3]:PCIe1 Led control
[4]:PCIe1 Button Status Read
[5]:PCIe1 DMA Memory Test
[99]: Quit
Please input your selection:4
Button status mask:=0h
[0]:PCIe0 Led control
[1]:PCIe0 Button Status Read
[2]:PCIe0 DMA Memory Test
[3]:PCIe1 Led control
[4]:PCIe1 Button Status Read
[5]:PCIe1 DMA Memory Test
[99]: Quit
Please input your selection:

```

Figure 6-31 Screenshot of PCIe1 Button Status Report

13. Type 2 followed by an ENTERY key to select PCIe1 DMA Testing item. The DMA test result will be report as shown in [Figure 6-32](#).



```

C:\Users\User\Desktop\manual\windows_app\PCIE_FUNDAMENTAL.exe

Led control success, mask=fh
[0]:PCIe0 Led control
[1]:PCIe0 Button Status Read
[2]:PCIe0 DMA Memory Test
[3]:PCIe1 Led control
[4]:PCIe1 Button Status Read
[5]:PCIe1 DMA Memory Test
[99]: Quit
Please input your selection:4
Button status mask:=0h
[0]:PCIe0 Led control
[1]:PCIe0 Button Status Read
[2]:PCIe0 DMA Memory Test
[3]:PCIe1 Led control
[4]:PCIe1 Button Status Read
[5]:PCIe1 DMA Memory Test
[99]: Quit
Please input your selection:5
DMA-Memory (Size = 524288 bytes) pass
[0]:PCIe0 Led control
[1]:PCIe0 Button Status Read
[2]:PCIe0 DMA Memory Test
[3]:PCIe1 Led control
[4]:PCIe1 Button Status Read
[5]:PCIe1 DMA Memory Test
[99]: Quit
Please input your selection:

```

Figure 6-32 Screenshot of PCIe0 DMA Memory Test Result

14. Type 99 followed by an ENTERY key to exit this test program

## ■ Development Tools

- Quartus Prime Standard 18.0
- Visual C++ 2012

## ■ Demonstration Source Code Location

- Quartus Project: Demonstrations\PCIe\_Fundamental\_x2
- Visual C++ Project: Demonstrations\PCIe\_SW\_KIT\PCIE\_FUNDAMENTAL\_x2

## ■ FPGA Application Design

**Figure 6-33** shows the system block diagram in the FPGA system. In the Qsys, Altera PIO controller is used to control the LED (User LED and Bracket LED) and monitor the Button Status, and the On-Chip memory is used for performing DMA testing. The PIO controllers and the On-Chip memory are connected to the PCI Express Hard IP controller through the Memory-Mapped Interface.

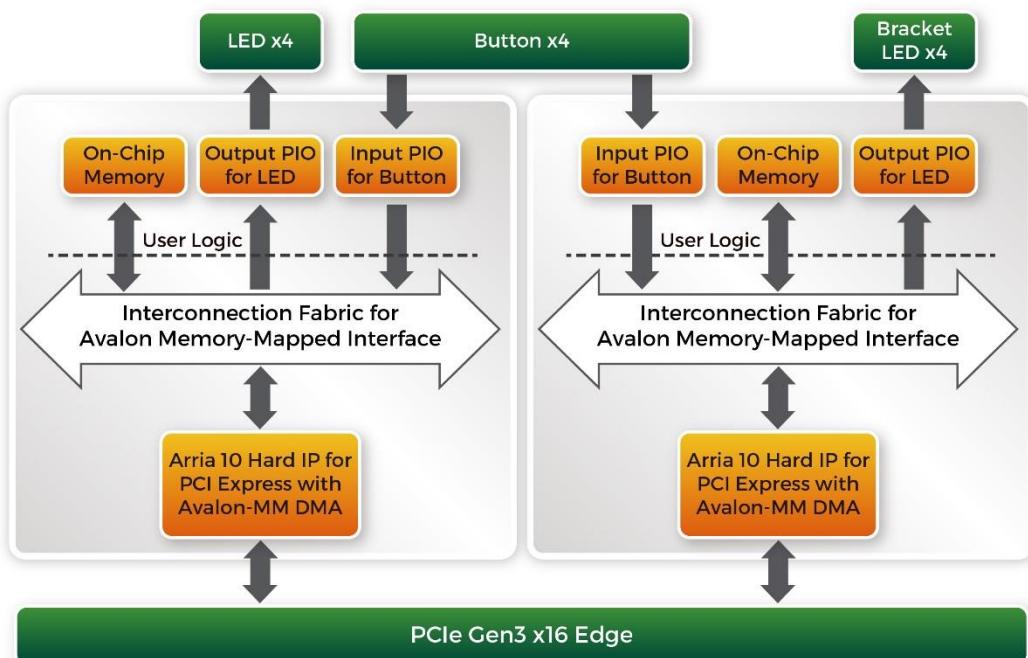


Figure 6-33 Hardware block diagram of the Dual PCIe reference design

## ■ Windows Based Application Software Design

The application software project is built by Visual C++ 2012. The project includes the following major files:

Name	Description
PCIE_FUNDAMENTAL.cpp	Main program
PCIE.c	Implement dynamically load for
PCIE.h	TERASIC_PCIE_AVMM.DLL
TERASIC_PCIE_AVMM.h	SDK library file, defines constant and data structure

The main program PCIE\_FUNDAMENTAL.cpp includes the header file "PCIE.h" and defines the controller address according to the FPGA design.

```
#include "PCIE.h"

#define DEMO_PCIE_USER_BAR          PCIE_BAR4
#define DEMO_PCIE_IO_LED_ADDR       0x40000010
#define DEMO_PCIE_IO_BUTTON_ADDR    0x40000020
#define DEMO_PCIE_MEM_ADDR          0x00000000

#define MEM_SIZE      (512*1024) //512KB
```

The base address of BUTTON and LED controllers are 0x4000010 and 0x4000020 based on PCIE\_BAR4, in respectively. The on-chip memory base address is 0x00000000 relative to the DMA controller.

Before accessing the FPGA through PCI Express, the application first calls PCIE\_Load to dynamically load the TERASIC\_PCIE\_AVMM.DLL. Then, it call PCIE\_Open twice to open two PCI Express devices:

```
hPCIE_0 = PCIE_Open(DEFAULT_PCIE_VID, DEFAULT_PCIE_DID, 0);
hPCIE_1 = PCIE_Open(DEFAULT_PCIE_VID, DEFAULT_PCIE_DID, 1);
```

The constant DEFAULT\_PCIE\_VID and DEFAULT\_PCIE\_DID used in PCIE\_Open are defined in TERASIC\_PCIE\_AVMM.h. If developers change the Vender ID and Device ID and PCI Express IP, they also need to change the ID value define in TERASIC\_PCIE\_AVMM.h. The third parameter (0 and 1 in this case) is used to specify the PCIe device. 0 means the first device found in the PCIe bus with the given Vender ID and Device ID. 1 means the second device found in the PCIe bus with the given Vender ID and Device ID. If the return value of PCIE\_Open is zero, it means the driver cannot be accessed successfully. In this case, please make sure:

- The FPGA is configured with the associated bit-stream file and the host is rebooted.
- The PCI express driver is loaded successfully.

The LED control is implemented by calling PCIE\_Write32 API, as shown below:

```
bPass = PCIE_Write32(hPCIE, DEMO_PCIE_USER_BAR, DEMO_PCIE_IO_LED_ADDR, (DWORD)Mask);
```

The button status query is implemented by calling the **PCIE\_Read32** API, as shown below:

```
PCIE_Read32(hPCIe, DEMO_PCIE_USER_BAR, DEMO_PCIE_IO_BUTTON_ADDR, &Status);
```

The memory-mapped memory read and write test is implemented by **PCIE\_DmaWrite** and **PCIE\_DmaRead** API, as shown below:

```
PCIE_DmaWrite(hPCIe, LocalAddr, pWrite, nTestSize);  
PCIE_DmaRead(hPCIe, LocalAddr, pRead, nTestSize);
```

## Transceiver Verification

This chapter describes how to verify the FPGA transceivers for the QSFP+ by using the test code provided in the TR10a-LPQ system CD.

### 7.1 Function of the Transceiver Test Code

The transceiver test code is used to verify the transceiver channels for the QSFP+ ports through an external loopback method. The transceiver channels are verified with the data rates 10.3125 Gbps with PRBS31 test pattern.

### 7.2 Loopback Fixture

To enable an external loopback of transceiver channels, one of the following two fixtures are required:

- QSFP+ Cable, as shown in [Figure 7-1](#).
- QSFP+ Loopback fixture, as shown in [Figure 7-2](#).



Figure 7-1 Optical QSFP+ Cable



**Figure 7-2 QSFP+ Loopback Fixture**

**Figure 7-3** shows the FPGA board with one QSFP+ cable installed. **Figure 7-4** shows the FPGA board with two QSFP+ loopback fixtures installed.



**Figure 7-3 One QSFP+ Cables Installed**

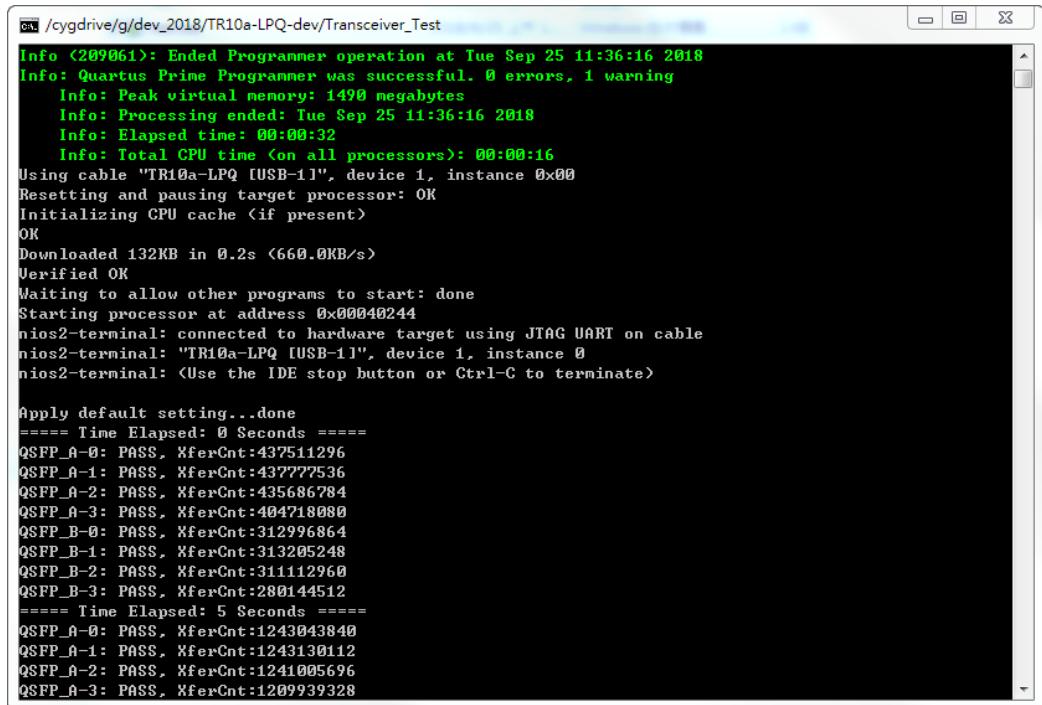


Figure 7-4 Two QSFP+ Loopback Fixtures Installed

## 7.3 Testing

The transceiver test code is available in the folder System CD\Tool\Transceiver\_Test. Here are the procedures to perform transceiver channel test:

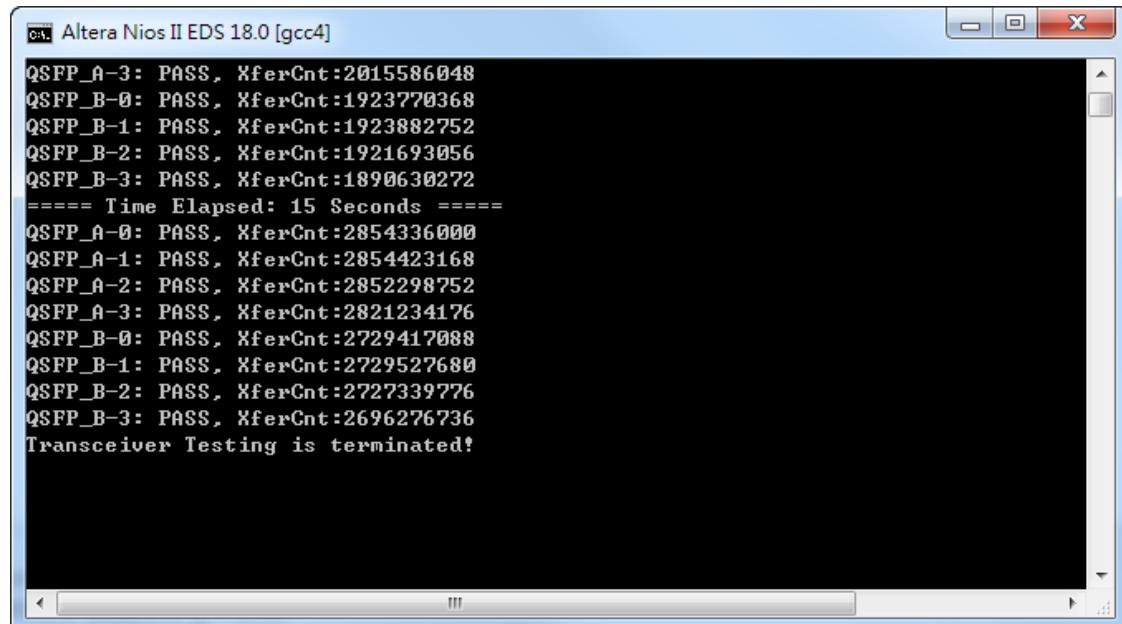
1. Copy Transceiver\_Test folder to your local disk.
2. Ensure that the FPGA board is NOT powered on.
3. Plug-in the QSFP+ loopback fixtures.
4. Connect your FPGA board to your PC with a mini USB cable.
5. Power on the FPGA board
6. Execute 'test.bat' in the Transceiver\_Test folder under your local disk.
7. The batch file will download .sof and .elf files, and start the test immediately. The test result is shown in the Nios-Terminal, as shown in **Figure 7-5**.
8. To terminate the test, press one of the BUTTON0~3 buttons on the FPGA board. The loopback test will terminate as shown in **Figure 7-6**.



```
cmd /cygdrive/g/dev_2018/TR10a-LPQ-dev/Transceiver_Test
Info <209861>: Ended Programmer operation at Tue Sep 25 11:36:16 2018
Info: Quartus Prime Programmer was successful. 0 errors, 1 warning
  Info: Peak virtual memory: 1490 megabytes
  Info: Processing ended: Tue Sep 25 11:36:16 2018
  Info: Elapsed time: 00:00:32
    Info: Total CPU time <on all processors>: 00:00:16
Using cable "TR10a-LPQ [USB-1]", device 1, instance 0x00
Resetting and pausing target processor: OK
Initializing CPU cache <if present>
OK
Downloaded 132KB in 0.2s (660.0KB/s)
Verified OK
Waiting to allow other programs to start: done
Starting processor at address 0x00040244
nios2-terminal: connected to hardware target using JTAG UART on cable
nios2-terminal: "TR10a-LPQ [USB-1]", device 1, instance 0
nios2-terminal: <Use the IDE stop button or Ctrl-C to terminate>

Apply default setting...done
===== Time Elapsed: 0 Seconds =====
QSFP_A-0: PASS, XferCnt:437511296
QSFP_A-1: PASS, XferCnt:437777536
QSFP_A-2: PASS, XferCnt:435686784
QSFP_A-3: PASS, XferCnt:404718080
QSFP_B-0: PASS, XferCnt:312996864
QSFP_B-1: PASS, XferCnt:313205248
QSFP_B-2: PASS, XferCnt:311112960
QSFP_B-3: PASS, XferCnt:280144512
===== Time Elapsed: 5 Seconds =====
QSFP_A-0: PASS, XferCnt:1243043840
QSFP_A-1: PASS, XferCnt:1243130112
QSFP_A-2: PASS, XferCnt:1241005696
QSFP_A-3: PASS, XferCnt:1209939328
```

Figure 7-5 QSFP+ Transceiver Loopback Test in Progress



```
Altera Nios II EDS 18.0 [gcc4]
QSFP_A-3: PASS, XferCnt:2015586048
QSFP_B-0: PASS, XferCnt:1923770368
QSFP_B-1: PASS, XferCnt:1923882752
QSFP_B-2: PASS, XferCnt:1921693056
QSFP_B-3: PASS, XferCnt:1890630272
===== Time Elapsed: 15 Seconds =====
QSFP_A-0: PASS, XferCnt:2854336000
QSFP_A-1: PASS, XferCnt:2854423168
QSFP_A-2: PASS, XferCnt:2852298752
QSFP_A-3: PASS, XferCnt:2821234176
QSFP_B-0: PASS, XferCnt:2729417088
QSFP_B-1: PASS, XferCnt:2729527680
QSFP_B-2: PASS, XferCnt:2727339776
QSFP_B-3: PASS, XferCnt:2696276736
Transceiver Testing is terminated!
```

Figure 7-6 QSFP Transceiver Loopback Done

## Chapter 8

# TR10a-LPQ Dashboard

The TR10a-LPQ Dashboard is a board management system. It can automatically adjust fan speed according to board temperature. Also, it can automatically shutdowns FPGA power when the board temperature is too high to avoid FPGA damaged due to over temperature. It also can report board status to the Host PC via JTAG or UART bus. The reported status includes FPGA/Board temperature, fan speed, FPGA core power and 12V input power. **Figure 8-1** shows the block diagram of the TR10a-LPQ Dashboard.

In the host PC, there are two Dashboard GUI software are provided. One is UART based software, it can be used in Windows system. Another is JTAG based software, it can be used both in Windows and Linux. It is a TCL program based on Intel FPGA System Console, so the System Console should be installed before running the program.

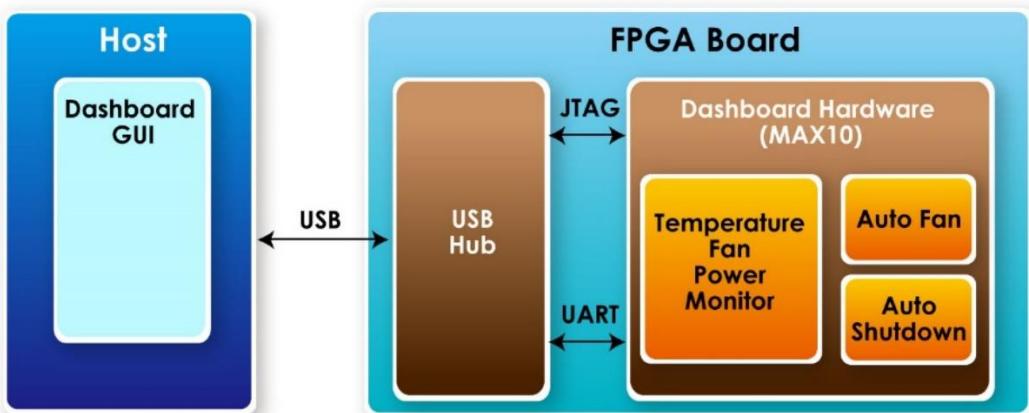


Figure 8-1 Block Diagram of the TR10a-LPQ Dashboard

## 8.1 Dashboard Connected via USB Blaster

### II

This section describes how to monitor the TR10a-LPQ board status via the Dashboard GUI based on Intel FPGA System Console. As described in overview, the Dashboard GUI is TCL program, it runs in Host PC via System Console, and connects to system controller (Max 10 FPGA) built in TR10a-LPQ board, receive the board status data. The USB Blaster II connector on the TR10a-LPQ board is hardware circuit which implements the JTAG protocol, users need to connect the board to Host PC via the USB Blaster II connector. The Dashboard GUI can run in Windows and Linux OS. Users need to prepare the materials in Host PC and settings on the board. The details are described as below.

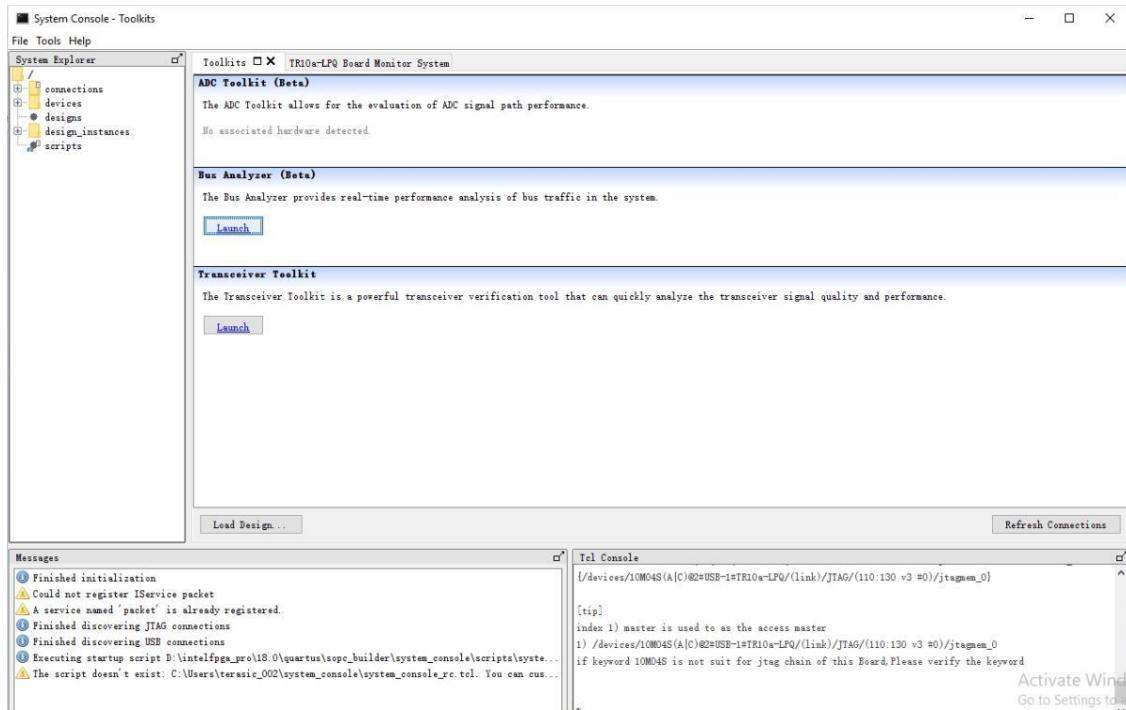
### ■ Software and Tools Installed on Host PC

- **Quartus Prime Software (18.0 or later):** The System Console tool is built in Quartus software, so the Quartus software should be installed before using the Dashboard GUI based on System Console.
- **USB Blaster II Driver:** The Dashboard GUI based on System Console allows the Host PC connect to the TR10a-LPQ board via JTAG interface, so users need to install USB Blaster II driver on Host PC.
- **Dashboard GUI Tool:** It is Dashboard GUI main program, users can find it in Tool\Dashboard GUI\System console of the TR10a-LPQ System CD, and copy the folder to the Host PC.

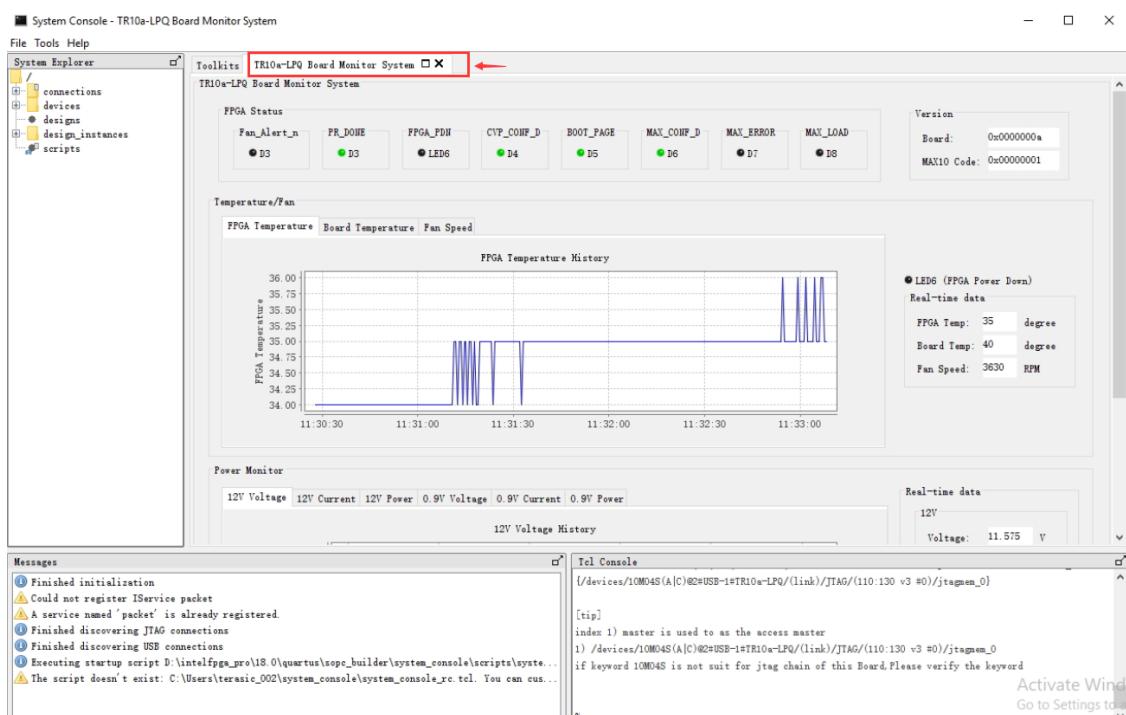
### ■ Connection Setting

1. Refer to the TR10a-LPQ\_Quick\_Start Guide included in the product package, make sure the host PC power is off and plug the TR10a-LPQ board into the PCIe slot of Host PC, then power on the host PC. If only want to use the TR10a-LPQ board, users can connect the external power adapter to the 2x2 power connector of the board then power on the board.
2. Connect the TR10a-LPQ USB Blaster II connector to the host PC USB port through the micro USB cable.
3. Execute the Dashboard GUI application on the host PC, execute the test.bat in the

System Console folder of the TR10a-LPQ System CD. As shown in **Figure 8-2**, the System Console window appears. As shown in **Figure 8-3**, click the TR10a-LPQ Board Monitor System, it will show the main monitor GUI, such as LED status, FPGA and board temperature. The details will be described below.



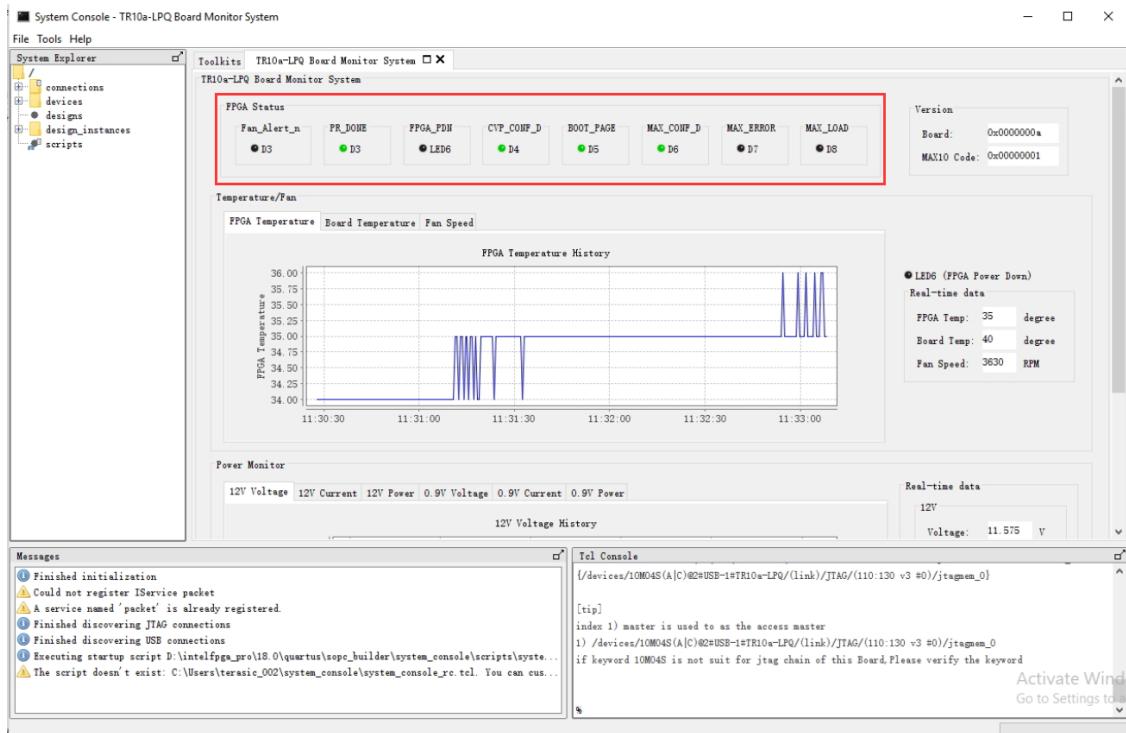
**Figure 8-2 System Console Window**



**Figure 8-3 TR10a-LPQ Board Monitor System Sheet**

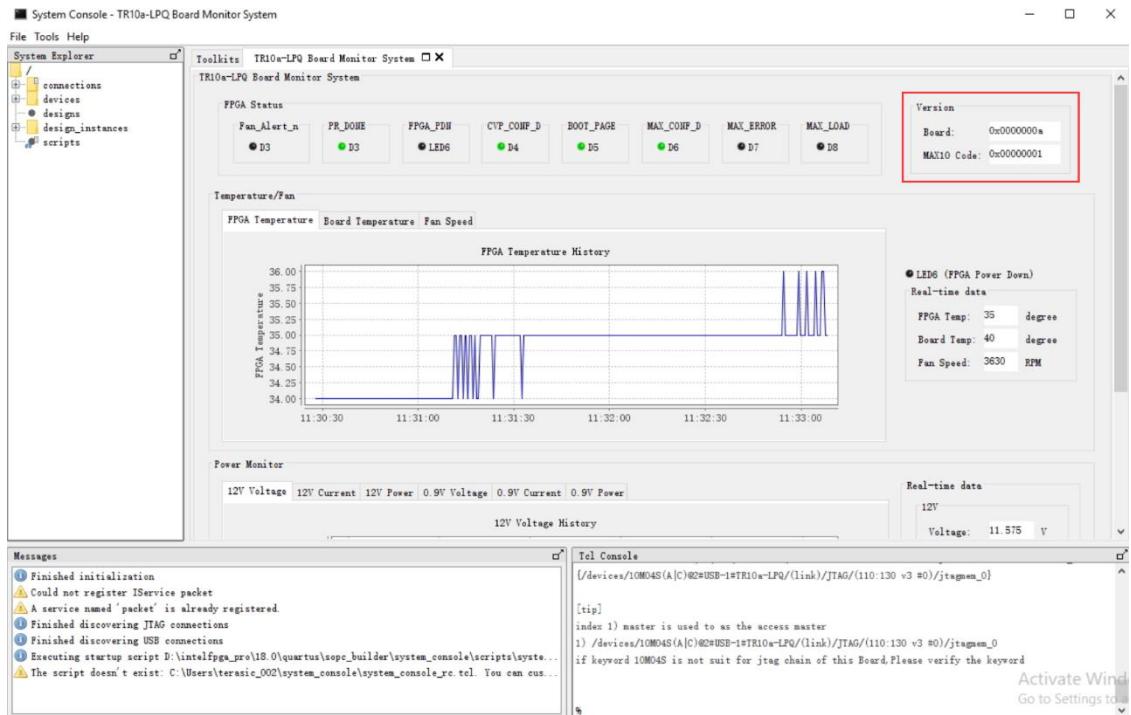
## ■ Dashboard GUI Function Introduction

- **FPGA Status:** As shown in **Figure 8-4**, it indicates the TR10a-LPQ status LED number. For these LEDs function, please refer to **Table 2-1** in section 2.2.



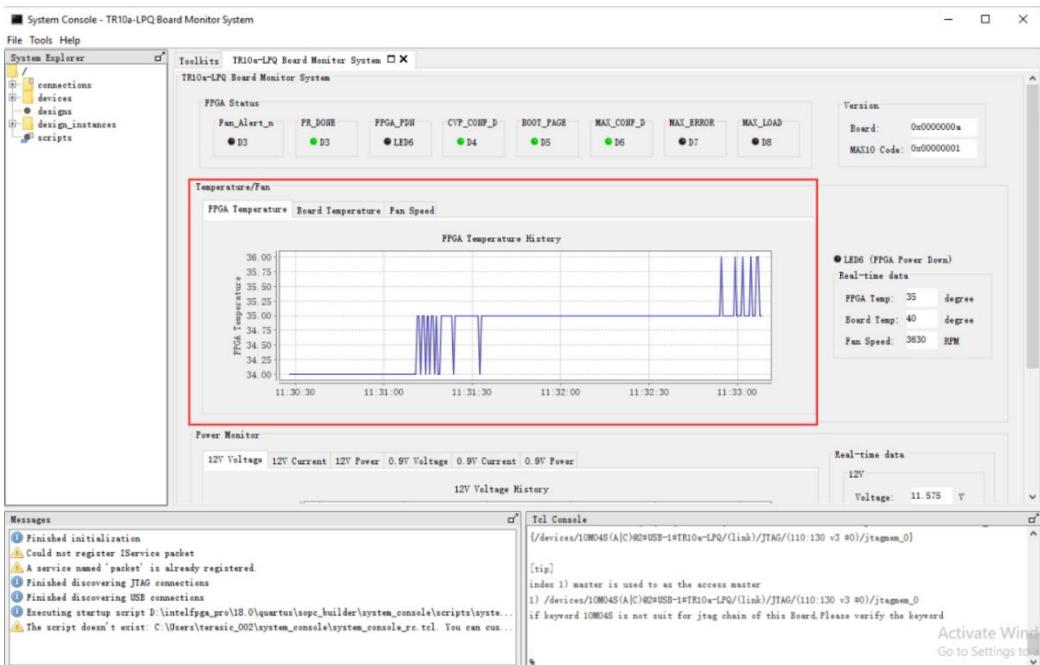
**Figure 8-4 FPGA Status Section**

- **Version:** It will show the version of the TR10a-LPQ board and the code in the system controller (MAX 10), as shown in **Figure 8-5**.

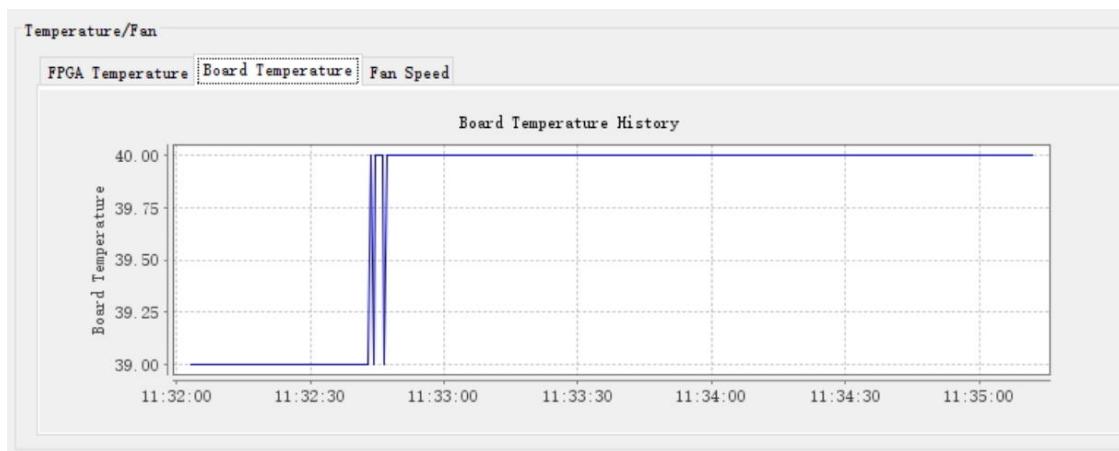


**Figure 8-5 Version Section**

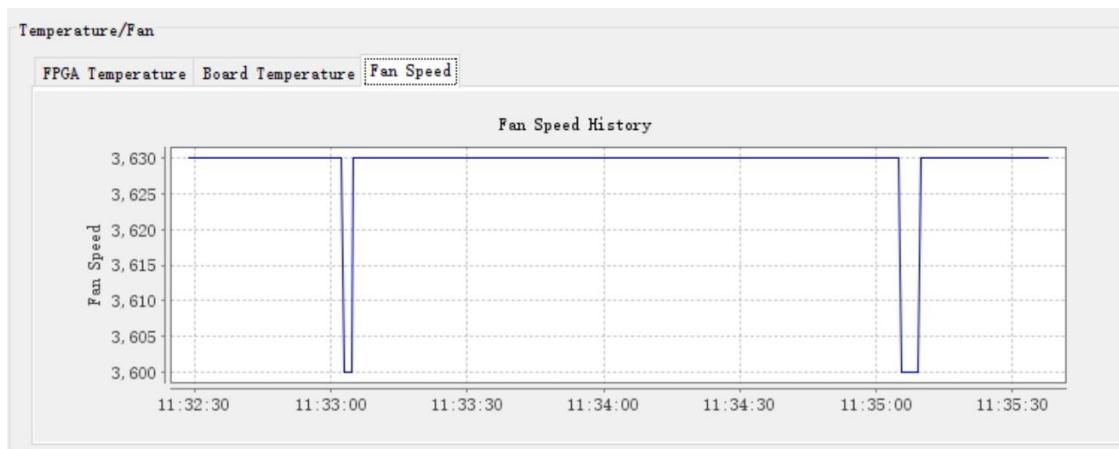
- **Temperature/Fan:** The Dashboard GUI will real-time show the fan speed, TR10a-LPQ board ambient and FPGA temperature. Users can know the board temperature in time. The information will be refreshed per 0.5 second, and displays through diagram and number, as shown in **Figure 8-6, Figure 8-7** and **Figure 8-8**.



**Figure 8-6 Temperature/Fan Section**

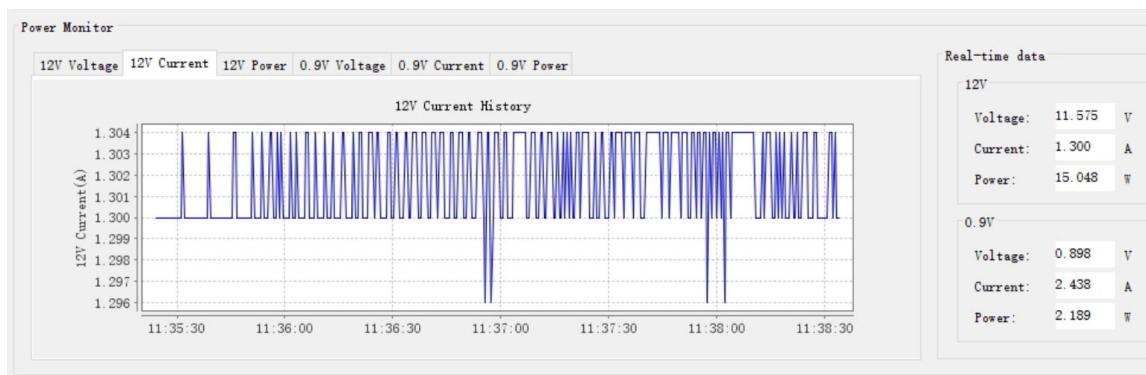


**Figure 8-7 Board Temperature GUI**



**Figure 8-8 Fan Speed GUI**

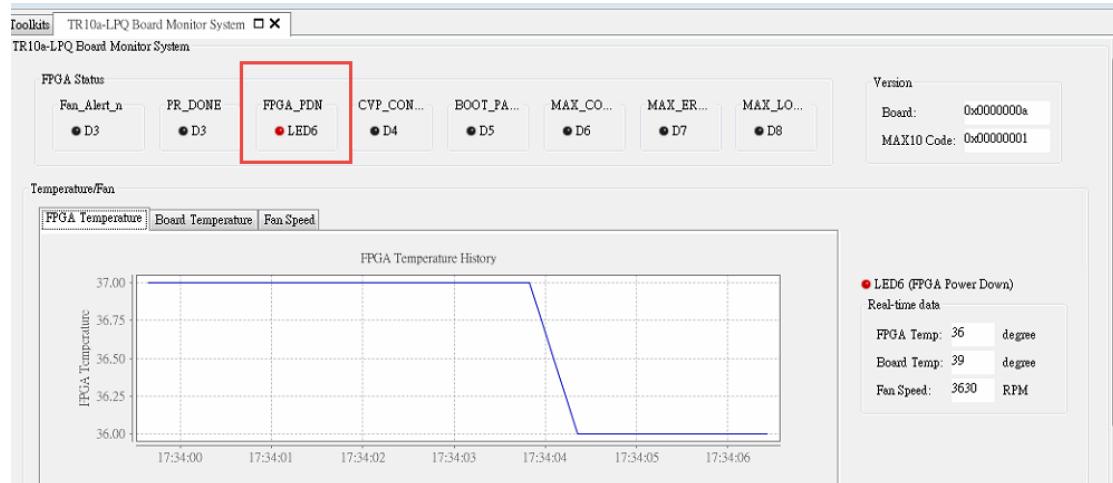
- **Power Monitor:** It will show the 12V/0.9V real-time voltage, current and power consumption of the TR10a-LPQ board, as shown in [Figure 8-9](#).



**Figure 8-9 Power Monitor Section**

- **FPGA Power Down:** It is a board protection function provided by the system

controller. When the TR10a-LPQ board ambient temperature or FPGA temperature is over 95 degree set by the system, the FPGA power will be shut down to protect the board. In this case, the FPGA\_PDN LED will be light on as shown in **Figure 8-10**. Users need to press the MAX\_RTS button or restart the power to remove this status.



**Figure 8-10 FPGA\_PDN LED Status**

- **Log File:** Besides show the board status in real-time, it will restore the data with .csv format document to the log folder in the same directory of test.bat, as shown in **Figure 8-11** and **Figure 8-12**.

scripts > log			
Name	Date modified	Type	Size
log_20181026.csv	26/10/2018 11:41	CSV File	134 KB

**Figure 8-11 .CSV Format Log File**

	A	B	C	D	E	F	G	H	I	J	K								
1	Time	FPGA	Tem	Board	Ten	Fan	Speed	12V	Volta	12V	Curre	12V	Power	0.9V	Volta	0.9V	Curre	0.9V	Power(W)
2	10:28:04	28	33	3630	11.575	1.254167	14.517	0.897705	2.098	1.883									
3	10:28:04	28	33	3630	11.575	1.254167	14.517	0.897705	2.098	1.883									
4	10:28:04	28	33	3630	11.575	1.254167	14.517	0.897705	2.076	1.864									
5	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897705	2.084	1.871									
6	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897705	2.094	1.88									
7	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897705	2.096	1.882									
8	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897705	2.114	1.898									
9	10:28:04	28	33	3630	11.575	1.254167	14.517	0.897705	2.116	1.9									
10	10:28:04	28	33	3630	11.575	1.254167	14.517	0.897705	2.122	1.905									
11	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897705	2.128	1.91									
12	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897705	2.122	1.905									
13	10:28:04	28	33	3630	11.575	1.254167	14.517	0.897705	2.092	1.878									
14	10:28:04	28	33	3660	11.575	1.254167	14.517	0.897705	2.121	1.904									
15	10:28:04	28	33	3660	11.575	1.258333	14.565	0.897705	2.104	1.889									
16	10:28:04	28	33	3660	11.575	1.258333	14.565	0.897705	2.12	1.903									
17	10:28:04	28	33	3660	11.575	1.258333	14.565	0.897705	2.116	1.9									
18	10:28:04	28	33	3630	11.575	1.254167	14.517	0.897949	2.134	1.916									
19	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897705	2.11	1.894									
20	10:28:04	28	33	3630	11.575	1.254167	14.517	0.897705	2.128	1.91									
21	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897705	2.144	1.925									
22	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897949	2.132	1.914									
23	10:28:04	29	33	3630	11.575	1.254167	14.517	0.897705	2.124	1.907									
24	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897949	2.112	1.896									
25	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897461	2.122	1.904									
26	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897705	2.096	1.882									
27	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897705	2.108	1.892									
28	10:28:04	28	33	3630	11.575	1.254167	14.517	0.897705	2.128	1.91									
29	10:28:04	28	33	3630	11.575	1.254167	14.517	0.897705	2.12	1.903									
30	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897705	2.126	1.909									
31	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897461	2.132	1.913									
32	10:28:04	28	33	3630	11.575	1.258333	14.565	0.897949	2.126	1.909									

Figure 8-12 Contents of the log file

## 8.2 Dashboard Connected via UART

This section will describe another way to connect to the Dashboard GUI. Through the USB to UART connector on the TR10a-LPQ board, the host PC connects to the system controller on the board, the UART based Dashboard GUI runs on the host PC can receive the TR10a-LPQ board information, such as voltage, temperature and fan speed. The UART based Dashboard GUI only supports windows OS at present. The usage preparation and installation details are described as below:

### ■ Software and Tools Installed on Host PC

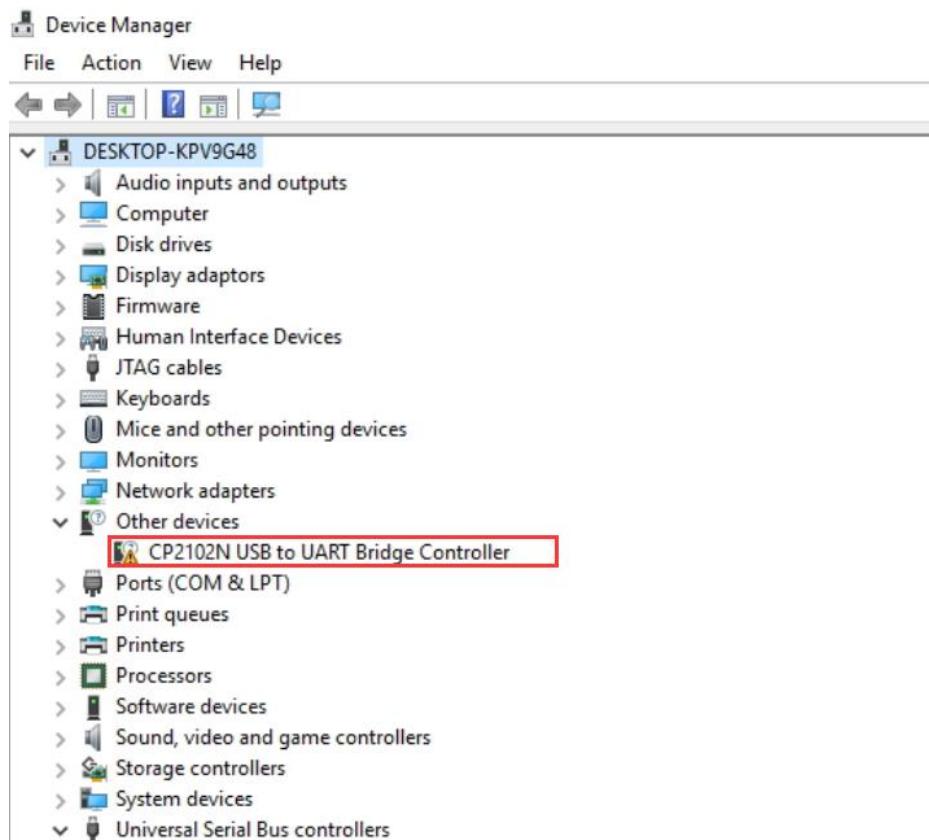
- **Install USB to UART driver:** Connect the board to the host PC through the USB to UART connector. The driver should be installed, users can find it in the Tool folder in the board system CD.
- **Dashboard GUI Tool:** It is the UART based Dashboard GUI main program, users can find it in Tool\dashboard\_gui\UART in the TR10a-LPQ system CD and copy it to the host PC.

### ■ Connection Setting

1. Make sure the host PC power is off and plug the TR10a-LPQ board into the PCIe slot of Host PC, then power on the host PC. If only want to use the TR10a-LPQ board, users can connect the external power adapter to the 2x2 power connector of the board then power on the board.
2. Connect the TR10a-LPQ USB Blaster II connector to the host PC USB port through micro USB cable. Please note that the system console based and UART based Dashboard GUI are use the same USB Blaster II connector. The USB HUB on the board can process the USB signal.

## ■ Install Driver

When connect the TR10a-LPQ board to the host PC, users also need to install USB to UART driver besides the USB Blaster II driver. As shown in **Figure 8-13**, one USB to UART device is shown in PC Device Manager.



**Figure 8-13 Uninstalled USB to UART device**

As described in previous steps, copy the device driver to the host PC and install it, as shown in **Figure 8-14** and **Figure 8-15**. Please note that the COM Port number is different in different host PC.

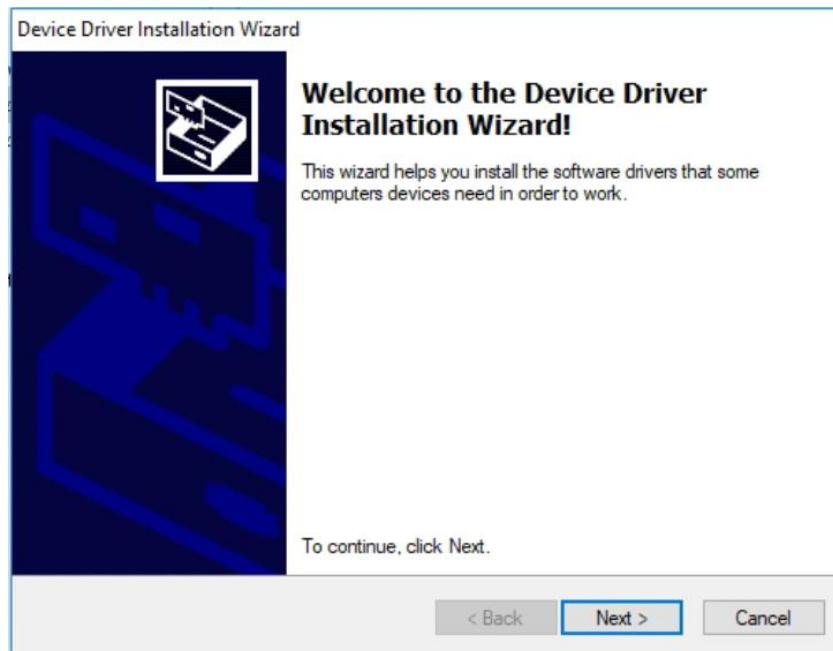


Figure 8-14 Install USB to UART driver

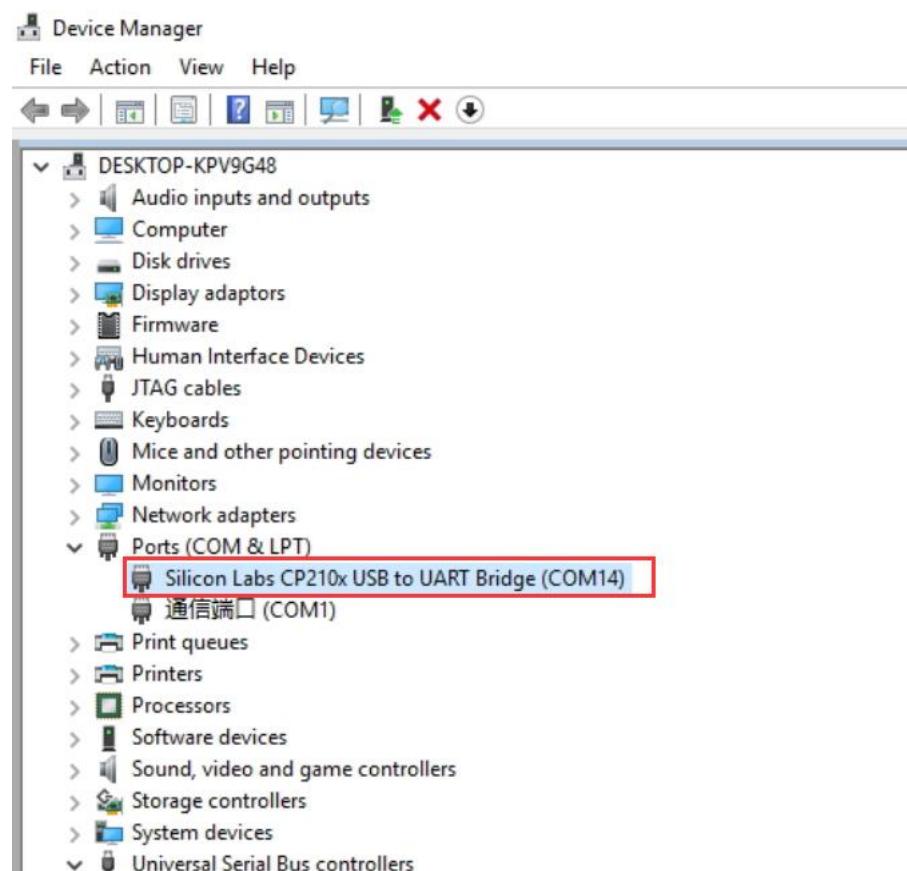


Figure 8-15 The USB to UART device after driver is installed successfully

## ■ Run Dashboard GUI

As described in previous steps, find the Tool\dashboard\_gui\UART in TR10a-LPQ system CD and copy the folder to the host PC. Execute the Dashboard.exe, a window will show as **Figure 8-16**. It will describe the detail functions as below.



**Figure 8-16 UART based Dashboard GUI**

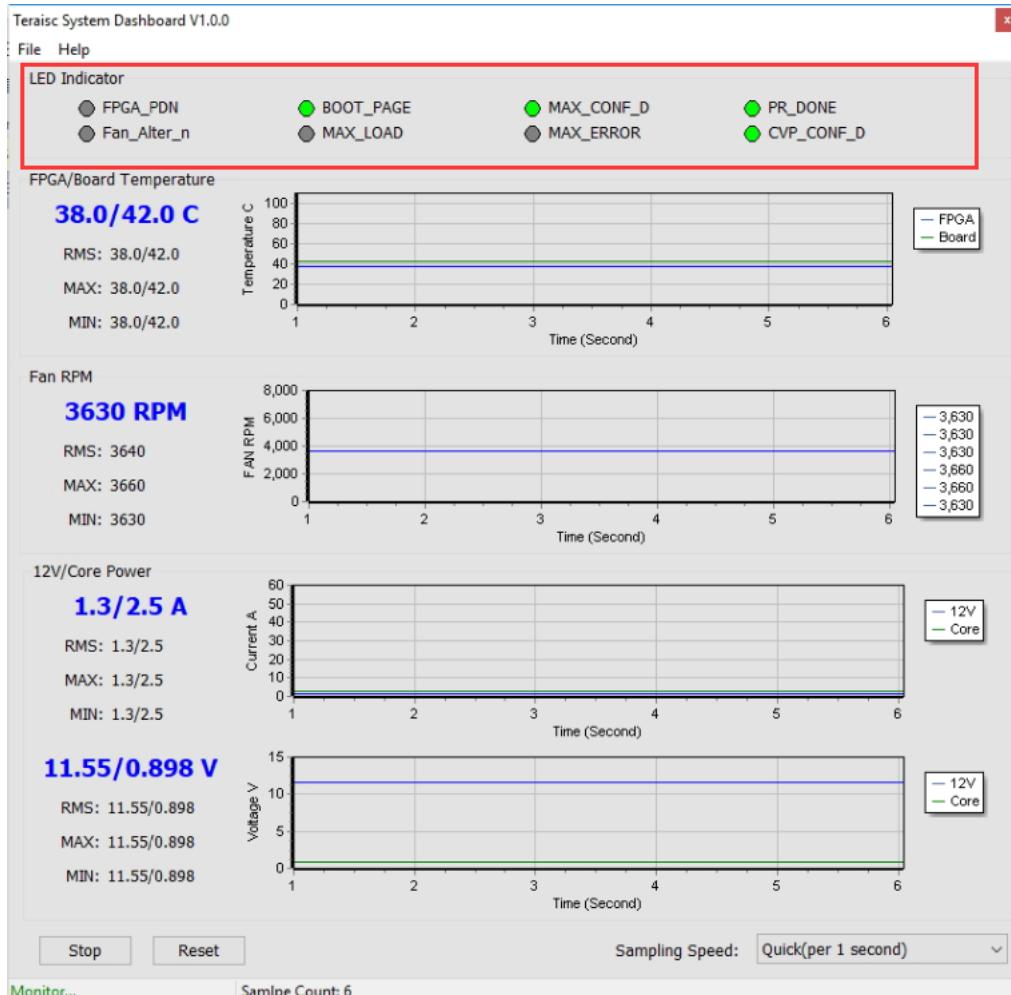
## ■ Dashboard GUI function introduction

- **Start/Stop:** As shown in **Figure 8-17**, there is a Start button at the bottom-left of the GUI window. Click it to run the program (Start will change to Stop), it will show the TR10a-LPQ board status. Users can press Stop button to stop the status data transmission and display.
- **Reset Button:** Press this button to clear the historical data shown in GUI, and record the data again.



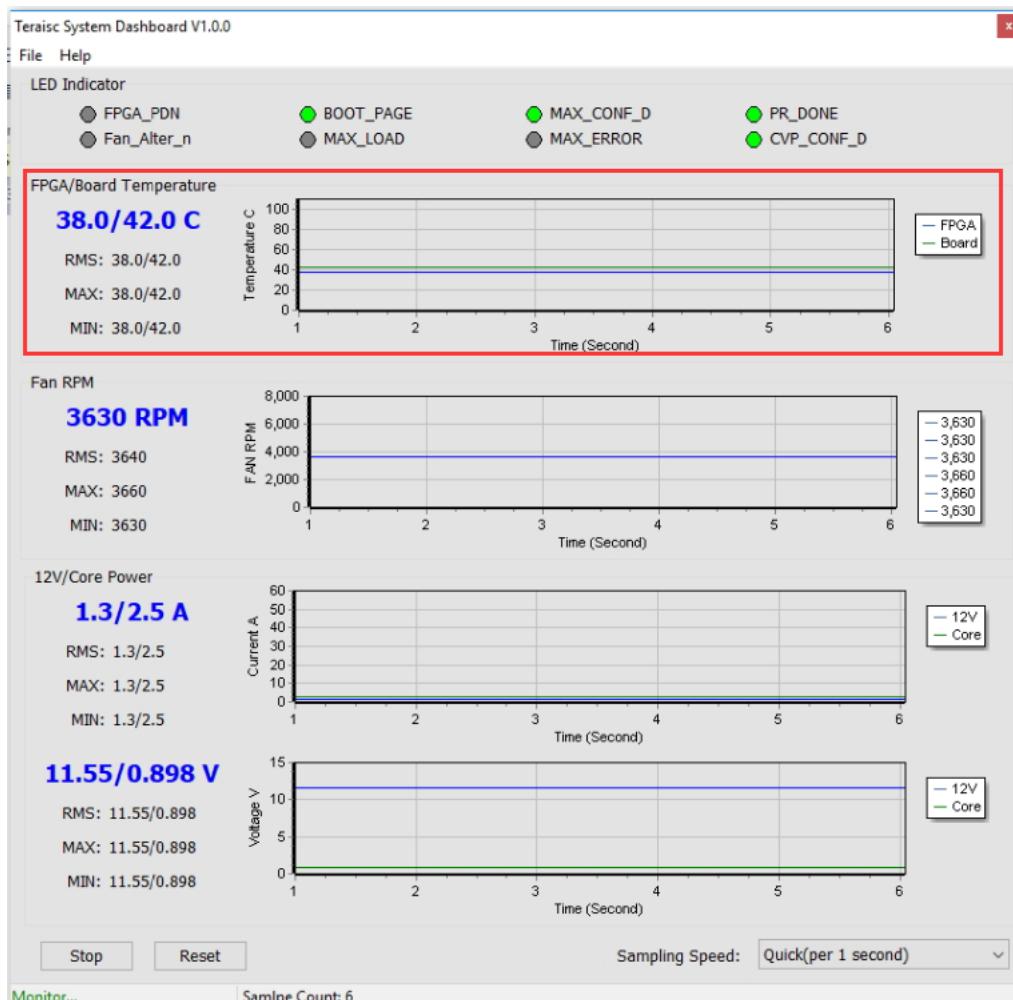
**Figure 8-17 Start and Reset button**

- **FPGA Status:** As shown in **Figure 8-18**, it will show the status LED number on the TR10a-LPQ board. For these LEDs function, please refer to **Table 2-1** in section 2.2.



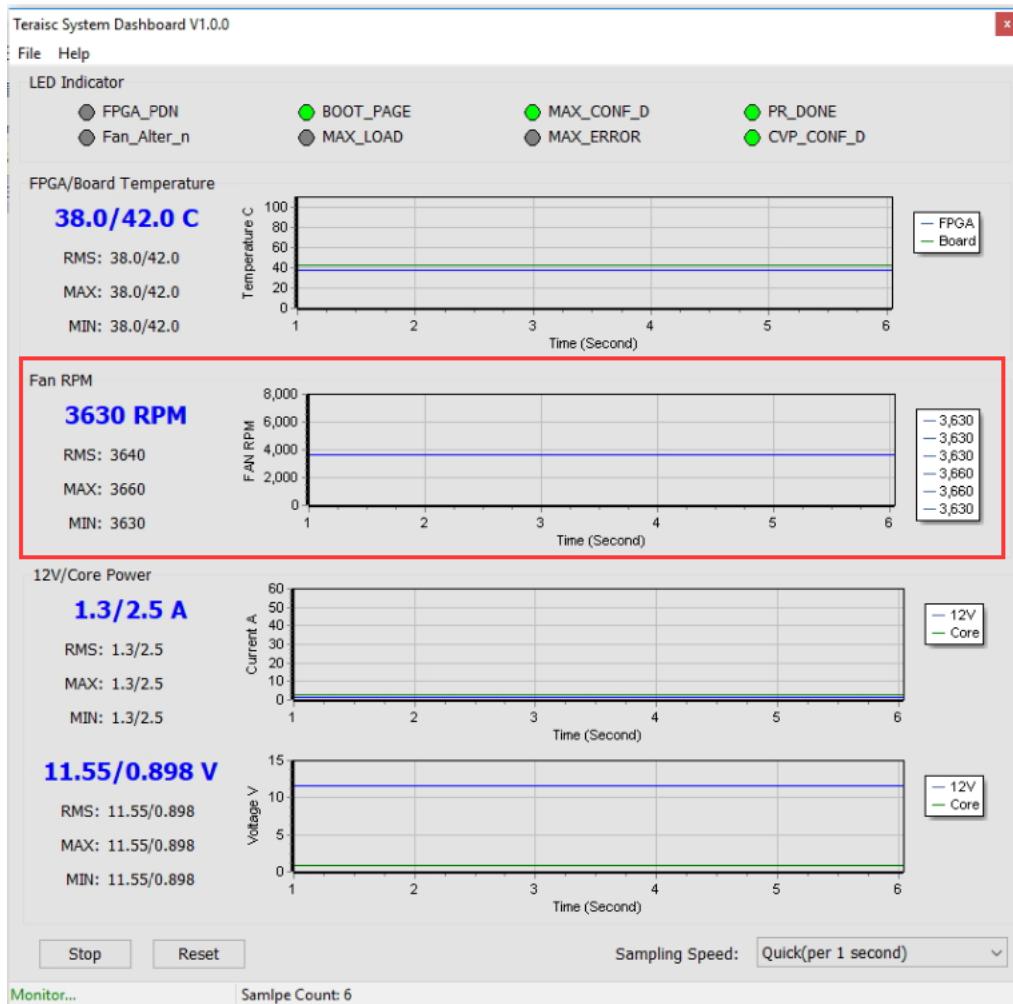
**Figure 8-18 FPGA Status section**

- FPGA/Board Temperature:** The Dashboard GUI will real-time show the fan speed, TR10a-LPQ board ambient and FPGA temperature. Users can know the board temperature in time. The information will be refreshed per 0.5 second, and displays through diagram and number, as shown in **Figure 8-19**.



**Figure 8-19 Temperature section**

- **Fan RPM:** It displays the real-time speed of the fan on the TR10a-LPQ board, as shown in **Figure 8-20**.



**Figure 8-20 FAN RPM section**

- **12V/Core Power monitor:** It displays the real-time 12V/Core Power (0.9V) voltage and consumption current on the TR10a-LPQ board, as shown in **Figure 8-21**.



**Figure 8-21 Power Monitor Section**

- Sampling Speed:** It can change interval time that the Dashboard GUI sample the board status. Users can adjust it to 1s/10s/1min/Full Speed (0.1s) to sample the board status, as shown in **Figure 8-22** and **Figure 8-23**.

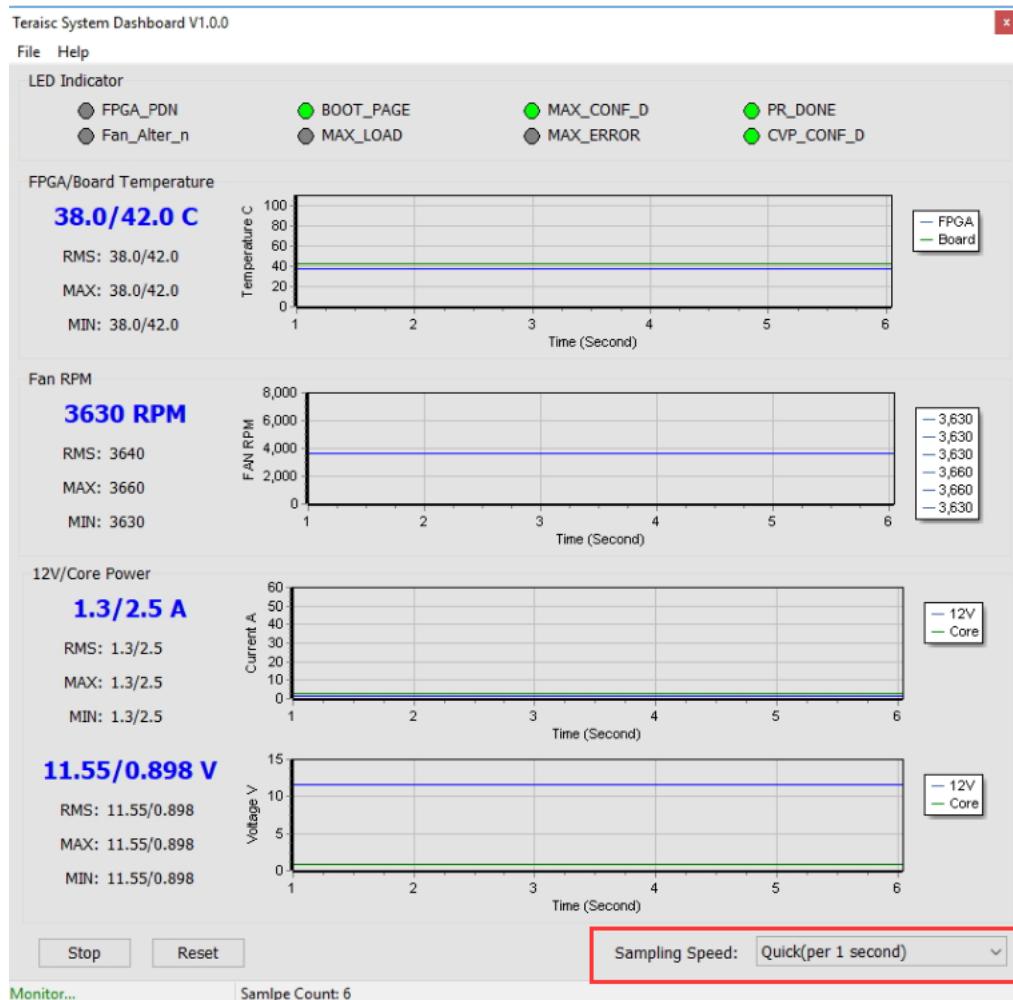


Figure 8-22 Sampling Speed section

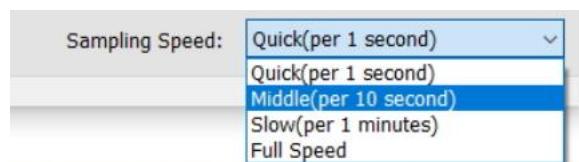
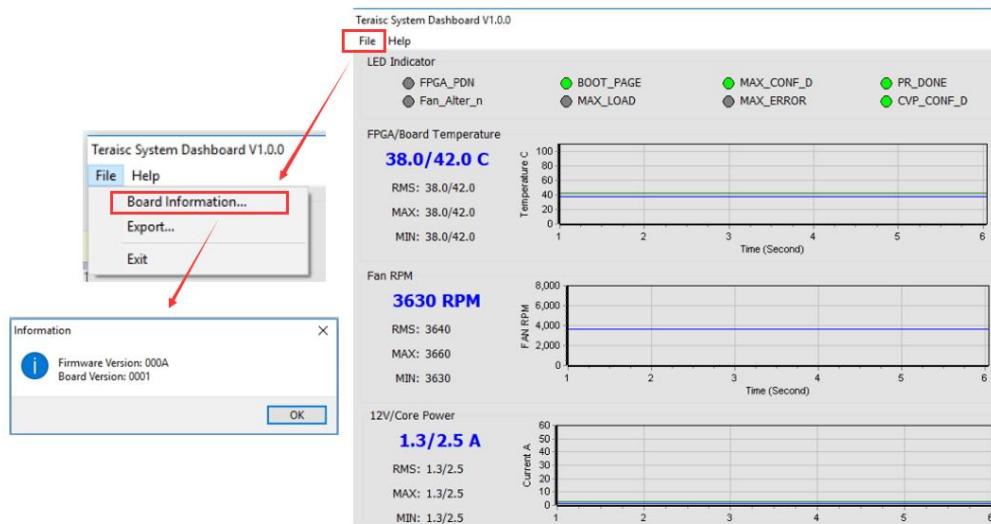


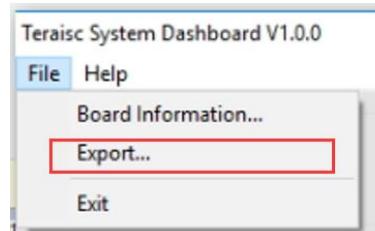
Figure 8-23 Options of Sampling Speed

- Board Information:** There is a File page on the upper left of the Dashboard GUI program window, click the Board Information to get the current software version and the TR10a-LPQ board version, as shown in **Figure 8-24**.

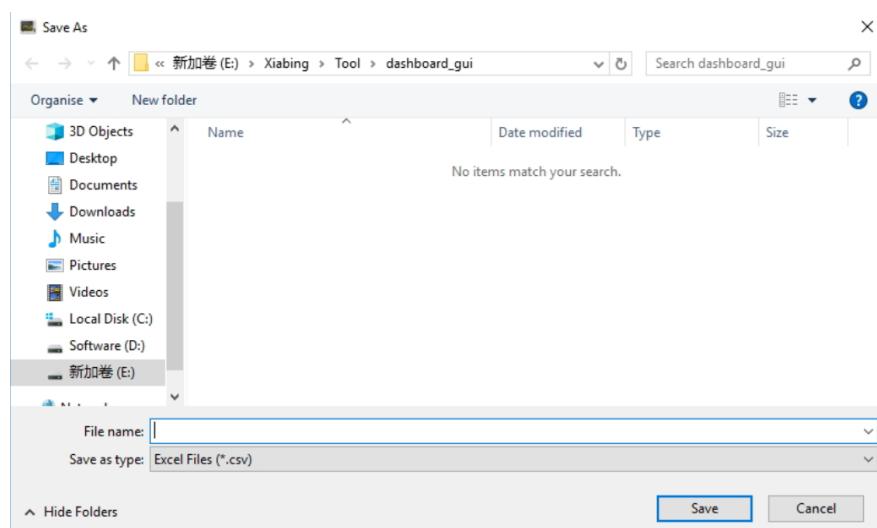


**Figure 8-24 Board Information**

- **Log File:** On the upper left of the Dashboard GUI program window, click the Export in the File page to save the board temperature, fan speed and voltage data in .csv format document, as shown in **Figure 8-25** and **Figure 8-26**.



**Figure 8-25 Export the log file**



**Figure 8-26 Export the log file in .csv format**

# ***Additional Information***

## **Getting Help**

Here are the addresses where you can get help if you encounter problems:

### **■ Terasic Technologies**

9F., No.176, Sec.2, Gongdao 5th Rd,  
East Dist, HsinChu City, Taiwan, 30070  
Email: support@terasic.com  
Web: [www.terasic.com](http://www.terasic.com)  
TE10a-HL Web: [TR10a-LPQ.terasic.com](http://TR10a-LPQ.terasic.com)

### **■ Revision History**

Date	Version	Changes
2018.11	First publication	

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