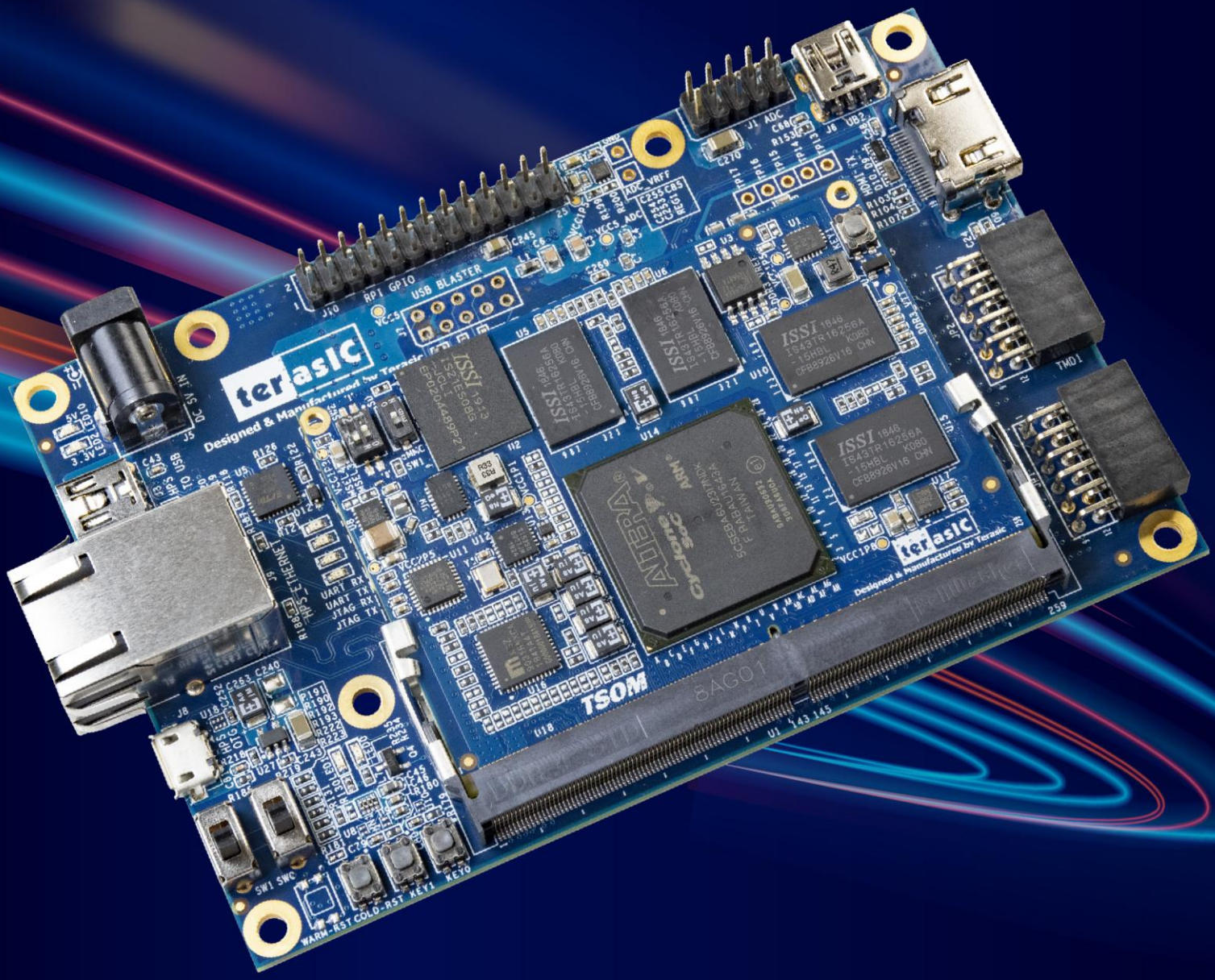
TSoM

TSoM EVALUATION Kit Manual



terasIC
www.terasic.com

Copyright © Terasic Inc. All Rights Reserved.

TABLE OF CONTENTS

Chapter 1 Introduction 3

1.1 Package Contents 3

1.2 TSoM Design Package 4

1.3 Getting Help 4

Chapter 2 Board Specification 5

Chapter 2 5

2.1 Layout and Components 5

2.2 Block Diagram 6

Chapter 3 System Interface 9

Chapter 3 9

3.1 Settings of FPGA Configuration Mode 9

3.2 Configuration of Cyclone V SoC FPGA on TSoM evalu-ation kit 11

3.3 Board Status Elements 18

3.4 Board Reset Elements 18

Chapter 4 HPS Fabric Components 20

Chapter 4 20

4.1 Ethernet RJ45 20

4.2 USB OTG Connector 21

4.3 UART to USB 22

4.4 Micro SD Card 23

4.5 QSPI Flash (DNI) 23

4.6 Raspberry Pi 2x13 GPIO 24

Chapter 5 FPGA Fabric Components 28

Chapter 5 28

5.1 User Push-buttons, Switches and LEDs 28

5.2 TMD Header 30
5.3 A/D Converter and Analog Input 31
5.4 HDMI TX Interface 33
Chapter 6 Examples For FPGA 35
Chapter 6 35
6.1 HDMI TX 35
6.2 DDR3_RTL 38
Chapter 7 Programming the EPCS Device 41
Chapter 8 eMMC Programming 53
Appendix 61
Chapter 7 61
Chapter 8 61
Chapter 9 61
9.1 Revision History 61

Chapter 1
Introduction

TSoM (Terasic SoC System on Module) Evaluation Kit is composed of TSoM module and Based Board(TSoM-BB). TSoM module is small, integrated single-board computers with Cyclone® V SoC at the core. The SoC SoM includes DDR3 memory, flash memory, power management, common interface controllers. Users can install the TSoM based board on it through the 260-pin edge connector, combined to a complete FPGA evaluation kit.

TSOM-BB is a based board developed based on TSoM card. The main purpose is providing expansion interface, power and JTAG configuration function for TSoM, it connects the FPGA and HPS fabric I/O of TSoM to many application interfaces, such as USB, Ethernet, HDMI, Micro SD card and so on, it expanded the FPGA I/O which are connected to 260-pin edge connector to a variety of applications. The TSoM based board also provides USB Blaster II circuit, users can configure and debug the FPGA on TSoM through the JTAG interface. TSoM based board provides power source to TSoM through the 260-pin edge connector. With the TSoM based board, users can use TSoM Evaluation Kit to develop various FPGA projects.

1.1 Package Contents

Figure 1-1 shows a photograph of TSoM Evaluation Kit.

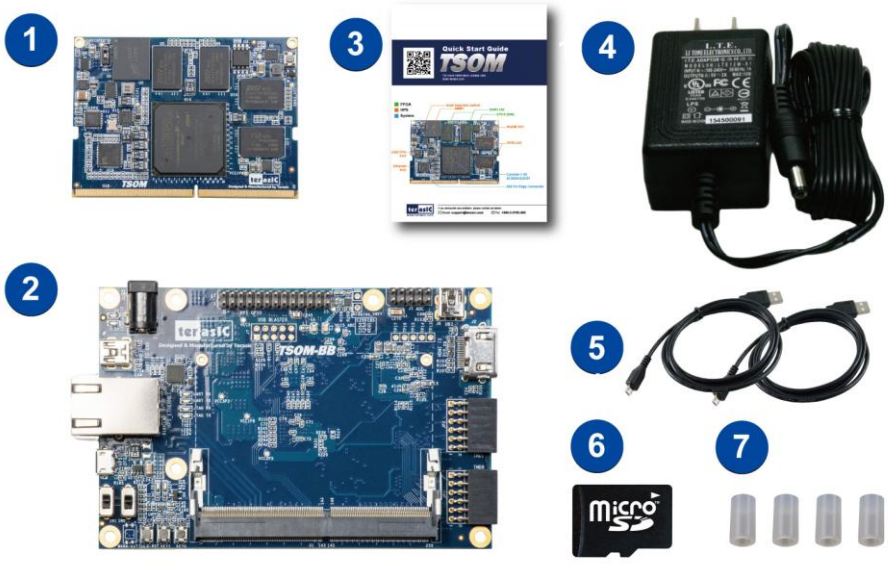


Figure 1-1 TSoM Evaluation Kit Package Contents

The TSoM Evaluation Kit package includes:

1. TSOM Module (installed)

2. TSOM Based board (TSOM-BB)
3. Quick Start Guide
4. Power DC Adapter (5V)
5. Type A to Mini-B USB Cable x2
6. MicroSD card (installed)
7. Four Silicon Footstands

1.2 TSoM Design Package

The TSoM Evaluation Kit design package contains all the documents and supporting materials associated with TSoM Evaluation Kit, including the user manual, reference designs, and device datasheets.

Users can download this design package from the link: http://TSoM.terasic.com/cd.

1.3 Getting Help

Here are the addresses where you can get help if you encounter any problems:
Terasic Technologies
9F., No.176, Sec.2, Gongdao 5th Rd, East Dist, Hsinchu City, 30070. Taiwan
Email: support@terasic.com
Tel.: +886-3-575-0880
Website: TSoM.terasic.com

Chapter 2
Board Specification

This chapter provides an introduction to the features and design characteristics of the board.

2.1 Layout and Components

Figure 2-1 and **Figure 2-2** shows a photograph of the TSoM Evaluation Kit (TSoM module board and TSOM Based Board). It depicts the layout of the board and indicates the location of the connectors and key components.

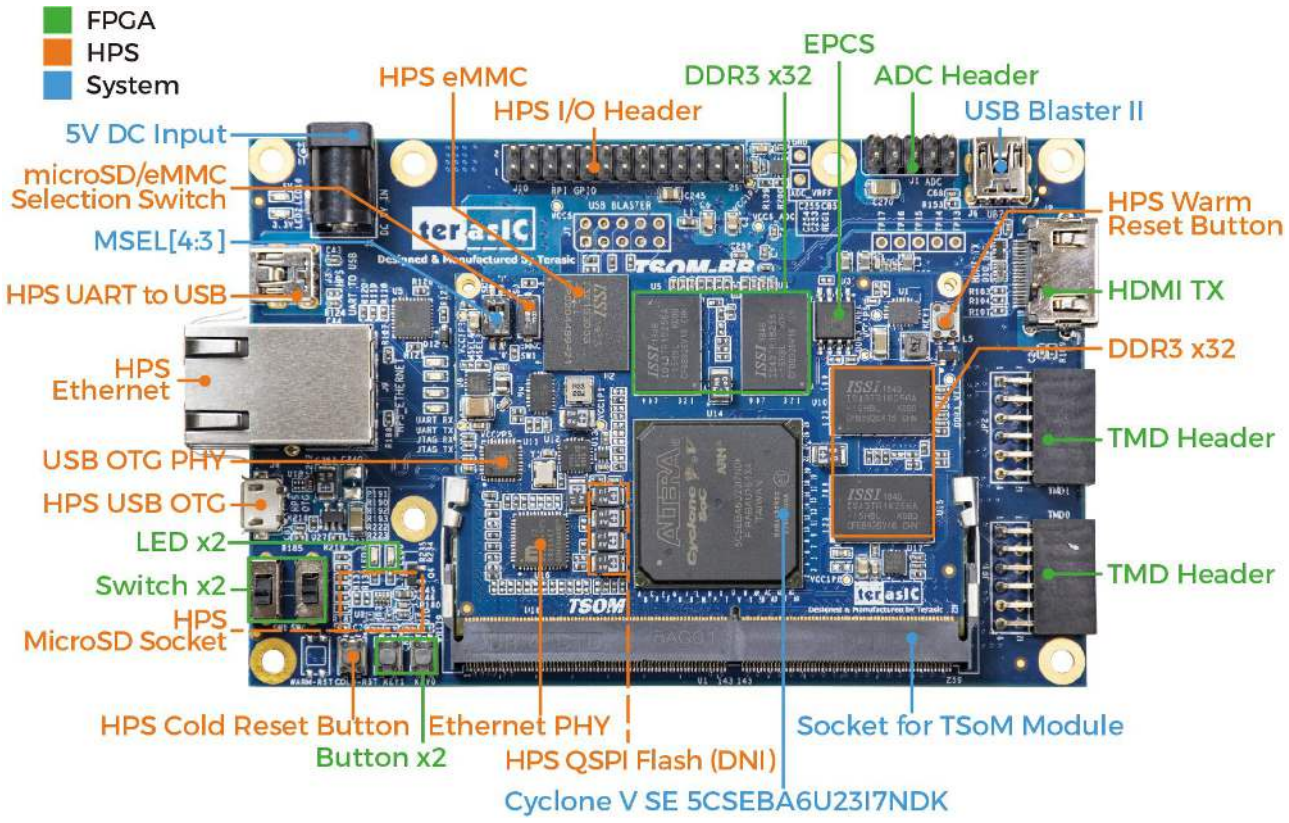


Figure 2-1 TSoM Evaluation Kit (Top View)

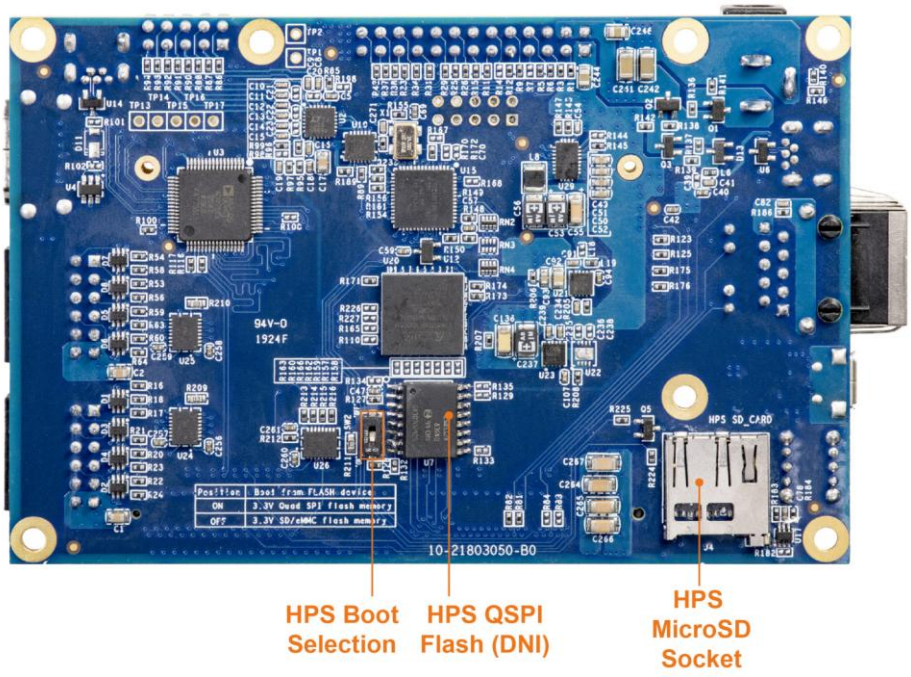


Figure 2-2 TSoM Evaluation Kit (Back View)

2.2 Block Diagram

Figure 2-3 is the block diagram of the TSoM Evaluation Kit and **Figure 2-4** shows the block diagram of the TSoM Module board

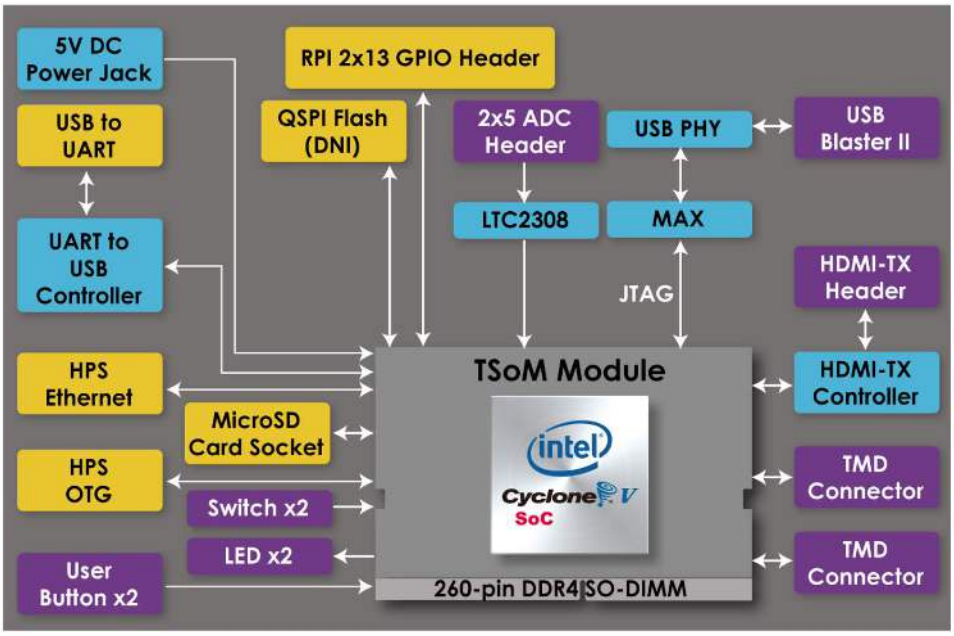


Figure 2-3 Block diagram of the TsoM evaluation kit

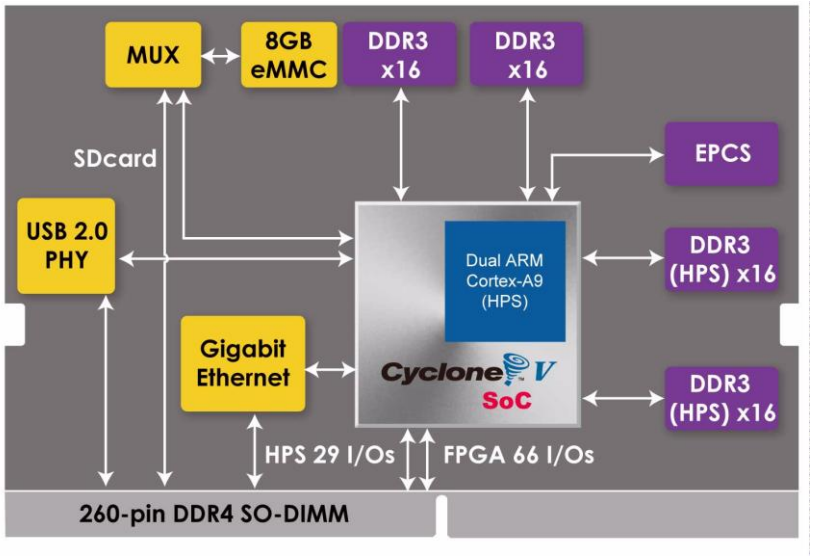


Figure 2-4 Block diagram of the TSoM Module

Detailed information about TSoM module and TSOM based board are listed below.

- **TSoM Module**
  - FPGA: Cyclone V SE 5CSEBA6U23I7NDK (110K LEs)
  - Interface: DDR4 Edge (include 3.3V power source)
  - Dimension: 50 mm x 70 mm
  - **FPGA Fabric side:**
    - DDR3 SDRAM 1GB, 32bit – 303MHz (Soft IP)
    - LVDS Transmitter x15 & LVDS Receiver x17 pairs & GPIO x3 (Total GPIO x67)
    - EPCS64
  - **HPS Fabric side:**
    - Boot Selection DIP Switch: boot from eMMC or MicroSD Card
    - DDR3 SDRAM 1GB, 32bit - 400MHz
    - USB 2.0 PHY
    - Gigabit Ethernet PHY
    - 3.3V GPIO x25 (Can/UART/SPI/I2C/Trace Buses)
    - 1.5V GPI x4 (Input pins)
    - eMMC 8GB
- **TSOM based board**

- **System:**
  - Power source: 5V DC
  - on-board USB Blaster II
  - DDR4 socket for TSOM installation
- **FPGA Fabric:**
  - LED x 2, Key x 2, Switch x 2
  - HDMI TX v1.4, 1080P Full-HD, Compatible with HDCP v1.4
  - TMD Header x2 (support 16 GPIO)
  - ADC, 8-channel, 12-bit, 500Ksps
- **HPS Fabric:**
  - MicroSD Socket
  - Optional 512Mb QSPI FLASH (Need to rework Boot Selection resistor on Module)
  - USB to UART (USB OTG PHY, Mini-B Connector)
  - Ethernet (RJ45 Connector)
  - USB OTG (Micro-AB Connector)
  - 2x13 GPIO (include I2C/UART/SPI), Compatible with Raspberry Pi Expansion IO

Chapter 3
System Interface

This chapter provides an instruction for the system interface of the TSoM evaluation kit.

3.1 Settings of FPGA Configuration Mode

Since the factory setting of MSEL[4:0] on the TSoM module is FPPx32 mode(See **Figure 3-1**). It means that when the TSoM evaluation kit is power on, the FPGA is configured from the HPS fabric. When the software on the HPS is running, the FPGA can be configured via HPS.

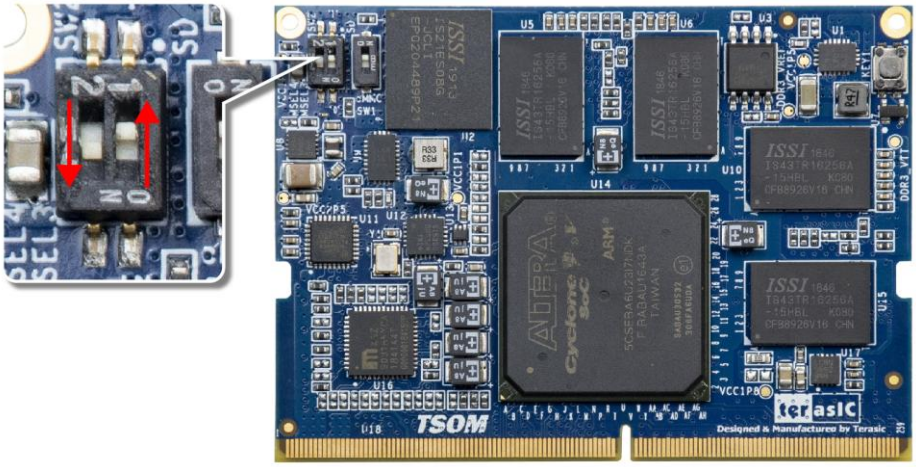


Figure 3-1 TsoM module is setting to FPPx32 mode

As shown in the **Figure 3-2**, there are 3 storage devices can be supported on TSoM evaluation kit to boot HPS: SD Card, QSPI flash and eMMC flash. The eMMC flash is embedded in the TSoM module. The SD Card and QSPI Flash are on the TSoM based board.

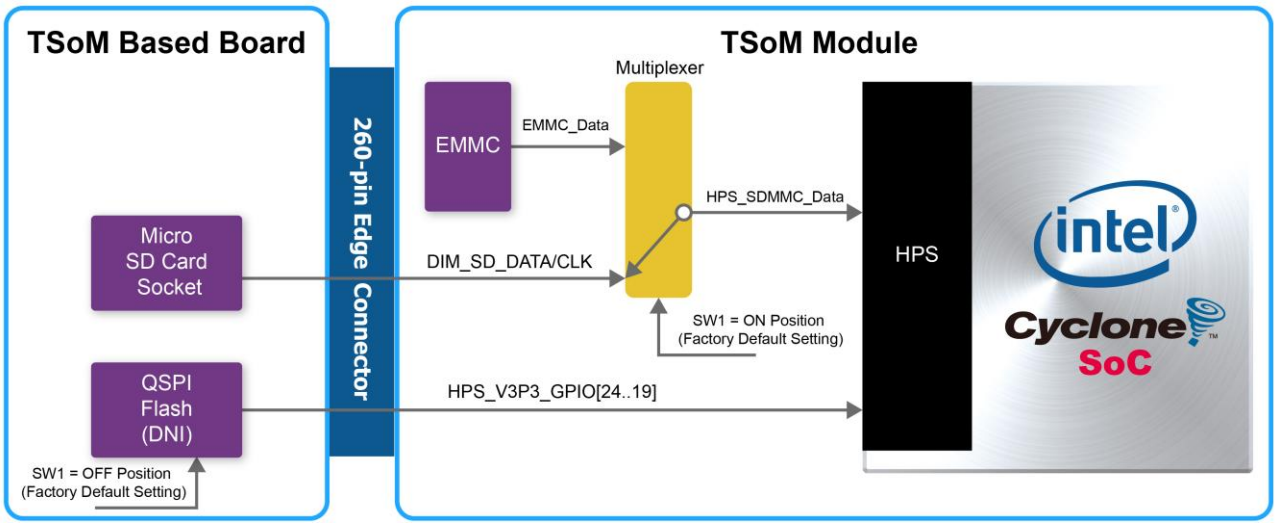


Figure 3-2 Boot device for HPS on the TsoM evaluation kit

As described in section 3.1 of the TSoM module manual, the SD card shares the same HPS data bus as the eMMC flash. Therefore, only one of these two storage devices can be used to boot HPS at the same time. Users can switch between the two boot devices through the switch SW1 on the TSOM module board (See **Figure 3-3**). The factory default boot device is SD card interface (SW1 is set to "ON" position).

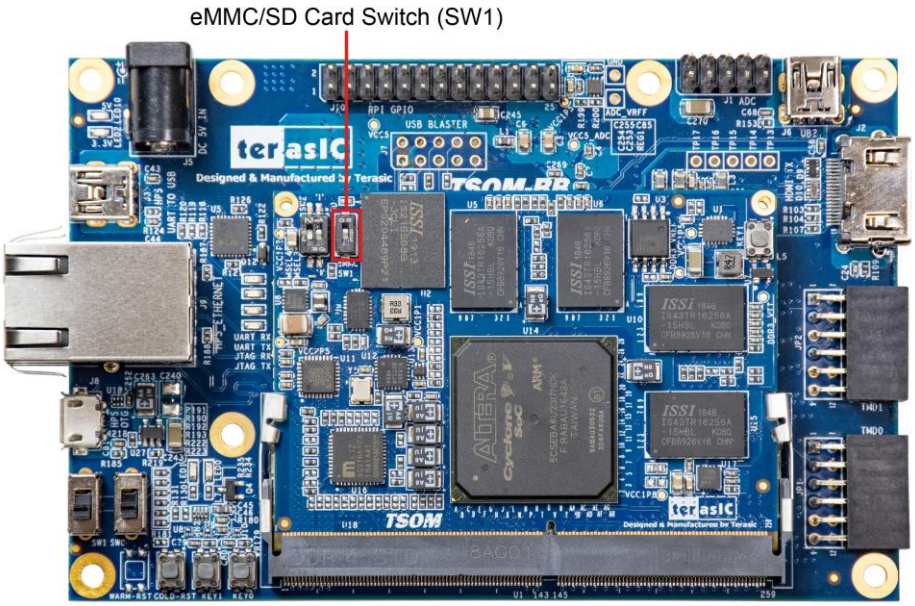


Figure 3-3 eMMC/SD Card select switch

The QSPI Flash is the option function and don't install on the board . Users can apply it on their own if needed. After the user installs the QSPI flash, user can adjust the SW2 on the back of the TSoM evaluation kit (See **Figure 3-4**). Switch it to "ON" position that will change the HPS boot source to QSPI flash.

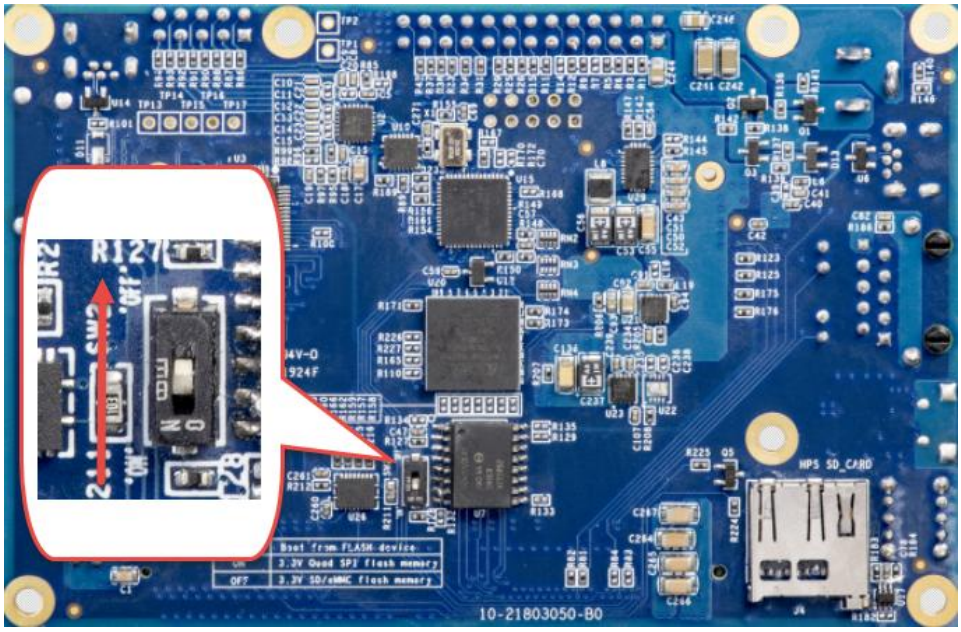


Figure 3-4 QSPI flash/SD Card select switch(Setting to SD Card)

Also, if the user wants to the FPGA is configured by EPCS on TSoM evaluation kit when power on. Then refer to section 3.1 of the TSoM module manual for EPCS part. Modify the SW2 on the TSoM module to AS mode (See **Figure 3-5**).

Figure 3-5 SW2 Setting Resistors (AS Mode)

3.2 Configuration of Cyclone V SoC FPGA on TSoM evalu-ation kit

There are two types of programming method supported by TSoM evaluation kit:

1. **JTAG programming**: It is named after the IEEE standards Joint Test Action Group. The

configuration bit stream is downloaded directly into the Cyclone V SoC FPGA. The FPGA will retain its current status as long as the power keeps applying to the board; the configuration information will be lost when the power is off.

2. **AS programming**: The other programming method is Active Serial configuration. The configuration bit stream is downloaded into the serial configuration device (EPCS64), which provides non-volatile storage for the bit stream. The information is retained within EPCS64 even if the TSoM evaluation kit board is turned off. When the board is powered on, the configuration data in the EPCS64 device is automatically loaded into the Cyclone V SoC FPGA.

■ JTAG Chain on TSoM Evaluation Kit

The FPGA device can be configured through JTAG interface on TSoM evaluation kit board, but the JTAG chain must form a closed loop, which allows Quartus II programmer to the detect FPGA device. **Figure 3-6** illustrates the JTAG chain on TSoM evaluation kit board.
In addition, the TSoM evaluation kit has one external JTAG Header (J7) reserved for users to connect to JTAG chain of the TSoM evaluation kit via external blaster. The J7 header is not installed, so users need to solder a 2.54mm 2 x 5 male pin header if it is necessary.

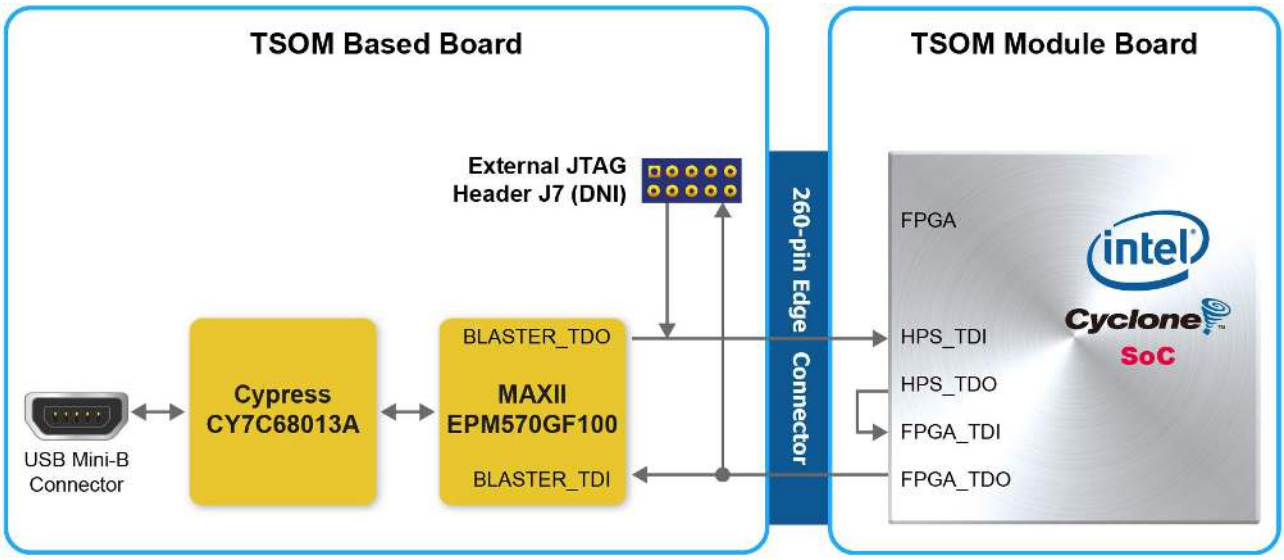


Figure 3-6 Path of the JTAG chain

■ Configure the FPGA in JTAG Mode

There are two devices (FPGA and HPS) on the JTAG chain. The following shows how the FPGA is programmed in JTAG mode step by step.
Open the Quartus II programmer, please Choose **Tools > Programmer**. The Programmer window opens. Please click "**Hardware Setup**", as circled in **Figure 3-7**.

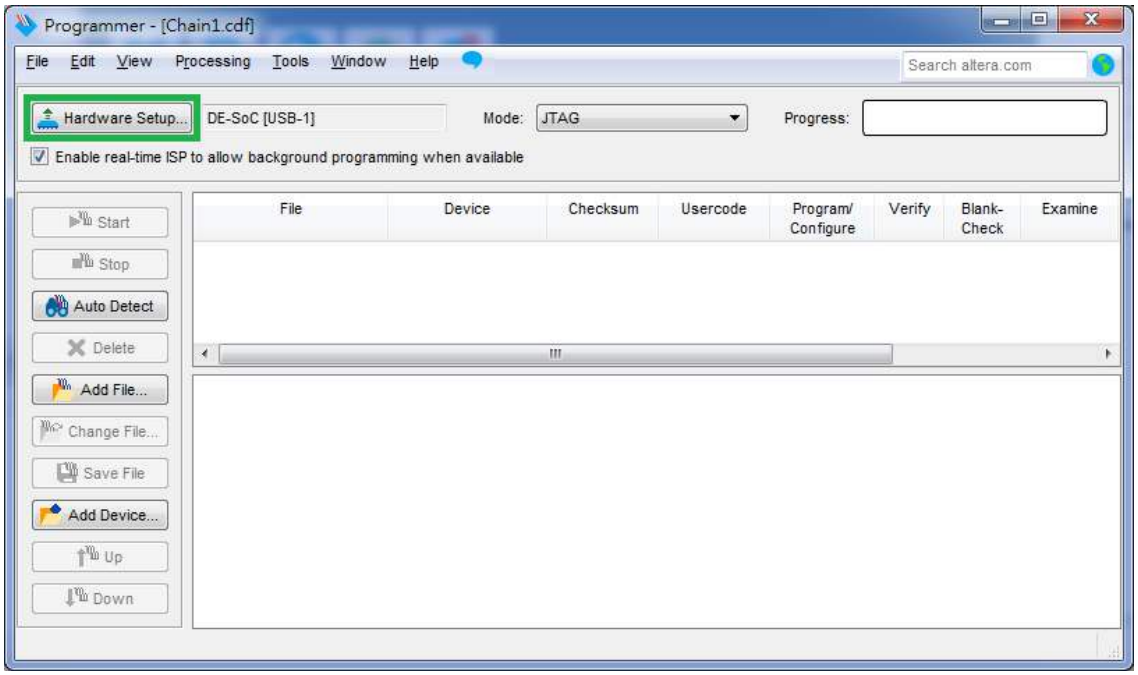


Figure 3-7 Programmer Window

If it is not already turned on, turn on the DE-SoC [USB-1] option under currently selected hardware and click "**Close**" to close the window. See **Figure 3-8**.

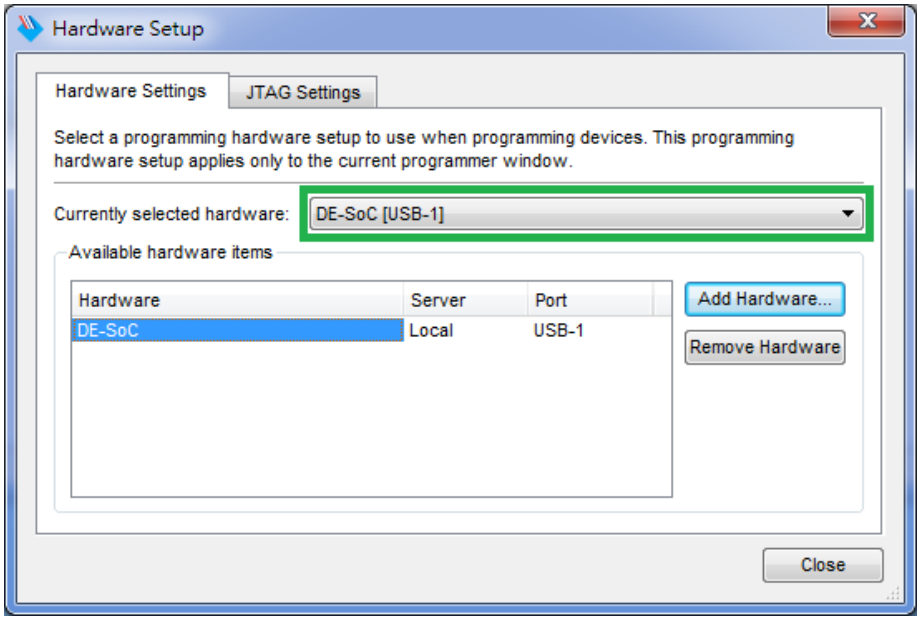


Figure 3-8 Hardware Setting

Return to the Quartus II programmer and click "**Auto Detect**", as circled in **Figure 3-9**.

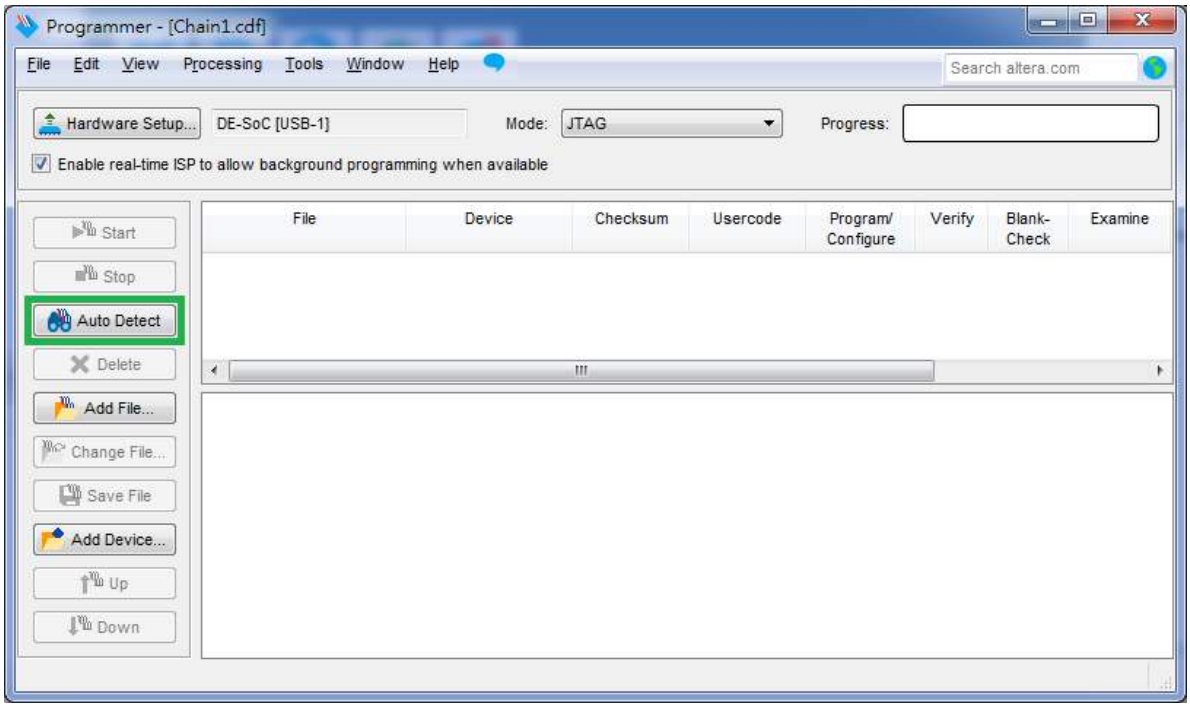


Figure 3-9 Detect FPGA device in JTAG mode

If the device is detected, the window of the selection device is opened, Please select detected device associated with the board and click "**OK**" to close the window, as circled in **Figure 3-10**.

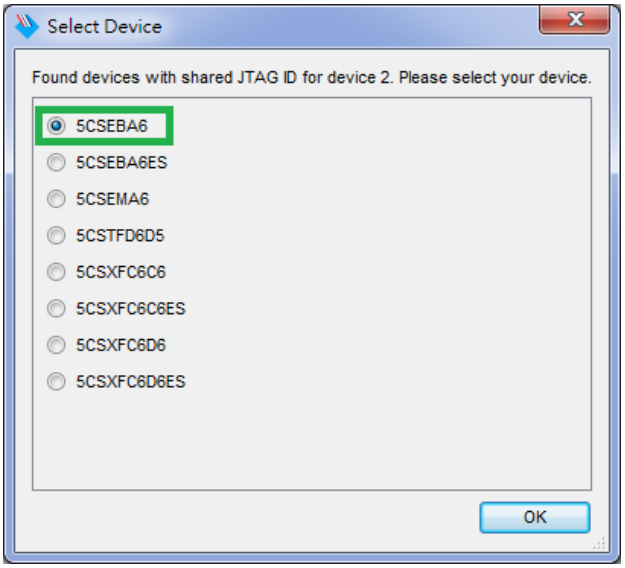


Figure 3-10 Select 5CSEBA6 device

Both FPGA and HPS are detected, as shown in **Figure 3-11**.

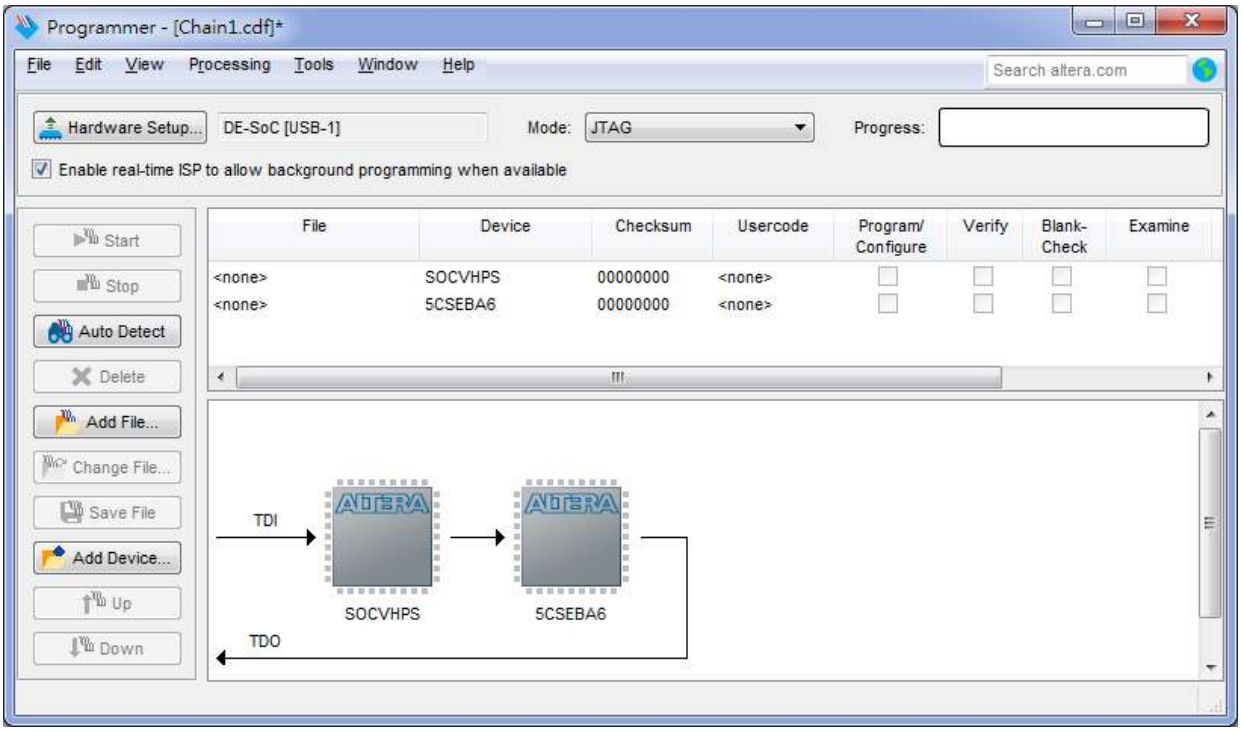


Figure 3-11 FPGA and HPS detected in Quartus programmer

Right click on the FPGA device and open the .sof file to be programmed, as highlighted in **Figure 3-12**.

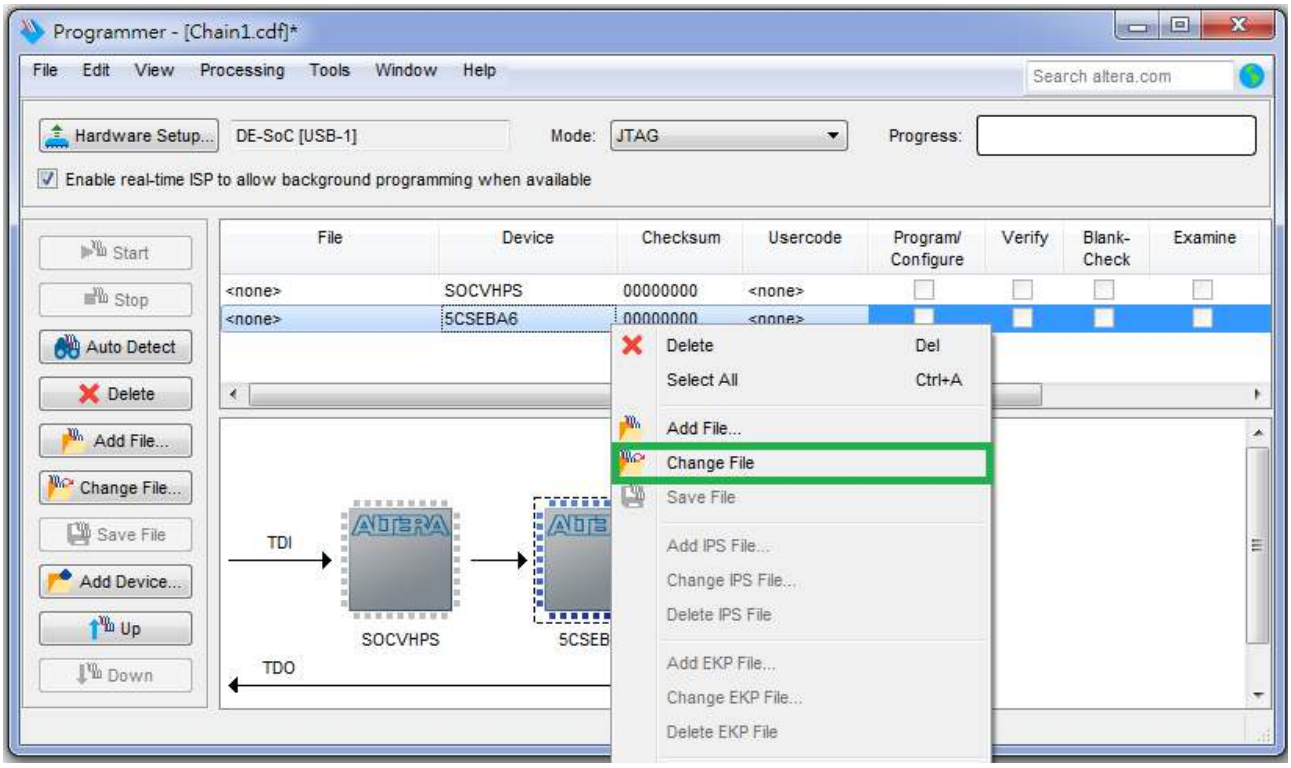


Figure 3-12 Open the .sof file to be programmed into the FPGA device

Select the .sof file to be programmed, as shown in **Figure 3-13**.

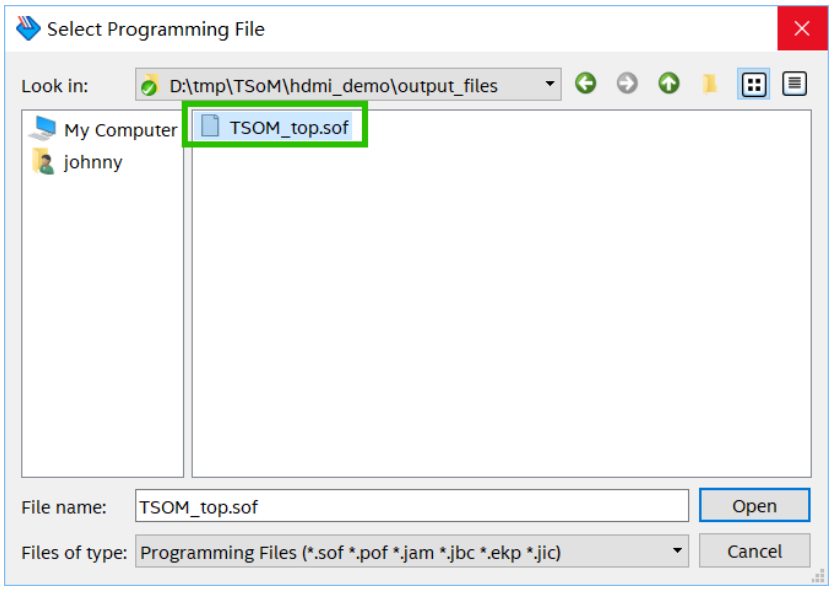


Figure 3-13 Select the .sof file to be programmed into the FPGA device

Click "**Program/Configure**" check box and then click "**Start**" button to download the .sof file into the FPGA device, as shown in **Figure 3-14**.

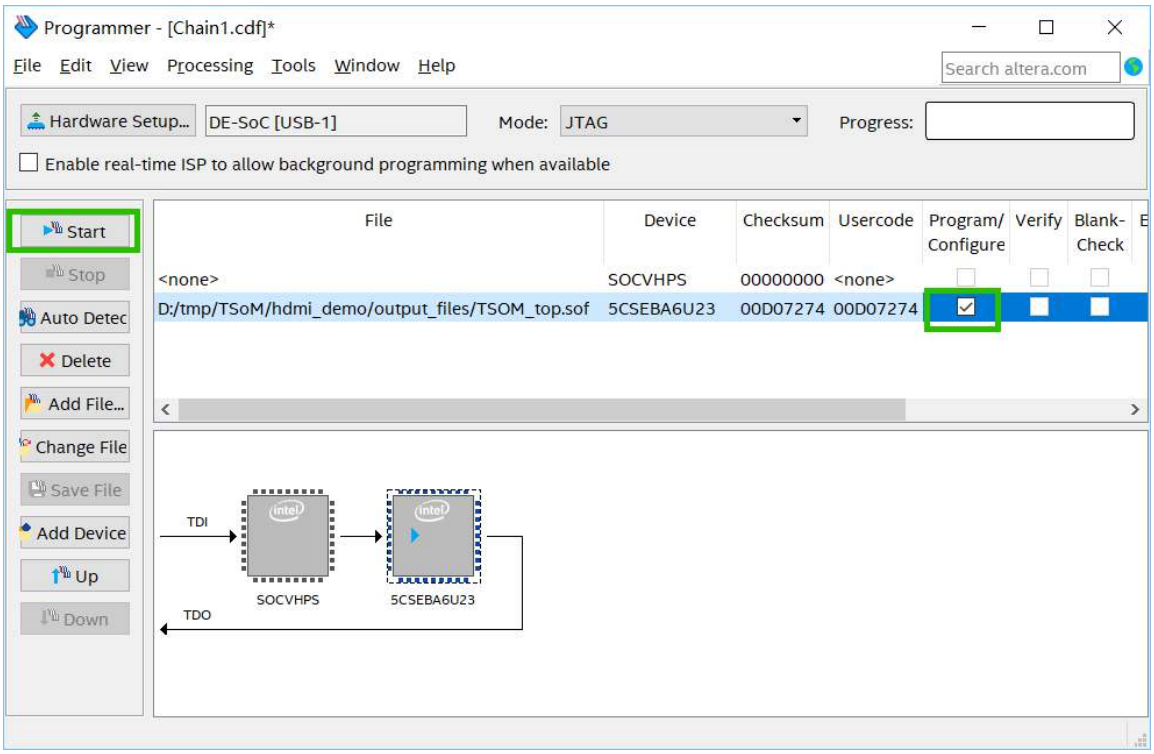


Figure 3-14 Program .sof file into the FPGA device

■ Configure the FPGA in AS Mode

The TSoM evaluation kit board uses a serial configuration device (EPCS64) to store configuration data for the Cyclone V SoC FPGA. This configuration data is automatically loaded from the serial configuration device chip into the FPGA when the board is powered up.

Users need to use Serial Flash Loader (SFL) to program the serial configuration device via JTAG interface. The FPGA-based SFL is a soft intellectual property (IP) core within the FPGA that bridge the JTAG and Flash interfaces. The SFL Megafunction is available in Quartus II. **Figure 3-15** shows the programming method when adopting SFL solution.

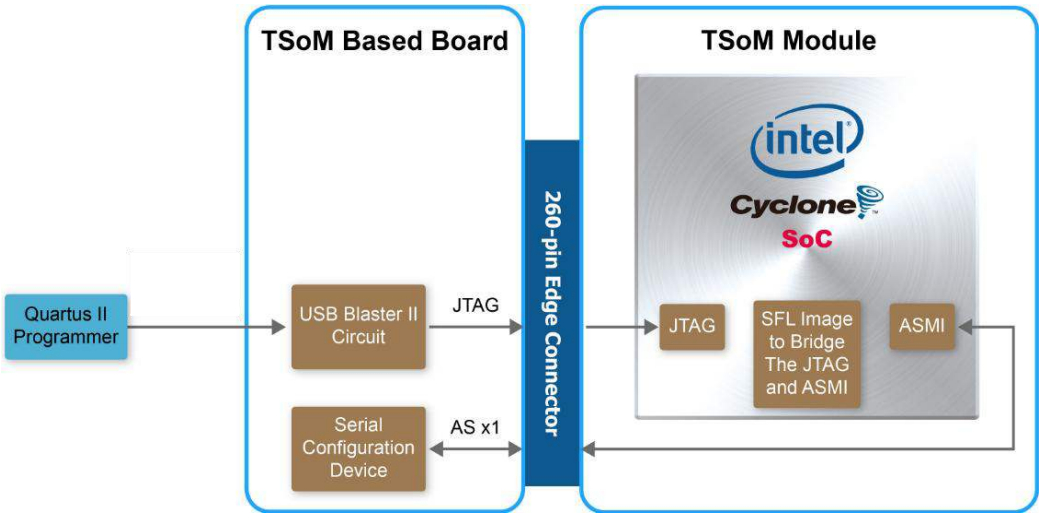


Figure 3-15 Programming a serial configuration device with SFL solution

3.3 Board Status Elements

In addition to the 9 LEDs that FPGA/HPS device can control, there are 6 indicators which can indicate the board status (See **Figure 3-16**), please refer the details in **Table 3-1**.

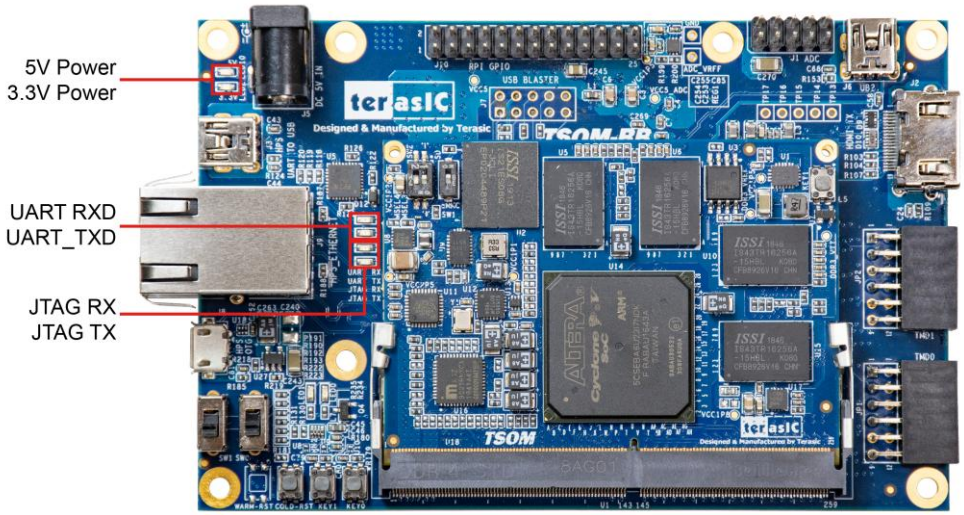


Figure 3-16 LED Indicators on TSoM evaluation kit

Table 3-1 LED Indicators

Board Reference	LED Name	Description
LED2	3.3-V Power	Illuminate when 3.3V power is active.
LED10	5-V Power	Illuminate when 5V power is active.
LED4	JTAG_TX	Illuminate when data is transferred from JTAG to USB Host.
LED5	JTAG_RX	Illuminate when data is transferred from USB Host to JTAG.
TXD1	UART TXD	Illuminate when data is transferred from FT232R to USB Host.
RXD1	UART RXD	Illuminate when data is transferred from USB Host to FT232R.

3.4 Board Reset Elements

There are two HPS reset buttons on TSoM evaluation kit, HPS (cold) reset and HPS warm reset, as shown in **Figure 3-17**. **Table 3-2** describes the purpose of these two HPS reset buttons. **Figure 3-18** is the reset tree for TSoM evaluation kit.

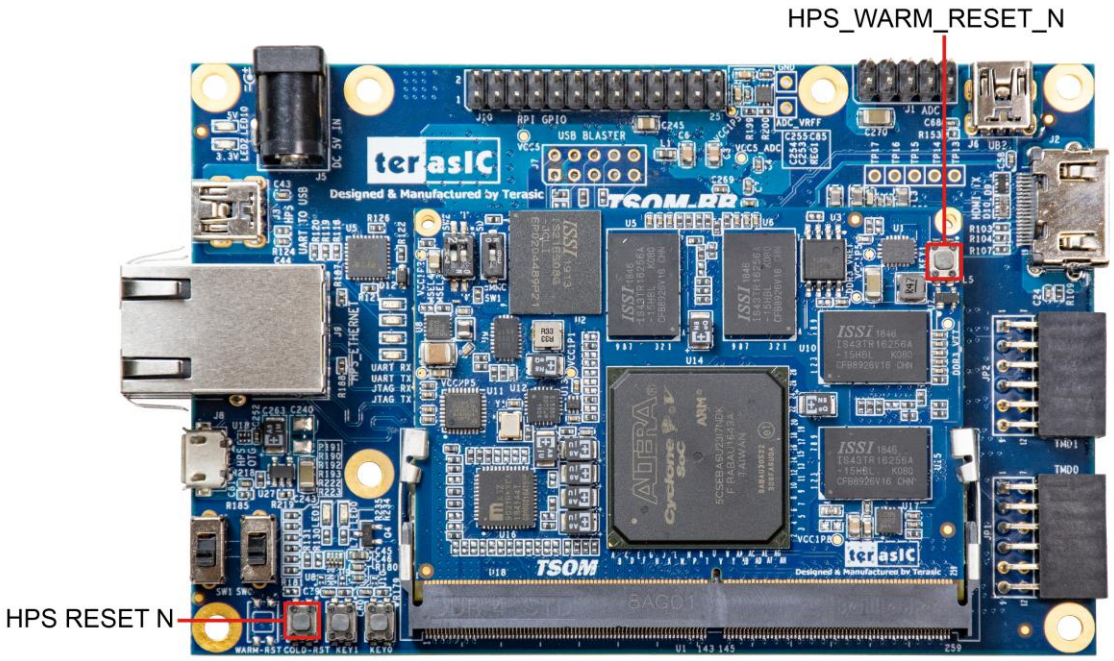


Figure 3-17 HPS cold and warm reset buttons on TSoM evaluation kit

Table 3-2 Description of Two HPS Reset Buttons on TSoM evaluation kit

Board Reference	Signal Name	Description
Button1(TSoM Based board)	HPS_RESET_N	Cold reset to the HPS, Ethernet PHY and USB host device. Active low input which resets all HPS logics that can be reset.
KEY1 (TSoM Module board)	HPS_WARM_RST_N	Warm reset to the HPS block. Active low input affects the system reset domain for debug purpose.

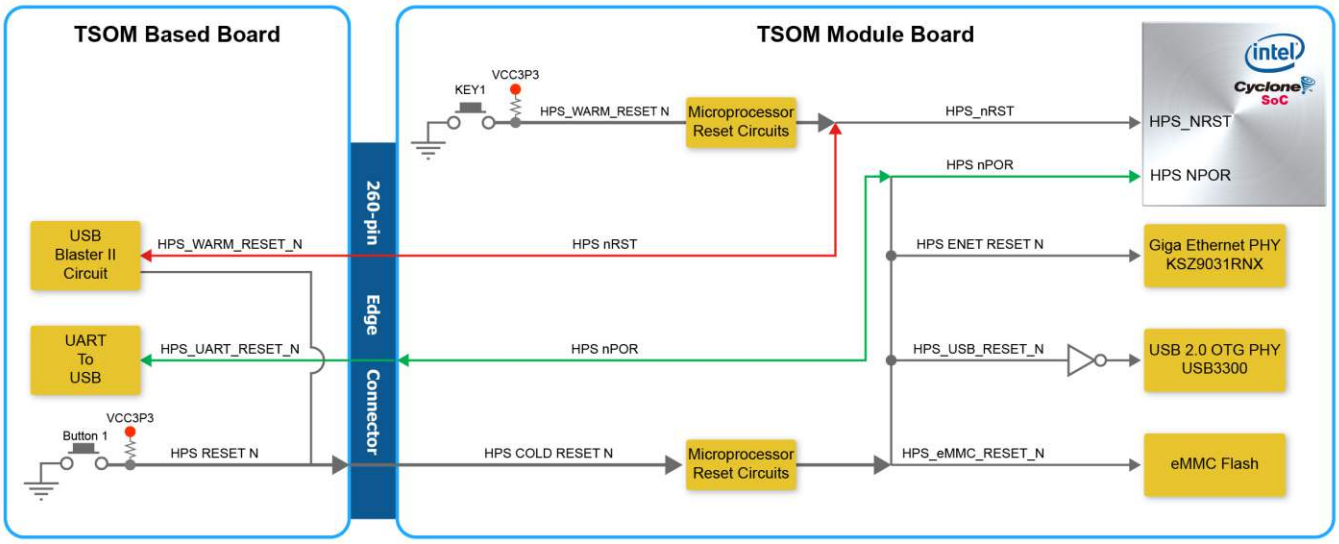


Figure 3-18 HPS reset tree on TSoM evaluation kit board

Chapter 4
HPS Fabric Components

This chapter describes the interfaces connected to TSoM Based Board. Users can access these interfaces via the HPS processor on the TSoM module.

4.1 Ethernet RJ45

The board supports a RJ-45 connector, which is provided by the TsoM Based Board. **Figure 4-1** shows the connections between the TSoM module, 260 Pin edge connector and RJ-45 connector.

The pin assignment of Ethernet PHY and HPS is listed in **Table 4-1**.

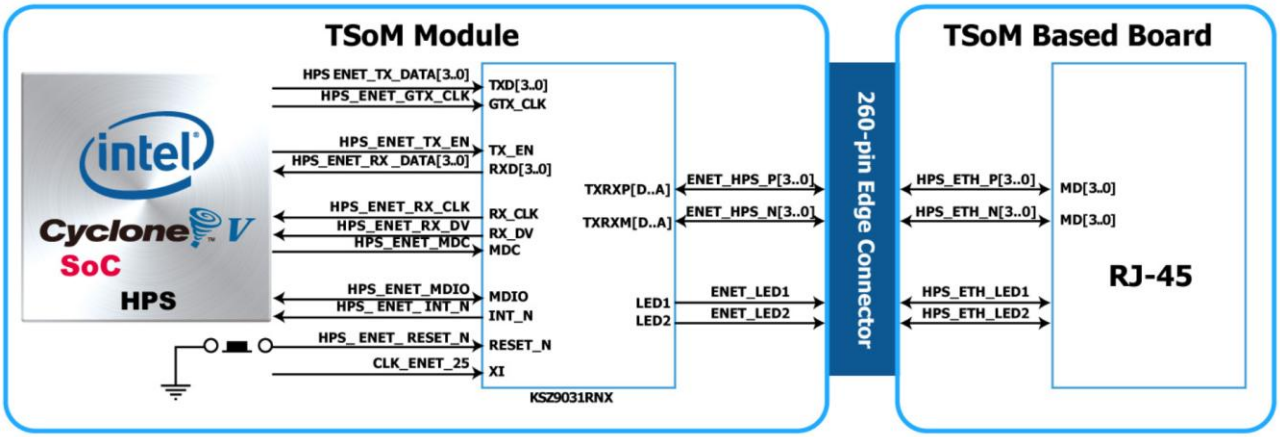


Figure 4-1 The connections between the TSoM module, 260 Pin edge connector and RJ-45 connector

Table 4-1 The pin assignment of Ethernet PHY and HPS on the TSoM module

Signal Name	FPGA Pin No.	Description	I/O Standard
HPS_ENET_TX_EN	A12	GMII and MII transmit enable	3.3V
HPS_ENET_TX_DATA[0]	A16	MII transmit data[0]	3.3V
HPS_ENET_TX_DATA[1]	J14	MII transmit data[1]	3.3V
HPS_ENET_TX_DATA[2]	A15	MII transmit data[2]	3.3V
HPS_ENET_TX_DATA[3]	D17	MII transmit data[3]	3.3V
HPS_ENET_RX_DV	J13	GMII and MII receive data valid	3.3V
HPS_ENET_RX_DATA[0]	A14	GMII and MII receive data[0]	3.3V
HPS_ENET_RX_DATA[1]	A11	GMII and MII receive data[1]	3.3V
HPS_ENET_RX_DATA[2]	C15	GMII and MII receive data[2]	3.3V
HPS_ENET_RX_DATA[3]	A9	GMII and MII receive data[3]	3.3V
HPS_ENET_RX_CLK	J12	GMII and MII receive clock	3.3V
HPS_ENET_MDIO	E16	Management Data	3.3V

HPS_ENET_MDC	A13	Management Data Clock Reference	3.3V
HPS_ENET_INT_N	B14	Interrupt Open Drain Output	3.3V
HPS_ENET_GTX_CLK	J15	GMII Transmit Clock	3.3V

There are two LEDs, green LED (LEDG) and yellow LED (LEDY), which represent the status of Ethernet PHY (KSZ9031RN). The LED control signals are connected to the LEDs on the RJ-45 connector. The state and definition of LEDG and LEDY are listed in **Table 4-2**. For instance, the connection from board to Gigabit Ethernet is established once the LEDG lights on.

Table 4-2 State and Definition of LED Mode Pins

LED (State)		LED (Definition)		Link /Activity
LEDG	LEDY	LEDG	LEDY	
H	H	OFF	OFF	Link off
L	H	ON	OFF	1000 Link / No Activity
Toggle	H	Blinking	OFF	1000 Link / Activity (RX, TX)
H	L	OFF	ON	100 Link / No Activity
H	Toggle	OFF	Blinking	100 Link / Activity (RX, TX)
L	L	ON	ON	10 Link/ No Activity
Toggle	Toggle	Blinking	Blinking	Link / Activity (RX, TX)

4.2 USB OTG Connector

The board has an USB interfaces (using the SMSC USB3300 controller), which is provided by TsoM Based Board. A SMSC USB3300 device in a 32-pin QFN package device is used to interface to a single Type AB Micro-USB connector. This device supports UTMI+ Low Pin Interface (ULPI) to communicate to USB 2.0 controller in HPS. As defined by OTG mode, the PHY can operate in Host or Device modes. When operating in Host mode, the interface will supply the power to the device through the Micro-USB interface. **Figure 4-2** shows the connections between the TSoM module, 260 Pin edge connector and RJ-45 connector. **Table 4-3** lists the pin assignment of USB OTG PHY to HPS.

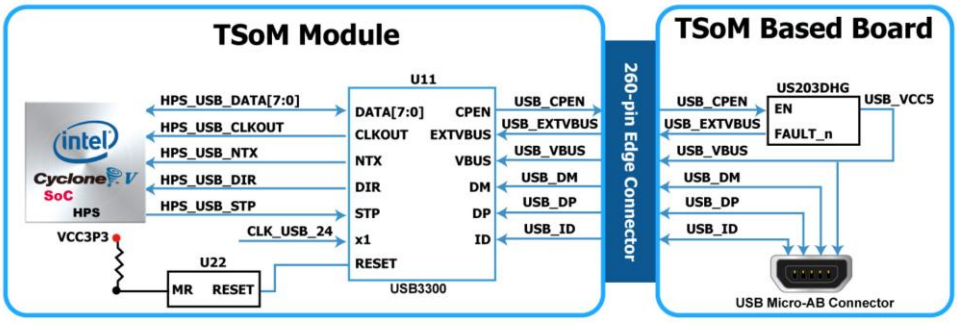


Figure 4-2 The connections between the TSoM module, 260 Pin edge connector and USB OTG interface

Table 4-3 The pin assignment of USB OTG PHY to HPS on the TsoM module

Signal Name	HPS Pin No.	Description	I/O Standard
HPS_USB_CLKOUT	G4	Reference Clock Output	3.3V
HPS_USB_DATA[1]	C10	HPS_USB_DATA[1]	3.3V
HPS_USB_DATA[1]	F5	HPS_USB_DATA[1]	3.3V
HPS_USB_DATA[2]	C9	HPS_USB_DATA[2]	3.3V
HPS_USB_DATA[3]	C4	HPS_USB_DATA[3]	3.3V
HPS_USB_DATA[4]	C8	HPS_USB_DATA[4]	3.3V
HPS_USB_DATA[5]	D4	HPS_USB_DATA[5]	3.3V
HPS_USB_DATA[6]	C7	HPS_USB_DATA[6]	3.3V
HPS_USB_DATA[7]	F4	HPS_USB_DATA[7]	3.3V
HPS_USB_DIR	E5	Direction of the Data Bus	3.3V
HPS_USB_NXT	D5	Throttle the Data	3.3V
HPS_USB_STP	C5	Stop Data Stream on the Bus	3.3V

4.3 UART to USB

The board has one UART interface connected for communication with the HPS on the TsoM module. This interface doesn't support HW flow control signals. The physical interface is implemented by UART-USB onboard bridge from a FT232R chip to the host with an USB Mini-B connector. More information about the chip is available on the manufacturer's website, or in the directory \Datasheets\UART_TO_USB of TSOM-BB system CD. **Figure 4-3** shows the connections between the HPS, 260-pinFT232R chip, and the USB Mini-B connector.

Table 4-4 lists the pin assignment of UART interface connected to the HPS of TsoM module.

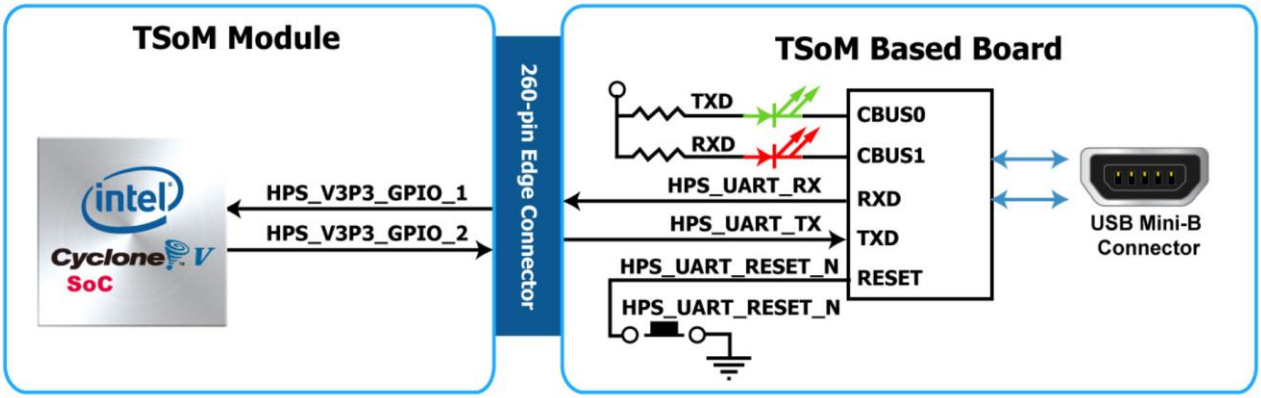


Figure 4-3 Connections between the HPS and FT232R Chip

Table 4-4 Pin Assignment of UART Interface

Signal Name	260-pin Edge Connector Pin No.	FPGA Pin No.	Description	I/O Standard
HPS_UART_RX	PIN_63	PIN_A22	HPS UART Receiver	3.3V
HPS_UART_TX	PIN_65	PIN_B21	HPS UART Transmitter	3.3V

4.4 Micro SD Card

The board supports Micro SD card interface with x4 data lines. It serves not only an external storage for the HPS on the TsoM module, but also an alternative boot option for the board. Figure 4-4 shows signals connected between the HPS, 260 Pin edge connector and Micro SD card socket.

Table 4-5 lists the pin assignment of Micro SD card socket to the HPS.

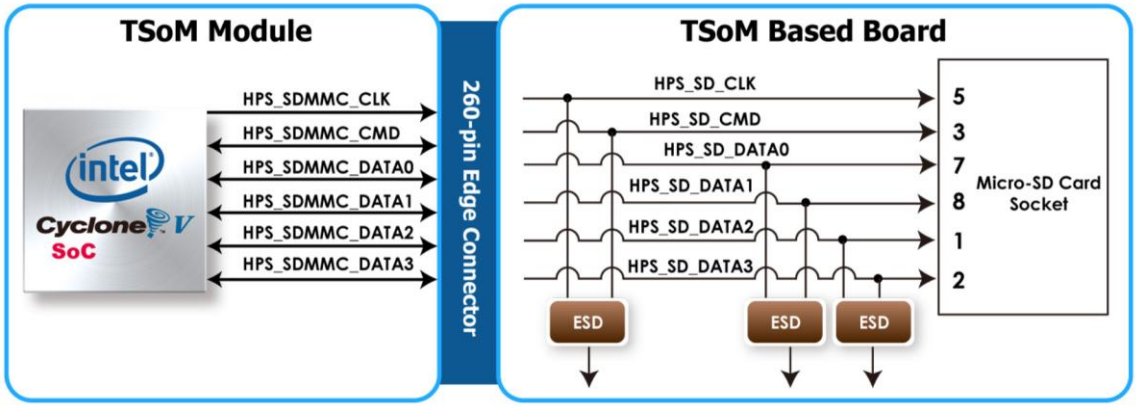


Figure 4-4 Connections between the HPS, 260 Pin edge connector and and SD card socket

Table 4-5 Pin Assignment of Micro SD Card Socket

Signal Name	260-pin Edge Connector Pin No.	FPGA Pin No	Description	I/O Standard
HPS_SD_CLK	PIN_113	PIN_B8	HPS SD Clock	3.3V
HPS_SD_CMD	PIN_111	PIN_D14	HPS SD Command Line	3.3V
HPS_SD_DATA[0]	PIN_115	PIN_C13	HPS SD Data[0]	3.3V
HPS_SD_DATA[1]	PIN_117	PIN_B6	HPS SD Data[1]	3.3V
HPS_SD_DATA[2]	PIN_119	PIN_B11	HPS SD Data[2]	3.3V
HPS_SD_DATA[3]	PIN_121	PIN_B9	HPS SD Data[3]	3.3V

4.5 QSPI Flash (DNI)

The board supports a 512M-bit serial NOR flash device (which is not installed (DNI)) for

non-volatile storage of HPS boot code, user data and program. The device is connected to HPS dedicated interface. It may contain secondary boot code.

This device has a 4-bit data interface and uses 3.3V CMOS signaling standard. Connections between Cyclone V SoC FPGA and Flash are shown in **Figure 4-5**.

To program the QSPI flash, the HPS Flash Programmer is provided both as part of the Intel Quartus Prime suite and as part of the free Intel Quartus Prime Programmer. The HPS Flash Programmer sends file contents over an Intel download cable, such as the USB Blaster II, to the HPS, and instructs the HPS to write the data to the flash memory.

Below summarizes the pins on the flash device. Signal names are from the device datasheet and directions are relative to the Cyclone V SoC FPGA.

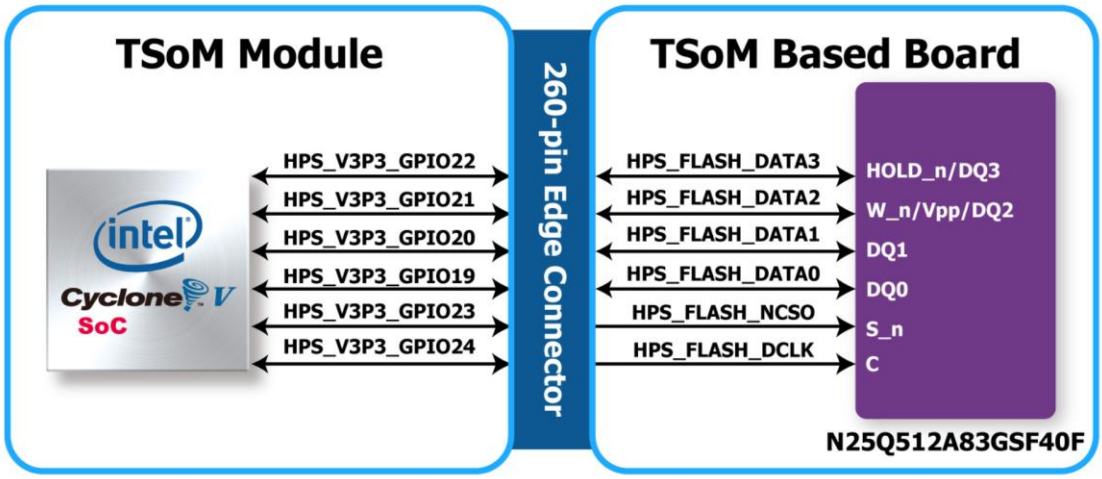


Figure 4-5 Connections between the HPS, 260 Pin edge connector and QSPI Flash

Table 4-6 Pin Assignment of QSPI Flash

Signal Name	260-pin Edge Connector Pin No.	FPGA Pin No	Description	I/O Standard
HPS_FLASH_DATA0	PIN_99	PIN_A8	HPS FLASH Data0	3.3V
HPS_FLASH_DATA1	PIN_101	PIN_H16	HPS FLASH Data1	3.3V
HPS_FLASH_DATA2	PIN_103	PIN_A7	HPS FLASH Data2	3.3V
HPS_FLASH_DATA3	PIN_105	PIN_J16	HPS FLASH Data3	3.3V
HPS_FLASH_DCLK	PIN_109	PIN_C14	HPS FLASH Data Clock	3.3V
HPS_FLASH_NCSO	PIN_107	PIN_A6	HPS FLASH Chip Enable	3.3V

4.6 Raspberry Pi 2x13 GPIO

The board provides one Raspberry Pi 2x13 expansion header, which has 17 pins connected directly to the Cyclone V SoC HPS. It also come with It also comes with two DC +5V (VCC5), two DC +3.3V (VCC3P3), and five GND pins. **Figure 4-6** and **Figure 4-7** shows I/O distribution of the

Raspberry Pi header. In addition to being used as the HPS GPIO, user can also use the corresponding peripheral controller in the HPS such as the SPI and UART interfaces. **Table 4-7** shows all the pin assignments of the Raspberry Pi 2x13 GPIO header.

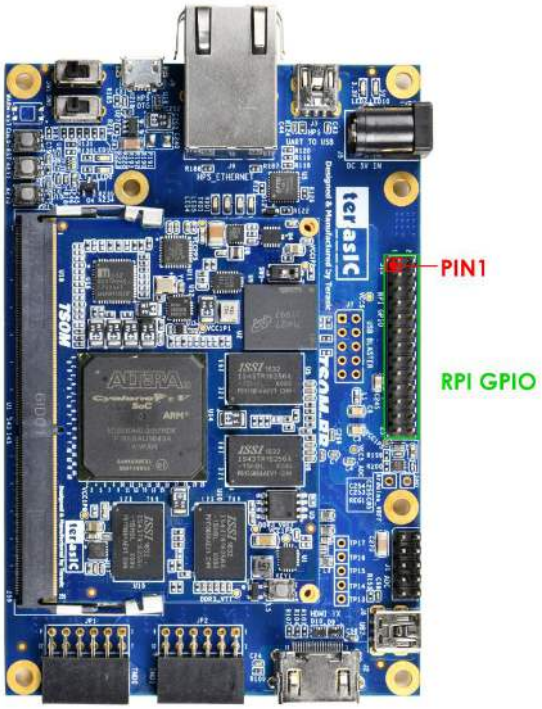


Figure 4-6 Raspbery Pi 2x13 expansion header

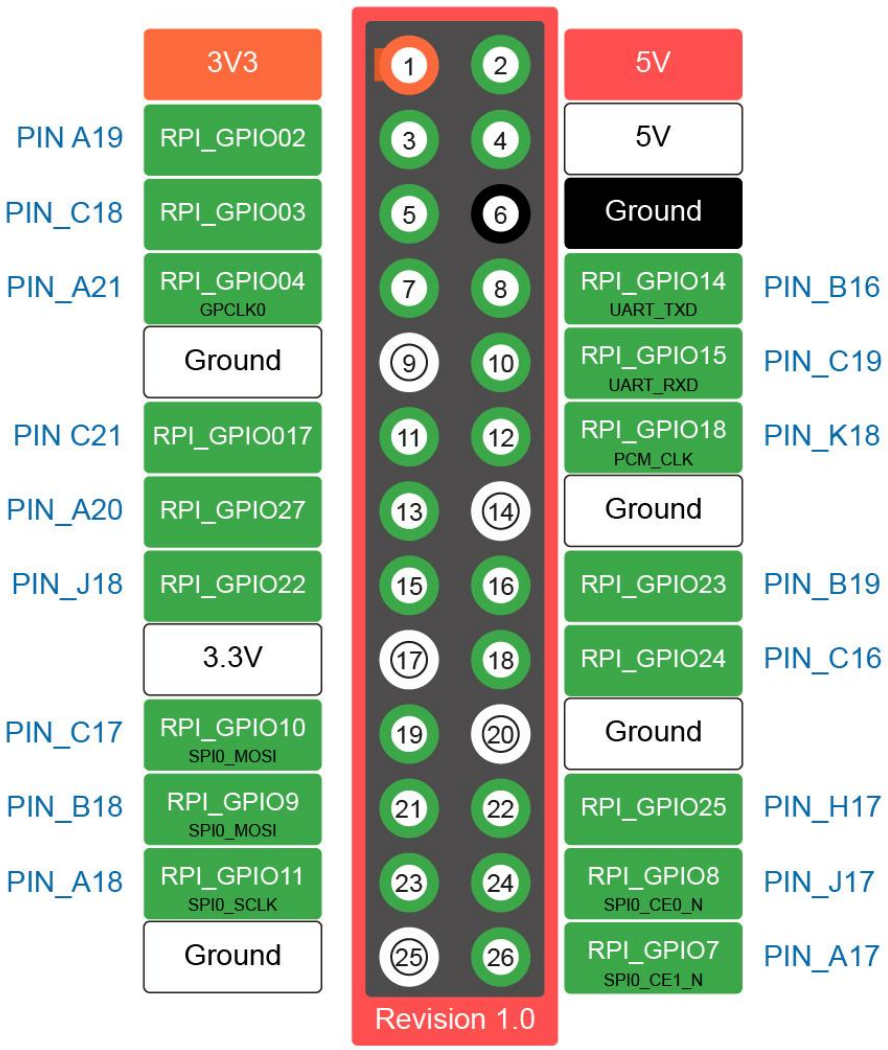


Figure 4-7 Raspbery Pi 2x13 expansion header

Table 4-7 Pin Assignment of Raspbery Pi GPIO

Signal Name	260-pin Edge Connector Pin No.	FPGA Pin No	Description	I/O Standard
RPI_GPIO02	PIN_75	PIN_A19	RPI GPIO Connection 0	3.3V
RPI_GPIO03	PIN_77	PIN_C18	RPI GPIO Connection 0	3.3V
RPI_GPIO04	PIN_67	PIN_A21	RPI GPIO Connection 0	3.3V
RPI_GPIO07	PIN_87	PIN_A17	RPI GPIO Connection 0	3.3V
RPI_GPIO08	PIN_85	PIN_ J17	RPI GPIO Connection 0	3.3V
RPI_GPIO09	PIN_83	PIN_B18	RPI GPIO Connection 0	3.3V
RPI_GPIO10	PIN_81	PIN_C17	RPI GPIO Connection 0	3.3V
RPI_GPIO11	PIN_79	PIN_A18	RPI GPIO Connection 0	3.3V
RPI_GPIO14	PIN_93	PIN_B16	RPI GPIO Connection 0	3.3V
RPI_GPIO15	PIN_91	PIN_C19	RPI GPIO Connection 0	3.3V

RPI_GPIO17	PIN_61	PIN_C21	RPI GPIO Connection 0	3.3V
RPI_GPIO18	PIN_69	PIN_K18	RPI GPIO Connection 0	3.3V
RPI_GPIO22	PIN_73	PIN_J18	RPI GPIO Connection 0	3.3V
RPI_GPIO23	PIN_95	PIN_B19	RPI GPIO Connection 0	3.3V
RPI_GPIO24	PIN_97	PIN_C16	RPI GPIO Connection 0	3.3V
RPI_GPIO25	PIN_89	PIN_H17	RPI GPIO Connection 0	3.3V
RPI_GPIO27	PIN_71	PIN_A20	RPI GPIO Connection 0	3.3V

Chapter 5
FPGA Fabric Components

This section describes the interfaces connected to the FPGA. Users can control or monitor different interfaces with user logic from the FPGA.

5.1 User Push-buttons, Switches and LEDs

The TSoM Based Board has two push-buttons connected to the FPGA, as shown in **Figure 5-1**. Schmitt trigger circuit is implemented and act as switch debounce in **Figure 5-2** for the push-buttons connected. The two push-buttons named KEY0 and KEY1 coming out of the Schmitt trigger device are connected directly to the Cyclone V SoC FPGA. The push-button generates a low logic level or high logic level when it is pressed or not, respectively. Since the push-buttons are debounced, they can be used as clock or reset inputs in a circuit.

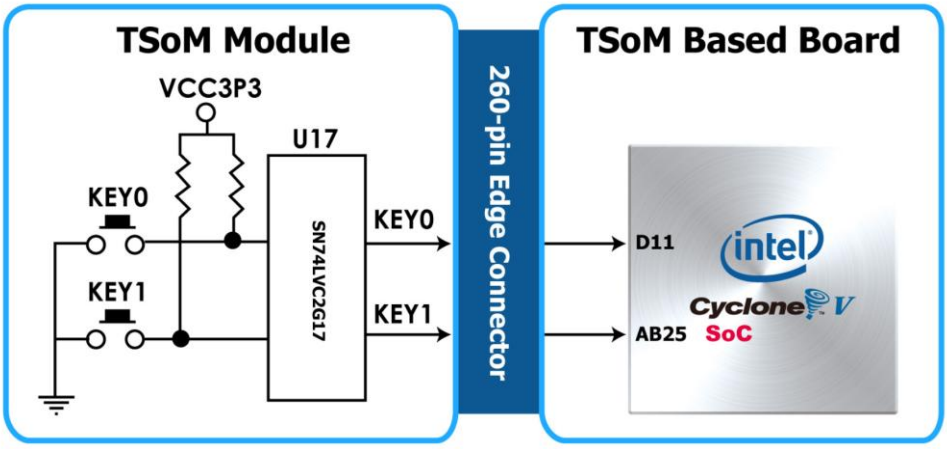


Figure 5-1 Connections between the push-buttons and the Cyclone V SoC FPGA

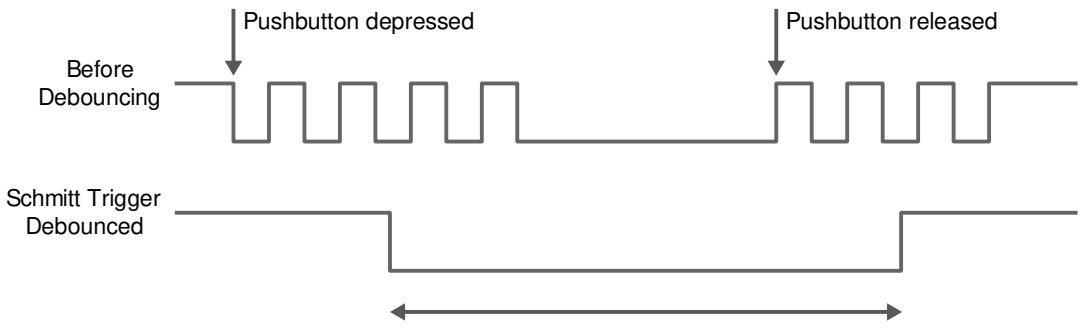


Figure 5-2 Switch debouncing

There are two slide switches connected to the FPGA, as shown in **Figure 5-3**. These switches are not debounced and to be used as level-sensitive data inputs to a circuit. Each switch is

connected directly and individually to the FPGA. When the switch is set to the DOWN position (towards the edge of the board), it generates a low logic level to the FPGA. When the switch is set to the UP position, a high logic level is generated to the FPGA.

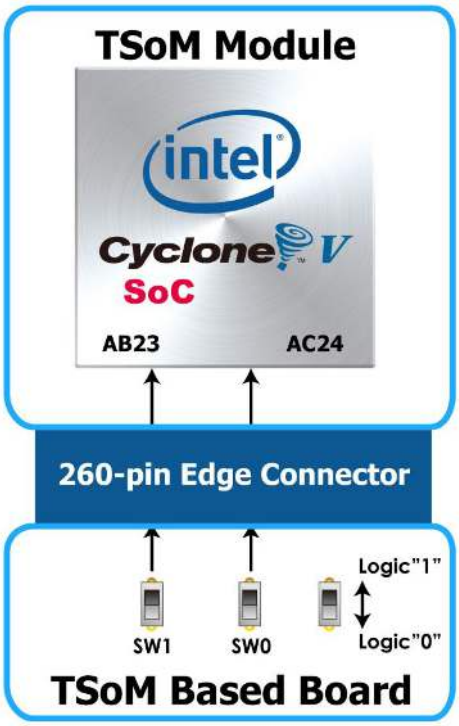


Figure 5-3 Connections between the slide switches and the Cyclone V SoC FPGA

There are also two user-controllable LEDs connected to the FPGA. Each LED is driven directly and individually by the Cyclone V SoC FPGA; driving its associated pin to a high logic level or low level to turn the LED on or off, respectively. **Figure 5-4** shows the connections between LEDs and Cyclone V SoC FPGA. **Table 5-1**, **Table 5-2** and **Table 5-3** list the pin assignment of user push-buttons, switches, and LEDs.

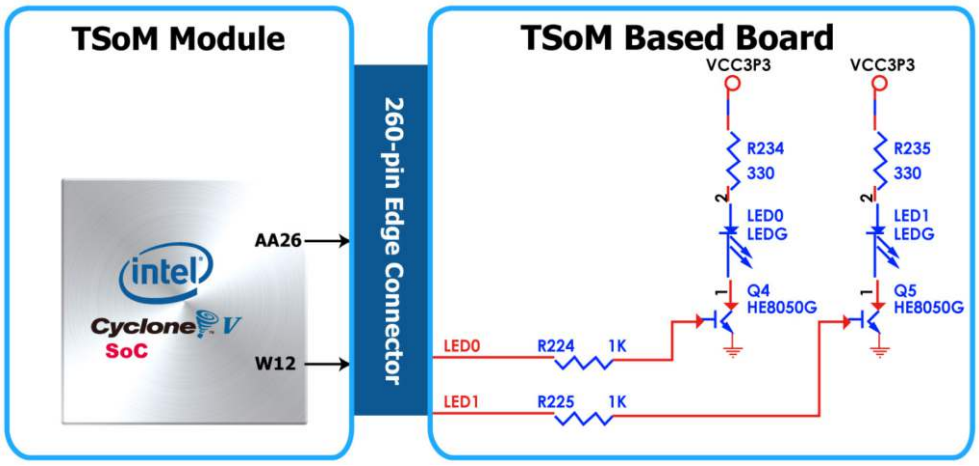


Figure 5-4 Connections between the LEDs and the Cyclone V SoC FPGA

Table 5-1 Pin Assignment of Slide Switches

Signal Name	260-pin Edge Connector Pin No.	FPGA Pin No.	Description	I/O Standard
SW0	PIN_112	PIN_AC24	Slide Switch[0]	3.3V
SW1	PIN_114	PIN_AB23	Slide Switch[1]	3.3V

Table 5-2 Pin Assignment of Push-buttons

Signal Name	260-pin Edge Connector Pin No.	FPGA Pin No.	Description	I/O Standard
KEY0	PIN_37	PIN_D11	Push-button[0]	3.3V
KEY1	PIN_39	PIN_AB25	Push-button[1]	3.3V

Table 5-3 Pin Assignment of LEDs

Signal Name	260-pin Edge Connector Pin No.	FPGA Pin No.	Description	I/O Standard
LED0	PIN_205	PIN_AA26	LED [0]	3.3V
LED1	PIN_206	PIN_W12	LED [1]	3.3V

5.2 TMD Header

The board has two TMD connectors, each connector has 8 user pins connected to the 260-pin Edge Connector (to Cyclone V SoC FPGA). It also comes with DC +3.3V (VCC3P3), and two GND pins. **Figure 5-5** shows the I/O distribution of the TMD connector. The maximum power consumption allowed for a daughter card connected to one or two TMD ports is shown in **Table 5-4** and **Table 5-5**, shows all the pin assignments of the TMD connectors.

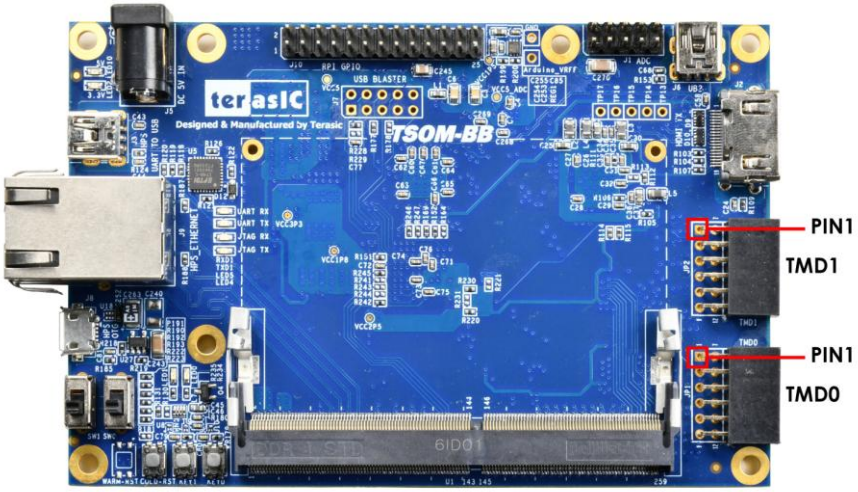


Figure 5-5 TMD Pin Arrangement

Table 5-4 Voltage and Max. Current Limit of TMD Connector(s)

Supplied Voltage	Max. Current Limit
3.3V	1.5A

Table 5-5 all Pin Assignment of Expansion Headers

Signal Name	260-pin Edge Connector Pin No.	FPGA Pin No.	Description	I/O Standard
TMD0_IO0	PIN_239	PIN_AH6	TMD0 IO[0]	3.3V
TMD0_IO1	PIN_241	PIN_AH5	TMD0 IO[1]	3.3V
TMD0_IO2	PIN_245	PIN_AF7	TMD0 IO[2]	3.3V
TMD0_IO3	PIN_247	PIN_AH2	TMD0 IO[3]	3.3V
TMD0_IO4	PIN_251	PIN_AE8	TMD0 IO[4]	3.3V
TMD0_IO5	PIN_253	PIN_AF9	TMD0 IO[5]	3.3V
TMD0_IO6	PIN_257	PIN_AG5	TMD0 IO[6]	3.3V
TMD0_IO7	PIN_259	PIN_AH4	TMD0 IO[7]	3.3V
TMD1_IO0	PIN_240	PIN_AF11	TMD1 IO[0]	3.3V
TMD1_IO1	PIN_242	PIN_AF10	TMD1 IO[1]	3.3V
TMD1_IO2	PIN_246	PIN_AE12	TMD1 IO[2]	3.3V
TMD1_IO3	PIN_248	PIN_AD12	TMD1 IO[3]	3.3V
TMD1_IO4	PIN_252	PIN_AD10	TMD1 IO[4]	3.3V
TMD1_IO5	PIN_254	PIN_AE9	TMD1 IO[5]	3.3V
TMD1_IO6	PIN_258	PIN_V11	TMD1 IO[6]	3.3V
TMD1_IO7	PIN_260	PIN_W11	TMD1 IO[7]	3.3V

5.3 A/D Converter and Analog Input

The TsoM Based Board has an analog-to-digital converter (LTC2308).

The LTC2308 is a low noise, 500ksps, 8-channel, 12-bit ADC with a SPI/MICROWIRE compatible serial interface. This ADC includes an internal reference and a fully differential sample-and-hold circuit to reduce common mode noise. The internal conversion clock allows the external serial output data clock (SCK) to operate at any frequency up to 40MHz.

It can be configured to accept eight input signals at inputs ADC_IN0 through ADC_IN7. These eight input signals are connected to a 2x5 header, as shown in **Figure 5-6**.

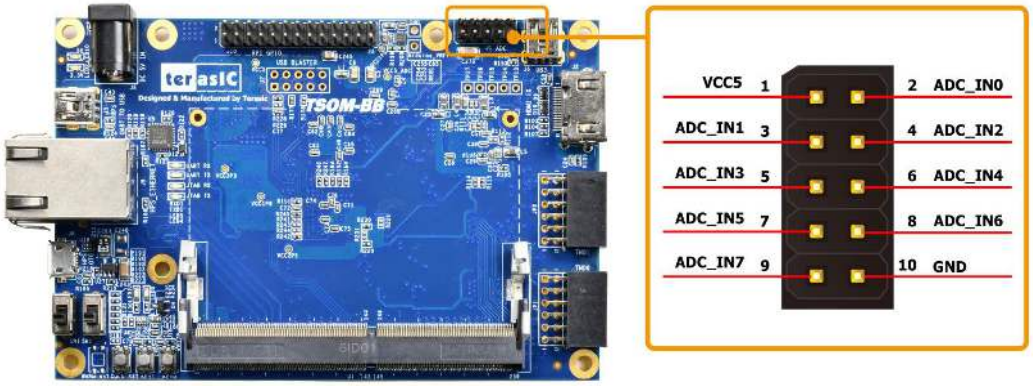


Figure 5-6 Signals of the 2x5 Header

These Analog inputs are shared with the Arduino's analog input pin (ADC_IN0 ~ ADC_IN5), **Figure 5-7** shows the connections between the FPGA, 2x5 header, Arduino Analog input, and the A/D converter.

More information about the A/D converter chip is available in its datasheet. It can be found on manufacturer's website or in the directory \Datasheet\ADC of TSoM Based Board system CD.

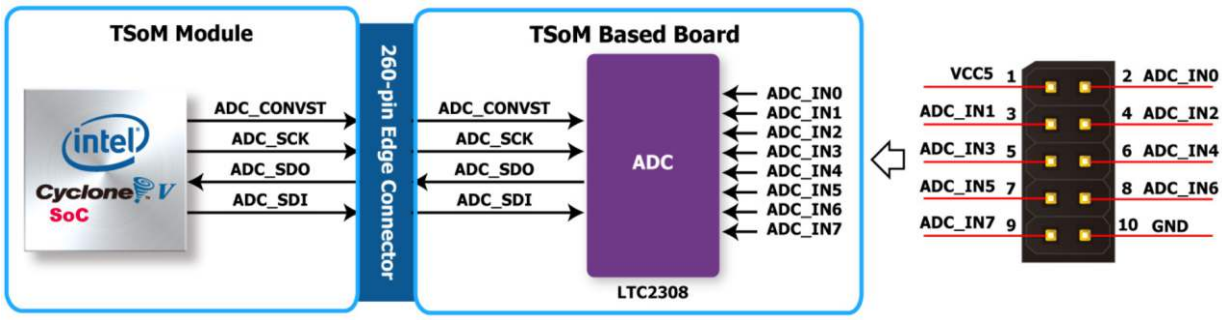


Figure 5-7 Connections between the FPGA, 2x5 header, and the A/D converter

Table 5-6 Pin Assignment of ADC

Signal Name	260-pin Edge Connector Pin No.	FPGA Pin No.	Description	I/O Standard
ADC_CONVST	PIN_84	PIN_Y19	Conversion Start	3.3V
ADC_SCK	PIN_82	PIN_AA20	Serial Data Clock	3.3V
ADC_SDI	PIN_96	PIN_AA13	Serial Data Input (FPGA to ADC)	3.3V

ADC_SDO	PIN_94	PIN_Y13	Serial Data Out (ADC to FPGA)	3.3V

5.4 HDMI TX Interface

The development board provides High Performance HDMI Transmitter via the Analog Devices ADV7513 which incorporates HDMI v1.4 features, including 3D video support, and 165 MHz supports all video formats up to 1080p and UXGA. The ADV7513 is controlled via a serial I2C bus interface, which is connected to pins on the Cyclone V SoC FPGA. A schematic diagram of the audio circuitry is shown in **Figure 5-8**. Detailed information on using the ADV7513 HDMI TX is available on the manufacturer's website, or under the Datasheets\HDMI folder on the Kit System CD.

Table 5-7 lists the HDMI Interface pin assignments and signal names relative to the Cyclone V SoC device.

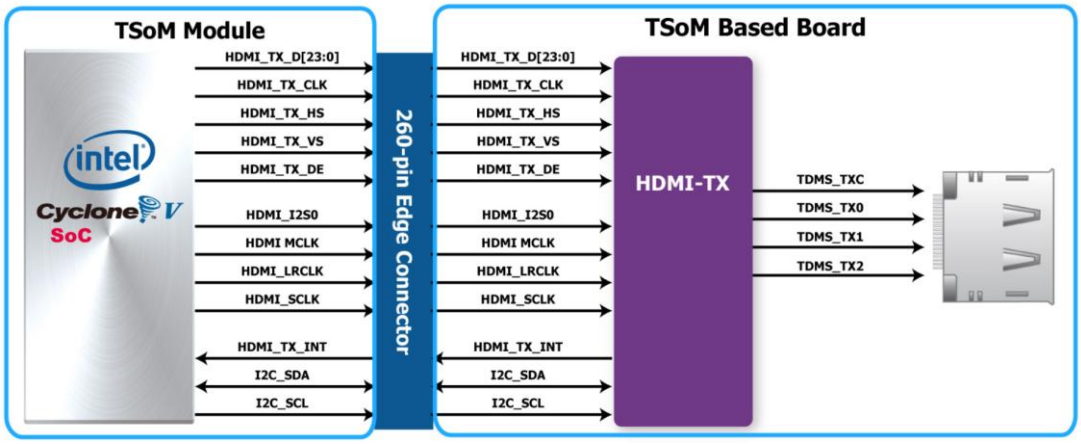


Figure 5-8 Connections between the Cyclone V SoC FPGA and HDMI Transmitter Chip

Table 5-7 HDMI Pin Assignments, Schematic Signal Names, and Functions

Signal Name	260-pin Edge Connector Pin No.	FPGA Pin No.	Description	I/O Standard
HDMI_TX_D0	PIN_221	PIN_AC4	Video Data bus	3.3-V
HDMI_TX_D1	PIN_223	PIN_AD4	Video Data bus	3.3-V
HDMI_TX_D2	PIN_227	PIN_AD5	Video Data bus	3.3-V
HDMI_TX_D3	PIN_229	PIN_AE6	Video Data bus	3.3-V
HDMI_TX_D4	PIN_233	PIN_AF5	Video Data bus	3.3-V
HDMI_TX_D5	PIN_235	PIN_AF6	Video Data bus	3.3-V
HDMI_TX_D6	PIN_185	PIN_AH3	Video Data bus	3.3-V
HDMI_TX_D7	PIN_187	PIN_AH2	Video Data bus	3.3-V
HDMI_TX_D8	PIN_191	PIN_AE4	Video Data bus	3.3-V
HDMI_TX_D9	PIN_193	PIN_AF4	Video Data bus	3.3-V
HDMI_TX_D10	PIN_197	PIN_AE7	Video Data bus	3.3-V

HDMI_TX_D11	PIN_199	PIN_AF8	Video Data bus	3.3-V
HDMI_TX_D12	PIN_222	PIN_U10	Video Data bus	3.3-V
HDMI_TX_D13	PIN_224	PIN_V10	Video Data bus	3.3-V
HDMI_TX_D14	PIN_228	PIN_Y11	Video Data bus	3.3-V
HDMI_TX_D15	PIN_230	PIN_AA11	Video Data bus	3.3-V
HDMI_TX_D16	PIN_234	PIN_AD11	Video Data bus	3.3-V
HDMI_TX_D17	PIN_236	PIN_AE11	Video Data bus	3.3-V
HDMI_TX_D18	PIN_186	PIN_D12	Video Data bus	3.3-V
HDMI_TX_D19	PIN_188	PIN_C12	Video Data bus	3.3-V
HDMI_TX_D20	PIN_192	PIN_T13	Video Data bus	3.3-V
HDMI_TX_D21	PIN_194	PIN_T12	Video Data bus	3.3-V
HDMI_TX_D22	PIN_198	PIN_T11	Video Data bus	3.3-V
HDMI_TX_D23	PIN_200	PIN_U11	Video Data bus	3.3-V
HDMI_TX_CLK	PIN_203	PIN_AB26	Video Clock	3.3-V
HDMI_TX_DE	PIN_204	PIN_V12	Data Enable Signal for Digital Video.	3.3-V
HDMI_TX_HS	PIN_215	PIN_Y5	Horizontal Synchronization	3.3-V
HDMI_TX_VS	PIN_217	PIN_Y4	Vertical Synchronization	3.3-V
HDMI_TX_INT	PIN_181	PIN_D8	Interrupt Signal	3.3-V
HDMI_I2S0	PIN_211	PIN_AB4	I2S Channel 0 Audio Data Input	3.3-V
HDMI_MCLK	PIN_209	PIN_AA4	Audio Reference Clock Input	3.3-V
HDMI_LRCLK	PIN_212	PIN_Y8	Audio Left/Right Channel Signal Input	3.3-V
HDMI_SCLK	PIN_210	PIN_W8	I2S Audio Clock Input	3.3-V
I2C_SCL	PIN_218	PIN_T8	I2C Clock	3.3-V
I2C_SDA	PIN_216	PIN_U9	I2C Data	3.3-V

Chapter 6
Examples For FPGA

This chapter provides examples of advanced designs implemented by RTL or Qsys on the TSoM board. These reference designs cover the features of peripherals connected to the FPGA, such as A/D Converter. All the associated files can be found in the directory \Demonstrations\FPGA of TSoM System CD.

■ Installation of Demonstrations

Install the demonstrations on your computer:

Copy the folder Demonstrations to a local directory of your choice. It is important to make sure the path to your local directory contains NO space. Otherwise it will lead to error in Nios II.

Note Quartus Prime v17.1 or later is required for all TSoM demonstrations to support Cyclone V SoC device.

6.1 HDMI TX

This section gives instructions to program the HDMI transmitter to generate video pattern and audio source. The entire reference is composed into three parts: video design, audio design, and I2C design. A set of built-in video patterns and audio serial data will be sent to the HDMI transmitter to drive the HDMI display with speaker. Users can hear the beeping sound from the speaker when SW0 is set to 1 on the TSoM board. The resolution can be switched by pressing KEY1.

■ System Block Diagram

Figure 6-1 shows the system block diagram of this reference design. The HDMI Transmitter is configured via I2C interface by I2C Controller and I2C HDMI Config. It is necessary to configure the HDMI transmitter according to the desired settings.

An interrupt mechanism called Hot Plug Detect (HPD) is implemented in I2C HDMI config. to re-configure HDMI transmitter when HPD interrupt occurs.

The Video Patter Generator was designed to send video patter to HDMI transmitter. Its resolution can be changed by pressing KEY1. There must be a PLL Reconfig. To change the PLL dynamically to support different resolutions. The Audio PLL and Audio Generator were designed to send audio pattern to HDMI transmitter. The audio is transmitted via I2S interface in this demo. Users can choose to enable audio generator or not through SW0.

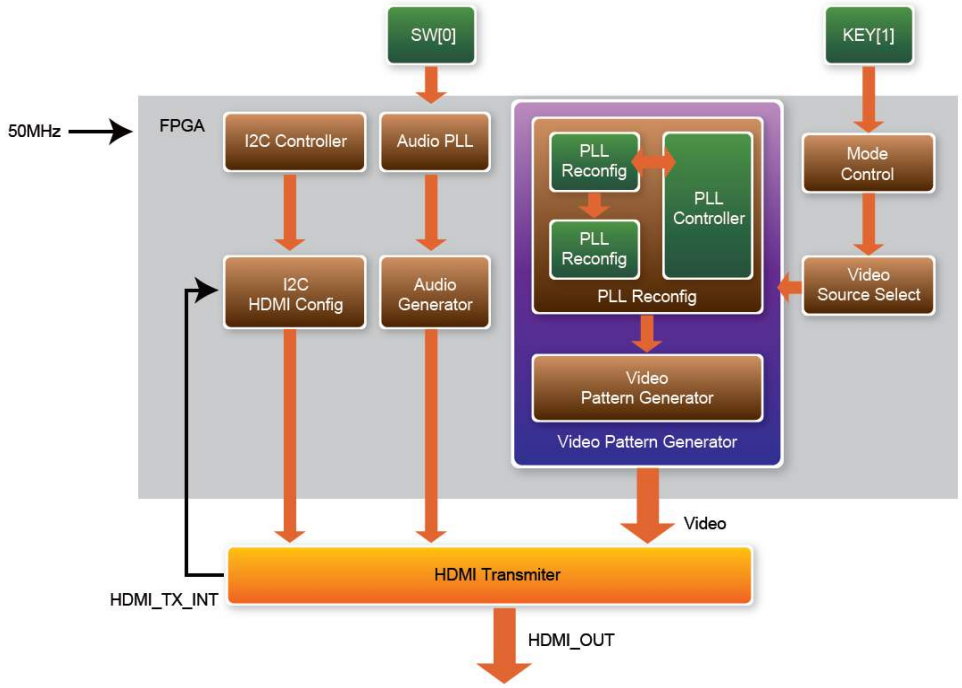


Figure 6-1 Block Diagram of the HDMI TX Demonstration

■ Register of HDMI Transmitter (ADV7513)

Users can save lots of developing time by paying attention to the settings of video format and audio frequency in register at address 0x15 and the format of register at address 0xAF prior to the development of HDMI transmitter. This demo uses 48KHz sampling rate and the video format is 24-bit RGB 4:4:4. For more details, please refer to the document ADV7513_Programming_Guide_R0.pdf.

■ Audio Generator

The ADV7513 can accommodate 2 to 8 channels of I2S audio at up to a 192 KHz sampling rate. The ADV7513 supports I2S standard, left-justified serial audio, and right-justified serial audio. Figure 6-2 shows the left-justified serial audio with I2S standard audio of 16-bit per channel.

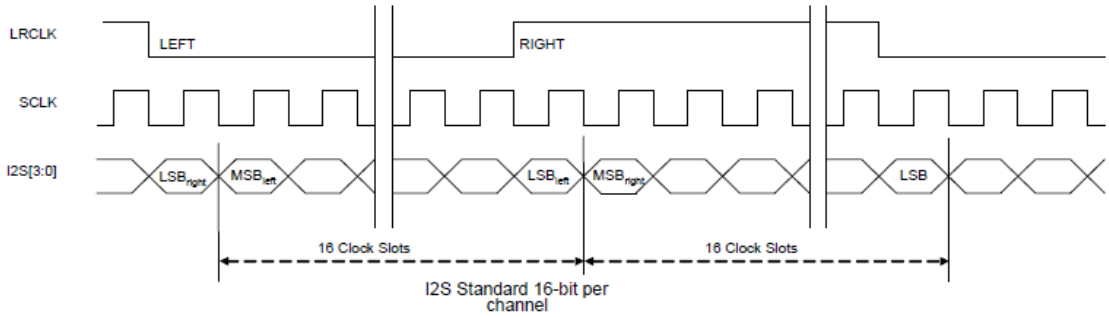


Figure 6-2 I2S standard audio with 16-bit per channel

If users want to modify the frequency of audio output, the register value at register 0x15 has to be modified according to the document ADV7513_Programming_Guide_R0.pdf. The I2S standard

uses MSB to LSB serial way of transmitting. This demo uses sinusoid signal to synthesis sound from a reference of look up table created by calculated sinusoid wave data.

■ Video Pattern Generator

The module “Video Pattern Generator” copes with generating video patterns to be presented on the LCD monitor. The pattern is composed in the way of 24-bit RGB 4:4:4 (RGB888 per color pixel without sub-sampling) color encoding, which corresponds to the parallel encoding format defined in Table 6-1 of the "ADV7513 Hardware User's Guide," as shown below.

Table 6-1 Display modes of the HDMI TX demonstration

Pixel Data [23:0]																	
17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R[7:0]						G[7:0]						B[7:0]					

A set of display modes is implemented for presenting the generated video patterns. The module “Video Source Selector” controls the selection of current video timing among built-in display modes listed in Table 6-2. The module "Mode Control" allows users to switch current display mode alternatively via KEY1.

Table 6-2 Built-in display modes for the HDMI TX demonstration

Pattern ID	Video Format	PCLK (MHZ)
0	640x480@60P	25
1	720x480@60P	27
2	1024x768@60P	65
3	1280x1024@60P	108
4	1920x1080@60P	148.5

■ Demonstration File Locations

- Hardware project directory: \HDMI_TX
- Bitstream used: DE10_Nano_HDMI_TX.sof
- Demo batch file : \HDMI_TX\demo_batch\test.bat

■ Demonstration Setup and Instructions

- Please make sure both Quartus Prime and USB-Blaster II driver are installed on the host PC.
- Connect the TSoM board to the LCD monitor through a HDMI cable.
- Power on the TSoM board
- Launch the **"test.bat"** batch file from the **"\HDMI_TX\demo_batch"** folder. After the

programming and configuration are successful, the screen should look like the one shown in Figure 6-3 .

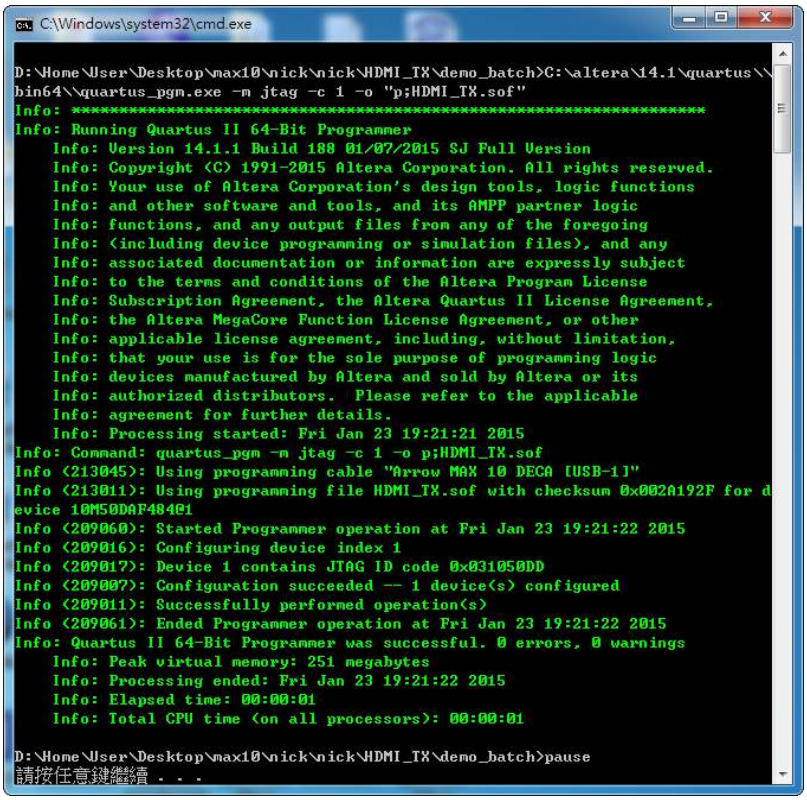


Figure 6-3 Launch the HDMI TX demonstration from the "demo_batch" folder

Wait for a few seconds for the LCD monitor to be powered up. There will be a pre-defined video pattern shown on the monitor, as shown in Figure 6-4. The SW0 is used to enable/disable the sound output on the TSoM board. When you switch the SW0 button to an upper position, you will hear a "beep" sound from the speaker of the HDMI display.

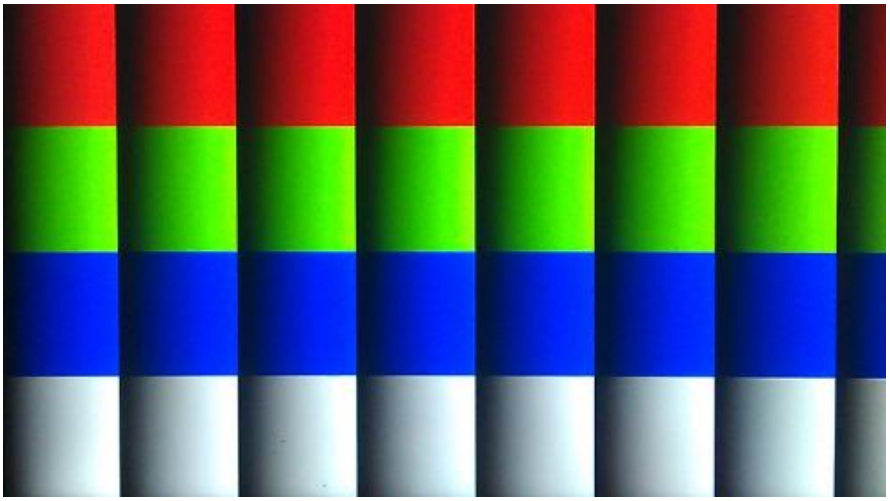


Figure 6-4 The video pattern in the HDMI TX demonstration

6.2 DDR3_RTL

This demonstration performs a memory test function for DDR3 on the TSoM evaluation kit. The

memory size of the DDR3 used in this test is 1 GB.

■ System Block Diagram

Figure 6-5 shows the function block diagram of this demonstration. The DDR3 controller uses 50 MHz as a reference clock. It generates one 300MHz clock as memory clock from the FPGA to the memory.

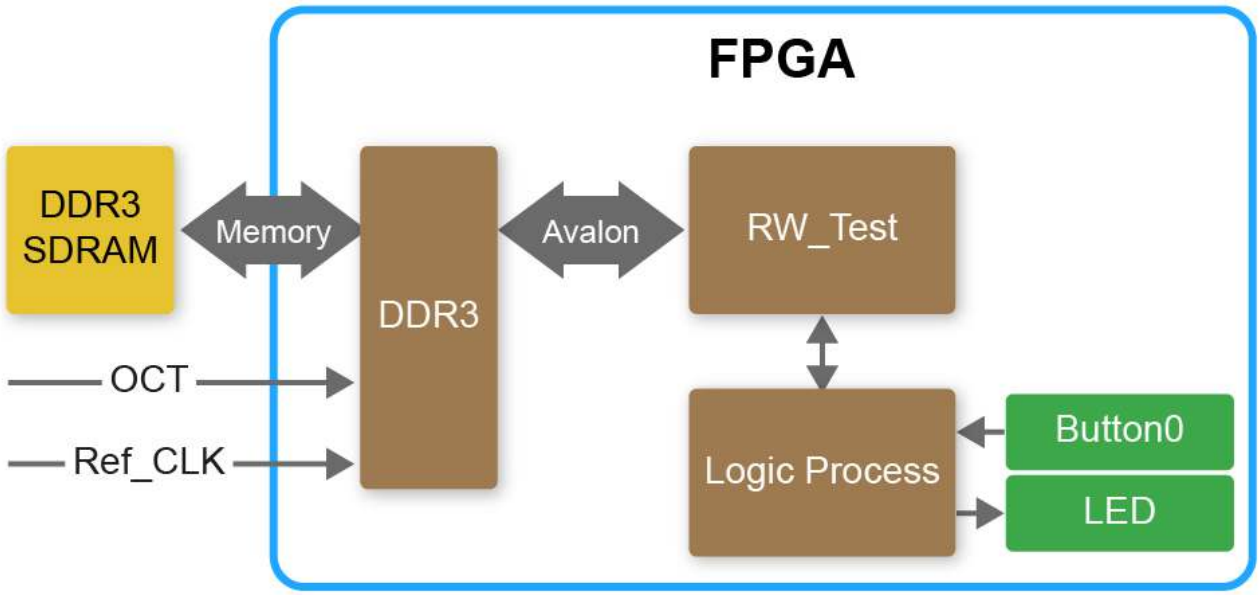


Figure 6-5 Block Diagram of the DDR3_RTL Demonstration

■ Intel DDR3 SDRAM Controller with UniPHY

To use intel DDR3 controller, please perform the three major steps below:

1. Create correct pin assignments for DDR3.
2. Setup correct parameters in the dialog of DDR3 controller.

■ Design Tools

- Quartus Prime v17.1
- Demonstration Source Code:
  - Project Directory: Demonstration\FPGA\DDR3
  - Bit Stream: DDR3\output_files\TSOM_top.sof
- Demonstration Batch File:

  Demo Batch File Folder: DDR3\demo_batch

  The demo batch file includes following files:

- Batch File: test.bat
- FPGA Configuration File: TSOM_top.sof

Demonstration Setup and Instructions by SOF File

Please follow below instructions to configure FPGA with .sof file through the usb-blaster JTAG interface to performance the demonstration.

- Make sure both Quartus Prime and USB-Blaster II driver are installed on the host PC.
- Connect TSoM evaluation kit to the host PC via USB cable. Install the USB-Blaster II driver if necessary.
- Power on the TSoM evaluation kit.
- Execute the demo batch file "test.bat" under the batch file folder \DDR3\demo_batch.
- Press KEY0 on TSoM evaluation kit to start the verification process. After approximately 1 seconds, LED0 stay on to indicate the DDR3 have passed the test. **Table 6-3** lists the LED indicators.
- If LED1 is not blinking, it means the 50MHz clock source is not working.
- If LED0 start blinking upon releasing KEY0, it indicates local_cal_success of the corresponding DDR3 fails.
- Press KEY0 again to regenerate the test control signals for a repeat test.

Table 6-3 LED Indicators

NAME	Description
LED0	DDR3 test result
LED1	50MHz clock source

Chapter 7
Programming the EPCS Device

This chpater describes how to program the serial configuration (EPCS) device with Serial Flash Loader (SFL) function via the JTAG interface. Users can program EPCS devices with a JTAG indirect configuration (.jic) file, which is converted from a user-specified SRAM object file (.sof) in Quartus. The .sof file is generated after the project compilation is successful. The steps of converting .sof to .jic in Quartus II are listed below.

■ Before Programming Begins

The FPGA should be set to AS x1 mode i.e. MSEL[4..0] = “10010” to use the EPCS as a FPGA configuration device. Note that the factory default mode is FPPx32 mode(MSEL[4:0]= "01010").

User can set the SW2 of the TSoM module to change the MSEL[4:0] to ASx1 mode as shown in **Figure 7-1** .

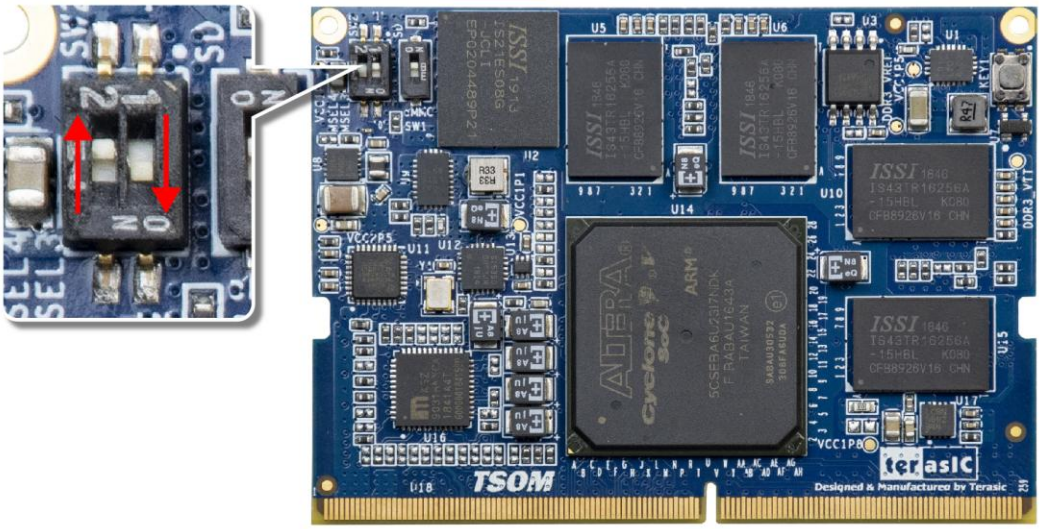
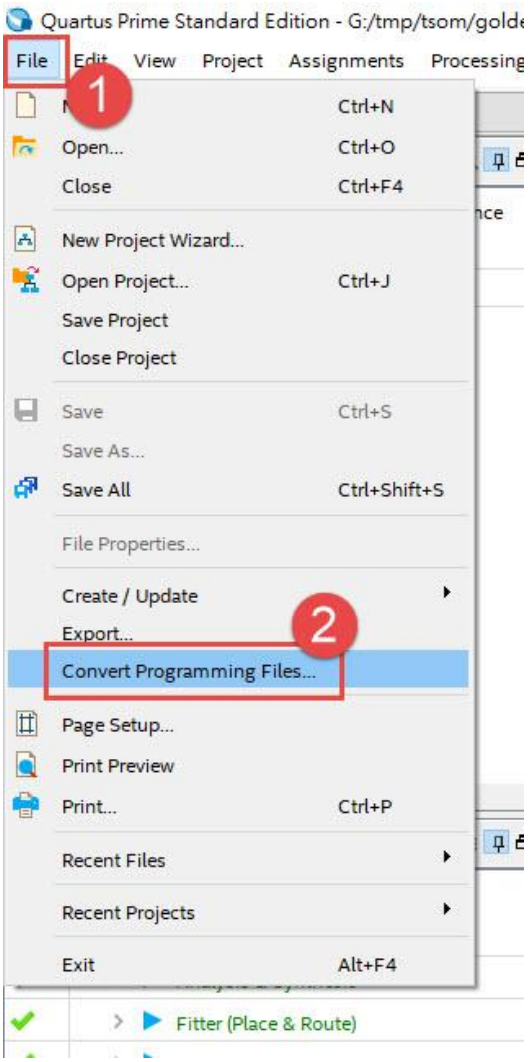


Figure 7-1 SW2 Setting Resistors (AS Mode)

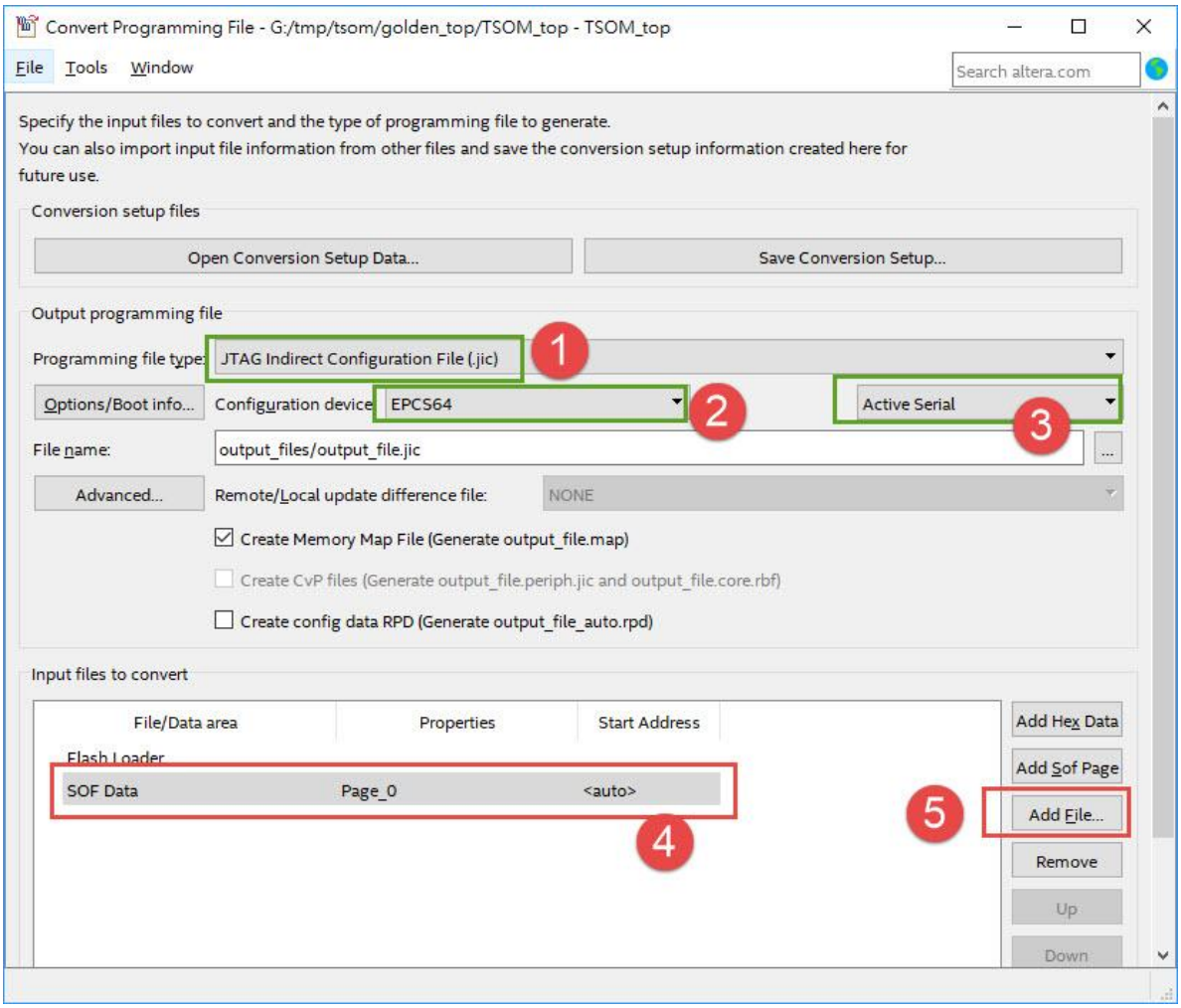
■ Convert .SOF File to .JIC File

To programme the design file into the EPCS device, a .jic file is required. Here's how to convert the .sof file generated by Quartus compile to .jic.

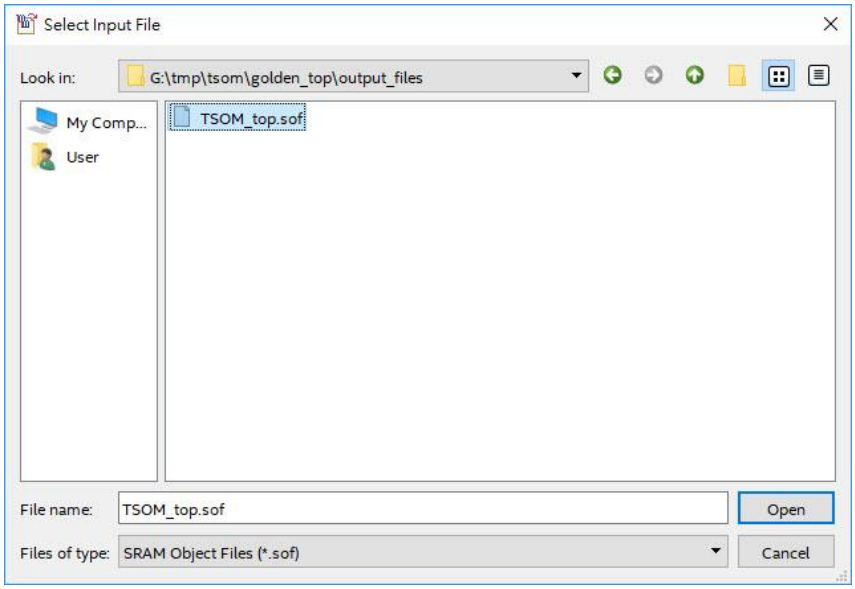
1. Choose Convert Programming Files from the File menu of Quartus II.



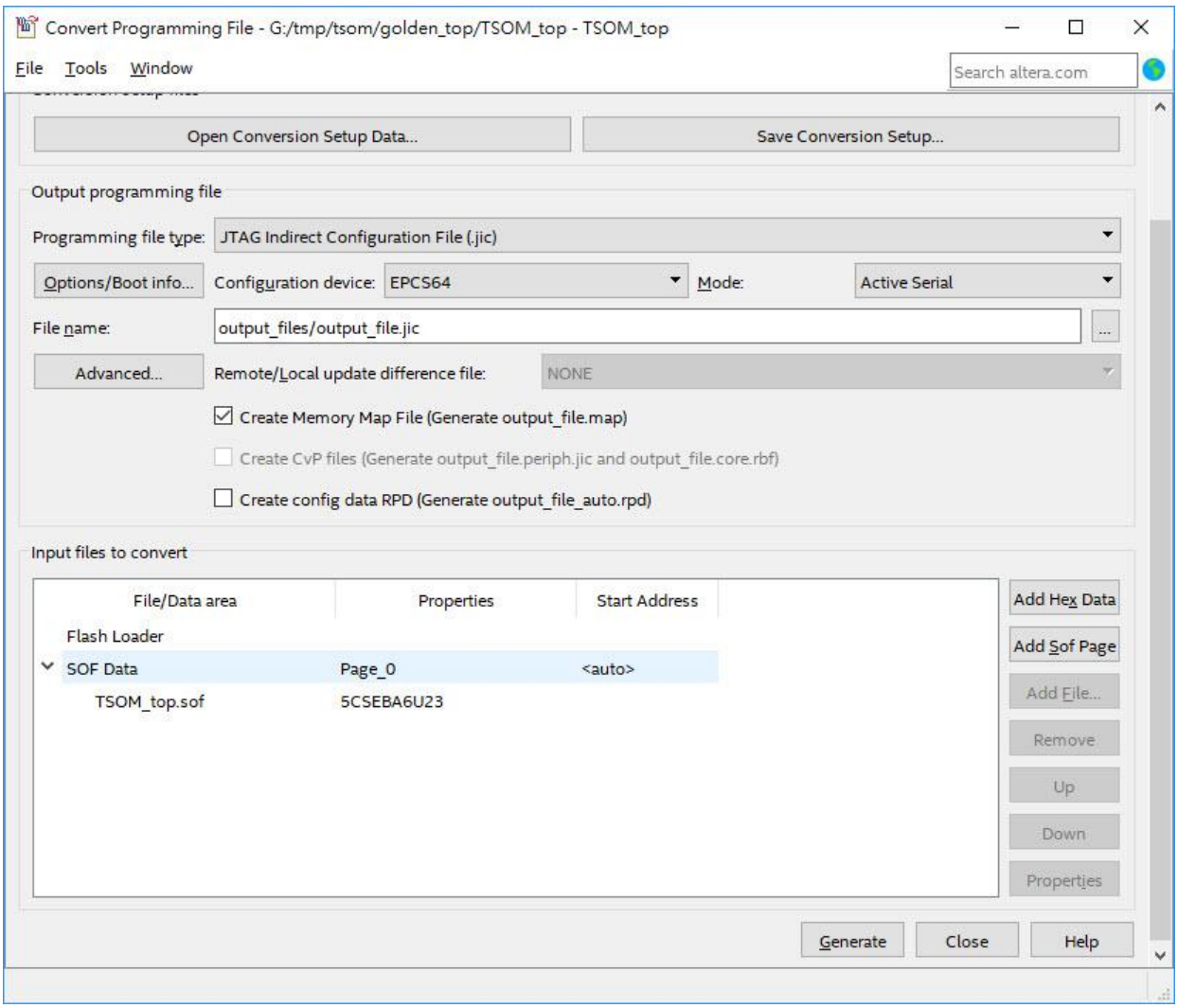
2. Select JTAG Indirect Configuration File (.jic) from the Programming file type field in the dialog of Convert Programming Files.



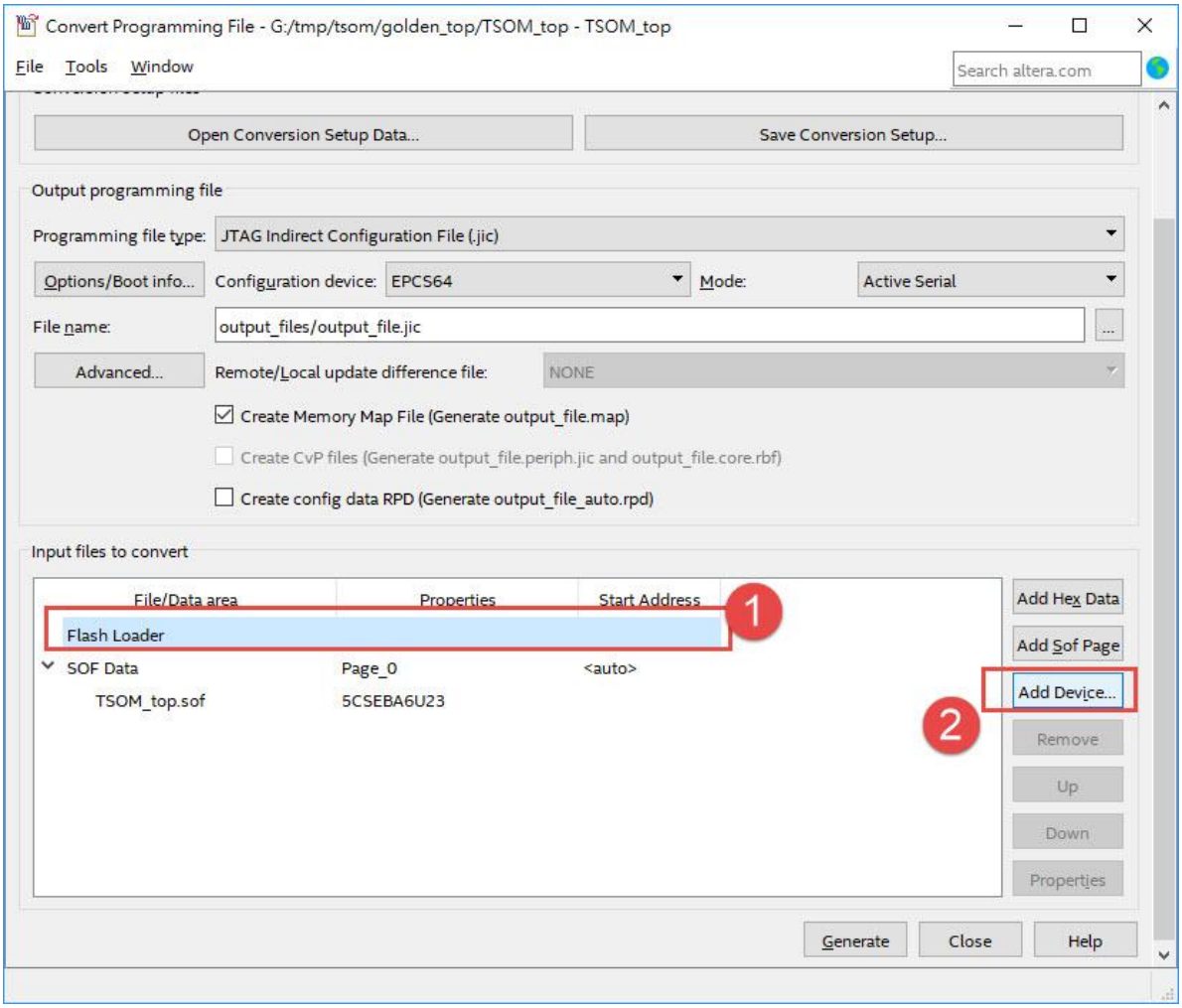
3. Choose EPCS64 from the Configuration device field.
4. Choose Active Serial from the Mode filed.
5. Browse to the target directory from the File name field and specify the name of output file.
6. Click on the SOF data in the section of Input files to convert.
7. Click Add File.
8. Select the .sof to be converted to a .jic file from the Open File dialog.



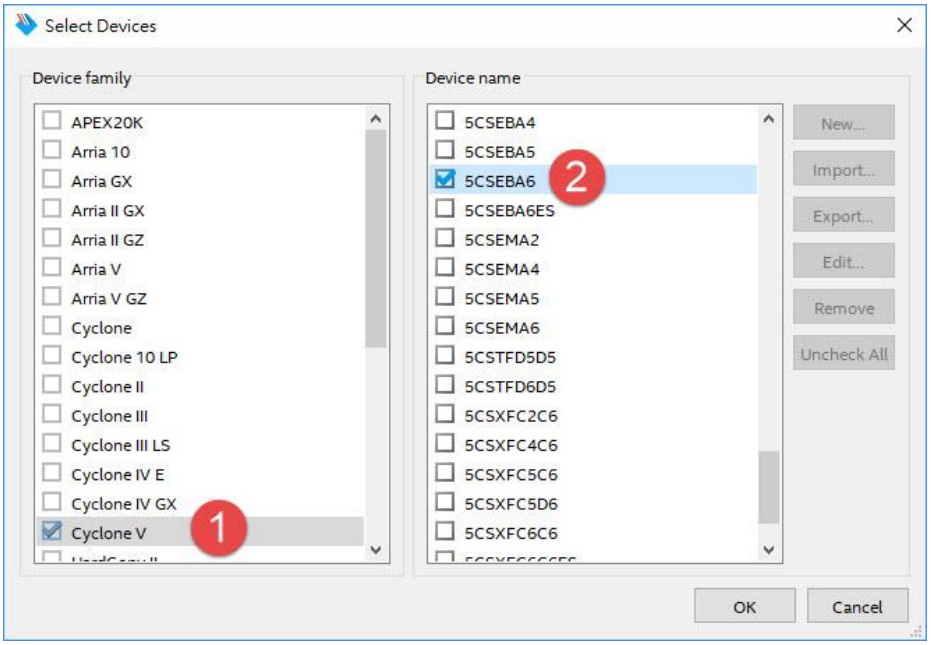
9. Click Open and the Convert Programming Files page will appear.



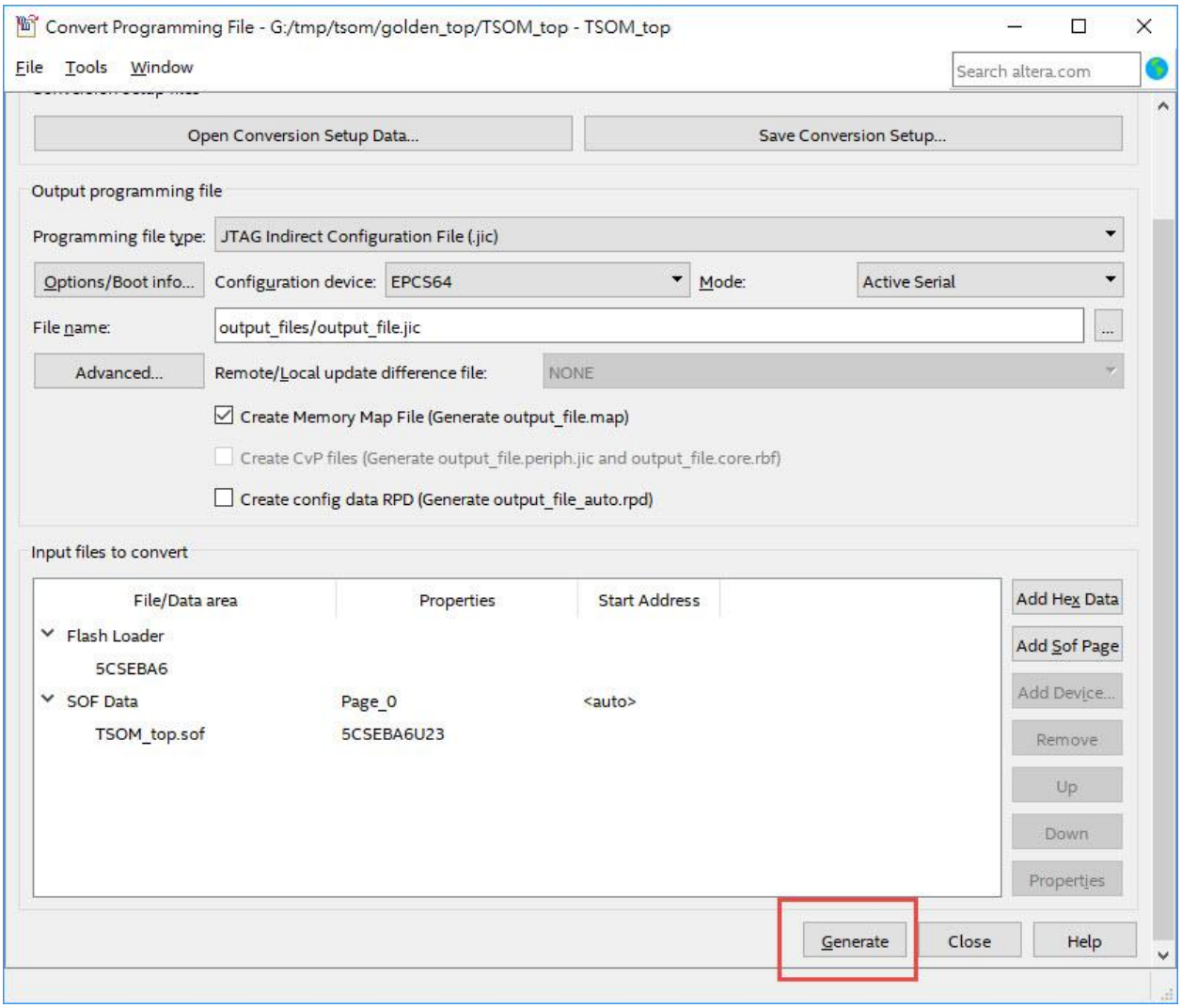
10. Click on the Flash Loader and click Add Device.



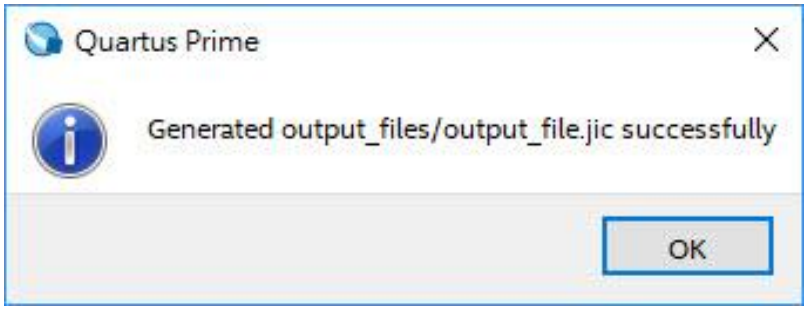
11. The Select Devices page will appear, please select the targeted FPGA to be programed into the EPCS.



12. Click OK and the Convert Programming Files page will appear.

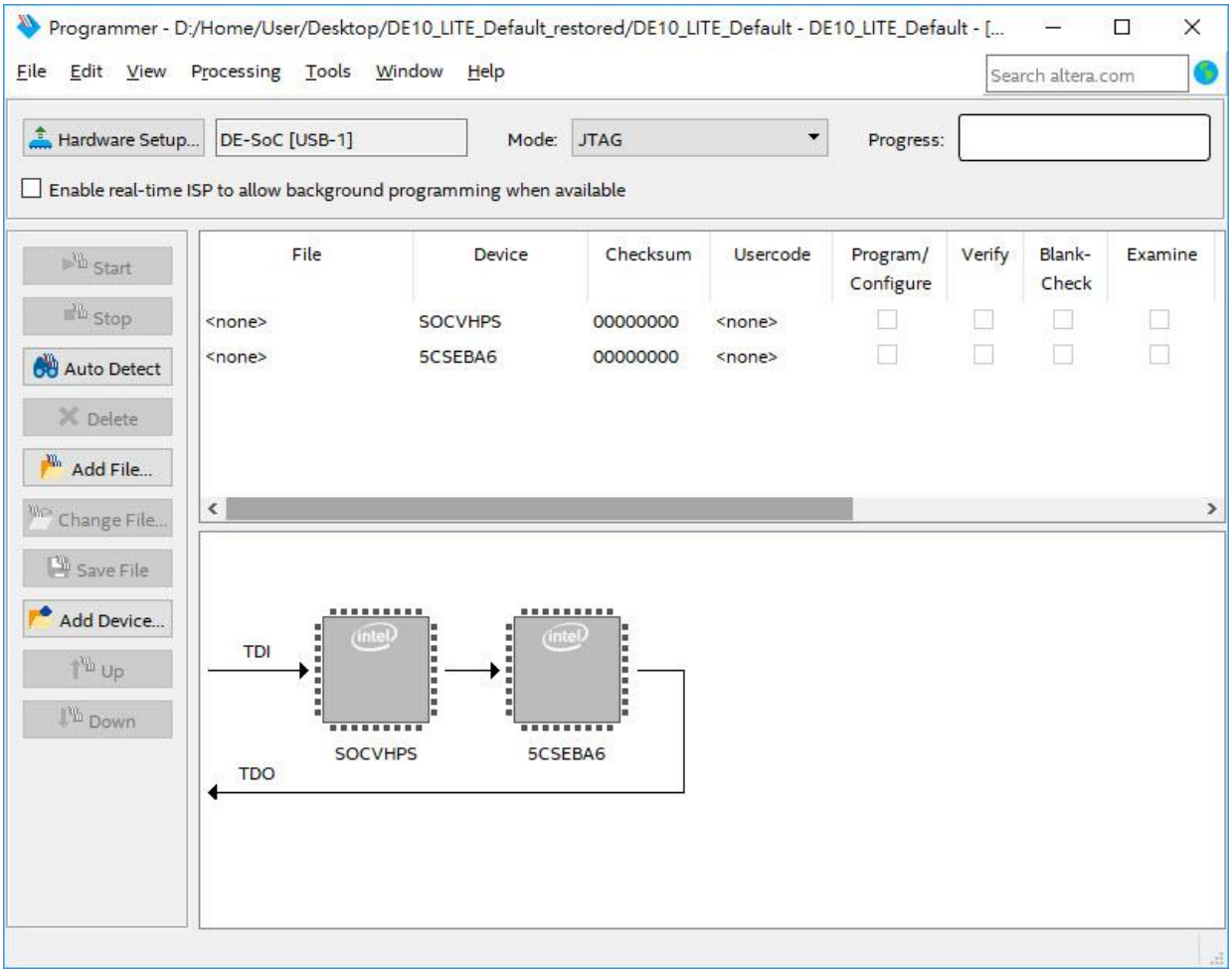


13. Click Generate and wait the .jic file is generated.

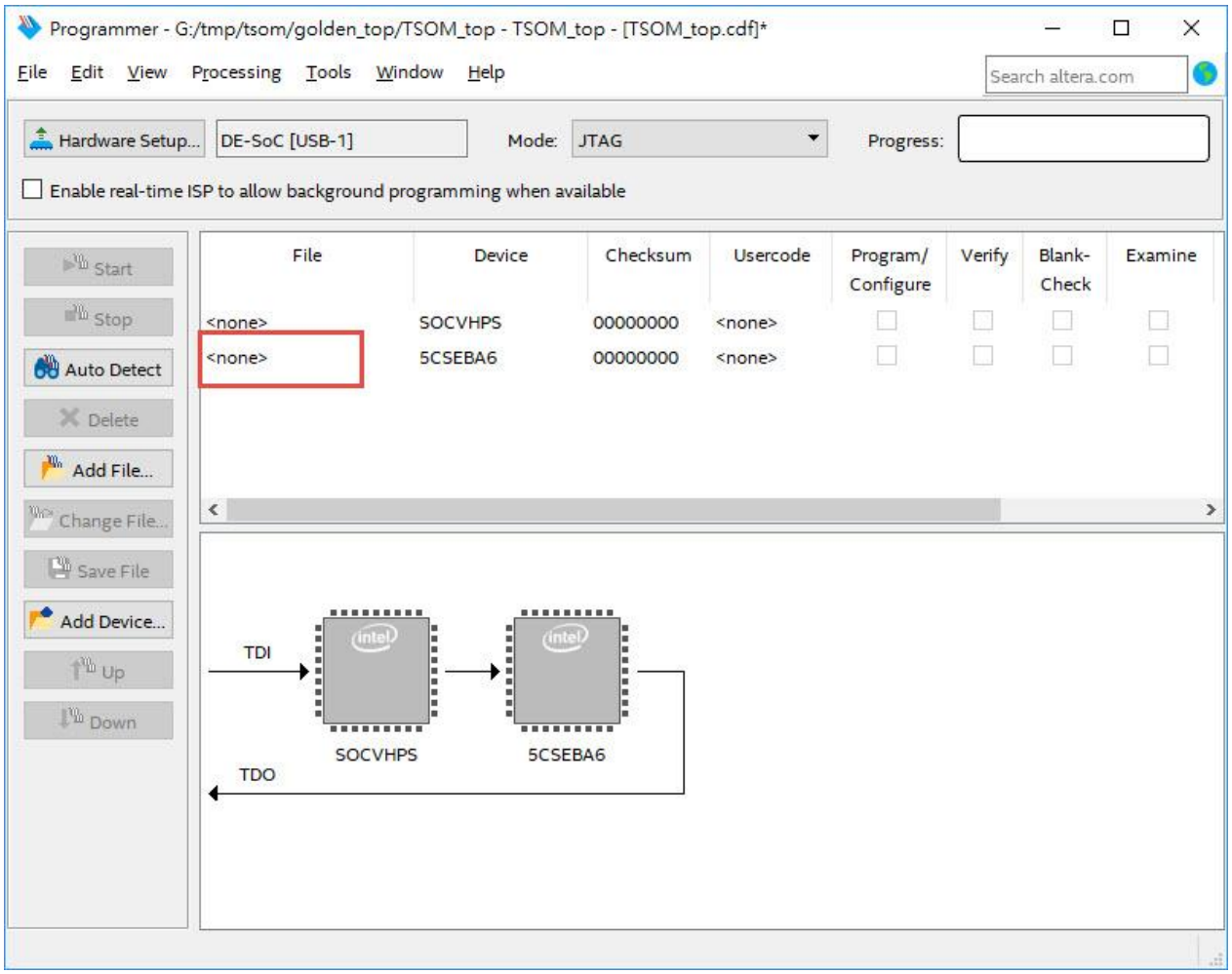


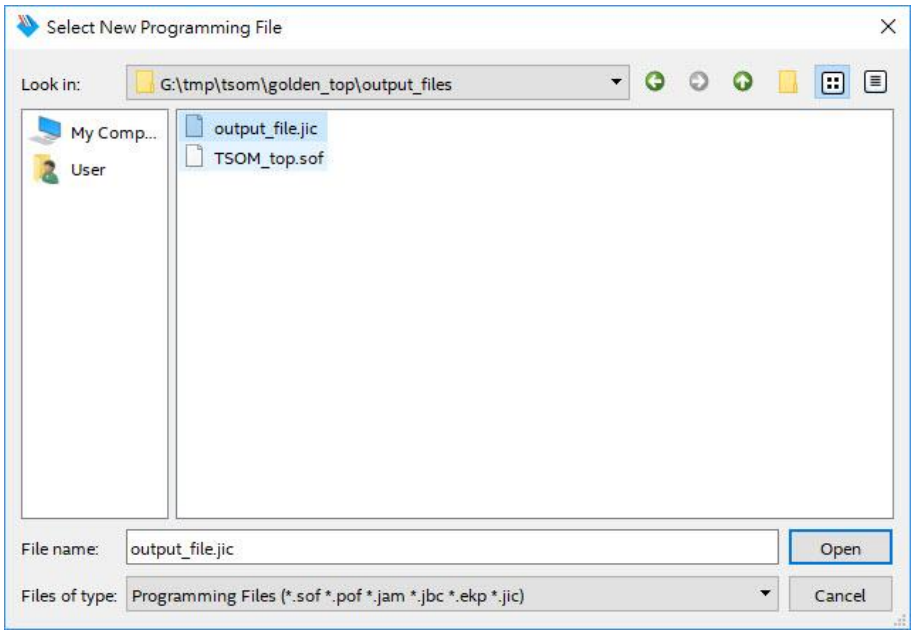
■ Write JIC File into the EPCS Device

1. Make sure the MSEL[4..0] is set to “10010” in AS mode.
2. Choose Programmer from the Tools menu and the Chain.cdf window will appear.
3. Click Auto Detect and then select the correct device (5CSEBA6). Both FPGA device and HPS should be detected



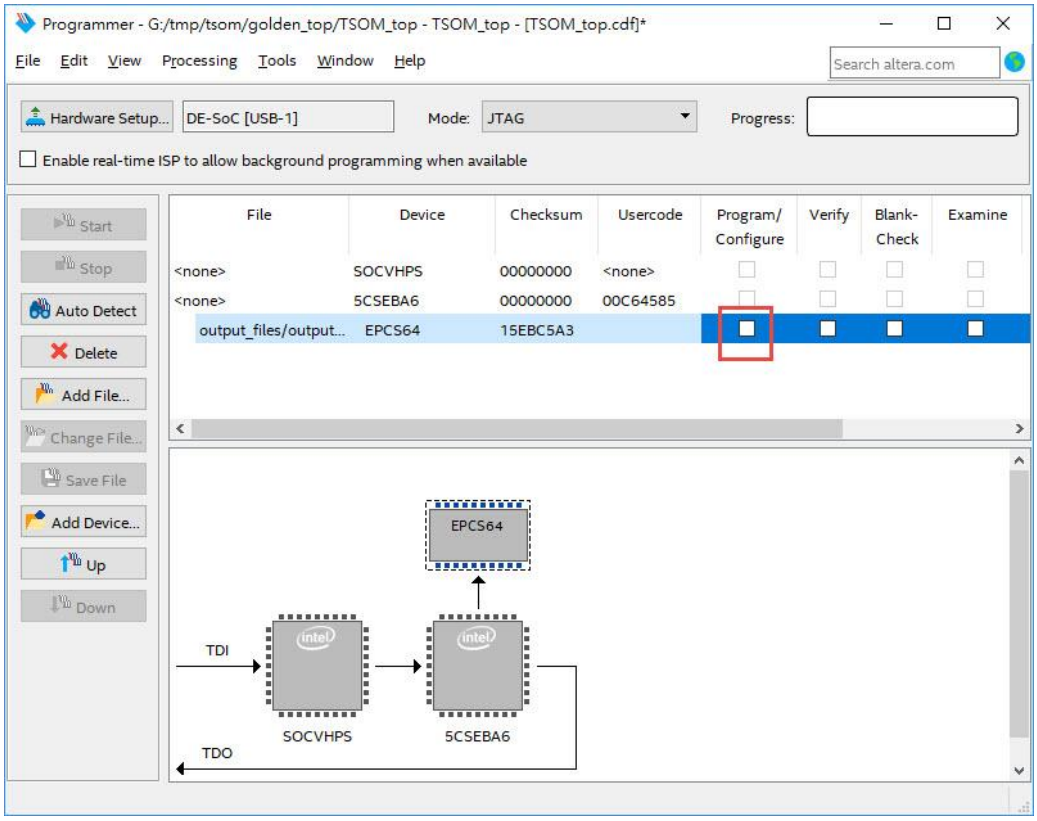
4. Double click the red rectangle region shown in below and the "Select New Programming File" page will appear. Select the .jic file to be programmed.



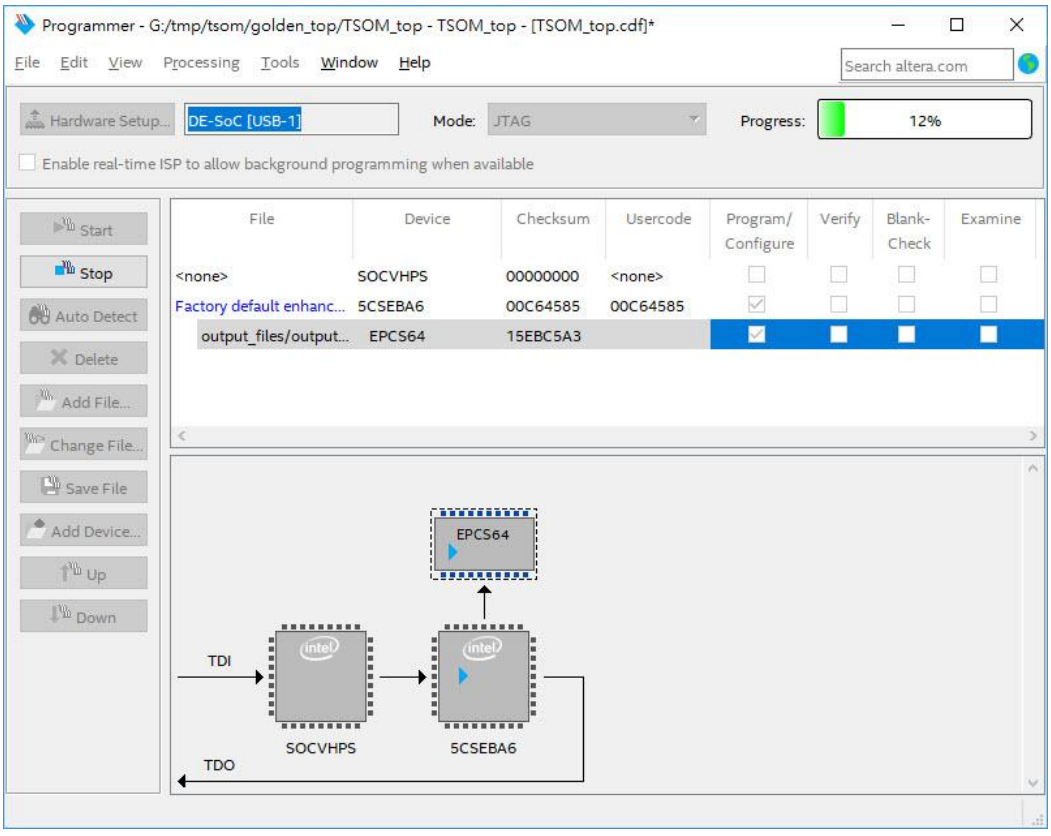


5. Program the EPCS device by clicking the corresponding Program/Configure box. A factory

default SFL image will be loaded.

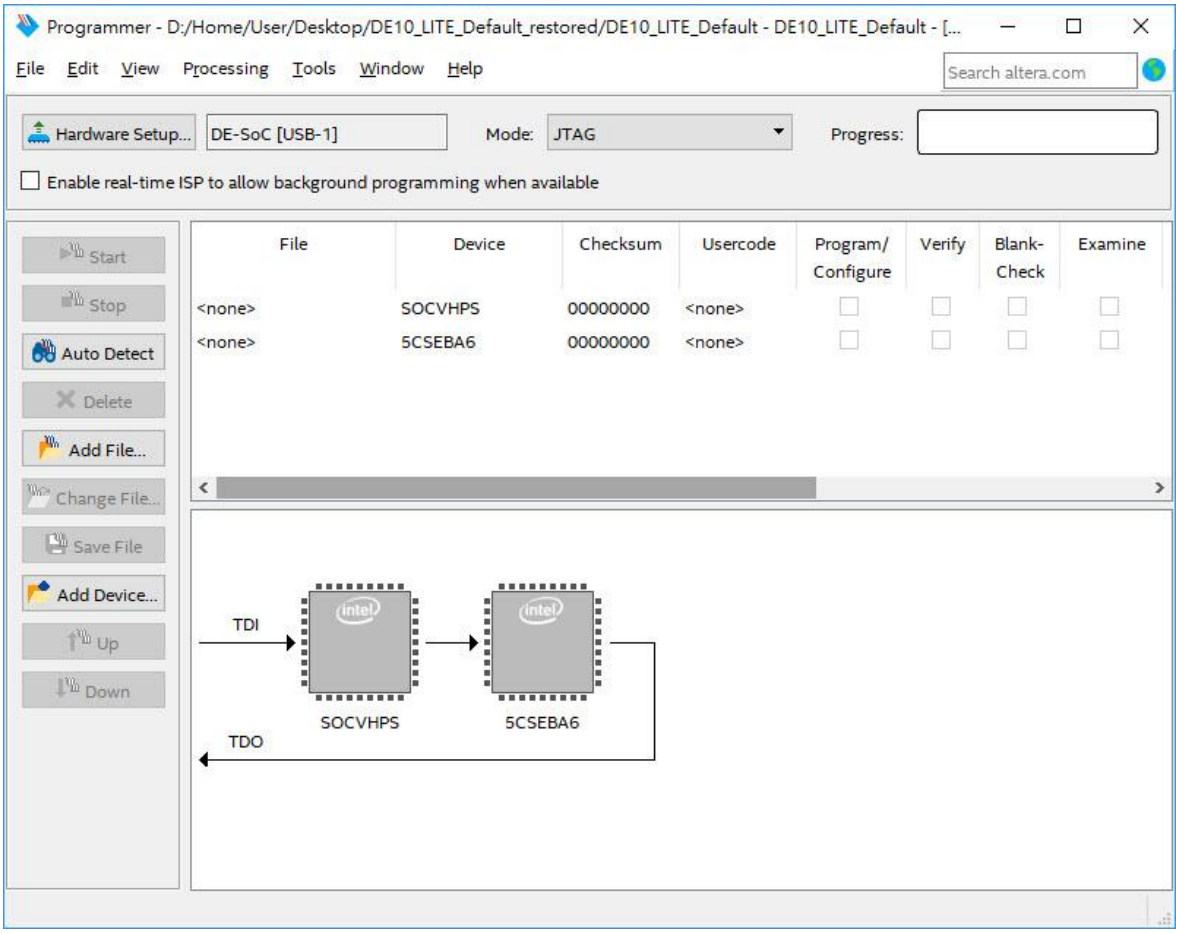


6. Click Start to program the EPCS device.

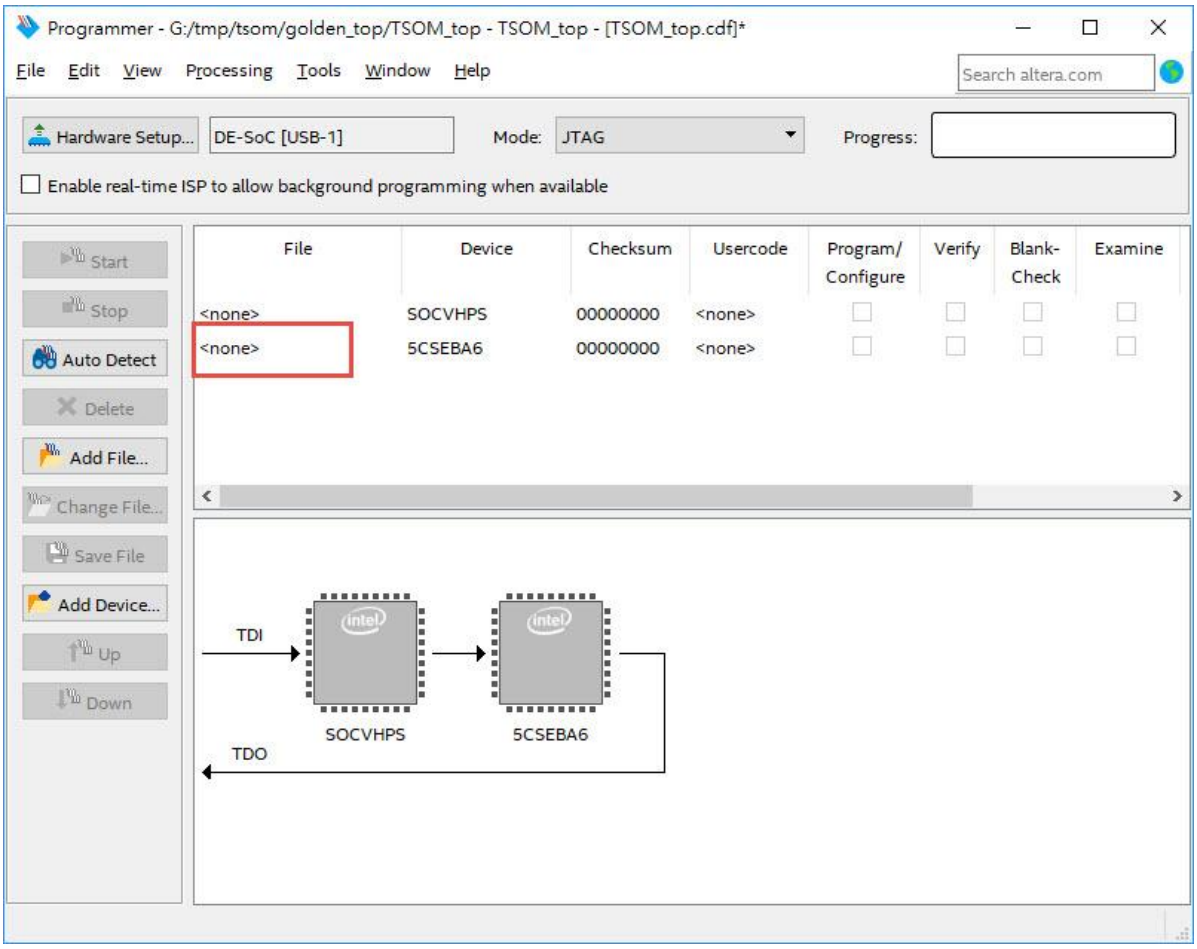


■ Erase the EPCS Device

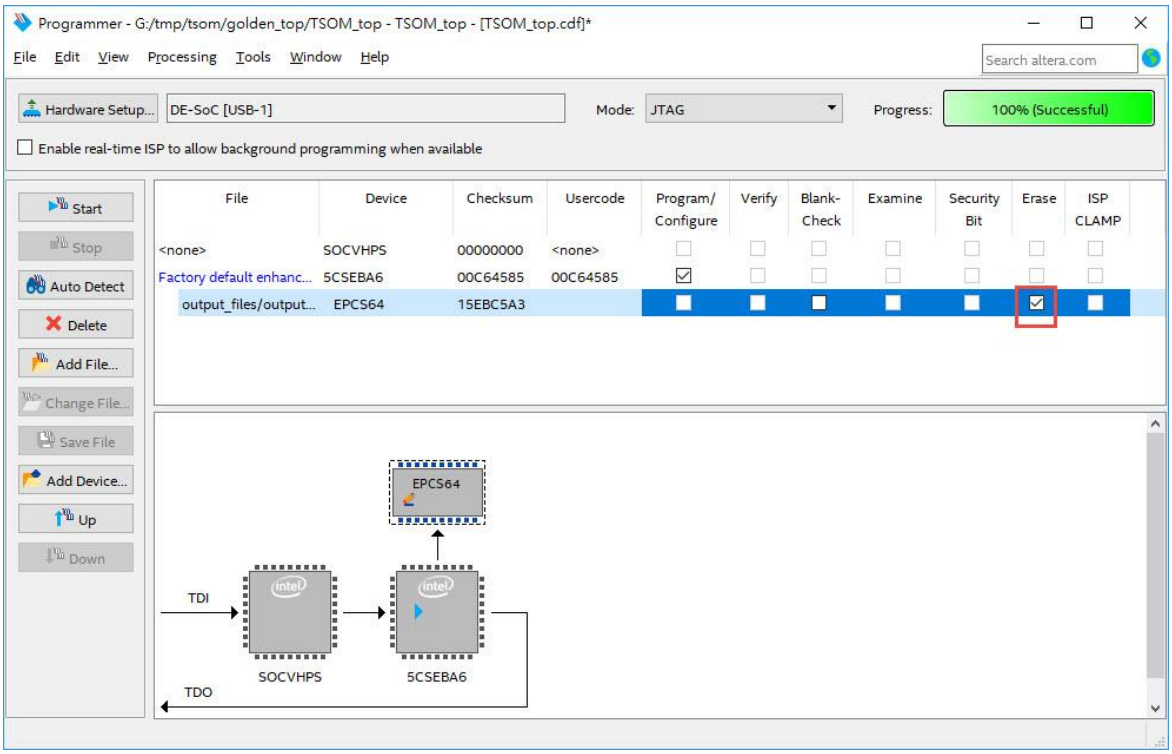
1. Erase the EPCS Device
2. Make sure the MSEL[4..0] is set to “10010” in AS mode.
3. Choose Programmer from the Tools menu and the Chain.cdf window will appear.
4. Click Auto Detect, and then select correct device, both FPGA device and HPS will detected.



5. Double click the red rectangle region shown in below, and the Select New Programming File page will appear. Select the correct .jic file.



6. Erase the EPCS device by clicking the corresponding Erase box. A factory default SFL image will be loaded.



7. Click Start to erase the EPCS device.

Chapter 8
eMMC Programming

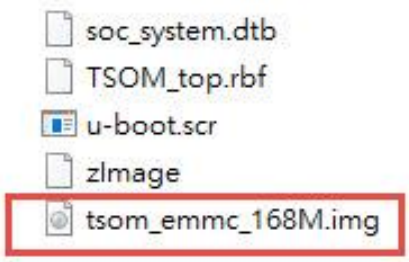
This guide will show you how to program the Linux image into the eMMC device on the TSoM module and explain how to update device tree and zImage in the eMMC device.

■ Re-flash linux image to emmc memory

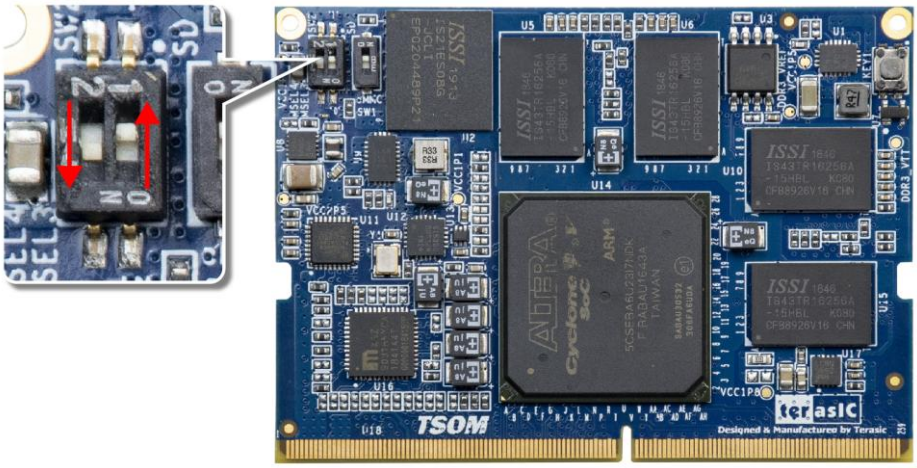
1. Prepare a SD card reader and a Micro SD card (minimum 4GB capacity,for Linux boot).
2. Download the image file form the link below and use the tool such as "Win32 Disk Imager" to write the linux image file(tsom_linux_console.zip) into the Mircro SD card.

   http://mail.terasic.com.tw/~johnny/release/tsom/tsom_linux_console.zip
3. Download the eMMC image file from the link below and extract it, then copy the image file(tsom_emmc_168M.img) to the fat partition of sdcard

   http://mail.terasic.com.tw/~johnny/release/tsom/tsom_emmc_168M.img.zip

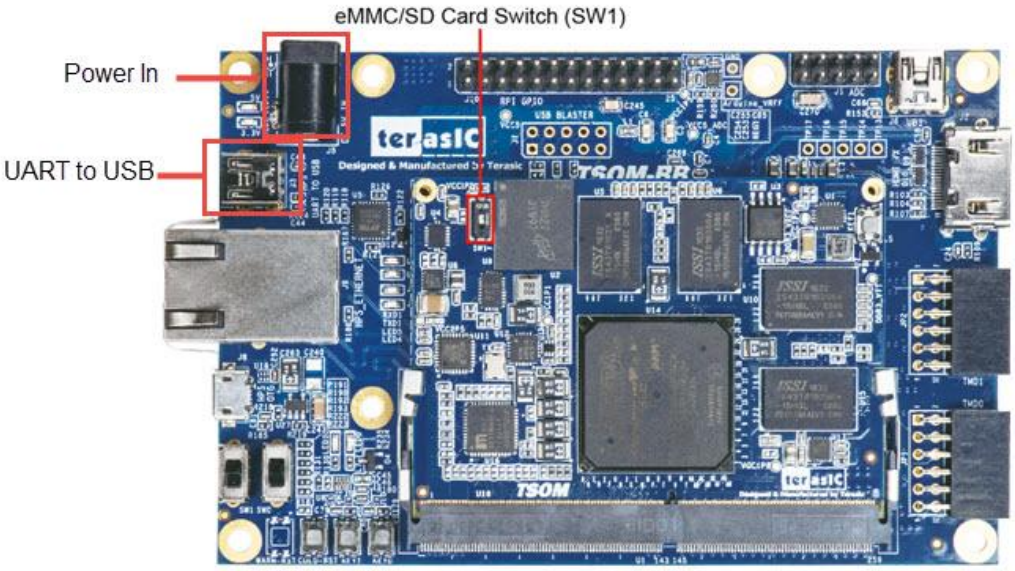


4. Insert the Micro SD card into the TSoM evaluation kit.
5. Make sure SW2 is set to FPPx32 mode(See the picture below), so the FPGA can be configured by HPS. The factory default mode is the FPPx32 mode.

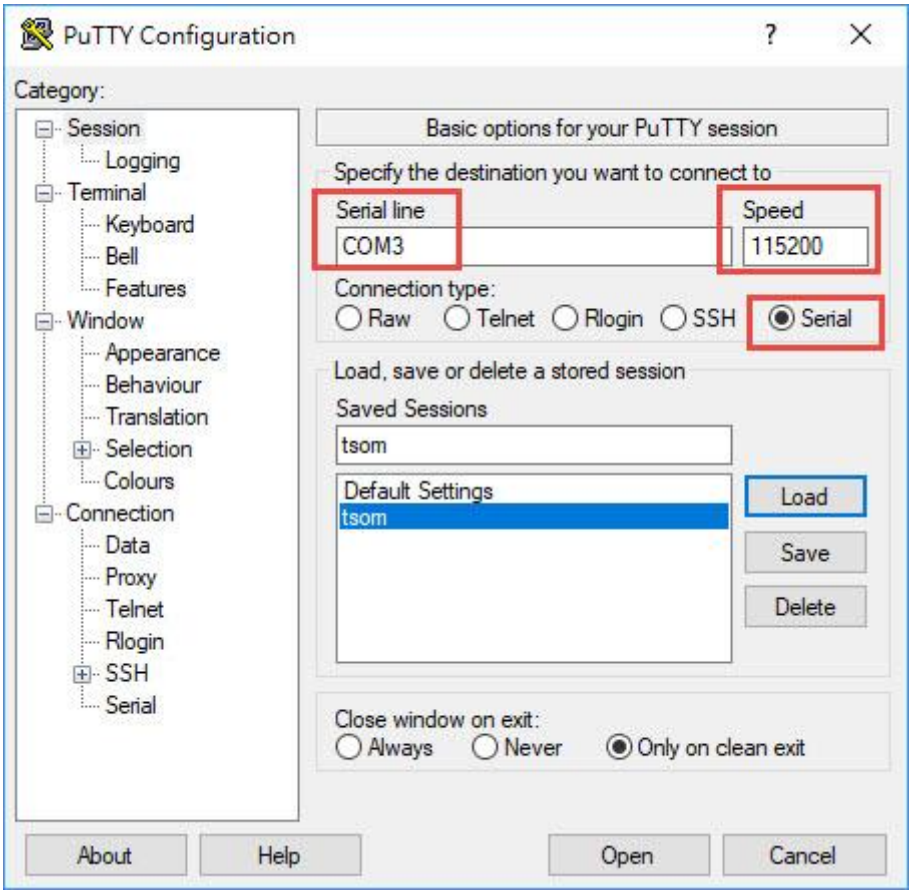


6. Make sure that SW1 on the TSoM is switch to the "ON" position, which represents the HPS boot from the SD Card.

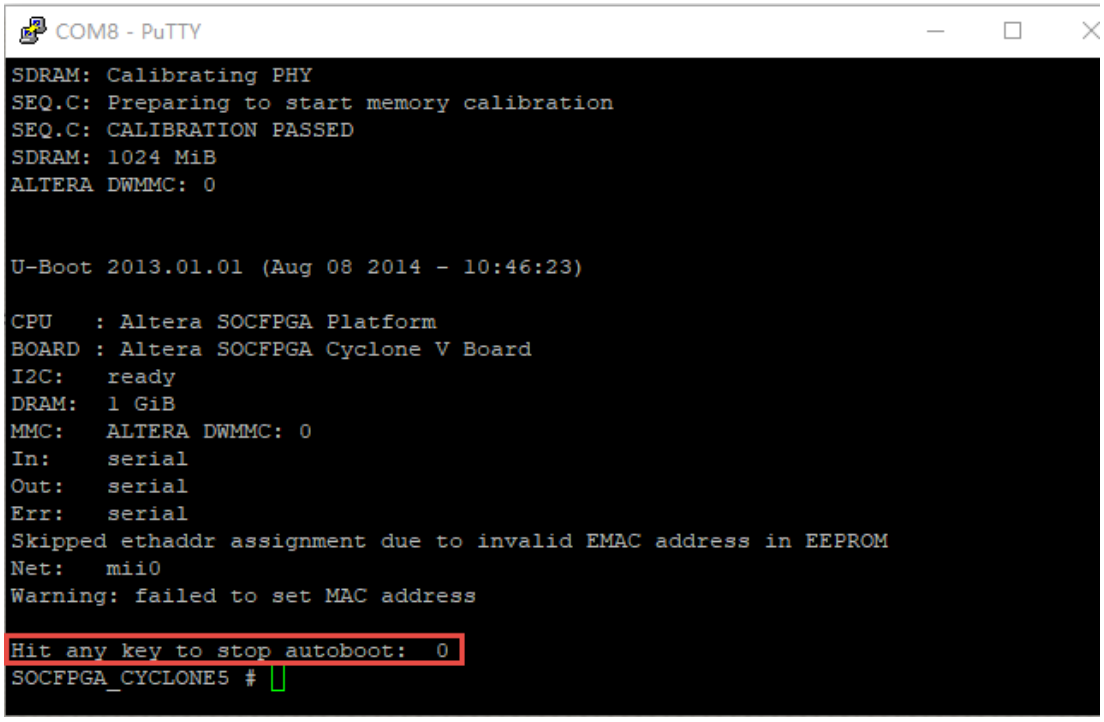
7. Connect the PC and TSoM evaluation kit via mini USB cable and connect the Power adapter to power on the board.



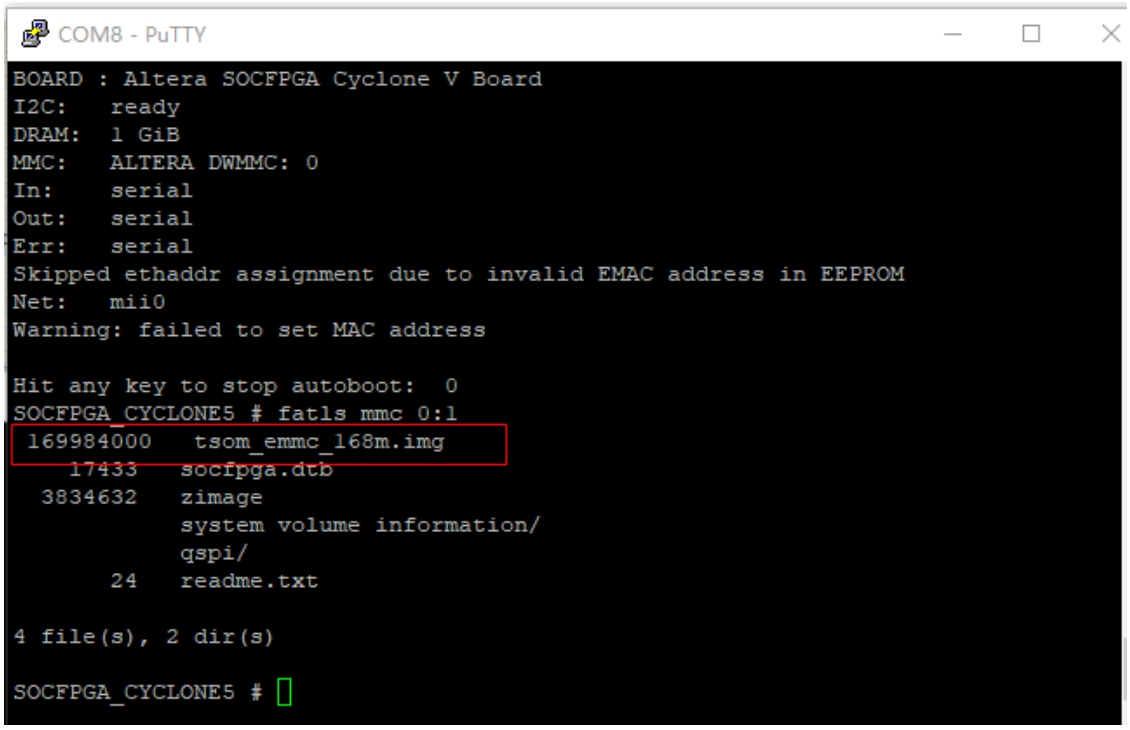
8. Use the terminal emulation program such as Putty on the operating system to connect to Linux running on TSoM



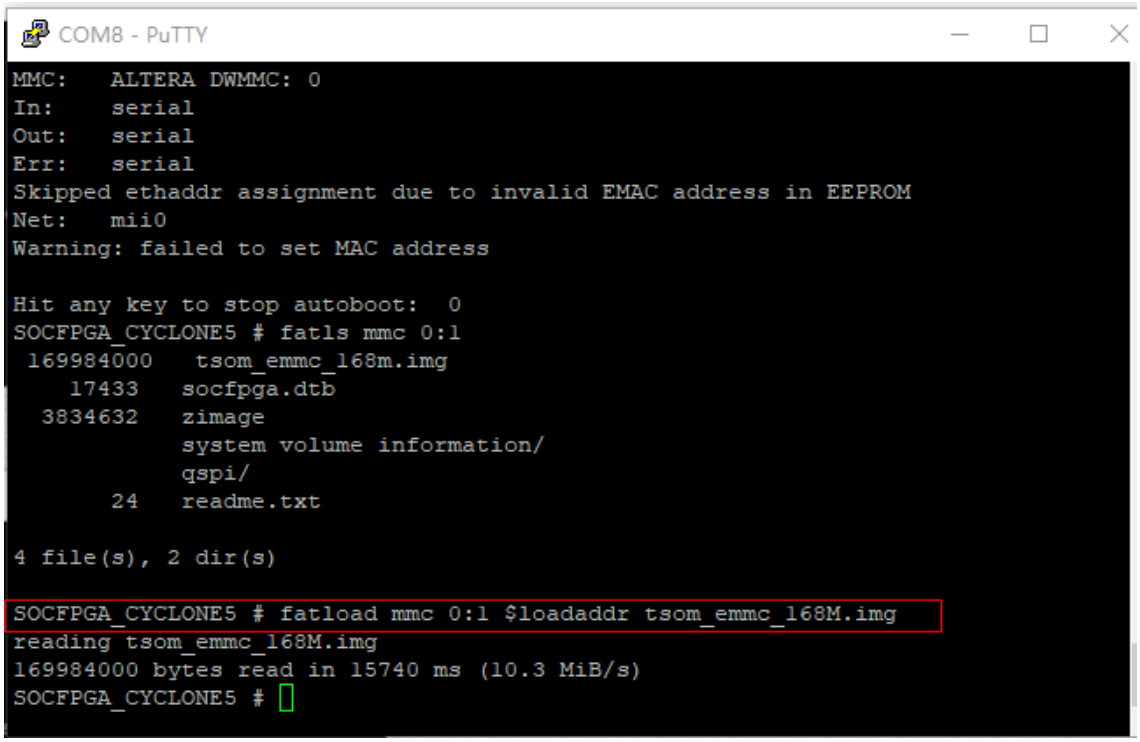
9. Press the CPU KEY1(WARM_RST) button on the TSoM module and wait for the "Hit any key to stop autoboot :5" to appear in the Putty window. Press any key to enter uboot.



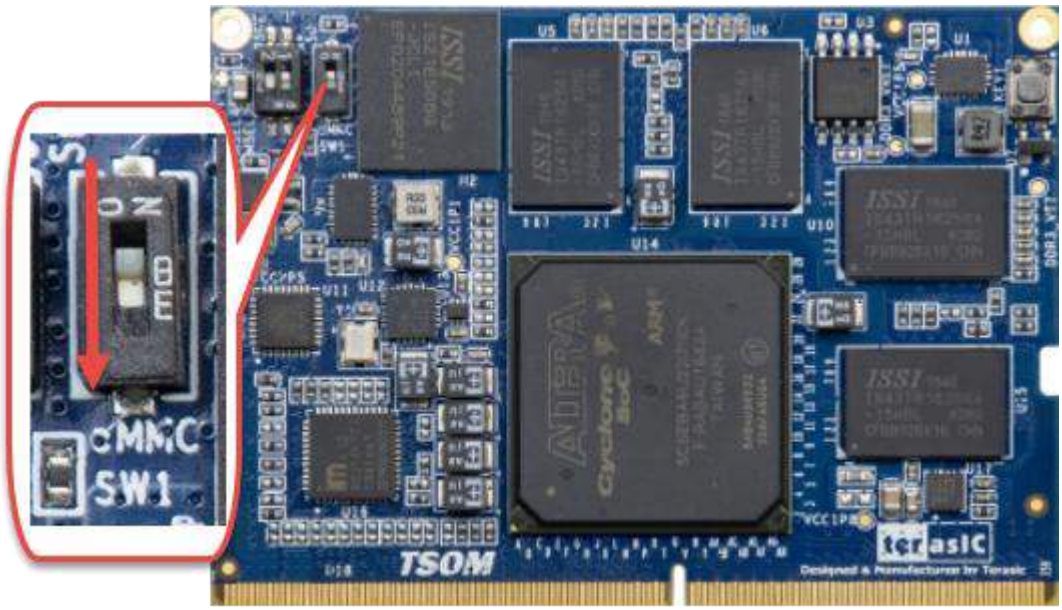
10. Enter the command "**fatls mmc 0:1**" to view the contents of the sdcard fat partition.



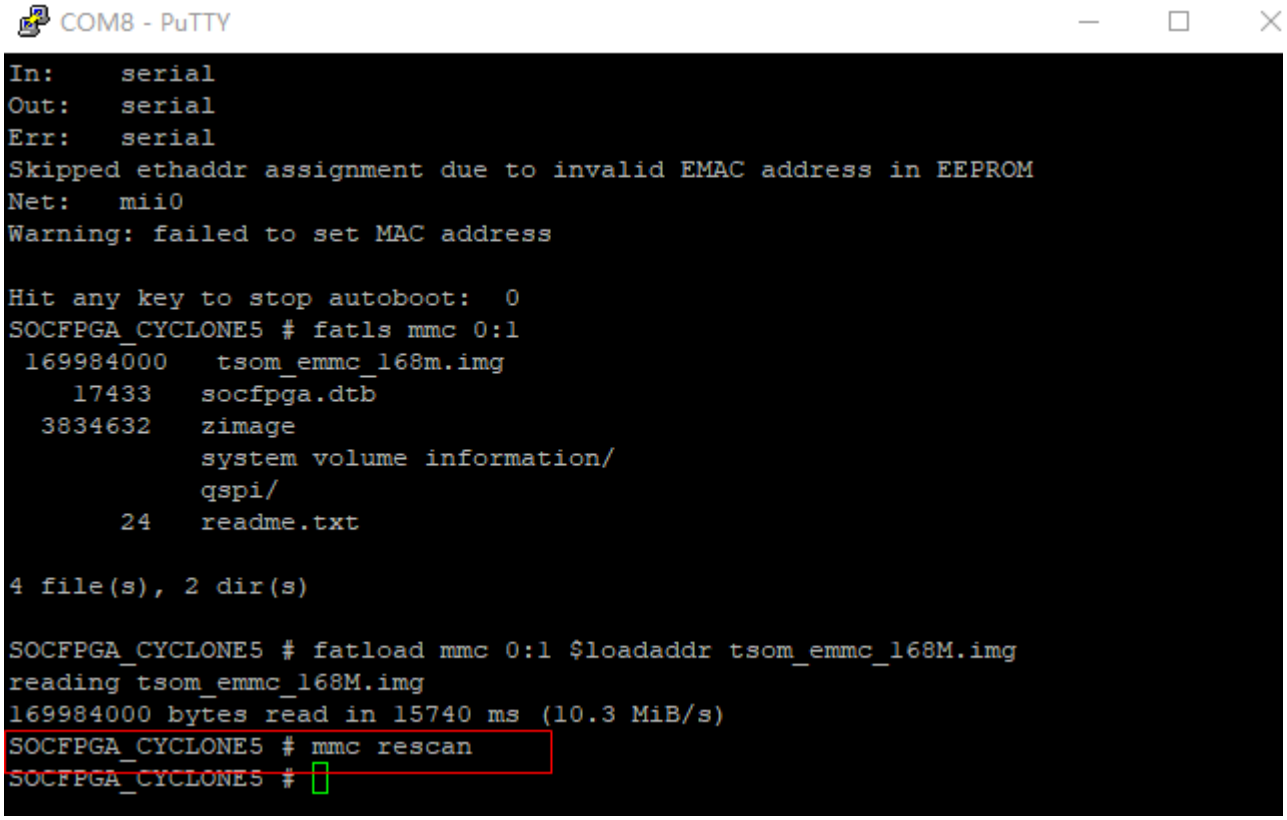
11. Enter the command "**fatload mmc 0:1 $loadaddr tsom_emmc_168M.img**" to load the .img file into the DDR3.



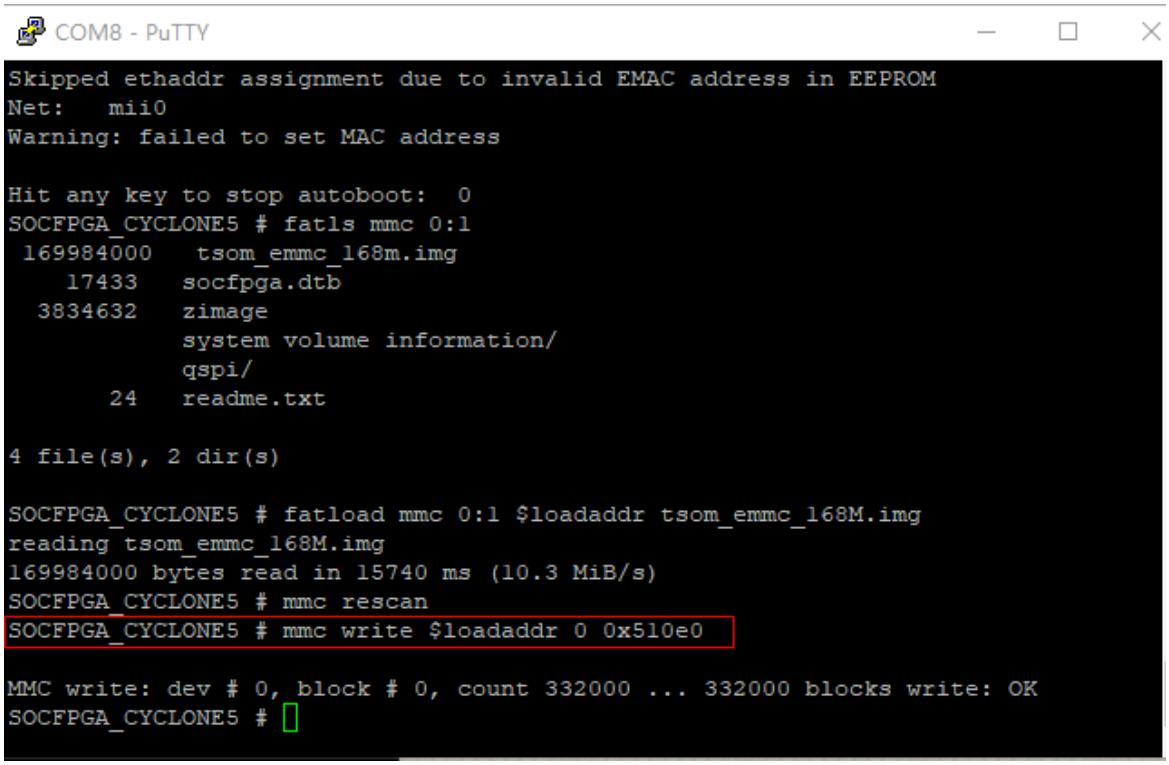
12. Switch SW1 to "OFF" position to switch to eMMC boot mode.



13. Enter the command "**mmc rescan**" to rescan the eMMC device.

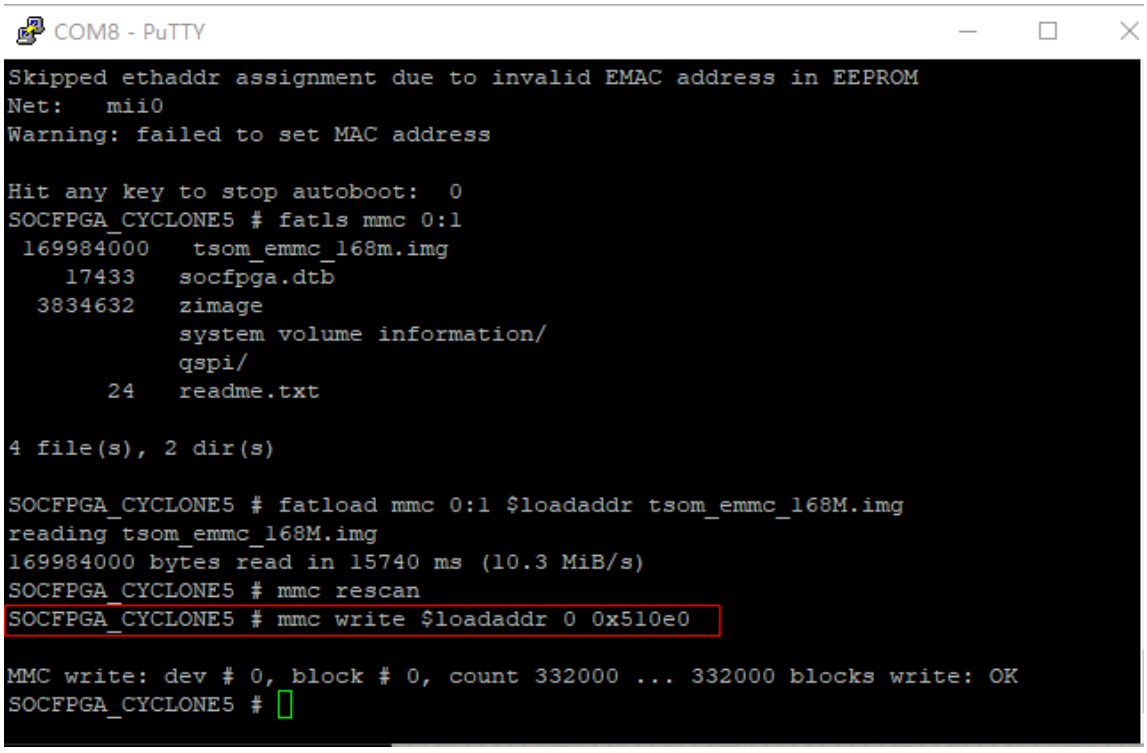


14. Enter the command "**mmc write $loadaddr 0 0x510e0**" to program image file to the eMMC device.



15. Note: The number "0x510e0" represents the image size, the unit is "block", each block has 512 bytes size. The size of the image file here is 169984000 bytes , i.e. 169984000/ 512=332000 (block) . 332000 converted to hexadecimal is 0x510e0.

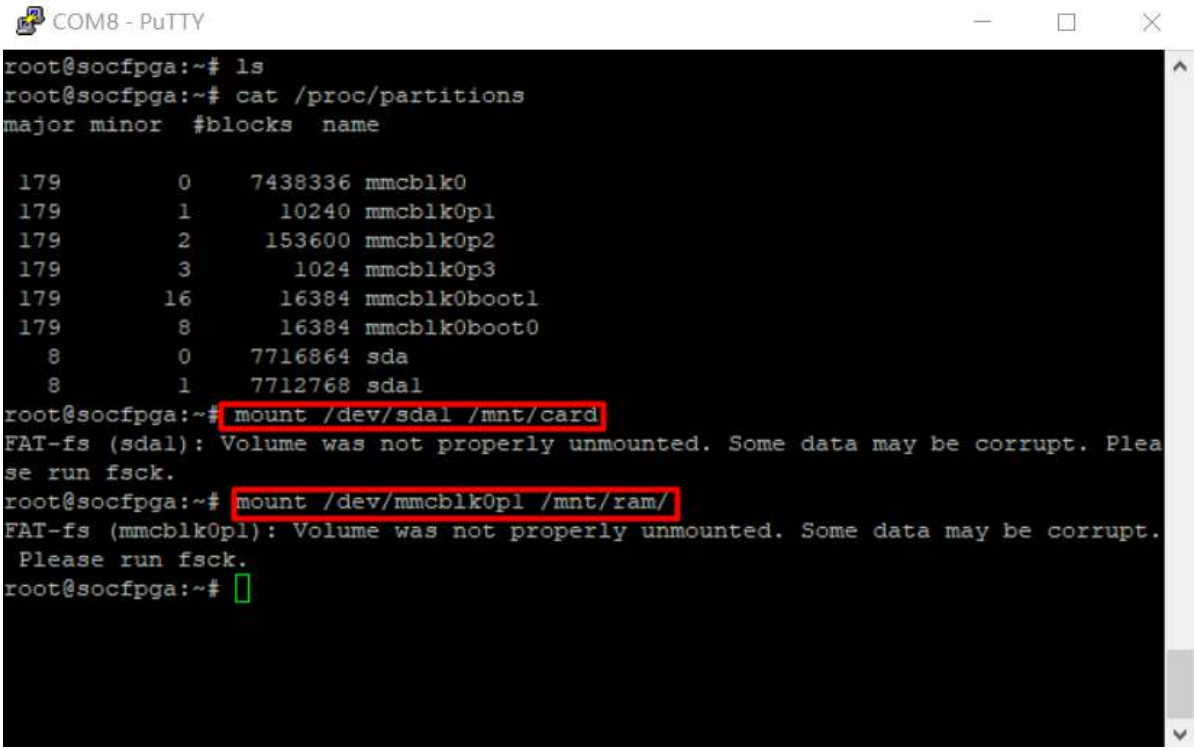
16. Press the COLD_RST button of the TSoM evaluation kit to reboot the board into linux. When the "login in" message appears that shows the programming eMMC success.



■ Update Device Tree and zImage in the eMMC

1. Before you update files to the eMMC, you should make sure the Tsom board can boot from eMMC correctly.
2. Copy your new device tree file(.dtb) and zImage files to USB flash drive.
3. Insert the USB flash drive to TSoM Board with USB OTG cable, then boot linux from eMMC
4. After the linux is boot, enter "root" to login the system, then, mount the USB flash drive and eMMC memory's partition one to linux. Commands: "**mount /dev/sda1 /mnt/card**" and "**mount /dev/mmcblk0p1 /mnt/ram/**".

   (sda is USB flash drive, mmcblk0p1 is emmc memory's partition one; ignore the information when you do mount)

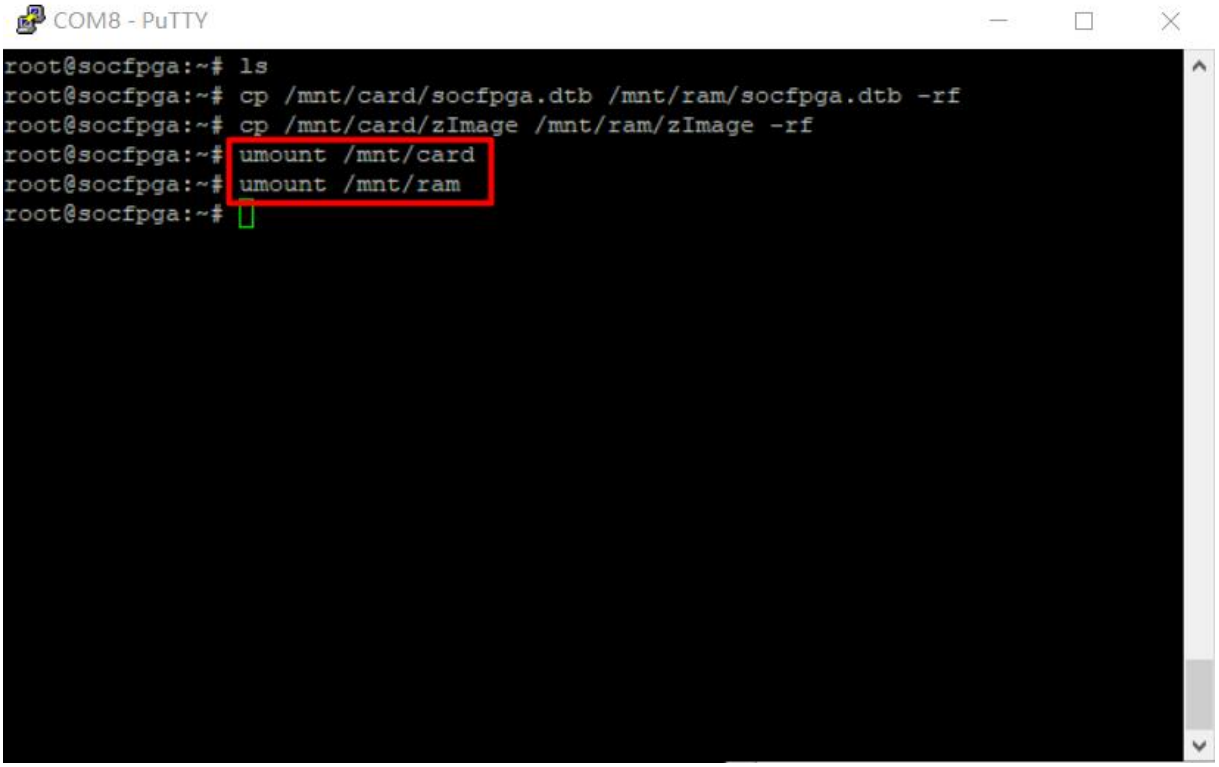


5. Copy your new files from the USB flash drive to the eMMC memory with commands

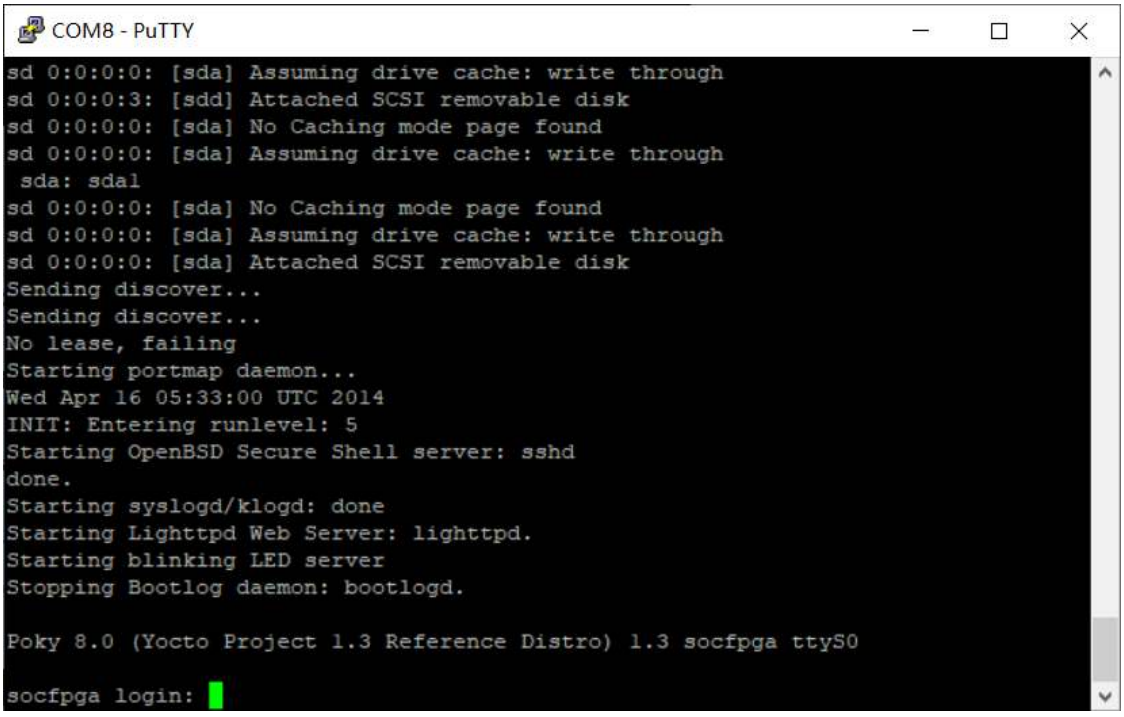
   "**cp /mnt/card/zImage /mnt/ram/zImage -rf**" and

   "**cp /mnt/card/soc_system.dtb /mnt/ram/soc_system.dtb -rf**".

6. Umount USB flash drive(command:"umount /mnt/ram") and eMMC memory's partition one(command:"umount/mnt/car").



7. Press the COLD_RST button to reboot TSoM board, then it will boot linux with your new updated files.



Appendix

9.1 Revision History

Version	Change Log
V1.0	Initial Version (Preliminary)
V1.1	Modify ch3 , ch7 and ch8 according rev B version
V1.2	Modify chapter 8

Copyright © Terasic Inc. All rights reserved.