
SmartFusion2 SoC FPGA Demo: Code Shadowing from SPI Flash to SDR Memory

User's Guide

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SmartFusion2 SoC FPGA - Code Shadowing from SPI Flash to SDR Memory

Introduction

This demo design shows SmartFusion[®]2 system-on-chip (SoC) field programmable gate array (FPGA) device capabilities for code shadowing from serial peripheral interface (SPI) flash memory to single data rate (SDR) synchronous dynamic random access memory (SDRAM) and executing the code from SDR SDRAM. [Figure 1](#) shows the top level block diagram for code shadowing from SPI flash to SDR demo.

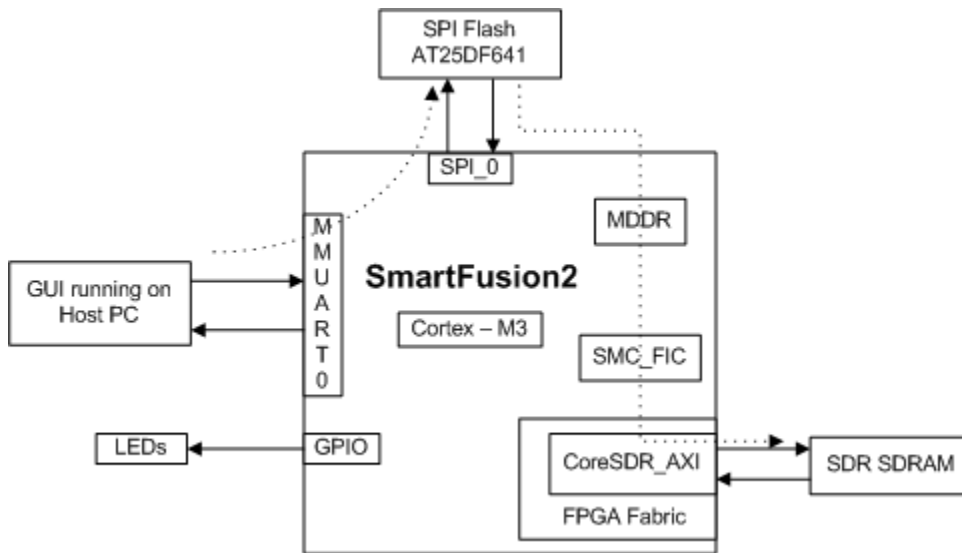


Figure 1. Top Level Block Diagram of the Demo

Code shadowing is a booting method that is used to execute an image from external faster volatile memories (DRAM). Code shadowing is the process of copying the code from nonvolatile memory to volatile memory for execution. Code shadowing is required when the nonvolatile memory associated with the processor does not support random access to the code for execute-in-place or insufficient nonvolatile random access memory exists. In performance critical applications, execution speed can be improved by code shadowing where code is copied to higher throughput RAM for faster execution. SDR/double data rate (DDR) SDRAM memories are used in an application that has a large application executable image and requires higher performance. Typically, the large executable images are stored in nonvolatile memory such as NAND flash or SPI flash and copied to volatile memory such as SDR/DDR SDRAM memory at power up for execution.

SmartFusion2 SoC FPGA device integrates fourth generation flash-based FPGA fabric, an ARM[®] Cortex[™]-M3 processor, and high performance communications interfaces on a single chip. SmartFusion2 SoC FPGA device has a soft memory controller fabric interface (SMC_FIC) which can be used to interface external bulk memories to the microcontroller subsystem (MSS) with a soft memory controller in the FPGA fabric. The Cortex-M3 processor can directly execute the instructions from external SDR memory through SDR controller in the FPGA fabric. The SmartFusion2 SoC FPGA cache controller and MSS DDR bridge handles the data flow for a better performance.

Demo Requirements

Hardware and Software Requirements

The hardware and software required to run the demo are listed in the below table.

Table 1. Required Hardware and Software to Run the Demo

Hardware	Version
SmartFusion2 Development Kit	Rev C or later
FlashPro4 programmer	
USB to Mini USB cable	
12 V Adapter	
Software	
FlashPro Programming Software	11.3
USB to UART drivers	
Microsoft .NET Framework 4 client for launching demo GUI	
Operating system	Windows XP SP2 – 32-bit/64-bit Windows 7 – 32-bit/64-bit

Design Files

The design files for this demo can be downloaded from the Microsemi website:
http://soc.microsemi.com/download/rsc/?f=SF2_CodeShadowing_SDR_DF.

Design files include:

1. Libero[®] System-on-Chip (SoC) project
2. Programming files
3. GUI executable
4. Sample application images
5. Linker scripts
6. Readme file

Refer to the Readme.txt file provided in the design files for the complete directory structure.

Demo Design Description

This demo design implements a bootloader application to load the target application executable image into SPI flash from host PC and copies it to the SDR SDRAM for execution. This design provides host interface over SmartFusion2 SoC FPGA multi-mode universal asynchronous/synchronous receiver/transmitter (MMUART) to load the target application executable image into SPI flash connected to the MSS SPI0 interface. If the executable target application is available in SPI flash, the code shadowing from SPI flash to SDR SDRAM can be started. The bootloader program running from the embedded nonvolatile memory (eNVM) jumps to the target application in the SDR SDRAM once the target application image is copied to SDR SDRAM.

In this demo design the external SDR SDRAM is interfaced with the SmartFusion2 SoC FPGA MSS through the SMC_FIC and a soft SDRAM controller (CoreSDR_AXI IP core) in the FPGA fabric. The CoreSDR_AXI IP core is interfaced with the MSS using AXI bus interface. This demo design is intended to be demonstrated on a SmartFusion2 SoC FPGA Development Kit. External component pin mappings are done according to the SmartFusion2 SoC FPGA Development Kit schematics.

The MSS and SDRAM controller (CoreSDR_AXI) in the FPGA fabric are operating at a clock frequency of 80 MHz which is derived using internal 25/50 MHz RC oscillator and fabric clock conditioning circuits (CCC). SDRAM controller timing parameters are set according to the system clock frequency of 80 MHz, as shown in [Appendix A – SDR Configurations](#). [Figure 2](#) shows the detailed block diagram of the demo design.

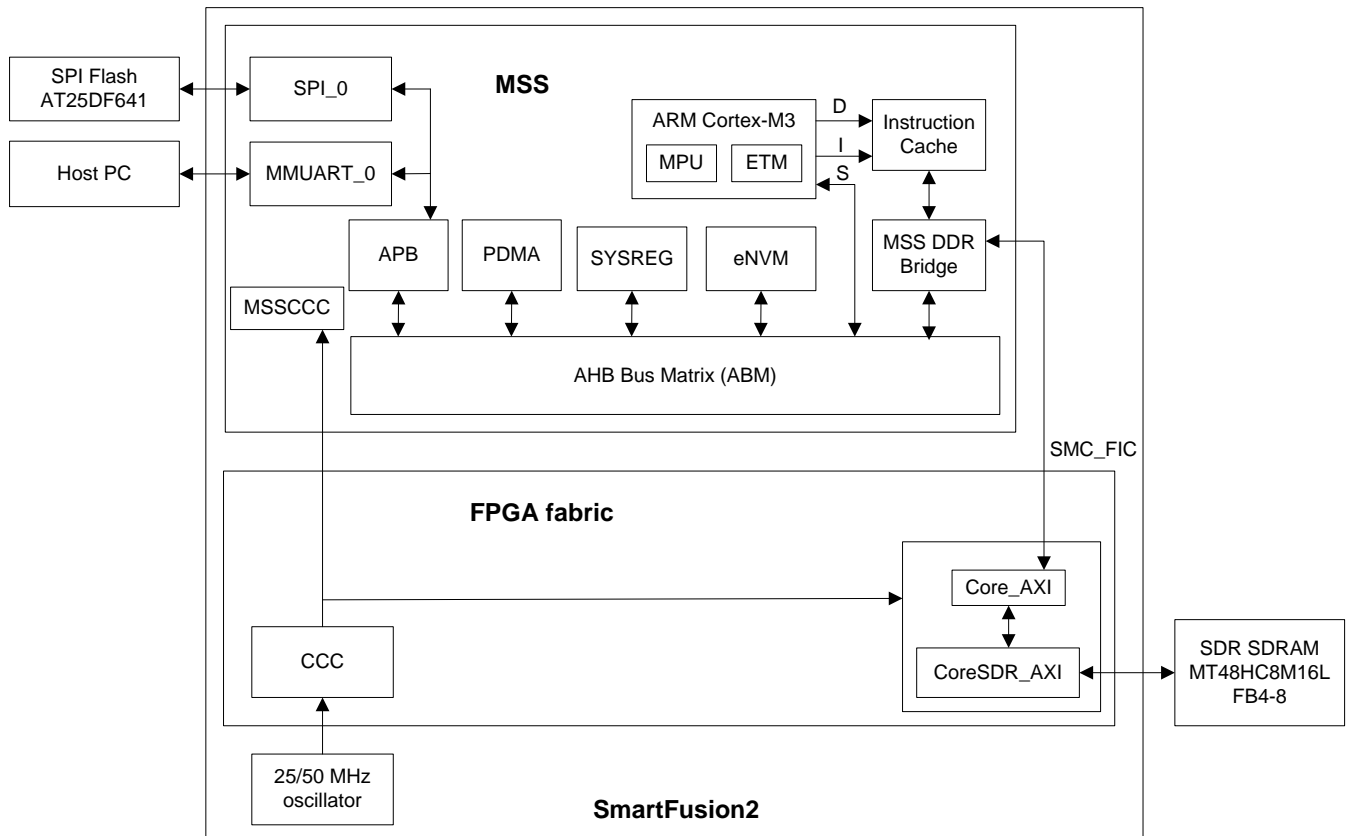


Figure 2. Code Shadowing from SPI Flash to SDR Memory Demo Block Diagram

This demo design involves the implementation of following tasks:

- Creating executable application image
- SPI flash loader to burn the application image into SPI flash memory
- Bootloader

Creating Application Image Targeting for SDR Memory

An image that can be executed from the SDR memory is required. To build the application image use the "production-execute-in-place-externalSDR.ld" linker description file that is included in the design files. This linker description file defines the SDRAM memory starting address as 0x00000000 since the bootloader application performs SDRAM memory remapping from 0xA0000000 to 0x00000000. This linked script creates an application image with instructions, data, and BSS sections in SDRAM whose starting address is 0x00000000. A simple light-emitting diode (LED) blinking, timer and switch based interrupt generation application image file is provided for this demo.

SPI Flash Loader

The SPI flash loader is implemented to load the on-board SPI flash memory with the executable target application image from the host PC through the MMUART_0 interface. The Cortex-M3 processor makes a buffer for the data coming over the MMUART_0 interface and initiates the peripheral DMA (PDMA) to write the buffered data into SPI flash through the MSS_SPI0.

Bootloader

This is the major part of the code shadowing demo which copies and boots the code from the SDR memory. The bootloader performs the following operations:

1. Copying the target application image from SPI flash memory to SDR SDRAM memory.
2. Remapping the SDRAM starting address from 0xA0000000 to 0x00000000 by writing to DDR_CR register.
3. Initializing the Cortex-M3 processor stack pointer as per the target application. The first location of the target application vector table contains the stack pointer value. The vector table of the target application is available starting from the address 0x00000000.
4. Loads the Program Counter (PC) to reset handler of the target application for executing the target application image from the SDR memory. Reset handler address of the target application is available in the vector table at the address 0x00000004.

The demo design architecture is described in [Figure 3](#).

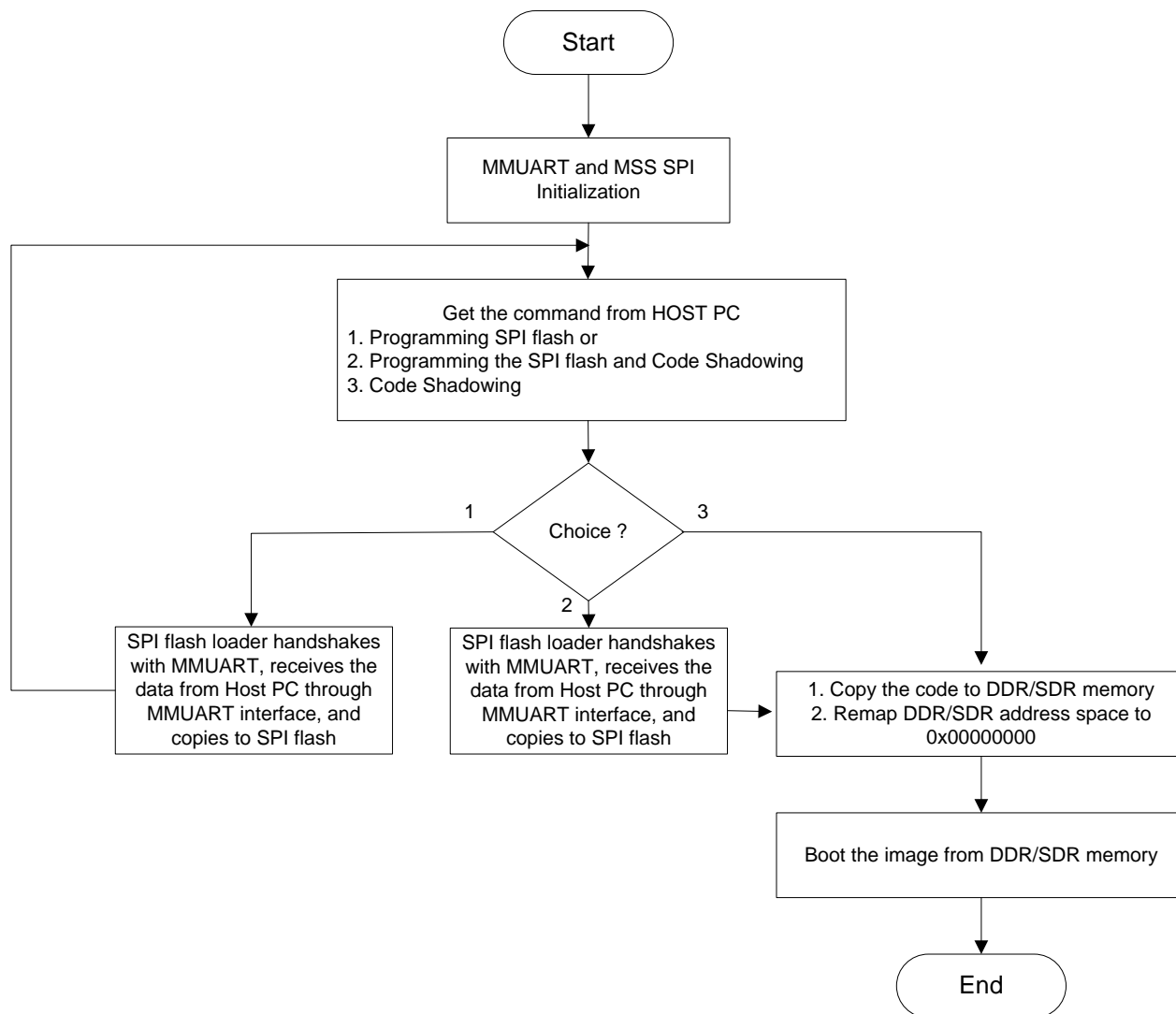


Figure 3. Design Flow

Running the Demo

The demo shows how to load the application image in the SPI flash and execute that application image from external SDR memories. This demo provides an example application image “sample_image_SDR.bin”. This image shows the welcome messages and timer interrupt message on the serial console and blinks the LED1 to LED8 on the SmartFusion2 Development Kit. To see the switch interrupt messages on the serial console, press **SW2** or **SW5** switch.

Demo Setup

1. Connect the FlashPro4 programmer to the J59 connector of SmartFusion2 SoC FPGA Development Kit.
2. Connect one end of the USB mini-B cable to the J24 connector provided on the SmartFusion2 SoC FPGA Development Kit. Connect the other end of the USB cable to the host PC.

Make sure that the USB to UART bridge drivers are automatically detected (can be verified in the Device Manager), as shown in Figure 4. From the detected four COM ports, select the one which location on its properties window should be as “on USB Serial Converter D”. Note the COM port number for serial port configuration.

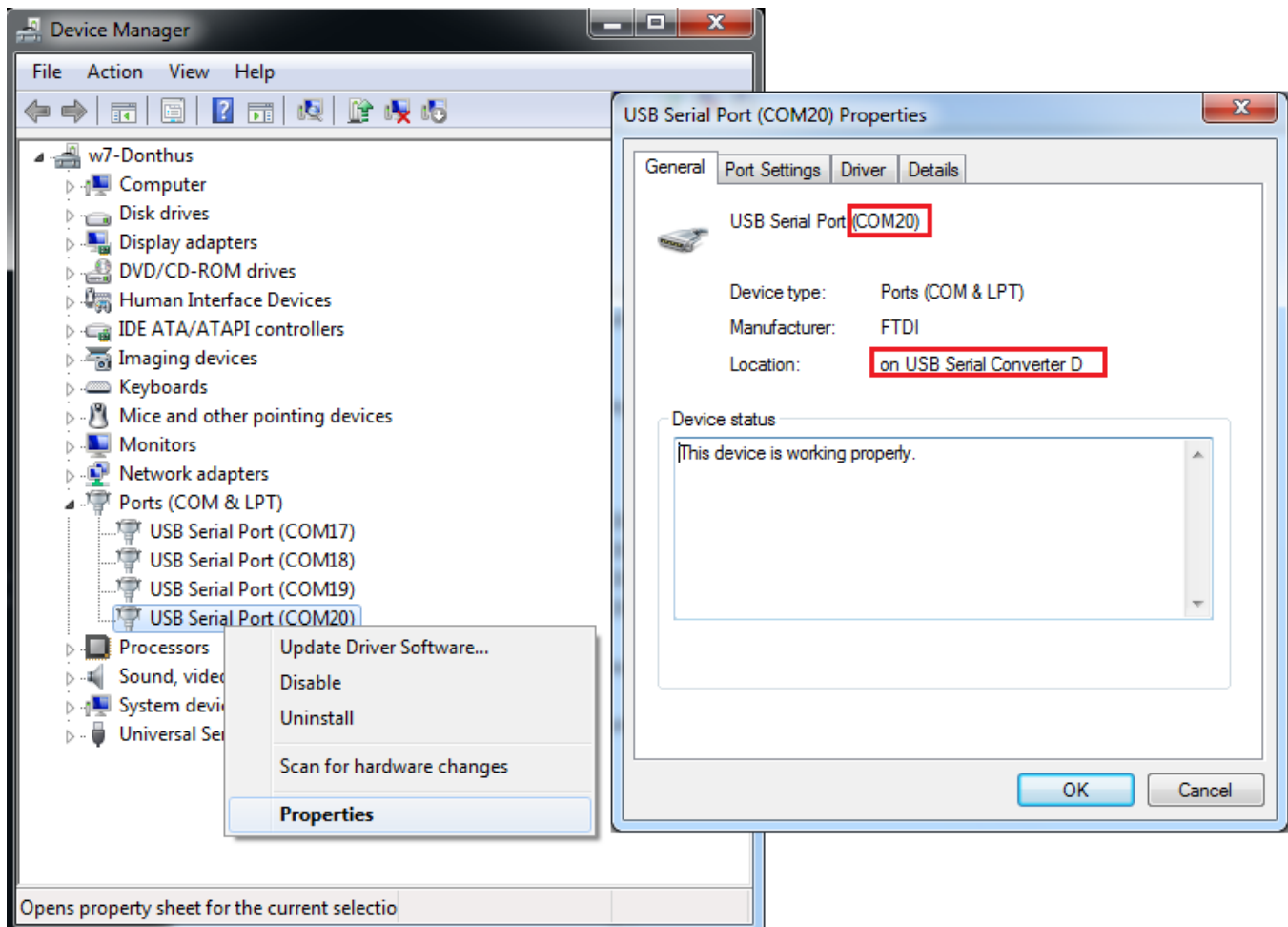


Figure 4. USB to UART Bridge Drivers

3. If USB to UART bridge drivers are not installed, download and install the drivers from www.microsemi.com/soc/documents/CDM_2.08.24_WHQL_Certified.zip.
4. Connect the jumpers on the SmartFusion2 SoC FPGA Development Kit, as shown in Table 2. While making the jumper connections the power supply switch SW7 on the board should be in **OFF** position.

Table 2. SmartFusion2 SoC FPGA Development Kit Jumper Settings

Jumper	Pin (from)	Pin (to)
J70, J93, J94, J117, J123, J142, J157, J160, J167, J225, J226, J227	1 (default)	2
J2	1 (default)	3
J23	2 (default)	3
J129, J133	2	3
For SPI to SPI Flash Connection		
J110, J118, J119, J121	1 (default)	2

5. Connect the power supply to J18 connector.

Figure 5 shows the board setup for running the code shadowing from SPI flash to SDR memory demo on SmartFusion2 SoC FPGA Development Kit.

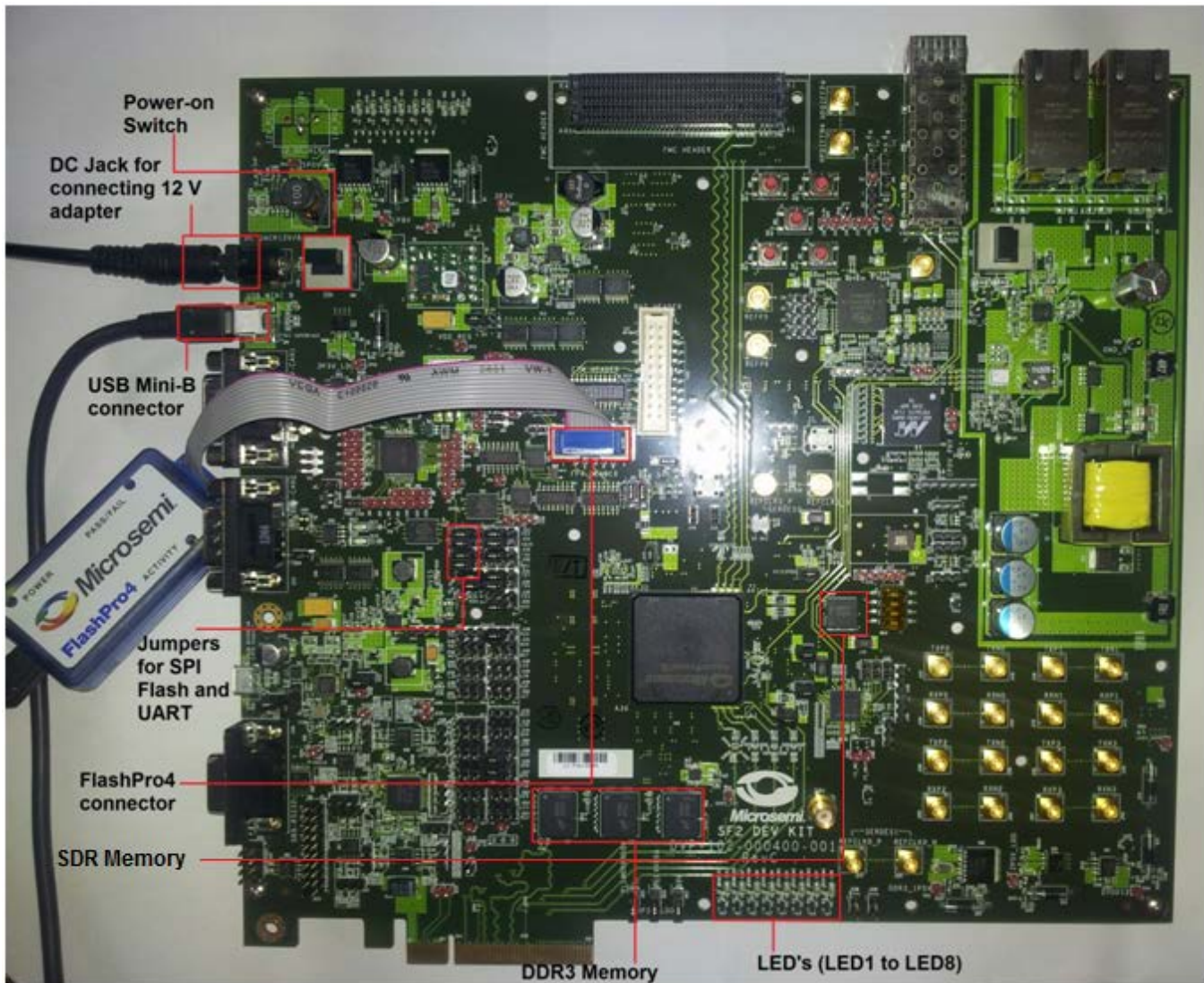


Figure 5. SmartFusion2 SoC FPGA Development Kit Setup

SPI Flash Loader and Code Shadowing Demo GUI

This is required to run the code shadowing demo. SPI Flash Loader and Code Shadowing Demo GUI is a simple graphic user interface that runs on the host PC to program the SPI flash and runs the code shadowing demo on the SmartFusion2 SoC FPGA Development Kit. UART is used as the underlining communication protocol between the host PC and SmartFusion2 SoC FPGA Development Kit. It also provides the serial console section to print the debug messages received from the application over the UART interface. [Figure 5](#) shows the SPI Flash Loader and Code Shadowing Demo GUI.

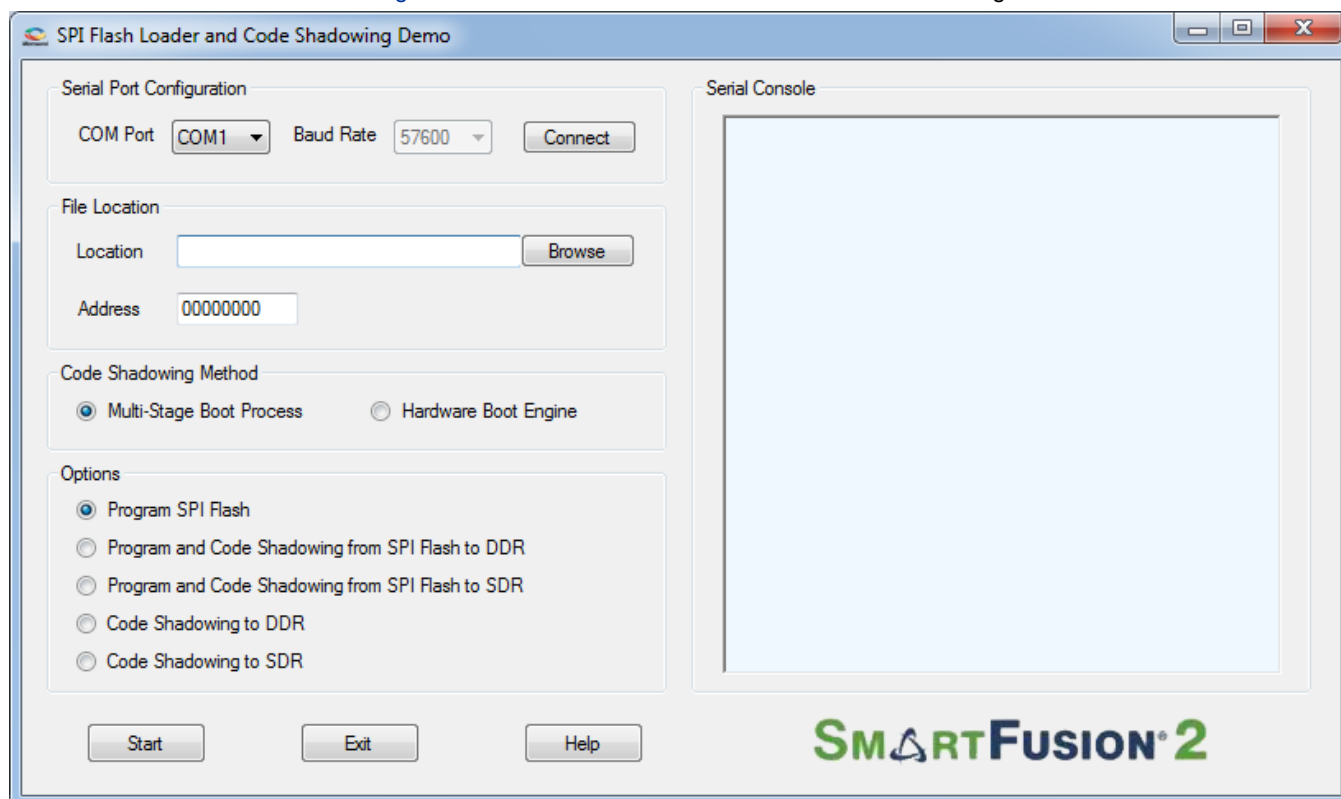


Figure 6. SPI Flash Loader and Code Shadowing Demo GUI

The GUI supports the following features:

- **Program SPI Flash:** Programs the image file into the SPI flash.
- **Program and Code Shadowing from SPI Flash to DDR:** Programs the image file into the SPI flash, copies it to the DDR memory, and boots the image from DDR memory.
- **Program and Code Shadowing from SPI Flash to SDR:** Programs the image file into the SPI flash, copies it to the SDR memory, and boots the image from SDR memory.
- **Code Shadowing to DDR:** Copies the existing image file from the SPI flash to the DDR memory and boots the image from DDR memory.
- **Code Shadowing to SDR:** Copies the existing image file from the SPI flash to the SDR memory and boots the image from SDR memory.

Click **Help** for more information on the GUI.

Running the Design

1. Switch the power supply switch SW7 to **ON** position.
2. Program the SmartFusion2 SoC FPGA device with the programming file provided in the design files (SF2_CodeShadowing_SDR_DF\Programming Files\CodeShadowing_SDR.stp) using the FlashPro design software.
3. Launch the **SPI Flash Loader and Code Shadowing Demo** GUI executable file available in the design files (SF2_CodeShadowing_SDR_DF\GUI Executable\SF2_FlashLoader.exe). Select the appropriate COM port (to which the USB Serial drivers are pointed) from the **COM Port** drop-down list.
4. Click **Connect**. After establishing the connection, the **Connect** changes to **Disconnect**.
5. Click **Browse** to select the example target executable image file provided with the design files (SF2_CodeShadowing_SDR_DF\Sample Application Images/sampleimage_SDR.bin”).

Note: To generate the Bin files refer to [Appendix-B – Generating Executable Bin File](#).

6. Keep the starting address of the SPI flash memory as default at 0x00000000.
7. Select the **Program and Code Shadowing from SPI Flash to SDR** option.
8. Click **Start** as shown in [Figure 7](#) to load the executable image into SPI flash and code shadowing from SDR memory.

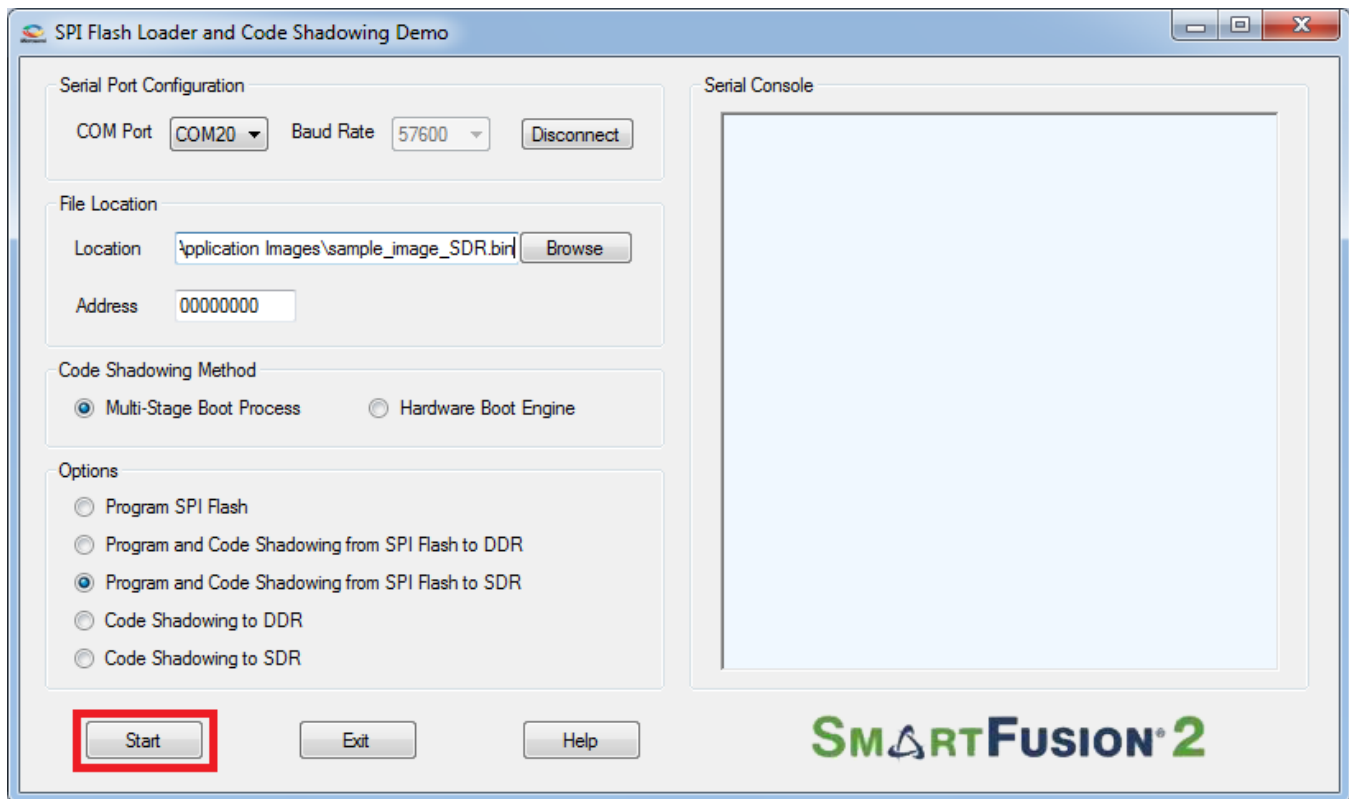


Figure 7. Starting the Demo

9. If the SmartFusion2 SoC FPGA device is programmed with a STAPL file in which MDDR is not configured for SDR memory then it shows an error message, as shown in [Figure 8](#).

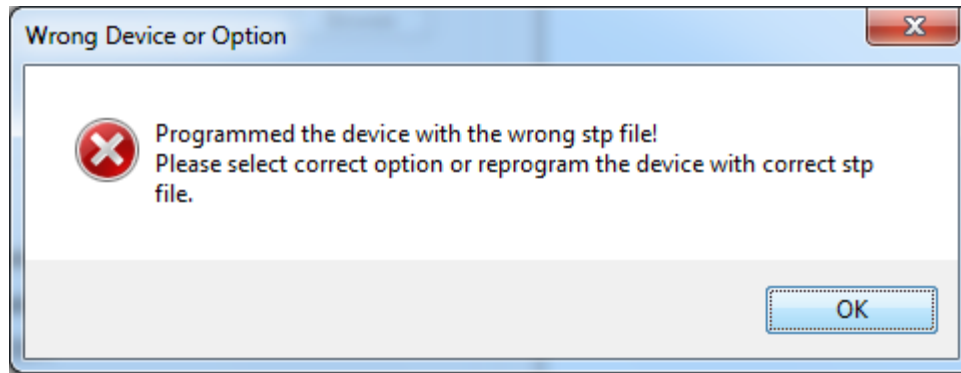


Figure 8. Wrong Option

10. The Serial Console section on the GUI shows the debug messages, as shown in **Error! Reference source not found.**
11. The GUI starts programming SPI flash after successfully erasing the SPI flash. The GUI shows the status of SPI flash writing, as shown in [Figure 9](#).

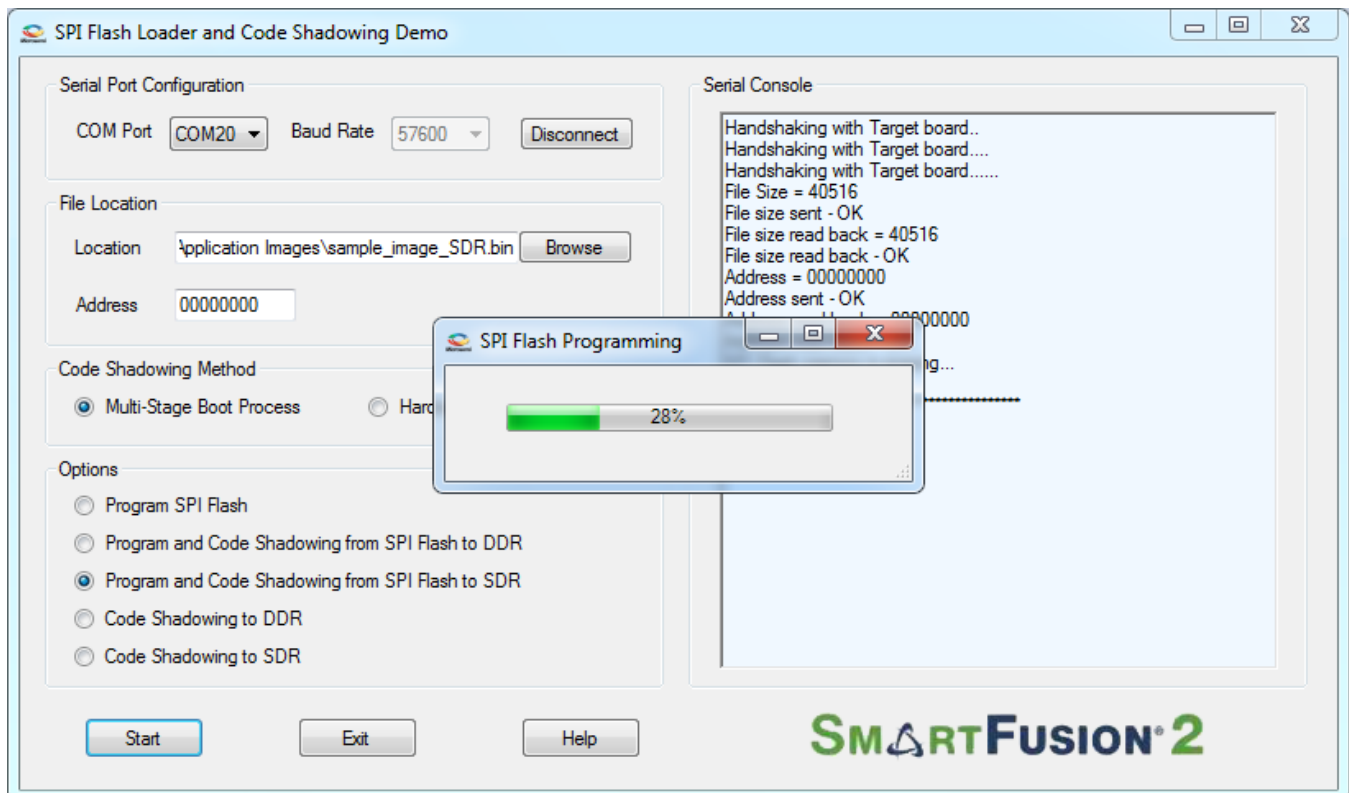


Figure 9. SPI Flash Programming

12. On programming the SPI flash successfully, the boot loader running on SmartFusion2 SoC FPGA copies the application image from SPI flash to SDR memory and boots the application image. If the provided image sample_image_SDR.bin is selected, the serial console shows the welcome message and timer interrupt messages as shown in [Figure 10](#). A running LED pattern is displayed on LED1 to LED8 on the SmartFusion2 SoC FPGA Development Kit. Press **SW2** and **SW5** switches to see switch interrupt messages on serial console.

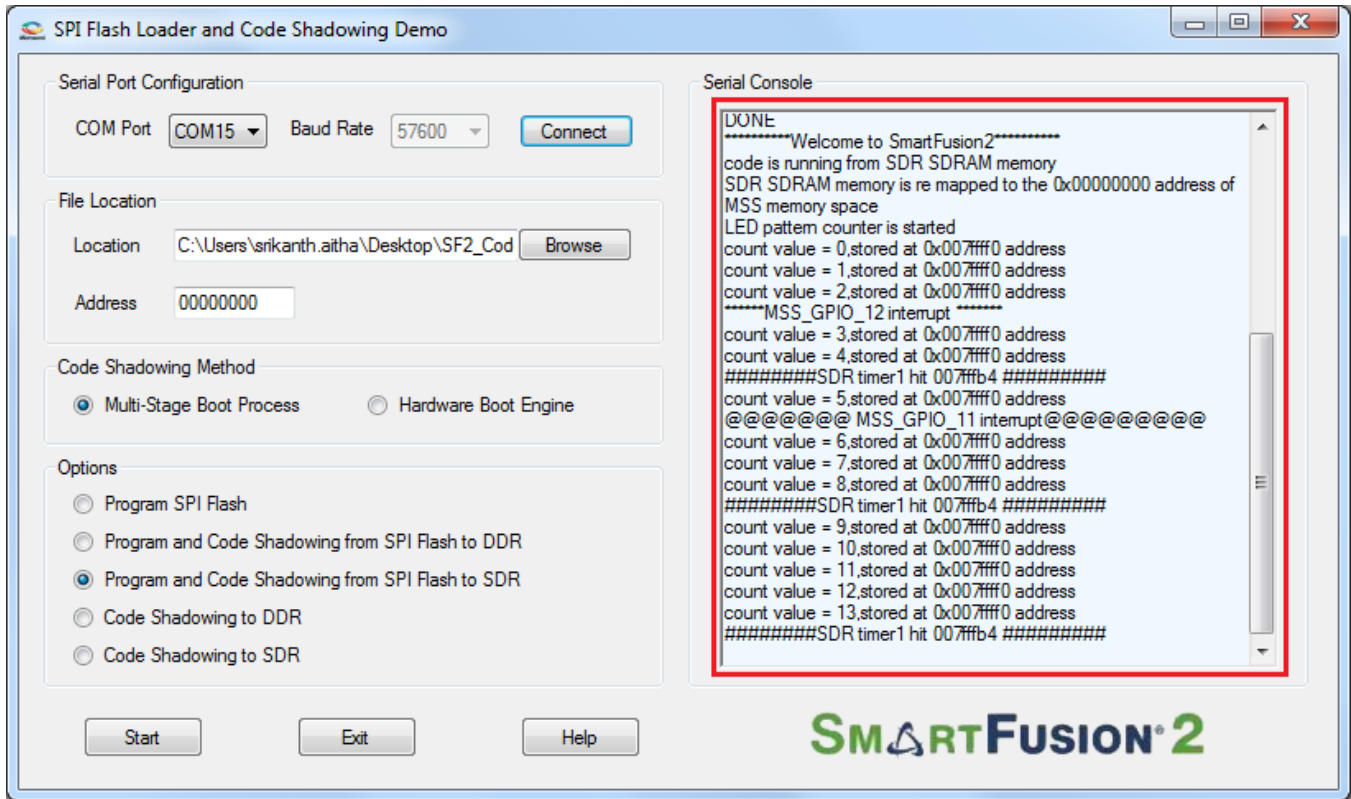


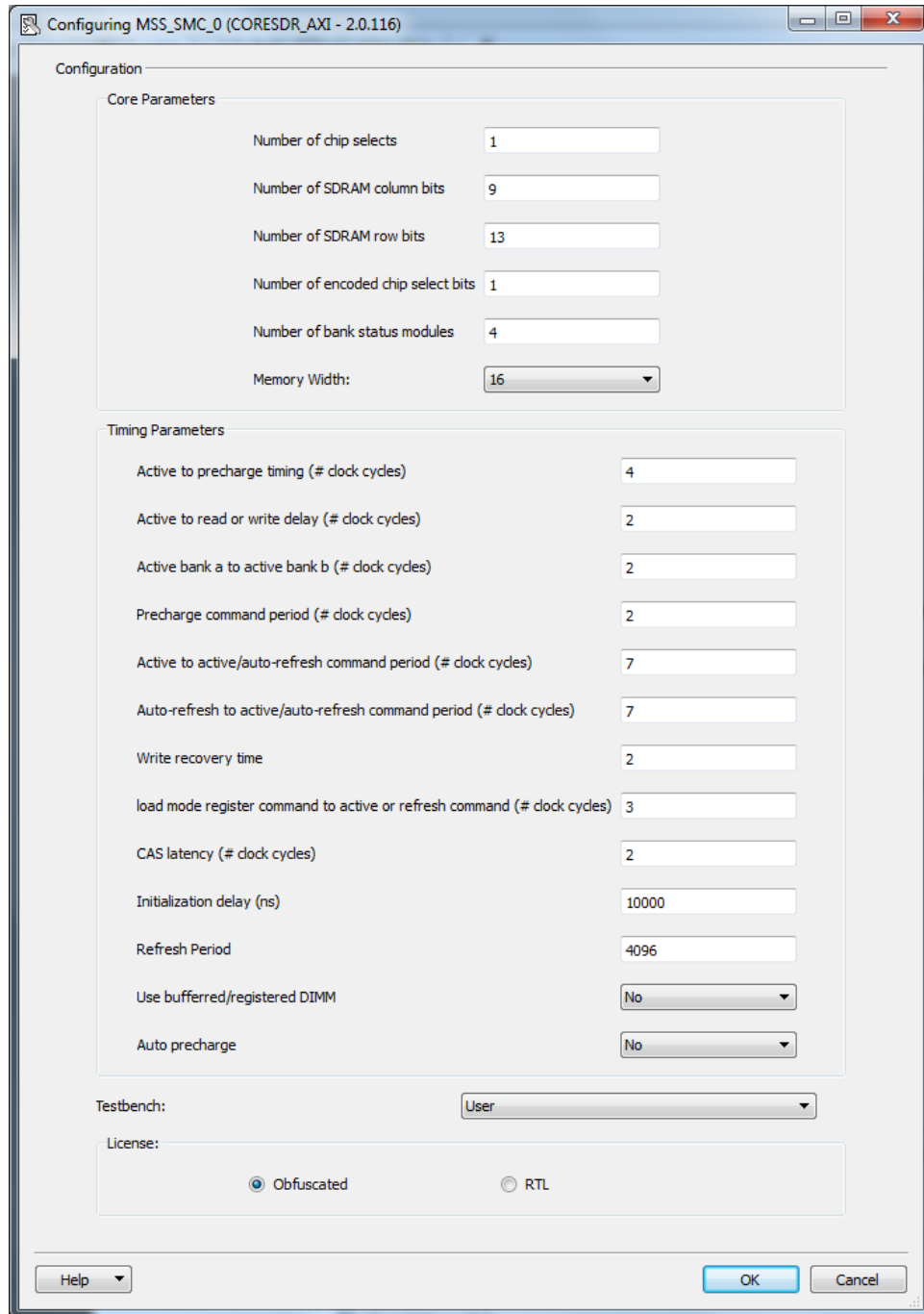
Figure 10. Running the Target Application Image from SDR Memory

Conclusion

This demonstration shows the capability of SmartFusion2 SoC FPGA device to interface with SDR memory and to run the executable image from the SDR memory by shadowing code from SPI flash memory.

Appendix A – SDR Configurations

Figure 11 shows the configuration of CoreSDR_AXI controller to interface with the external SDR SDRAM at 80 MHz speed.



Section	Parameter	Value
Core Parameters	Number of chip selects	1
	Number of SDRAM column bits	9
	Number of SDRAM row bits	13
	Number of encoded chip select bits	1
	Number of bank status modules	4
	Memory Width	16
Timing Parameters	Active to precharge timing (# clock cycles)	4
	Active to read or write delay (# clock cycles)	2
	Active bank a to active bank b (# clock cycles)	2
	Precharge command period (# clock cycles)	2
	Active to active/auto-refresh command period (# clock cycles)	7
	Auto-refresh to active/auto-refresh command period (# clock cycles)	7
	Write recovery time	2
	load mode register command to active or refresh command (# clock cycles)	3
	CAS latency (# clock cycles)	2
	Initialization delay (ns)	10000
	Refresh Period	4096
	Use buffered/registered DIMM	No
	Auto precharge	No
	Testbench:	User
License:	<input checked="" type="radio"/> Obfuscated <input type="radio"/> RTL	

Figure 11. SDRAM Controller Configurations

Appendix-B – Generating Executable Bin File

The executable bin file is required to program the SPI flash for running the code shadowing demo. To generate the executable bin file from “sample_image_SDR” SoftConsole project, follow the below steps:

1. Build the SoftConsole project with the linkerscript “production-execute-in-place-externalSDR.ld”.
2. Add the SoftConsole installation path, for example, C:\Microsemi\Libero_v11.3\SoftConsole\Sourcery-G++\bin, to the ‘Environment Variables’ as shown below.

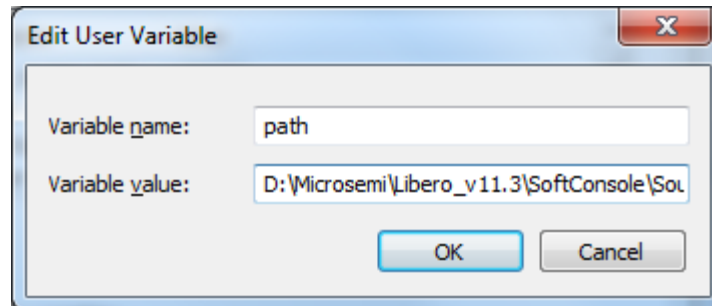


Figure 12. Adding SoftConsole Installation Path

3. Double-click batch file **Bin-File-Generator** in the SoftConsole/CodeShadowing_SDR_MSS_CM3/Sample_image_SDR folder, as shown below.

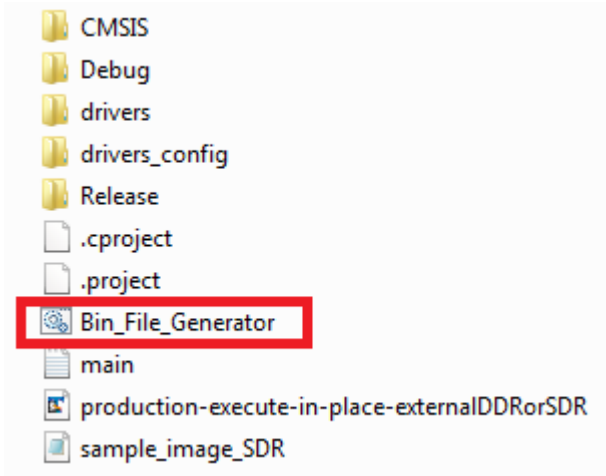


Figure 13. Bin File Generator

4. The **Bin-File-Generator** creates “sample_image_SDR.bin” file.

List of Changes

Revision	Changes	Page
Revision 4 (April 2014)	Updated the document for Libero SoC 11.3 software release (SAR 56872).	NA
Revision 3 (November 2013)	Updated the document for Libero SoC 11.2 software release (SAR 52965).	NA
Revision 2 (June 2013)	Updated the document for Libero SoC 11.0 software release (SAR 47704).	NA
Revision 1 (March 2013)	Updated the document for Libero SoC 11.0 Beta SP1 software release (SAR 44873).	NA

Note: The revision number is located in the part number after the hyphen. The part number is displayed at the bottom of the last page of the document. The digits following the slash indicate the month and year of publication

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