




## Microsemi DG0440 Running Modbus TCP Reference Design on SmartFusion2 Devices User Guide

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**Microsemi DG0440 Running Modbus TCP Reference Design on SmartFusion2 Devices**



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## Revision History

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

### Revision 7.0

Updated the document for Libero v11.8 software release.

### Revision 6.0

The following changes are done in revision 6.0 of this document.

- Libero SoC, FlashPro, and SoftConsole design requirements are updated in the Design Requirements, page 5.
- Throughout the guide, the names of SoftConsole projects used in the demo design and all the associated figures are updated.

### Revision 5.0

Updated the document for Libero v11.7 software release (SAR 76559).

### Revision 4.0

Updated the document for Libero v11.6 software release (SAR 72924).

### **Revision 3.0**

Updated the document for Libero v11.5 software release (SAR 63972).

### **Revision 2.0**

Updated the document for Libero v11.3 software release (SAR 56538).

### **Revision 1.0**

Updated the document for Libero v11.2 software release (SAR 53221).

## **Running Modbus TCP Reference Design on SmartFusion2 Devices Using lwIP and FreeRTOS**

### **Introduction**

Microsemi offers a reference design for SmartFusion®2 SoC FPGA devices that demonstrate the tri-speed ethernet medium access controller (TSEMAC) features of the SmartFusion2 SoC FPGA and implements the Modbus protocol. The reference design runs on the UG0557: SmartFusion2 SoC FPGA Advanced Development Kit User Guide. This demo guide describes.

- Usage of SmartFusion2 TSEMAC connected to a serial gigabit media independent interface (SGMII) PHY.
- Integration of SmartFusion2 MAC driver with the lightweight IP (lwIP) transmission control protocol (TCP) or IP stack and the free real time operating system (RTOS).
- Application layer with industrial automation protocol, Modbus on TCP or IP.
- How to run the reference design

The microcontroller subsystem (MSS) of the SmartFusion2 SoC FPGA has an instance of the TSEMAC peripheral. The TSEMAC can be configured between the host processor and the Ethernet network at the following data transfer rates (line speeds):

- 10 Mbps
- 100 Mbps
- 1000 Mbps

For more information on the TSEMAC interface for SmartFusion2 devices, see the UG0331: SmartFusion2 Microcontroller Subsystem User Guide.

### **Using the Modbus Protocol**

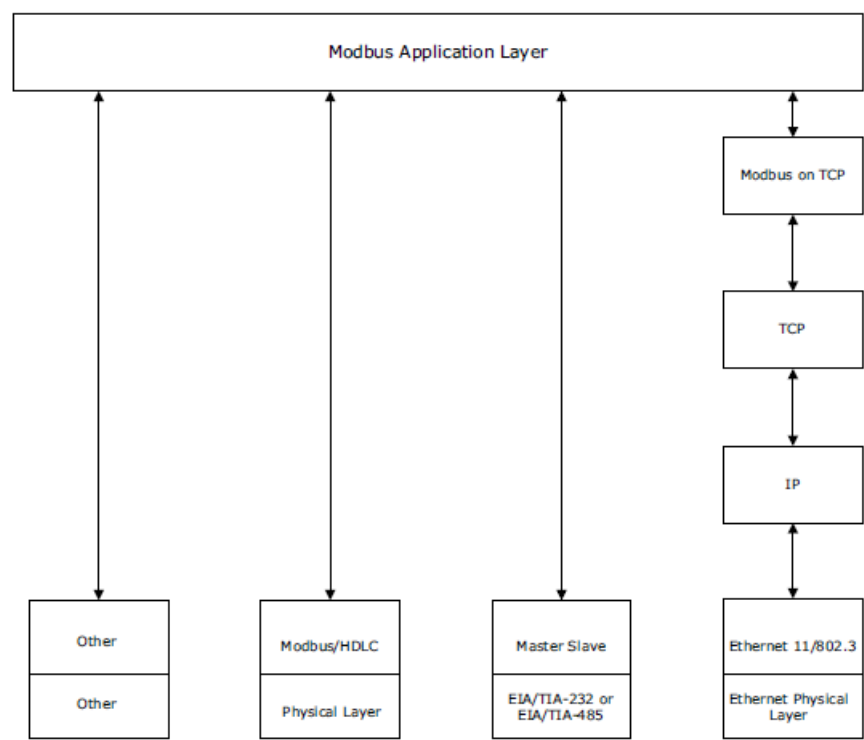
Modbus is an application layer messaging protocol present at the level seven of the open systems interconnection (OSI) model. It enables client or server communication between the devices connected in different types of buses or networks. It is a service protocol that offers many services specified by the function codes. The Modbus function codes are elements of Modbus request or reply protocol data units. The components of the Modbus protocol include:

- TCP or IP over Ethernet
- Asynchronous serial transmission over a variety of media
- Wire:
  - EIA/TIA-232-E
  - EIA-422
  - EIA/TIA-485-A Fiber

- Radio
- Modbus PLUS, a high-speed token passing network

The following figure describes the Modbus communication stacks for various communication networks.

Figure 1 • Modbus Communication Stack



Using Modbus Protocol on SmartFusion2 Device

The Modbus TCP server runs on the SmartFusion2 Advanced Development Kit and responds to the Modbus TCP client running on the host PC. The following figure shows the block diagram of the Modbus TCP server and application on the SmartFusion2 device.

Figure 2 • Block Diagram of Modbus TCP Server and Application on SmartFusion2

0RGEXV 7&3 \$SSOLFDWLRQ	0RGEXV 7&3 6HUYHU
	,Z,3 7&3 RU ,3 6WDFN
)UHH5726	)LUPZDUH
6PDUW)XVLRQ2 \$GYDQFHG 'HYHORSPHQW .LW (+:)	

Design Requirements

The following table lists the hardware and software design requirements.

Table 1 • Reference Design Requirements and Details

Design Requirements: Description

## Hardware

- SmartFusion2 Advanced Development Kit
  - USB A to mini-B cable
  - 12 V adapterRev A or later
- Ethernet cable RJ45
- Any one of the following serial terminal emulation programs:
  - HyperTerminal
  - TeraTerm
  - PuTTY
- Host PC or Laptop Windows 64-bit Operating System

## Software

- Libero® System-on-Chip (SoC) v11.8
- SoftConsole v4.0
- FlashPro programming software v11.8
- USB to UART drivers –
- MSS Ethernet MAC drivers v3.1.100
- A serial terminal emulation program HyperTerminal, TeraTerm, or PuTTY
- Browser Mozilla Firefox or Internet Explorer

## Demo Design

The following sections describe the demo design of the Modbus TCP reference design on SmartFusion2 devices using lwIP and FreeRTOS.

The demo design files are available for download at:

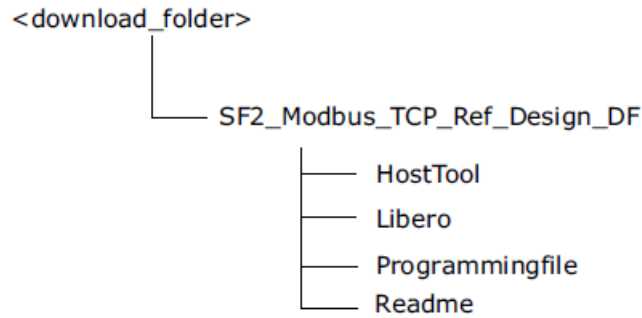
[http://soc.microsemi.com/download/rsc/?f=m2s\\_dg0440\\_liberov11p8\\_df](http://soc.microsemi.com/download/rsc/?f=m2s_dg0440_liberov11p8_df)

The demo design files include:

- Libero
- Programming files
- HostTool
- Readme

The following figure shows the top-level structure of the design files. For more information, see the Readme.txt file.

Figure 3 • Demo Design Files Top-Level Structure



### Demo Design Features

The reference design includes:

- Complete Libero SoC Verilog project
- SoftConsole firmware project

The reference design can support the following Modbus function codes depending on the free Modbus communications stack settings:

- Read input registers (function code 0x04)
- Read holding registers (function code 0x03)
- Write single registers (function code 0x06)
- Write multiple registers (function code 0x10)
- Read or Write multiple registers (function code 0x17)
- Read coils (function code 0x01)
- Write single coil (function code 0x05)
- Write multiple coils (function code 0x0F)
- Read discrete inputs (function code (0x02)

The reference design supports the following Modbus function codes for all free Modbus communications stack settings:

- Read input registers (function code 0x04)
- Read discrete inputs (function code (0x02)
- Write multiple coils (function code 0x0F)
- Read holding registers (function code 0x03)

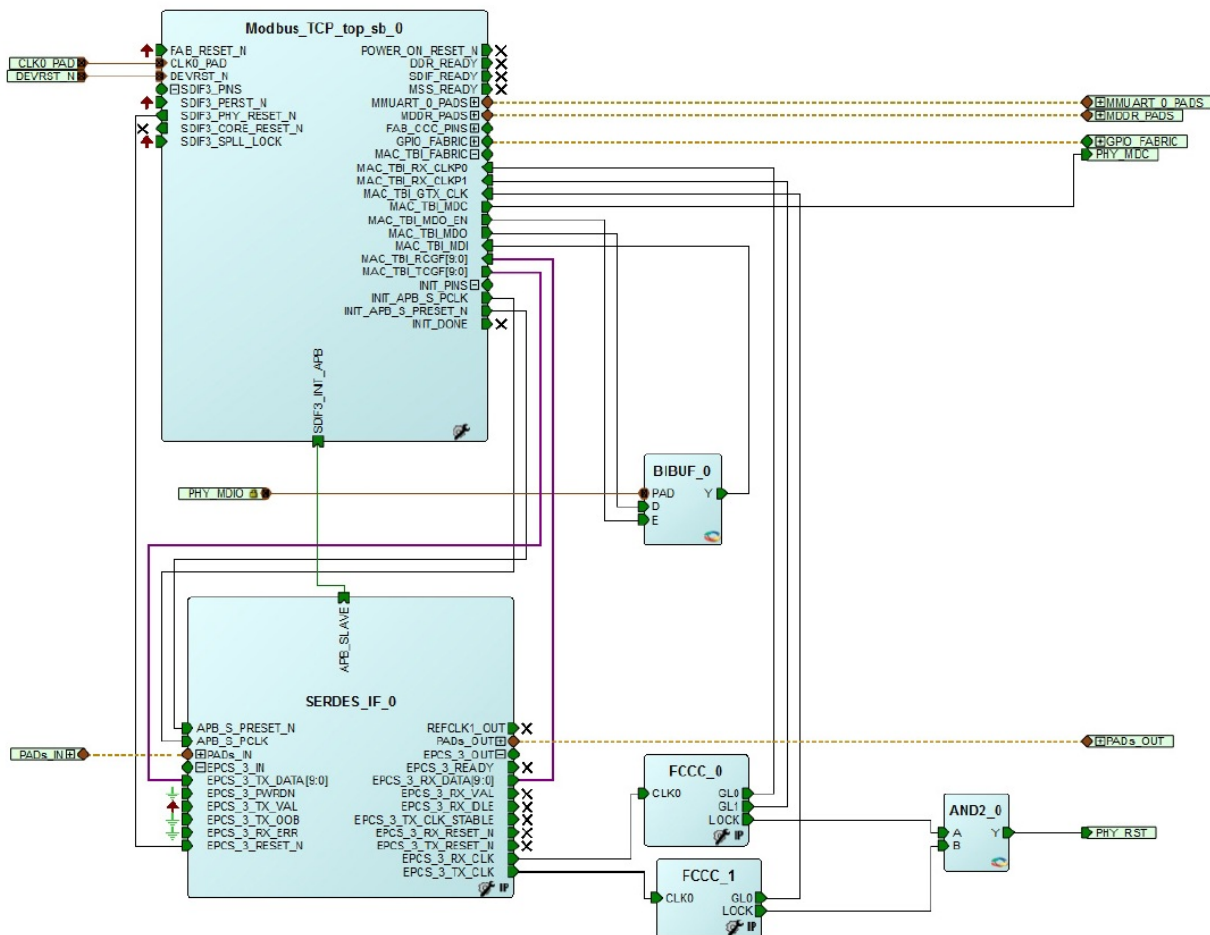
### Demo Design Description

The design is implemented using a SGMII PHY interface by configuring the TSEMAC for the ten-bit interface (TBI) operation. For more information on the TSEMAC TBI interface, see the UG0331: SmartFusion2 Microcontroller Subsystem User Guide.

### Libero SoC Hardware Project

The following figure shows the hardware design implementation on which the reference design slave firmware runs.

Figure 4 • Libero SoC Top-Level Hardware Design

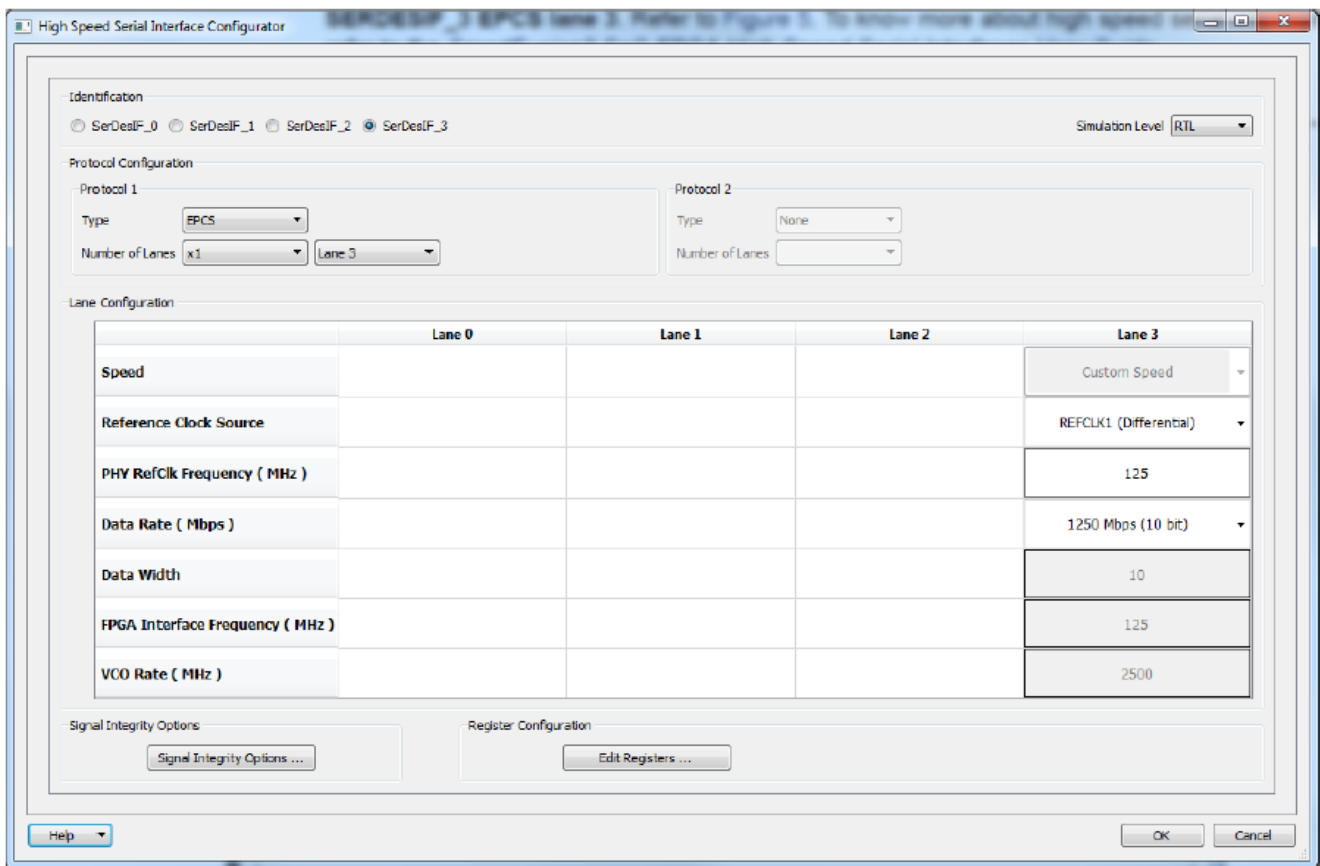


The Libero SoC hardware project uses the following SmartFusion2 MSS resources and IPs:

- TSEMAC TBI interface
- MMUART\_0 for RS-232 communications on the SmartFusion2 Advanced Development Kit
- Dedicated input pad 0 as the clock source
- General purpose input and output (GPIO) that interfaces the following:
  - Light emitting diodes (LEDs): 4 numbers
  - Push-buttons: 4 numbers
  - Dual in-line package (DIP) switches: 4 numbers
- The following board resources are associated with the Modbus commands:
  - LEDs (coils)
  - DIP switches (discrete inputs)
  - Push-buttons (discrete inputs)
  - Real time clock (RTC) (input registers)
- High-speed serial interface (SERDESIF) SERDES\_IF IP, configured for SERDESIF\_3 EPCS lane 3, see the following figure. To know more about high-speed serial interfaces, see the UG0447- SmartFusion2 and IGLOO2 FPGA High Speed Serial Interfaces User Guide.

The following figure shows the High Speed Serial Interface Configurator window.

Figure 5 • High Speed Serial Interface Configurator Window



## Package Pin Assignments

Package pin assignments for LED, DIP switches, push-button switches, and PHY interface signals are shown in the following table through Table 5, page 9.

Table 2 • LED to Package Pins Assignments

- Output Package Pin
- LED\_1 D26
- LED\_2 F26
- LED\_3 A27
- LED\_4 C26

Table 3 • DIP Switches to Package Pins Assignments

- Output Package Pin
- DIP1 F25
- DIP2 G25
- DIP3 J23
- DIP4 J22

Table 4 • Push Button Switches to Package Pins Assignments

- Output Package Pin
- SWITCH1 J25
- SWITCH2 H25



- SWITCH3 J24
- SWITCH4 H23

Table 5 • PHY Interface Signals to Package Pins Assignments

- Port Name Direction Package Pin
- PHY\_MDC Output F3
- PHY\_MDIO Input K7
- PHY\_RST Output F2

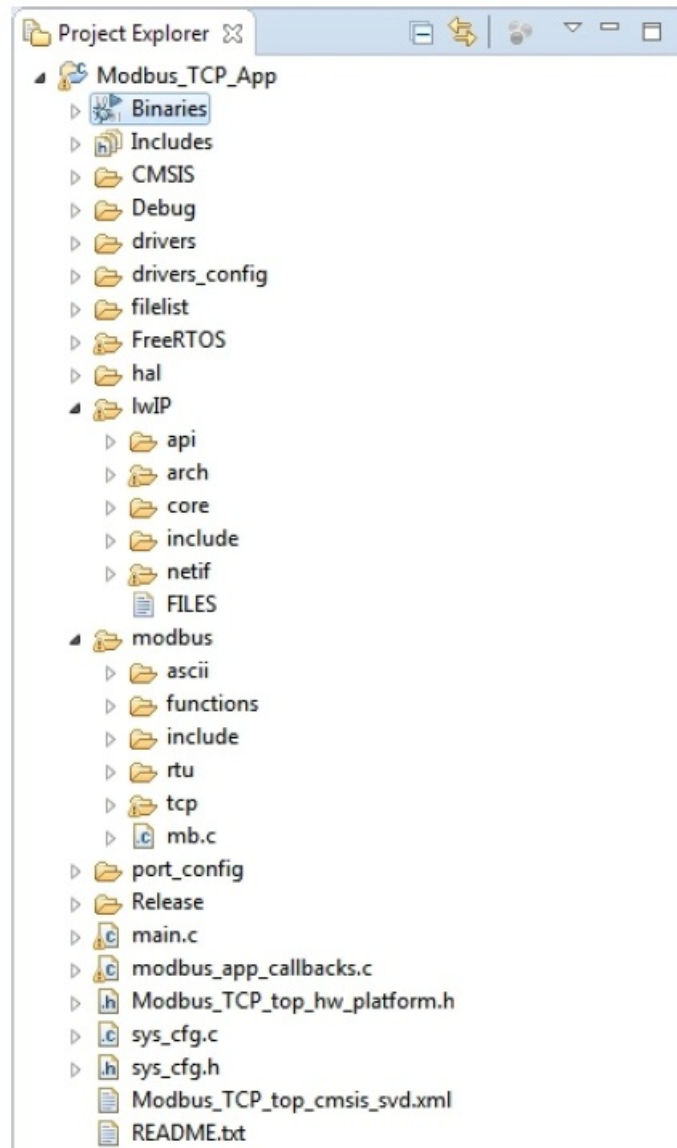
### SoftConsole Firmware Project

Invoke the SoftConsole project using standalone SoftConsole IDE. The following versions of the stack are used for the reference design:

- lwIP TCP or IP stack version 1.3.2
- Modbus TCP server version 1.5 ([www.freemodbus.org](http://www.freemodbus.org)) with enhancements for the complete function code support as Modbus TCP server
- FreeRTOS ([www.freertos.org](http://www.freertos.org))

The following figure shows SoftConsole software stacks directory structure of the design.

Figure 6 • SoftConsole Project Explorer Window



The SoftConsole workspace consists of the project, Modbus\_TCP\_App that has the Modbus TCP application (which uses lwIP and FreeRTOS) and all the firmware and hardware abstraction layers that correspond to the hardware design.

The following figure shows the driver versions used for the demo.

Figure 7 • Demo Design Driver Versions

	Generate	Instance Name	Core Type	Version	Compatible Hardware Instance
1	<input checked="" type="checkbox"/>	SmartFusion2_CMSIS_0	SmartFusion2_CMSIS	2.3.105	Modbus_TCP_top_sb_MSS
2	<input checked="" type="checkbox"/>	SmartFusion2_MSS_Ethernet_MAC_Driver_0	SmartFusion2_MSS_Ethernet_MAC_Driver	3.1.100	Modbus_TCP_top_sb_MSS:MAC
3	<input checked="" type="checkbox"/>	SmartFusion2_MSS_GPIO_Driver_0	SmartFusion2_MSS_GPIO_Driver	2.1.102	Modbus_TCP_top_sb_MSS:GPIO
4	<input type="checkbox"/>	SmartFusion2_MSS_HPDMAC_Driver_0	SmartFusion2_MSS_HPDMAC_Driver	2.2.100	Modbus_TCP_top_sb_MSS
5	<input checked="" type="checkbox"/>	SmartFusion2_MSS_MMUART_Driver_0	SmartFusion2_MSS_MMUART_Driver	2.1.100	Modbus_TCP_top_sb_MSS:MMUART_0
6	<input type="checkbox"/>	SmartFusion2_MSS_NVM_Driver_0	SmartFusion2_MSS_NVM_Driver	2.4.100	Modbus_TCP_top_sb_MSS
7	<input checked="" type="checkbox"/>	SmartFusion2_MSS_RTC_Driver_0	SmartFusion2_MSS_RTC_Driver	2.2.100	Modbus_TCP_top_sb_MSS:RTC
8	<input type="checkbox"/>	SmartFusion2_MSS_System_Services_Driver_0	SmartFusion2_MSS_System_Services_Driver	2.7.100	Modbus_TCP_top_sb_MSS
9	<input checked="" type="checkbox"/>	SmartFusion2_MSS_Timer_Driver_0	SmartFusion2_MSS_Timer_Driver	2.1.100	Modbus_TCP_top_sb_MSS

## Setting Up the Demo Design

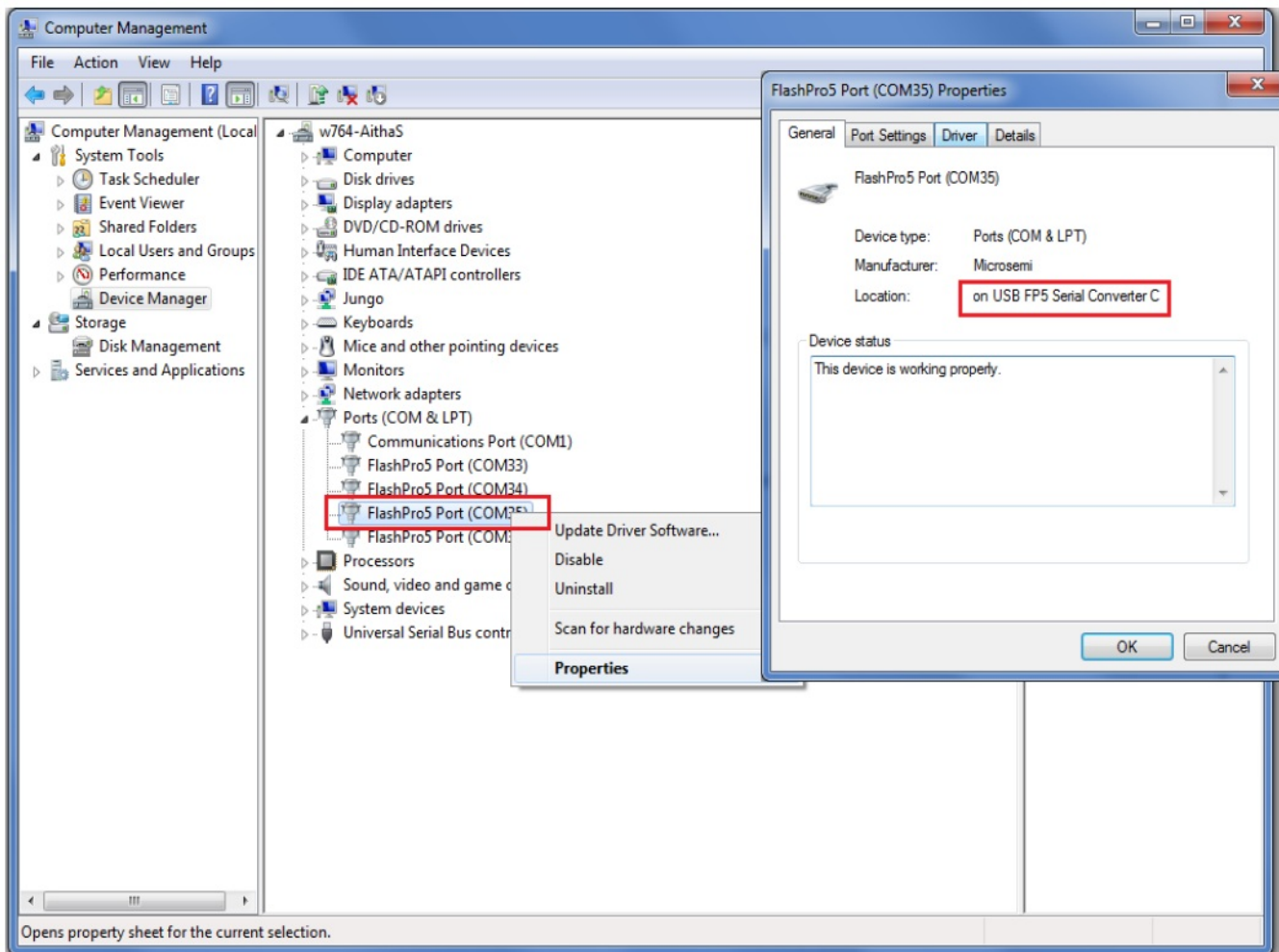
The following steps describe how to setup the demo for the SmartFusion2 Advanced Development Kit board:

1. Connect the host PC to the J33 connector using the USB A to mini-B cable. The USB to universal asynchronous receiver/transmitter (UART) bridge drivers are automatically detected.

2. From the detected four communication (COM) ports, right-click any one of the COM ports and select Properties. The selected COM port properties window is displayed, as shown in the following figure.
3. Ensure to have the Location as on USB FP5 Serial Converter C in the Properties window as shown in the following figure.

**Note:** Make a note of the COM port number for serial port configuration and ensure that the COM port Location is specified as on USB FP5 Serial Converter C.

Figure 8 • Device Manager Window



4. Install the USB driver if the USB drivers are not detected automatically.
5. Install the FTDI D2XX driver for serial terminal communication through the FTDI mini USB cable. Download the drivers and installation guide from:  
[www.microsemi.com/soc/documents/CDM\\_2.08.24\\_WHQL\\_Certified.zip](http://www.microsemi.com/soc/documents/CDM_2.08.24_WHQL_Certified.zip)
6. Connect the jumpers on the SmartFusion2 Advanced Development Kit board as shown in the following table.  
For information on jumper locations, see the Appendix: Jumper Locations, page 19.

**CAUTION:** Switch OFF the power supply switch, SW7, before making the jumper connections.

Table 6 • SmartFusion2 Advanced Development Kit Jumper Settings

- Jumper Pin From Pin To Comments
- J116, J353, J354, J54 1 2 These are the default jumper settings of the Advanced Development Kit board.

Ensure that the jumpers

- J123 2 3 are set accordingly.
- J124, J121, J32 1 2 JTAG programming via FTDI

7. Connect the power supply to the J42 connector in the SmartFusion2 Advanced Development Kit board.

8. This design example can run in both static IP and dynamic IP modes. By default, programming files are provided for dynamic IP mode.

- For static IP, connect the host PC to the J21 connector of the SmartFusion2 Advanced Development Kit board using an RJ45 cable.
- For dynamic IP, connect any one of the open network ports to the J21 connector of the SmartFusion2 Advanced Development Kit board using an RJ45 cable.

### Board Setup Snapshot

Snapshots of the SmartFusion2 Advanced Development Kit board with all the setup connections are given in the Appendix: Board Setup for Running the Modbus TCP Reference Design, page 18.

### Running the Demo Design

The following steps describe how to run the demo design:

1. Download the design file from:

[http://soc.microsemi.com/download/rsc/?f=m2s\\_dg0440\\_liberov11p8\\_df](http://soc.microsemi.com/download/rsc/?f=m2s_dg0440_liberov11p8_df)

2. Switch ON the power supply switch, SW7.

3. Start any serial terminal emulation program such as:

- HyperTerminal
- PuTTY
- TeraTerm

Note: In this demo HyperTerminal is used.

The configuration for the program is:

- Baud Rate: 115200
- 8 Data bits
- 1 Stop bit
- No parity
- No flow control

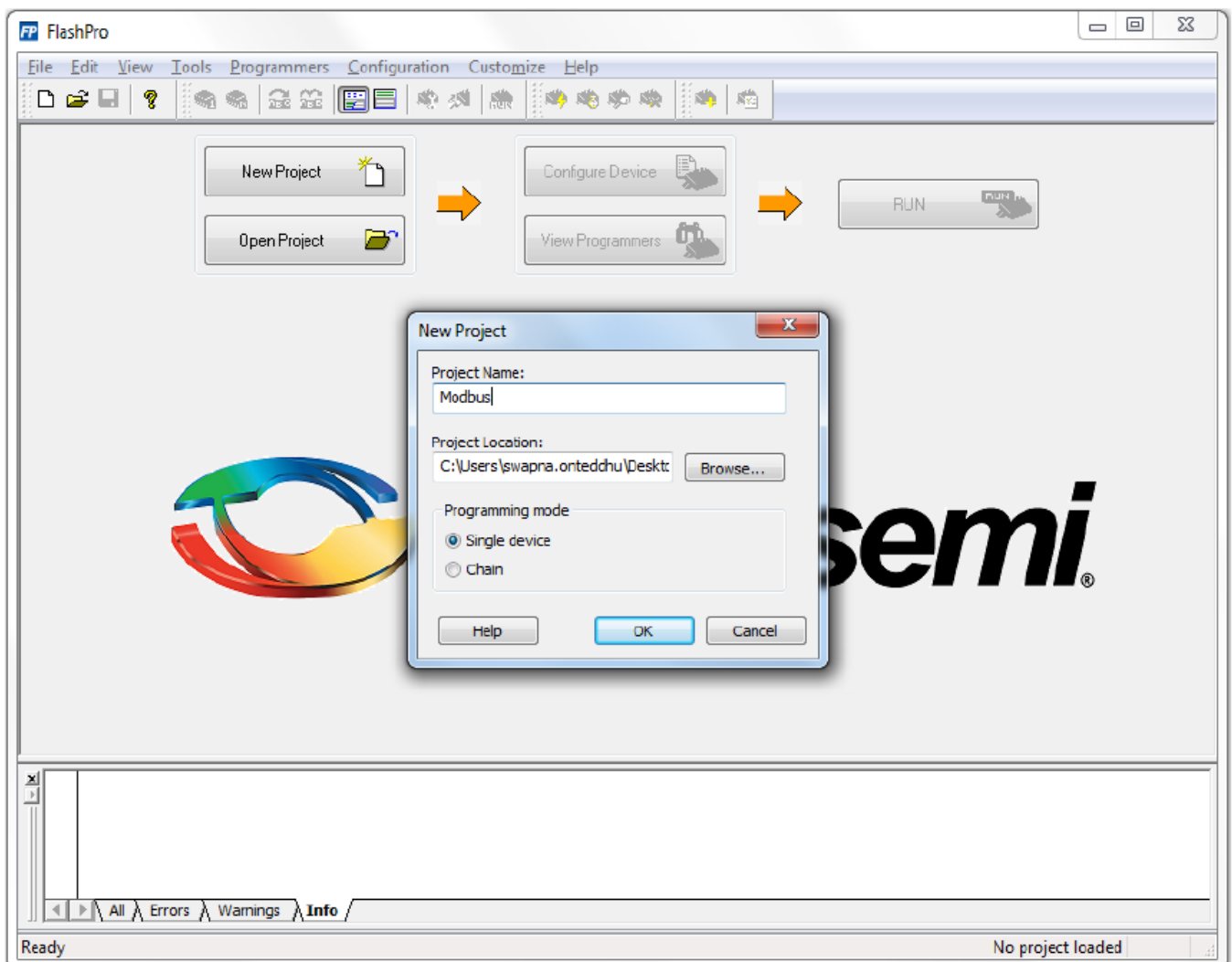
For information on configuring the serial terminal emulation programs, see the Configuring Serial Terminal Emulation Programs.

4. Launch the FlashPro software.

5. Click New Project.

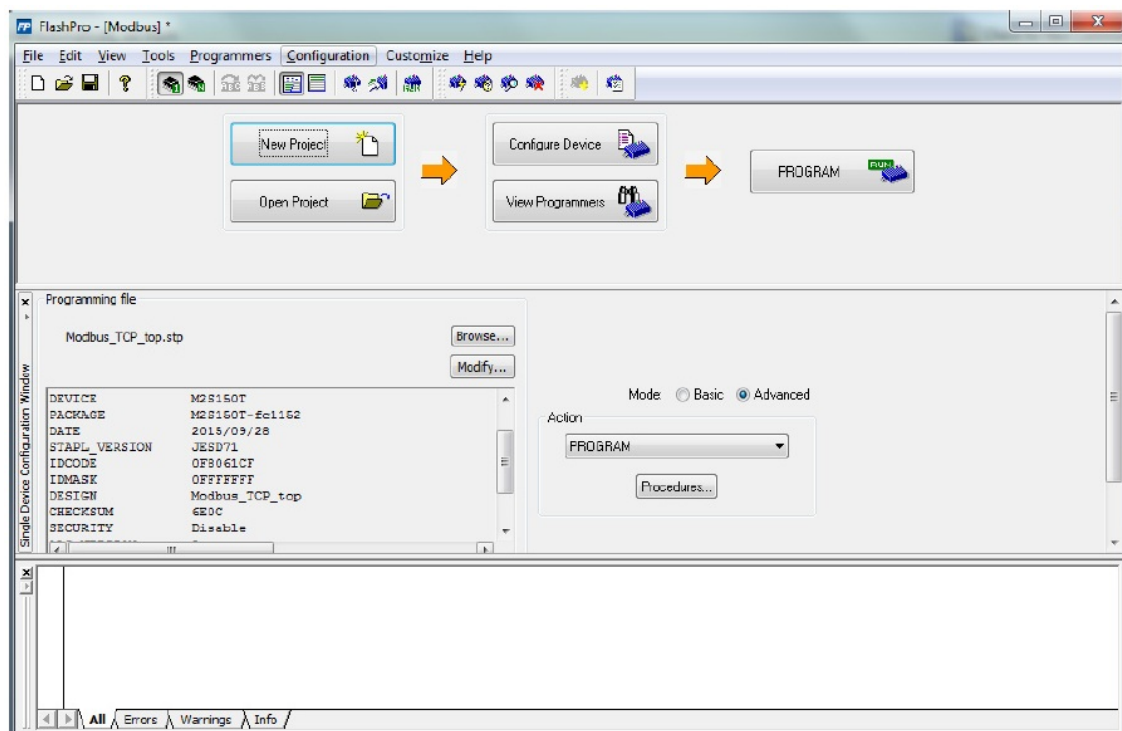
6. In the New Project window, enter the Project Name, as shown in the following figure.

Figure 9 • FlashPro New Project



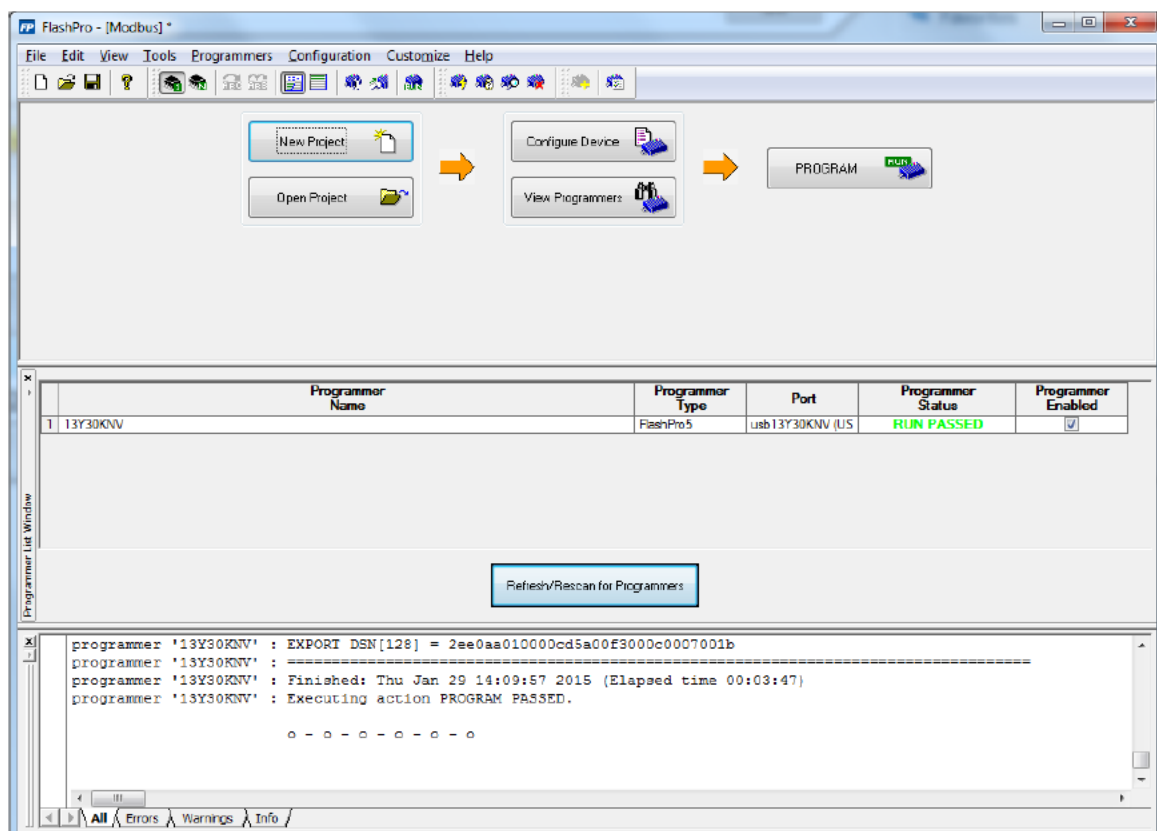
7. Click Browse and navigate to the location where you want to save the project.
  8. Select Single device as the Programming mode.
  9. Click OK to save the project.
  10. Click Configure Device.
  11. Click Browse and navigate to the location where the Modbus\_TCP\_top.stp file is located and select the file.
- The default location is:  
 (\SF2\_Modbus\_TCP\_Ref\_Design\_DF\Programmingfile\Modbus\_TCP\_top.stp). The required programming file is selected and is ready to be programmed in the device as shown in the following figure.

Figure 10 • FlashPro Project Configured



- Click PROGRAM to start programming the device. Wait until a message is displayed indicating that the program passed. This demo requires the SmartFusion2 device to be preprogrammed with the application code to activate the Modbus application. The SmartFusion2 device is preprogrammed with the Modbus\_TCP\_top.stp using FlashPro software.

Figure 11 • FlashPro Program Passed

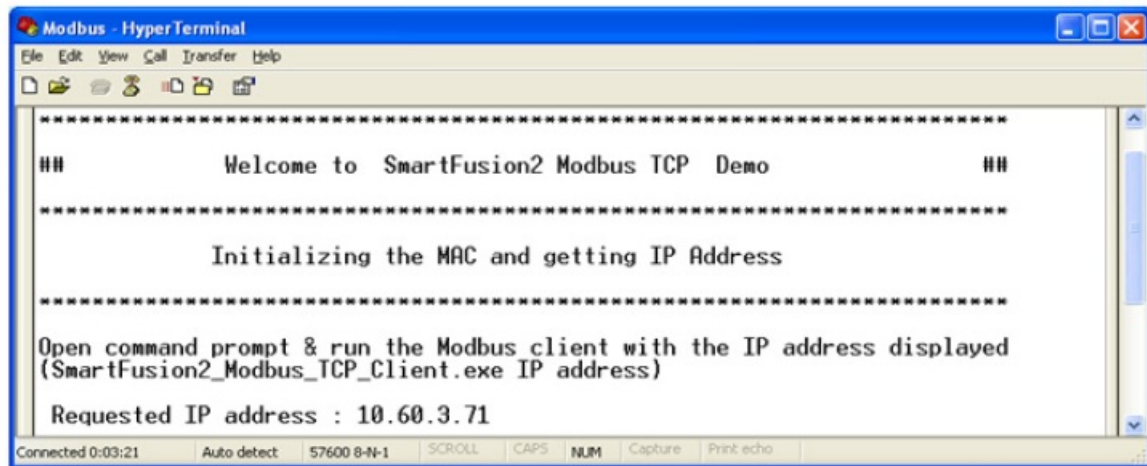


Note: To run the design in static IP mode, follow the steps mentioned in Appendix: Running the Design in Static IP Mode, page 20.

- Power cycle the SmartFusion2 Advanced Development board.

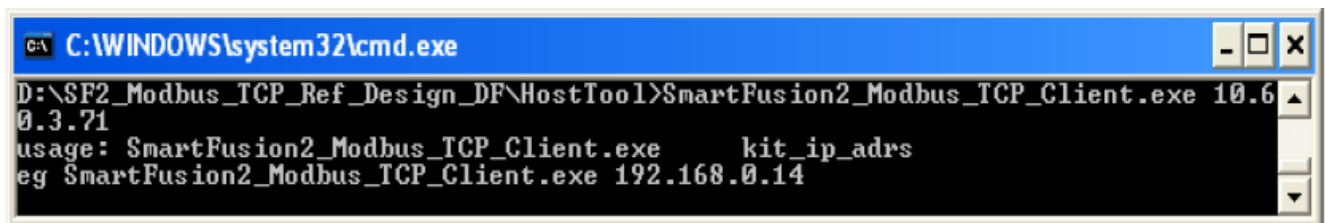
A welcome message with the IP address is displayed in the HyperTerminal window, as shown in the following figure.

Figure 12 • HyperTerminal with IP Address



Open a new command prompt on the host PC, go to the folder  
(\SF2\_Modbus\_TCP\_Ref\_Design\_DF\HostTool) where  
SmartFusion2\_Modbus\_TCP\_Client.exe file is present, enter the command:  
SmartFusion2\_Modbus\_TCP\_Client.exe <IP address> as shown in the following figure.

Figure 13 • Invoking the Modbus Client

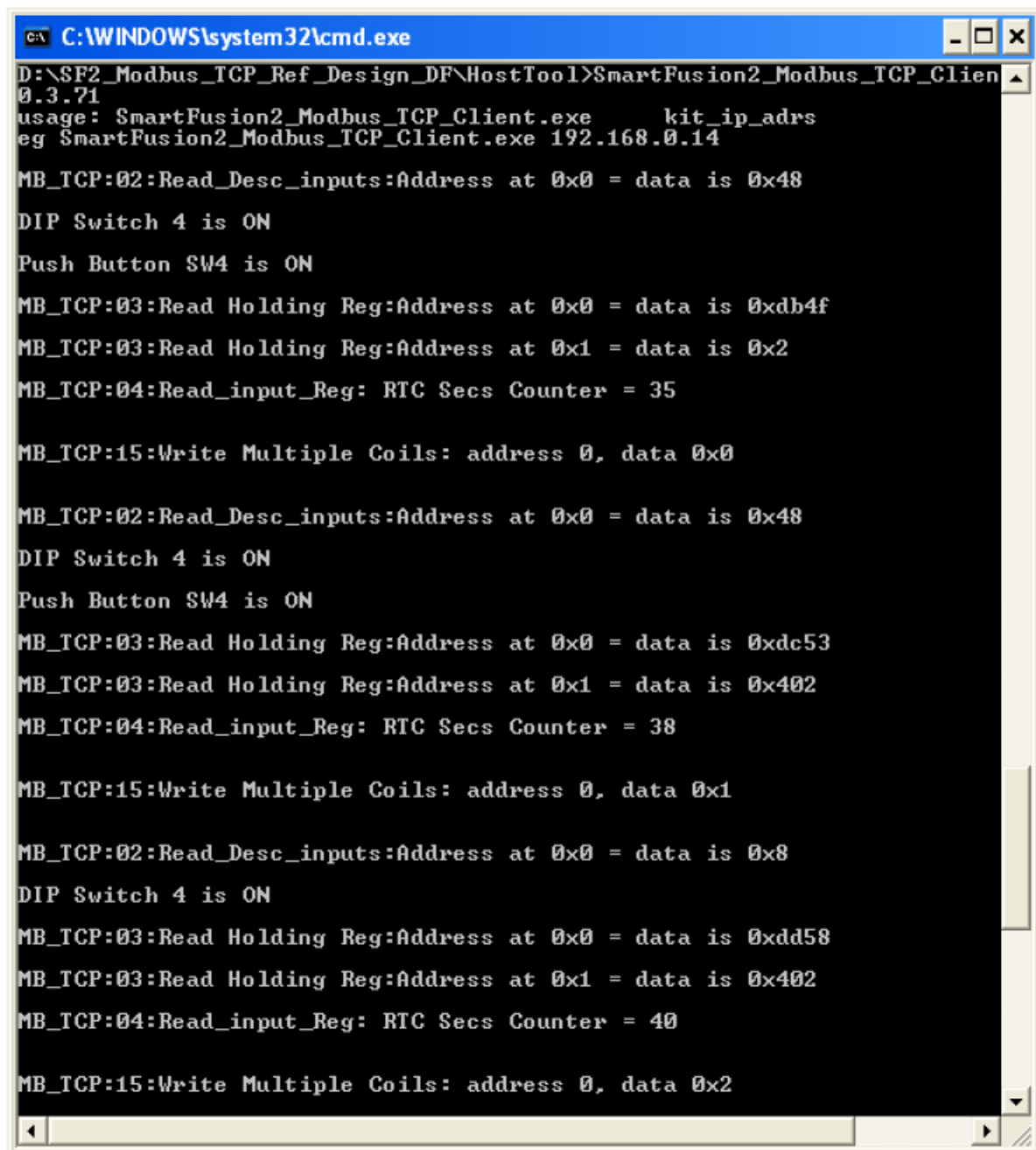


The following figure shows the Modbus TCP functions that are running. The functions are:

- Read discrete inputs (function code 02)
- Read holding registers (function code 03)
- Read input registers (function code 04)
- Write multiple coils (function code 15)

Figure 14 • Modbus Functional Codes Demonstration





```
C:\WINDOWS\system32\cmd.exe
D:\SF2_Modbus_TCP_Ref_Design_DF\HostTool>SmartFusion2_Modbus_TCP_Client
0.3.71
usage: SmartFusion2_Modbus_TCP_Client.exe    kit_ip_adrs
eg SmartFusion2_Modbus_TCP_Client.exe 192.168.0.14

MB_TCP:02:Read_Desc_inputs:Address at 0x0 = data is 0x48
DIP Switch 4 is ON
Push Button SW4 is ON
MB_TCP:03:Read Holding Reg:Address at 0x0 = data is 0xdb4f
MB_TCP:03:Read Holding Reg:Address at 0x1 = data is 0x2
MB_TCP:04:Read_input_Reg: RTC Secs Counter = 35

MB_TCP:15:Write Multiple Coils: address 0, data 0x0

MB_TCP:02:Read_Desc_inputs:Address at 0x0 = data is 0x48
DIP Switch 4 is ON
Push Button SW4 is ON
MB_TCP:03:Read Holding Reg:Address at 0x0 = data is 0xdc53
MB_TCP:03:Read Holding Reg:Address at 0x1 = data is 0x402
MB_TCP:04:Read_input_Reg: RTC Secs Counter = 38

MB_TCP:15:Write Multiple Coils: address 0, data 0x1

MB_TCP:02:Read_Desc_inputs:Address at 0x0 = data is 0x8
DIP Switch 4 is ON
MB_TCP:03:Read Holding Reg:Address at 0x0 = data is 0xdd58
MB_TCP:03:Read Holding Reg:Address at 0x1 = data is 0x402
MB_TCP:04:Read_input_Reg: RTC Secs Counter = 40

MB_TCP:15:Write Multiple Coils: address 0, data 0x2
```

See the Running Modbus Functions, page 17 for more information on the Modbus functions that are demonstrated in the reference design.

14. After running the demo, close HyperTerminal.

## Running Modbus Functions

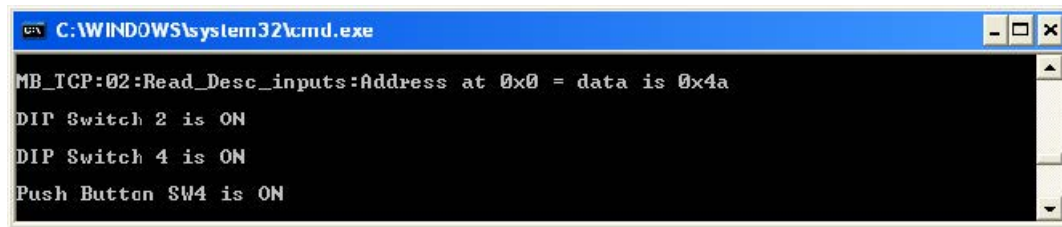
This section describes the Modbus functions that are demonstrated in the reference design.

### Read Discrete Inputs (function code 02)

GPIOs are connected to 4 DIP switches and 4 push-button switches. Switch ON and switch OFF the DIP switches and push-button switches on the SmartFusion2 Advanced Development Kit. Read discrete inputs functional code displays the statuses of switches as shown in the following figure.

Figure 15 • Read Discrete Inputs



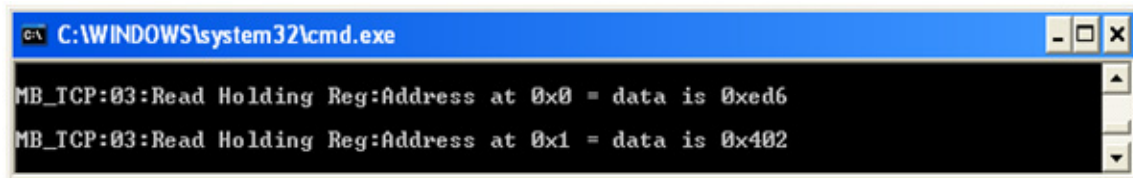


```
C:\WINDOWS\system32\cmd.exe
MB_TCP:02:Read_Desc_inputs:Address at 0x0 = data is 0x4a
DIP Switch 2 is ON
DIP Switch 4 is ON
Push Button SW4 is ON
```

### Read Holding Registers (function code 03)

The following figure shows the global buffer data defined in the firmware.

Figure 16 • Read Holding Registers

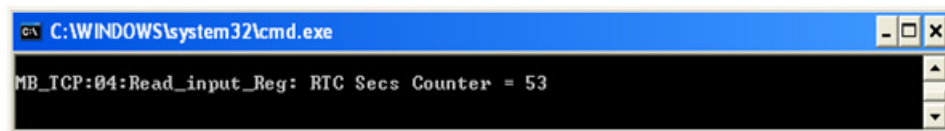


```
C:\WINDOWS\system32\cmd.exe
MB_TCP:03:Read Holding Reg:Address at 0x0 = data is 0xed6
MB_TCP:03:Read Holding Reg:Address at 0x1 = data is 0x402
```

### Read Input Registers (function code 04)

The following figure shows the number of seconds that the real-time counter (RTC) has counted.

Figure 17 • Read Input Registers

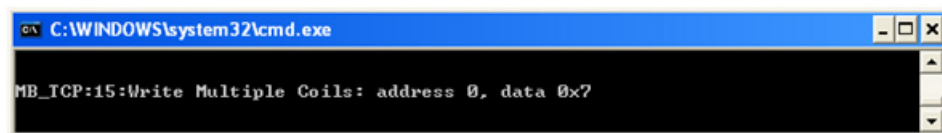


```
C:\WINDOWS\system32\cmd.exe
MB_TCP:04:Read_input_Reg: RTC Secs Counter = 53
```

### Write Multiple Coils (function code 0x0F)

The following figure shows the Write Multiple Coils register data for toggling the LEDs connected to GPIOs.

Figure 18 • Write Multiple Coils



```
C:\WINDOWS\system32\cmd.exe
MB_TCP:15:Write Multiple Coils: address 0, data 0x7
```

## Appendix: Board Setup for Running the Modbus TCP Reference Design

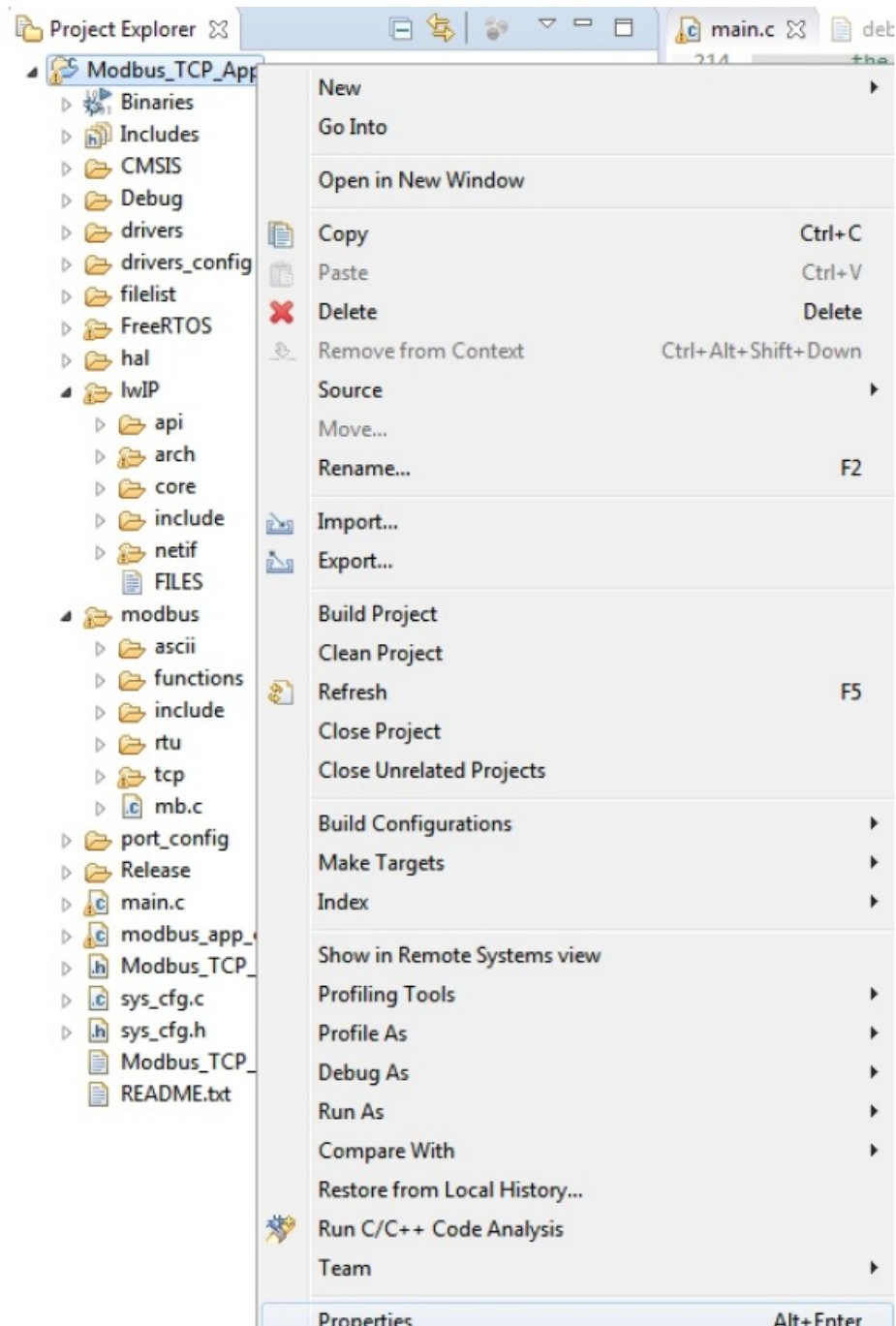
The following figure shows the board setup for running the reference design on the SmartFusion2 Advanced Development Kit board.

Figure 19 • SmartFusion2 Advanced Development Kit Board Setup



1. Right-click the Project Explorer window of SoftConsole project and go to Properties as shown in the following figure.

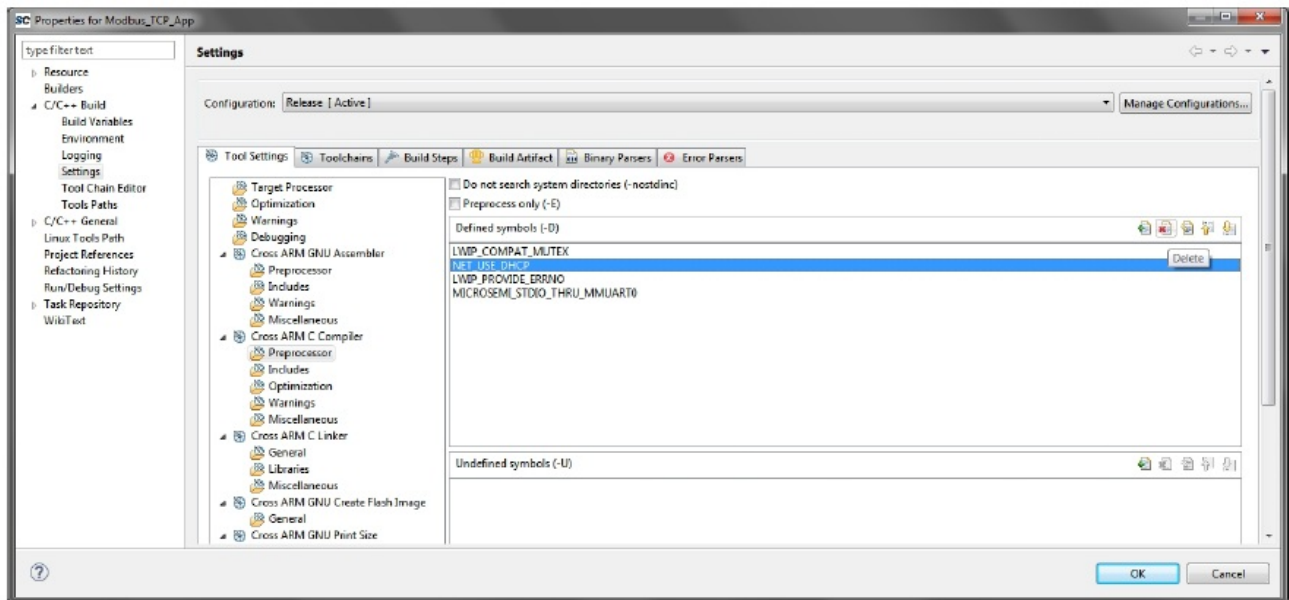
Figure 21 • Project Explorer Window of SoftConsole Project



2. Remove the symbol NET\_USE\_DHCP in Tool Settings of the Properties for Modbus\_TCP\_App window. The following figure shows the Properties for Modbus\_TCP\_App window.

Figure 22 • Project Explorer Properties Window





3. If the device is connected in static IP mode, the board static IP address is 169.254.1.23, then change the Host TCP/IP settings to reflect the IP address. See the following figure and Figure 24, Figure 23 • Host PC TCP/IP Settings

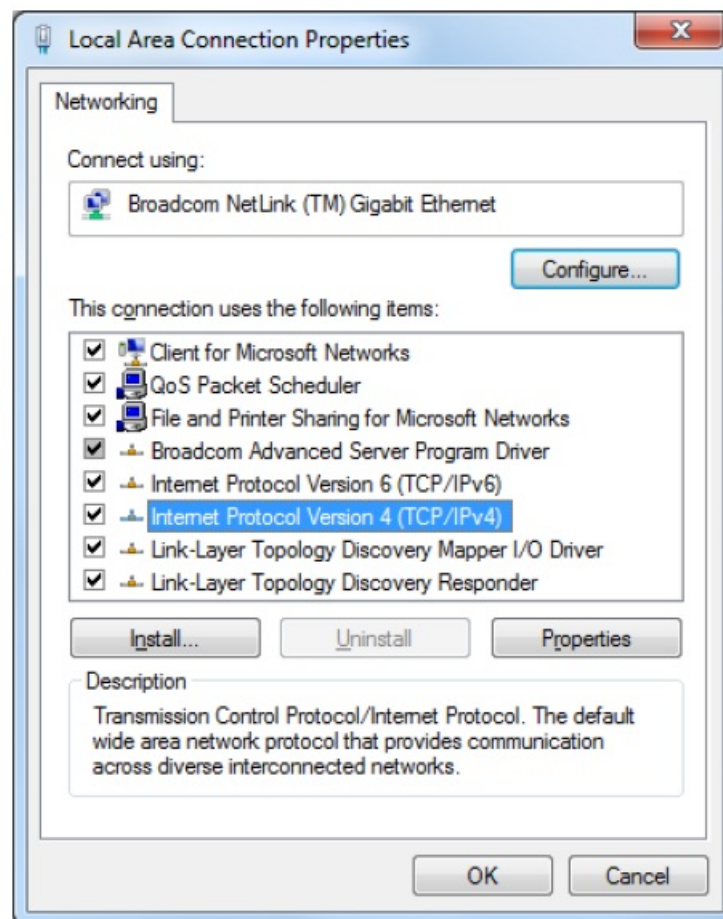
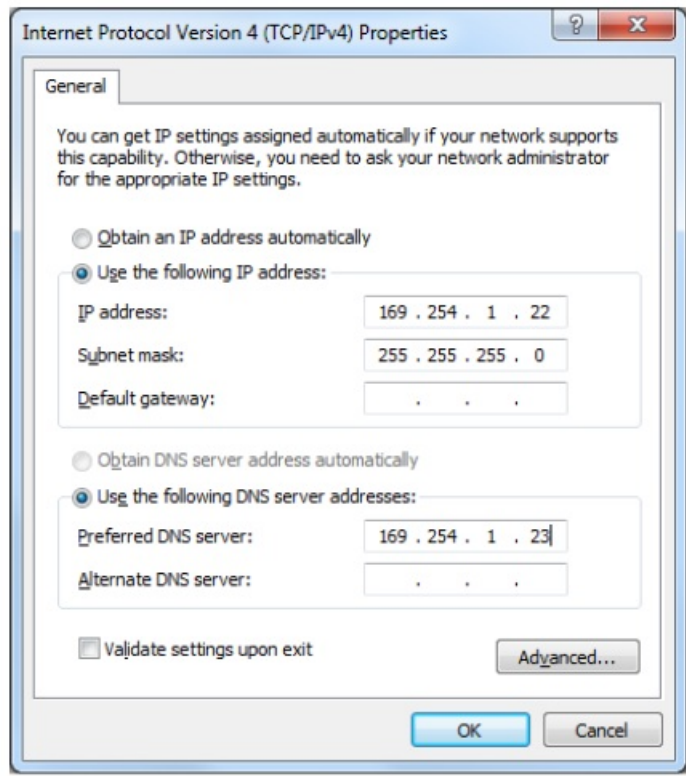



Figure 24 • Static IP Address Settings



**Note:** When these settings are configured, compile the design, load the design into Flash memory, and run the design using SoftConsole.

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## Documents / Resources

	<p><a href="#">Microsemi DG0440 Running Modbus TCP Reference Design on SmartFusion2 Devices</a> [pdf] User Guide</p> <p>DG0440 Running Modbus TCP Reference Design on SmartFusion2 Devices, DG0440, Running Modbus TCP Reference Design on SmartFusion2 Devices, Design on SmartFusion2 Devices</p>
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## References

- [FPGA Documentation | Microchip Technology](#)
- [FreeMODBUS - A free MODBUS ASCII/RTU and TCP implementation - SILA](#)
- [FreeRTOS - Market leading RTOS \(Real Time Operating System\) for embedded systems with Internet of Things extensions](#)
- [Microsemi | Semiconductor & System Solutions | Power Matters](#)
- [microsemi.com/index.php?option=com\\_docman&task=doc\\_download&gid=130815](http://microsemi.com/index.php?option=com_docman&task=doc_download&gid=130815)
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