
SmartFusion Modbus TCP Demo Using lwIP and FreeRTOS

User's Guide



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Introduction

SmartFusion™ intelligent mixed signal FPGAs integrate FPGA technology with hardened ARM® Cortex™-M3 based microcontroller subsystem (MSS) and programmable high-performance analog blocks built on a low power flash semiconductor process. The MSS consists of hardened blocks, such as a 100 MHz ARM Cortex-M3 processor, peripheral DMA (PDMA), embedded nonvolatile memory (eNVM), embedded SRAM (eSRAM), embedded FlashROM (eFROM), external memory controller (EMC), watchdog timer, I²C, SPI, 10/100 Ethernet controller, real-time counter (RTC), GPIO block, fabric interface controller (FIC), in-application programming (IAP), and system registers. The programmable analog block contains the analog compute engine (ACE) and analog front-end (AFE), consisting of ADCs, DACs, active bipolar prescalers (ABPS), comparators, current monitors, and temperature monitors.

The ethernet media access control (MAC) in SmartFusion is a high-speed media access control (MAC) ethernet controller with the following features:

- Carrier Sense Multiple Access with Collision Detection (CSMA/CD) algorithms defined by the IEEE 802.3 standard
- Complies with the low-pin-count reduced media independent interface (RMII™) specifications
- In-built DMA controller to move data between external RAM and TX/RX FIFOs

Refer to the [SmartFusion Microcontroller Subsystem User's Guide](#) for more details on 10/100 Ethernet MAC interface. This user guide explains how to run the demo design running the Modbus TCP server (www.freemodbus.org) on to the SmartFusion.

Modbus is an application layer messaging protocol, positioned at level 7 of the OSI model. It provides client/server communication between devices connected on different types of buses or networks. It is a confirmed service protocol and offers many services specified by function codes. The Modbus function codes are elements of Modbus Request/Reply Protocol Data Units.

Modbus is an application layer messaging protocol for client/server communication between devices connected on different types of buses or networks. It is currently implemented using:

- TCP/IP over ethernet
- Asynchronous serial transmission over a variety of media (wire: EIA/TIA-232-E, EIA-422, EIA/TIA-485-A; fiber, radio, etc.)
- Modbus PLUS, a high speed token passing network

Figure 1 illustrates the Modbus communication stack

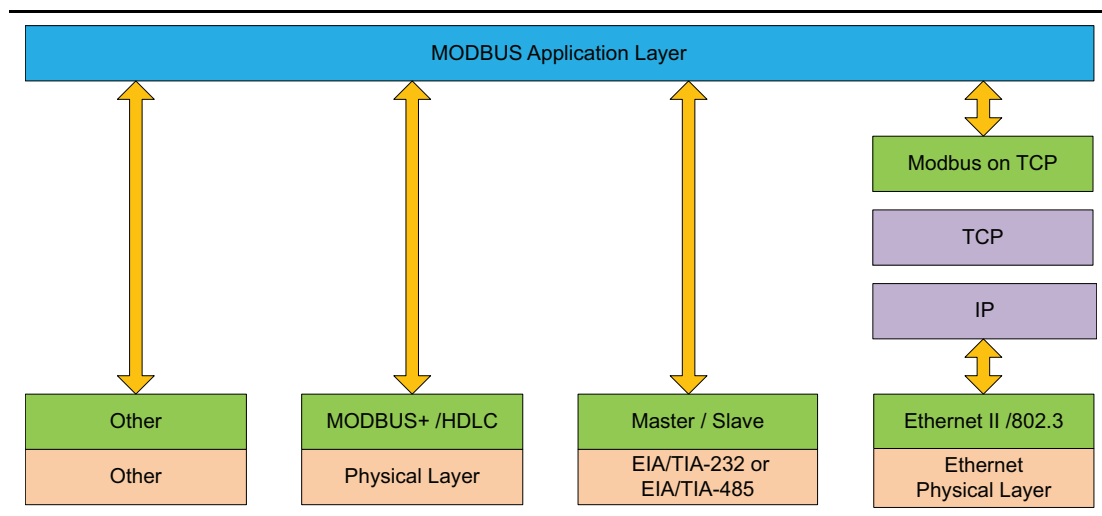


Figure 1 • Modbus Communication Stack

The complete specification for Modbus is available at www.modbus.org.

The Modbus TCP implementation guidelines can be referred from the following link:
www.modbus.org/docs/Modbus_Messaging_Implementation_Guide_V1_0b.pdf.

The source code used for this application note is from www.freemodbus.org with updates for the complete set of features of the Modbus.

This demo is designed for the [SmartFusion Development Kit](#) (A2F500-DEV-KIT) using lwIP and FreeRTOS. To familiarize yourself with the Microsemi SoC Product Group's tool chain and design flow, refer to the SmartFusion Tutorials on www.actel.com/products/smartfusion/docs.aspx#tutorial.

1 – Reference Design Features

The following versions of the stack are being used for this demo.

1. lwIP TCP/IP stack version 1.3.2 (www.sics.se/~adam/lwip/)
2. Modbus TCP server version 1.5 (www.freemodbus.org) with enhancements for the complete function code support as Modbus TCP Server
3. FreeRTOS version 6.0.1 (www.freertos.org)

Supported Modbus Function

Based on the FreeMODBUS communications stack, the reference design supports the following Modbus functions out of the box. This design example supports all the function code required for the Modbus Slave. These function codes are verified with the Modbus conformance test tool from www.modbus.org.

- 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/Write Multiple Registers (function code 0x17)
- Read Coils (function code 0x01)
- Write Single Coils (function code 0x05)
- Write Multiple Coils (function code 0x0F)
- Read Discrete Inputs (function code (0x02)

2 – Modbus TCP Server on SmartFusion

Figure 2-1 shows the block diagram of the software stacks used in this demo design.

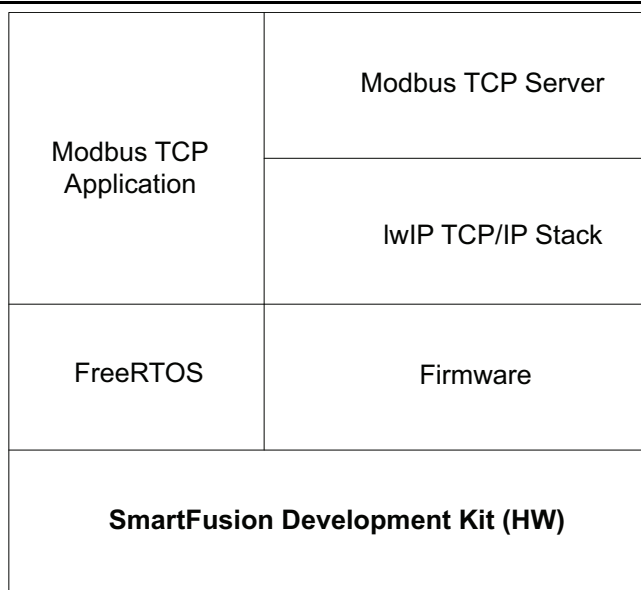


Figure 2-1 • Block Diagram of MODBUS TCP Server and Application on SmartFusion

This demo design describes the Modbus TCP Server running on the SmartFusion Development Kit and responding to the Modbus TCP Client running on development PC. The following function codes are demonstrated on SmartFusion:

- Read discrete inputs (fn code 02) for a mapped global data
- Read holding registers (fn code 03) for a mapped global data
- Read input register (fn code 04) for ACE current reading
- Write multiple coils (fn code 15) for toggling the LEDs using GPIOs

3 – Modbus TCP Demo Requirement

Microsemi SoC Products Group [SmartFusion Development Kit](#) (A2F500-DEV-KIT) is needed to run the demo design. As this demo is using the various software stacks, it is very hard to keep them running from the internal memories of the SmartFusion. Therefore, this demo is made to run from the external memories of the [SmartFusion Development Kit](#). Following are the jumper settings for the development kit to access the external memories.

Table 3-1 • Jumper Settings for Accessing the External Flash and RAM

Jumper	Pin	Pin
JP17	2	3
JP19	2	3
JP24	1	2
JP16	2	3

For additional information about the board, refer to the [SmartFusion Development Kit User's Guide](#). Add the SoftConsole installation path. For example, C:\Program Files\Actel\SoftConsole v3.2\Sourcery-G++\bin, to the 'Environment Variables'. This is required by the host tools to create the .bin file of the executable from .elf. [Figure 3-1](#) shows the Path settings in Environment Variables.

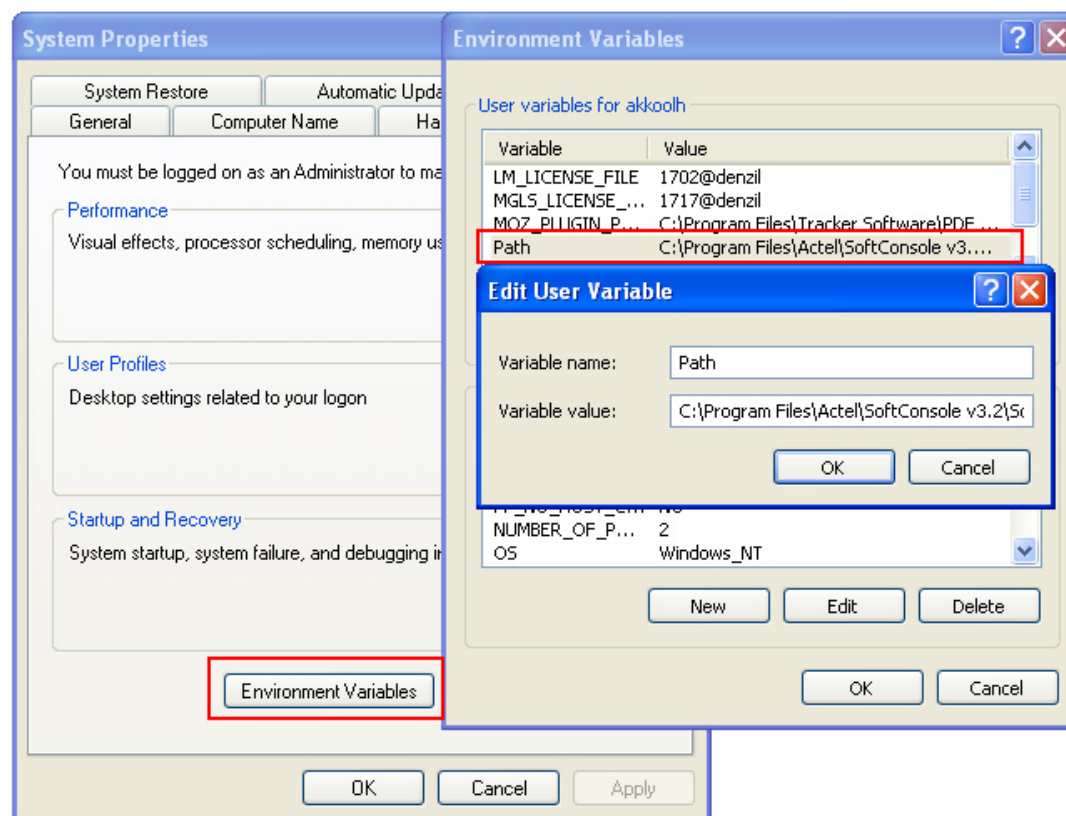


Figure 3-1 • PATH Settings in Environment Variables

4 – Running the Design

The design files are available on the Microsemi SoC Product Group's website for download on www.actel.com/download/rsc/?f=A2F_Modbus_TCP_Ref_Design_DF.

The zipped folder for this demo design contains the following components as shown in the figure below.

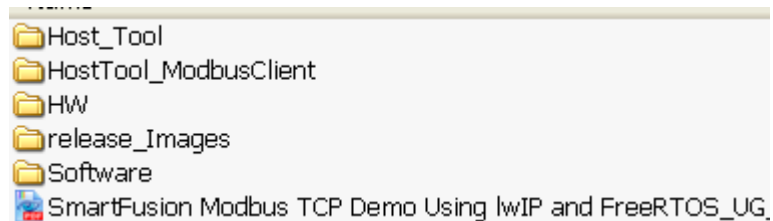


Figure 4-1 • Demo Directory Structure

1. Software: This directory contains the debug version of the demo. It can be used with the SoftConsole to debug from the external RAM.
2. HW: This directory contains the Libero project source for the HW used for this demo.
3. Host Tool & HostTool_ModbusClient: These are the tools to be used from the remote host to run this demo.
4. Release_Images: This folder contains the GUI interface to load the Image to external flash and execute the Image from external Flash. Debugging is not possible with this method. The remaining part of this section explains how to use the prebuild Image coming along with this demo.
5. Using the pre-build release images:
 - Connect the Ethernet cable and UART cable to A2F500 Dev Kit
 - Program the `top_level_modbus_tcp_server_A2F500.pdb` or the `top_level_modbus_tcp_server_A2F200.pdb` using FlashPro

- Double click the External Flash loader GUI tool (SmartFusion_Flash_Loader_V1.0.exe). This displays the GUI for running Modbus TCP demo (Figure 4-2).

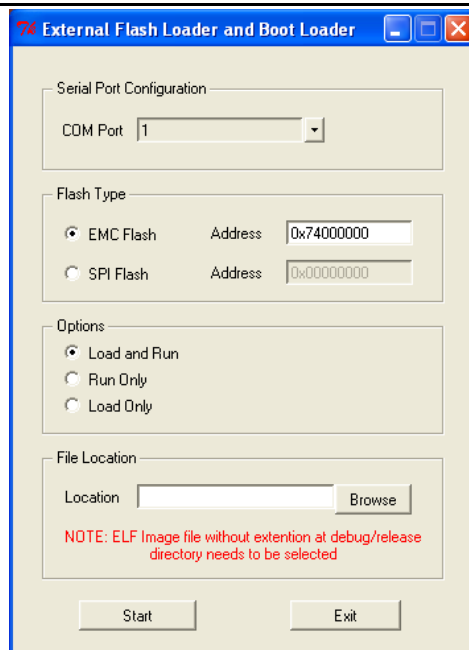


Figure 4-2 • GUI for Running MODBUS TCP Demo

6. Select a COM port to which the A2F500-DEV-KIT is connected from the drop-down list (Figure 4-3).

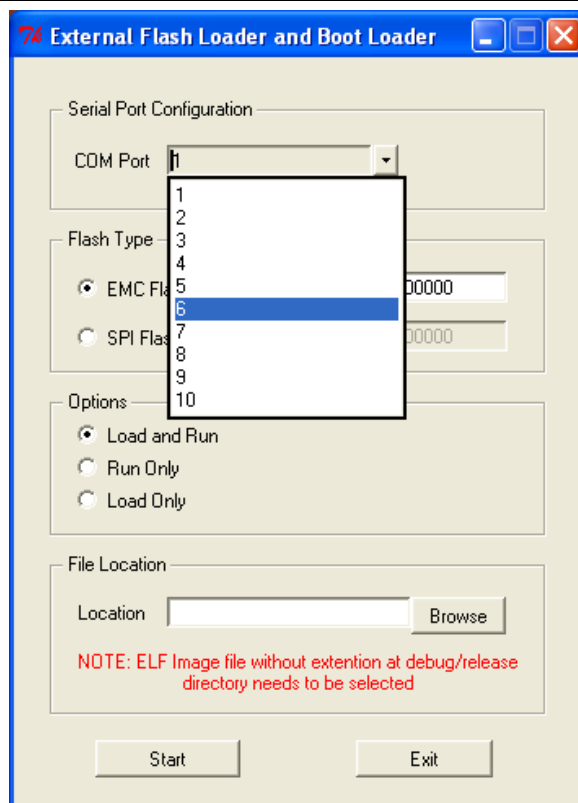


Figure 4-3 • COM Port Selection

'Flash Type' and 'Options' are EMC Flash and Load and Run respectively (Figure 4-4). These are the default settings for the TCP demo.

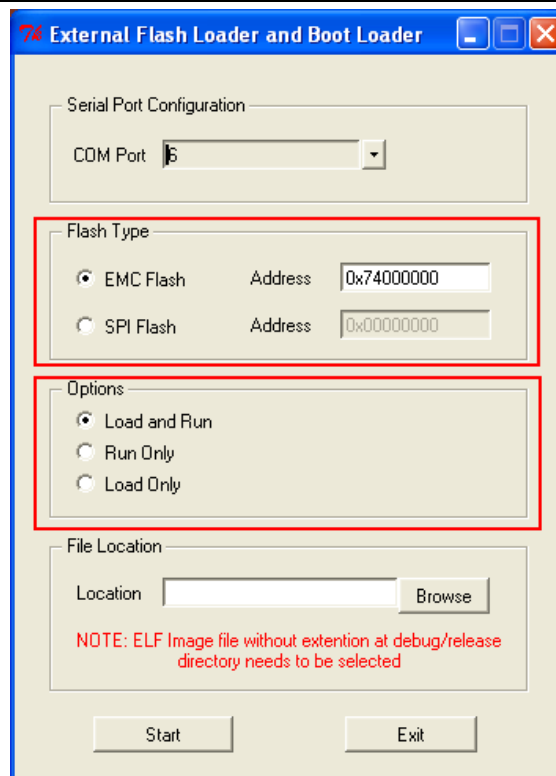
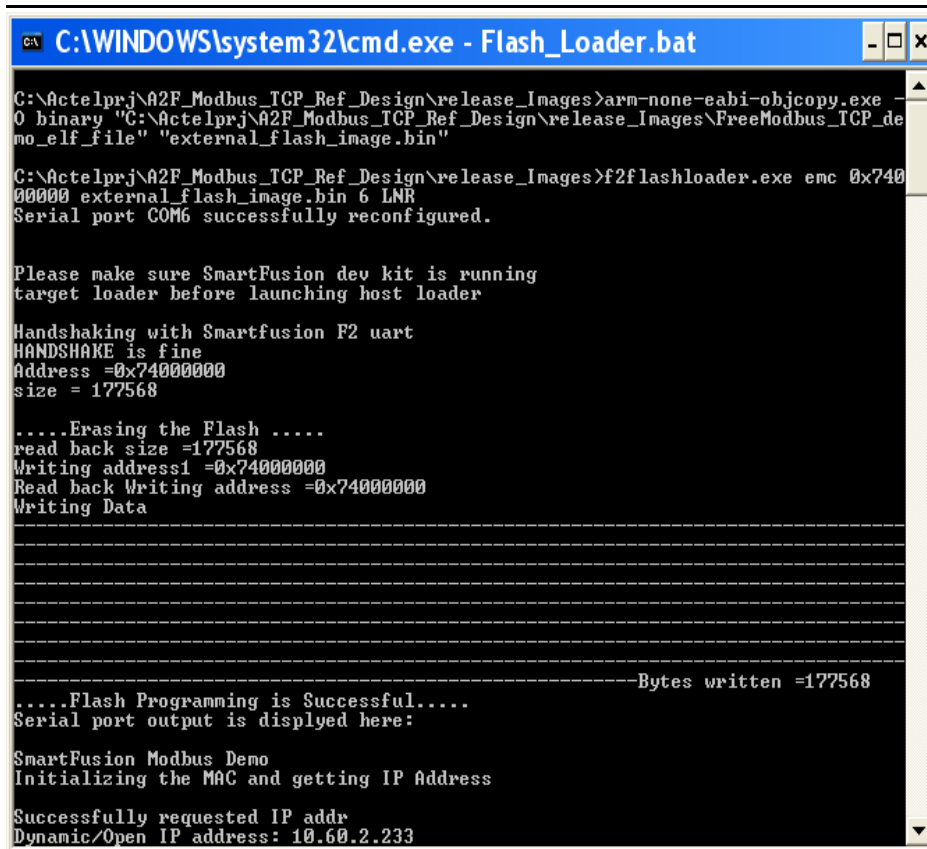


Figure 4-4 • Default Settings for MODBUS TCP Demo

7. Browse for the .elf file (FreeModbus_TCP_demo_elf_file) that is provided in the release_Images folder, then click **Start**. The Command Prompt Windows is displayed (Figure 4-5). This will program the external flash with modbus demo image and starts the demo.



```
C:\WINDOWS\system32\cmd.exe - Flash_Loader.bat

C:\Actelprj\A2F_Modbus_TCP_Ref_Design\release_Images>arm-none-eabi-objcopy.exe -O binary "C:\Actelprj\A2F_Modbus_TCP_Ref_Design\release_Images\FreeModbus_TCP_demo_elf_file" "external_flash_image.bin"

C:\Actelprj\A2F_Modbus_TCP_Ref_Design\release_Images>f2flashloader.exe enc 0x74000000 external_flash_image.bin 6 LMR
Serial port COM6 successfully reconfigured.

Please make sure SmartFusion dev kit is running
target loader before launching host loader

Handshaking with Smartfusion F2 uart
HANDSHAKE is fine
Address =0x74000000
size = 177568

.....Erasing the Flash .....
read back size =177568
Writing address1 =0x74000000
Read back Writing address =0x74000000
Writing Data

-----Bytes written =177568
.....Flash Programming is Successful.....
Serial port output is dispalyed here:

SmartFusion Modbus Demo
Initializing the MAC and getting IP Address

Successfully requested IP addr
Dynamic/Open IP address: 10.60.2.233
```

Figure 4-5 • EMC Flash Programming and Running MODBUS TCP Demo

8. Open a new command prompt and type the following command as shown in Figure 4-6 (run the modbus client, A2F_Modbus_TCP_Client.exe, with the IP address displayed in the above step as input): A2F_Modbus_TCP_Client.exe 10.60.2.233.

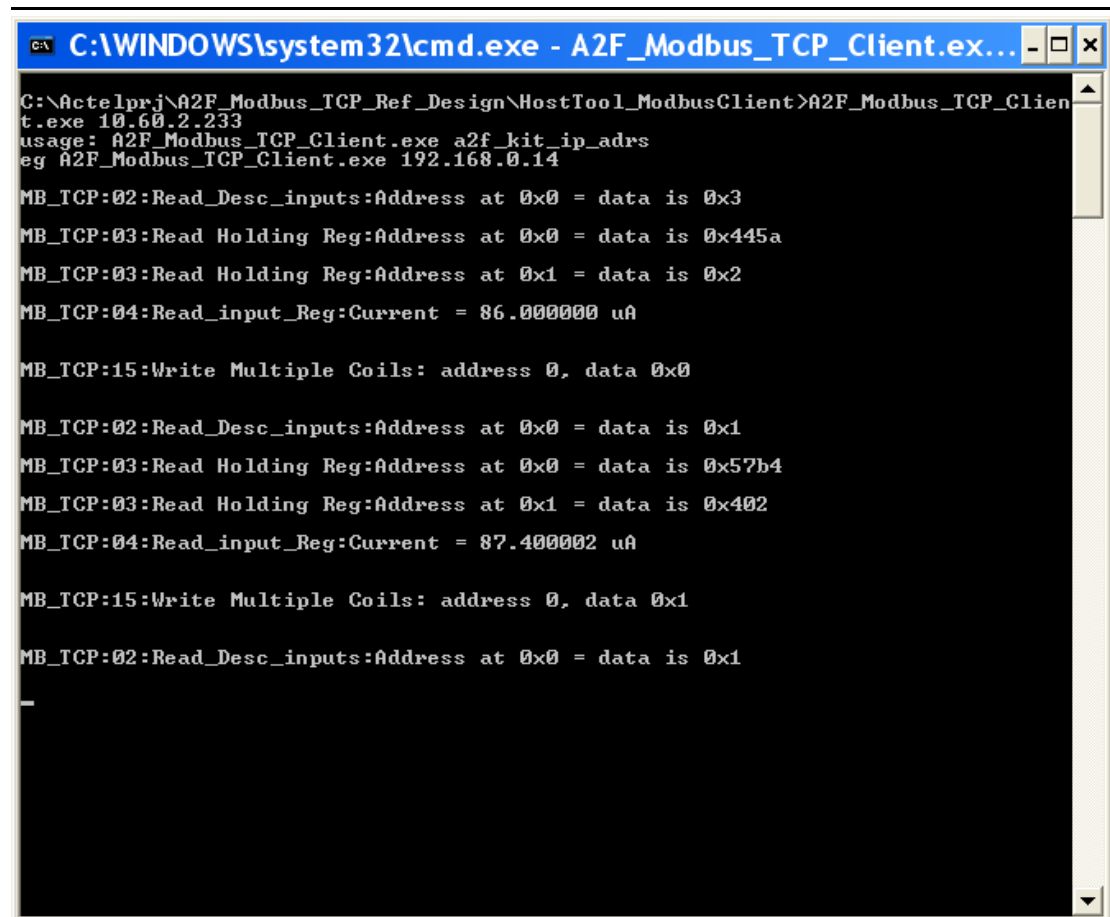


```
C:\WINDOWS\system32\cmd.exe

C:\Actelprj\A2F_Modbus_TCP_Ref_Design\HostTool_ModbusClient>A2F_Modbus_TCP_Client.exe 10.60.2.233
```

Figure 4-6 • Running the MODBUS Client

Figure 4-7 shows the current monitor values.



```

C:\WINDOWS\system32\cmd.exe - A2F_Modbus_TCP_Client.exe...
C:\Actelprj\A2F_Modbus_TCP_Ref_Design\HostTool_ModbusClient>A2F_Modbus_TCP_Client.exe 10.60.2.233
usage: A2F_Modbus_TCP_Client.exe a2f_kit_ip_adrs
eg A2F_Modbus_TCP_Client.exe 192.168.0.14

MB_TCP:02:Read_Desc_inputs:Address at 0x0 = data is 0x3
MB_TCP:03:Read Holding Reg:Address at 0x0 = data is 0x445a
MB_TCP:03:Read Holding Reg:Address at 0x1 = data is 0x2
MB_TCP:04:Read_input_Reg:Current = 86.000000 uA

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

MB_TCP:02:Read_Desc_inputs:Address at 0x0 = data is 0x1
MB_TCP:03:Read Holding Reg:Address at 0x0 = data is 0x57b4
MB_TCP:03:Read Holding Reg:Address at 0x1 = data is 0x402
MB_TCP:04:Read_input_Reg:Current = 87.400002 uA

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

MB_TCP:02:Read_Desc_inputs:Address at 0x0 = data is 0x1

```

Figure 4-7 • Current Monitor Values

9. This demo shows the Modbus TCP functions for:
 - Read Discrete inputs (fn code 02) for a mapped global data
 - Read Holding register (fn code 03) for mapped global data
 - Read Input Register (fn code 04) for ACE Current reading
 - Write Multiple Coils (fn code 15) for toggling the LEDs using GPIOs. The corresponding LED will go off as the data value shown for function 15 in [Figure 4-7](#).
10. Vary the POT values on the A2F500-DEV-KIT. The changes in the current will be reflected in the above command prompt window in [Figure 4-7](#).
11. Once the test has been done, close the command prompts. This is required to close the COM port opened by the tools.

Debug Mode

Refer to [Using UART with SmartFusion Libero Integrated Design Environment \(IDE\) and SoftConsole Flow Tutorial](#) to understand the flow for debugging mode.

5 – References

The following references were used in this document.

1. Microsemi SoC Products Group (formerly Actel) System Solutions home page:
www.actel.com/products/solutions/default.aspx
2. Microsemi SmartFusion intelligent mixed-signal FPGA home page:
www.actel.com/products/smartfusion/default.aspx
3. The Modbus Organization home page: www.modbus.org
 - FAQ: www.modbus.org/faq.php
 - Technical resources including specifications and links to free and commercial Modbus tools and resources: www.modbus.org/tech.php
4. Wikipedia page on Modbus: <http://en.wikipedia.org/wiki/Modbus>
5. FreeModbus home page: www.freemodbus.berlios.de/
 - API Documentation: www.freemodbus.berlios.de/api/index.html
 - Examples usage using Modpoll: www.freemodbus.berlios.de/index.php?idx=1
6. Selected suggested Modbus master tools for testing and exercising the reference design:
 - proconX Pty Ltd Modpoll[®] - a freeware (www.modbusdriver.com/info/LICENSE-FREE) PC hosted command line read-only Modbus master: www.modbusdriver.com/modpoll.html
 - Automated Solutions Inc Modbus RTU/ASCII Master ActiveX Control and example programs: www.automatedsolutions.com/demos/#MBACTIVEX. A 30 day trial demo version is available for download from Automated Solutions Inc: www.automatedsolutions.com/products/modbusrtu.asp.
7. Modbus tutorials and overviews
 - Automation.com[™] Introduction to Modbus: www.automation.com/resources-tools/articles-white-papers/fieldbus-serial-bus-io-networks/introduction-to-modbus
 - National Instruments[™] Introduction to Modbus: www.zone.ni.com/devzone/cda/tut/p/id/7675
 - AutomatedBuildings.com Introduction to the Modbus Protocol
 - Part 1: www.automatedbuildings.com/news/sep08/articles/cctrls/080819014909cctrls.htm
 - Part 2: www.automatedbuildings.com/news/dec08/articles/cctrls/081124120101cctrls.htm
8. lwIP TCP/IP Stack: www.sics.se/~adam/lwip/
9. freeRTOS Stack: www.freeRTOS.org

A – Product Support

Microsemi backs its products with various support services including Customer Service, a Customer Technical Support Center, a web site, an FTP site, electronic mail, and worldwide sales offices. This appendix contains information about contacting Microsemi SoC Products Group (formerly Actel) and using these support services.

Customer Service

Contact Customer Service for non-technical product support, such as product pricing, product upgrades, update information, order status, and authorization.

From Northeast and North Central U.S.A., call **650.318.4480**

From Southeast and Southwest U.S.A., call **650. 318.4480**

From South Central U.S.A., call **650.318.4434**

From Northwest U.S.A., call **650.318.4434**

From Canada, call **650.318.4480**

From Europe, call **650.318.4252** or **+44 (0) 1276 401 500**

From Japan, call **650.318.4743**

From the rest of the world, call **650.318.4743**

Fax, from anywhere in the world **650.318.8044**

Customer Technical Support Center

Microsemi staffs its Customer Technical Support Center with highly skilled engineers who can help answer your hardware, software, and design questions. The Customer Technical Support Center spends a great deal of time creating application notes and answers to FAQs. So, before you contact us, please visit our online resources. It is very likely we have already answered your questions.

Technical Support

Visit the Customer Support website (www.actel.com/support/search/default.aspx) for more information and support. Many answers available on the searchable web resource include diagrams, illustrations, and links to other resources on the website.

Website

You can browse a variety of technical and non-technical information on the SoC home page, at www.actel.com.

Contacting the Customer Technical Support Center

Highly skilled engineers staff the Technical Support Center from 7:00 a.m. to 6:00 p.m., Pacific Time, Monday through Friday. Several ways of contacting the Center follow:

Email

You can communicate your technical questions to our email address and receive answers back by email, fax, or phone. Also, if you have design problems, you can email your design files to receive assistance. We constantly monitor the email account throughout the day. When sending your request to us, please be sure to include your full name, company name, and your contact information for efficient processing of your request.

The technical support email address is soc_tech@microsemi.com.

Phone

Our Technical Support Center answers all calls. The center retrieves information, such as your name, company name, phone number and your question, and then issues a case number. The Center then forwards the information to a queue where the first available application engineer receives the data and returns your call. The phone hours are from 7:00 a.m. to 6:00 p.m., Pacific Time, Monday through Friday. The Technical Support numbers are:

650.318.4460

800.262.1060

Customers needing assistance outside the US time zones can either contact technical support via email (soc_tech@microsemi.com) or contact a local sales office. Sales office listings can be found on the website at www.actel.com/company/contact/default.aspx.

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