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Introduction

Overview

Modbus is a serial communications and application level protocol primarily targeting industrial network communications. The origins, rationale, and specifications for Modbus are summarized in the Modbus Organization FAQ [Reference 3], the Modbus Organization technical resources page [Reference 4], and also in various Modbus tutorials and introductory guides available on the web [Reference 9].

Reference Design Features

1. Modbus over serial line reference slave implementation based on a bare metal (non [Free]RTOS) implementation of the FreeModbus communications stack [Reference 6], targeting the Microsemi SmartFusion™ customizable system-on-chip (cSoC) device [Reference 2] A2F500-DEV-KIT board.

2. Supports Modbus serial line ASCII and RTU modes.

3. Supports RS-232 (point to point master and single slave) and RS-485 (bus-based multidrop master and multiple slaves) physical communication mediums.

4. Includes the complete Libero® System-on-Chip (SoC) software v10.0 SPB/MSS v2.4.105 hardware and SoftConsole (v3.3) firmware projects implementing the reference design Modbus slave which can be exercised using any third party Modbus master (including those which are PC hosted, mentioned in [Reference 9]) and which can be adapted and extended for customer specific requirements.

5. Supported Modbus functions—based on the FreeModbus communications stack, the reference design supports the following Modbus functions out of the box:
   a. Read Input Register (function code 0x04)
   b. Read Holding Registers (0x03)
   c. Write Single Register (0x06)
   d. Write Multiple Registers (0x10)
   e. Read/Write Multiple Registers (0x17)
   f. Read Coils (0x01)
   g. Write Single Coil (0x05)
   h. Write Multiple Coils (0x0F)
   i. Read Discrete Inputs (0x02)
   j. Report Slave ID (0x11)

   Refer to the FreeModbus API documentation [Reference 7] for information about extending the slave to support additional Modbus function codes.

6. Supports a variety of sample single bit read-only discrete input registers, single bit read-write coils registers, 16-bit read-only input registers and 16-bit read-write holding registers connected to board resources such as OLED (holding), LEDs (coils), DIP switches (discrete inputs), push-buttons (discrete inputs), and ACE analog voltage channel and RTC (inputs). The number and type of registers can be extended by the end user.

---

1. The reference design Libero SoC project can easily be retargeted to the SmartFusion A2F200-EVAL-KIT board, which supports only RS-232 (via the Silicon Laboratories CP2102 USB to UART bridge) communications and which does not support all of the hardware resources available on the A2F500-DEV-KIT board that are mapped to Modbus registers in the reference design slave implementation.
1 – Installing and Using the Reference Design

Installing the Reference Design

Download the design files from the Microsemi SoC Products Group website:
www.microsemi.com/soc/download/rsc/?f=MS_SF_Modbus_Ref_Design_DF
The reference design is delivered as a rar file and the contents should be extracted to a suitable folder on disk. Once extracted, the folder structure would be displayed as shown in Figure 1-1.

To get started with the reference design follow these steps:
1. Extract the contents of the reference design rar file.
2. Open the hardware project ..\SF_Modbus_RefdesigDF\A2F500\Modbus\Modbus.prj in Libero SoC IDE v10.0.
3. If necessary, bring the design through the project flow to create an STP for programming the target A2F500-DEV-KIT board.
4. Program the resulting STP to the A2F500-DEV-KIT board using FlashPro from within Libero SoC.
5. Launch the SoftConsole project and double-click Write Application Code under Develop Firmware in the Libero SoC design flow window.
6. Build the Release target. Right-click the Modbus_MSS_MSS_CM3_0_app and Modbus_MSS_MSS_CM3_0_hw_platform projects in the SoftConsole Project Explorer and choose Build Configurations > Set Active > Release and then right-click again and choose Build Project.
7. Download the release build to SmartFusion MSS Embedded NVM (ENVM). Right-click the Modbus_MSS_MSS_CM3_0_app project in the SoftConsole Project Explorer and choose DebugAs > Debug Configurations. In the Debug Configurations dialog, select the Modbus_MSS_MSS_CM3_0_app Debug in ENVM debug configuration and choose Debug. The release build firmware should download to ENVM, start running, and then stop at the breakpoint at main().

8. Terminate the debug session and close SoftConsole.

9. Power cycle the A2F500-DEV-KIT board and the firmware should run, displaying the following message on the OLED, lighting LEDs D2 and D4.

   Microsemi Corp v1.0
   SmartFusion Modbus

---

**Board Settings**

The design example is made to be working on SmartFusion development kit board and SmartFusion evaluation kit board with default board settings. Refer the following user’s guides for default board settings:

- SmartFusion Development Kit User’s Guide
- SmartFusion Evaluation Kit User’s Guide

**Default Communication Settings**

The default communication settings are as follows:

- Modbus serial RTU mode
- Modbus slave address 0x01
- MSS UART_0/Rs-232 physical layer communications (via the SmartFusion cSoC board’s Silicon Laboratories CP2102 USB to UART bridge)
  - 19200 baud
  - 8 data bits, as required by Modbus RTU mode. If the firmware is reconfigured to run in ASCII mode, the Modbus master must be configured to use 7 data bits, as required by Modbus ASCII.
  - Even parity
  - 1 stop bit

When connecting a Modbus master to the reference design slave, connect a USB cable from your PC to the A2F500-DEV-KIT board’s MSS UART_0/Silicon Laboratories CP2102 USB to UART bridge mini USB connector and make sure that you know what port number is allocated to the virtual USB COM port before configuring the master Modbus and communication settings. If you reconfigure the firmware to use MSS UART_1/RS-485, refer to the "RS-485 Communications" section on page 27.

**Using Modpoll**

Modpoll® is a simple command line read-only freeware Modbus master available from proconX Pty Ltd. [Reference 9]. Download and install/extract Modpoll, open a command shell, and change directory to the folder containing the modpoll.exe executable. Modpoll.exe -h displays help about the different command line options supported.
Read Input Registers

To query the reference design slave’s two 16-bit read-only input registers, which store the RTC in seconds and RV1 3.3 V pot voltage in mV, run Modpoll as follows:

```bash
modpoll.exe -m rtu -a 1 -r 1 -c 2 -t 3 -b 19200 -d 8 -p even COM4
```

The command line parameters are shown in Table 1-1:

<table>
<thead>
<tr>
<th>Command Line Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-m rtu</td>
<td>Modbus serial mode.</td>
</tr>
<tr>
<td>-a 1</td>
<td>Modbus target slave address.</td>
</tr>
<tr>
<td>-r 1</td>
<td>Offset from start of the relevant Modbus register block (as determined by the -t command line option below) to start reading.</td>
</tr>
<tr>
<td>-c 2</td>
<td>Number of values to poll.</td>
</tr>
<tr>
<td>-t 3</td>
<td>Poll 16-bit read-only input registers. See Table 2-3 on page 23 for details of the reference design slave’s Modbus register map.</td>
</tr>
<tr>
<td>-b</td>
<td>19200 Baud rate.</td>
</tr>
<tr>
<td>-p even</td>
<td>Even parity.</td>
</tr>
<tr>
<td>COM4</td>
<td>The PC virtual COM port for connecting to the A2F500-DEV-KIT board. Modify this according to your local setup.</td>
</tr>
</tbody>
</table>

Modpoll will continuously poll the two input registers supported by the reference design slave (RTC and RV1 pot voltage).
You should see the first register (RTC) counting up in seconds and the second one varying as you turn the RV1 pot on the A2F500-DEV-KIT board (Figure 1-2).

Read Discrete Input Registers

To query the 16 single-bit read-only discrete input registers, run Modpoll again with the following command line options:

```bash
modpoll.exe -m rtu -a 1 -r 1 -c 2 -t 3 -b 19200 -d 8 -p even COM4
```

This time use `-t 1 -c 16` to read the 16 single-bit read-only discrete inputs supported by the reference design slave. See Table 2-3 on page 23 for more information about the Modbus register map supported by the reference design slave.
As Modpoll polls the slave, toggle the A2F500-DEV-KIT board’s SW1-SW5 push-buttons and A2F_DIP DIP switches to see the effect that this has on the results reported by Modpoll (Figure 1-3).
Read Holding Registers

The 38 16-bit read-write holding registers contain (in their lower 8 bits) the values used to display characters in each of the OLED’s 38 (2 row x 19 column) character positions. Modpoll is a read-only Modbus master, so can read but not write these. To read these registers, run Modpoll as follows:

```plaintext
modpoll.exe -m rtu -a 1 -r 1 -c 38 -t 4:hex -1 -b 19200 -d 8 -p even COM4
```

In this case, `-c 38` tells Modpoll to read 38 registers, `-t 4:hex` tells it to read the holding registers and display them in hex, and `-1` tells it to poll once rather than continuously (Figure 1-4).

![Hex Display](image-url)
Read Coils Registers

To read eight 1-bit read-write coils registers (four of which are connected to the A2F500-DEV-KIT board’s LEDs), run Modpoll as follows:

    modpoll.exe -m rtu -a 1 -r 1 -c 8 -t 0 -l -b 19200 -d 8 -p even COM4

Note that the LEDs are active low, so a 0 means that the LED is on while 1 means that it is off (Figure 1-5).

```
C:\DEV\SandBox\Modbus\Modpoll\win32>modpoll.exe -m rtu -a 1 -r 1 -c 8 -t 0 -l -b 19200 -d 8 -p even COM4
modpoll - FieldTalk(tm) Modbus(R) Polling Utility
Copyright (c) 2002-2006 FOCUS Software Engineering Pty Ltd
Visit http://www.modbusdriver.com for Modbus libraries and tools.
Protocol configuration: Modbus RTU
Slave configuration...: Address/id = 1, start reference = 1, count = 8
Communication.........: COM4, 19200, 8, even
Data type...............: discrete output <coil>
Polling slave ...
[1]: 0
[2]: 0
[3]: 0
[4]: 0
[5]: 0
[6]: 0
[7]: 0
[8]: 0
```

Figure 1-5 • Read Coils Registers

Using Automated Solution’s MiniHMI

Automated Solutions Inc. [Reference 9] provides commercial software solutions for HMI and SCADA developers, including various Modbus solutions. Their product range includes a Modbus RTU/ASCII Master ActiveX Control and some example applications. Contact Automated Solutions Inc. or refer to their website for details about their commercial tools offerings and prices.

Automated Solutions Inc. also provides a free, full featured 30-day trial version of their Modbus RTU/ASCII Master ActiveX Control and example applications which can be used to exercise and demonstrate the features of the Microsemi SmartFusion Modbus reference design slave.

Obtain and install the demo or full version of the Automated Solutions Inc. Modbus RTU/ASCII Master ActiveX Control package. Refer to the documentation and help provided with the package and on the Automated Solutions Inc. website for more details about the capabilities of the ActiveX component and example applications.

The MiniHMI example application can be run from Start > All Programs > Automated Solutions ActiveX > Modbus Master > MiniHMI Example Application.
Read Input Registers

Run the MiniHMI example application. Click the Read Registers tab. Ensure that the Communications settings are configured appropriately to match your slave setup. See the "Default Communication Settings" section on page 8 for the default settings. The MiniHMI settings with the possible exception of Communications Port match the reference design slave default settings. Select the Modbus > Function > Input Registers radio button and in the Quantity field enter 2. Check the Auto Poll check box and MiniHMI should start, continuously polling the RTC and RV1 3.3 V pot input registers. The values of the registers should update as time passes and you rotate the RV1 pot. Clear the Auto Poll check box to stop continuous polling.

![Figure 1-6 • Polling with MiniHMI](image-url)
Read/Write Holding Registers

On the Read Registers tab, select the Modbus > Function > Output Registers radio button. Enter 38 in the Quantity field. Click the Sync Read button and MiniHMI should read back the 38 OLED character position holding registers.

![Figure 1-7 • Read Holding Registers](image)

To write to the holding registers in order to change what is displayed on the OLED, go to the Write Registers tab. Ensure that the Communications settings are configured correctly ("Default Communication Settings" section on page 8). Note that the Communications settings must be set independently on each tab and are not retained between runs.
Select the Modbus > Function > Multiple Out Regs radio button and enter a value between 1 and 38 in the Quantity field. In the register grid/spreadsheet view, enter as many values as you want to write to the OLED holding registers. All 16 bits of the values will be stored but only the lower 8 bits will be written to the OLED. Click the Sync Write button to flush the new values to the reference design Modbus slave. For example, to write 7’s to all OLED character positions, do the following:

![Figure 1-8 • Write to OLED Registers](image-url)
Read Discrete Inputs and Coils

To read the discrete inputs and coils, go to the **Read Discretes** tab. Ensure the Communications settings are set correctly, choose to read 8 or fewer coils or 16 or fewer discrete inputs and then click **Sync Read** to read once or Auto Poll to poll continuously. When reading the 16 discrete inputs, the MiniHMI GUI’s State view will reflect changes due to manual toggling of the A2F500-DEV-KIT board’s SW1-5 push-buttons or A2F_DIPS DIP switches.

---

*Figure 1-9 • Read Discrete Inputs and Coils*
Write Coils

To write the coils (LEDs), go to the **Write Discretes** tab. Ensure that the Communications settings are configured appropriately. Select **Single Coils** or **Multiple Coils** and enter a Quantity between 1 and 4 (or up to 8 but only coils 1-4 are actually connected to board resources/LEDs by default). Toggle any of the first four coils (00-04) in the State view and then click the **Sync Write** button to change the status of the LEDs. You should see the changes reflected on the A2F-DEV-KIT board itself.

Using Other Modbus Masters

Similar to the way proconX Pty Ltd Modpoll and the Automated Solutions Inc. Modbus RTU/ASCII ActiveX Component MiniHMI example application can be used to interact with the Microsemi SmartFusion Reference Design sample Modbus slave, any other Modbus compatible PC hosted or other master can also be used. The main issue is that the master Modbus and serial communications settings match the slave target settings.
2 – SoftConsole Firmware Project

Project Layout

The screenshot of the SoftConsole v3.3 Project Explorer in Figure 2-1 outlines the structure of the firmware project. To invoke SoftConsole project, double-click **Write Application Code** under **Develop Firmware** in the Libero SoC design flow window.

*Figure 2-1 • SoftConsole Project Explorer*
Table 2-1 summarizes the contents and purpose of each folder:

<table>
<thead>
<tr>
<th>Folder/File</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Includes</td>
<td>Project level include files/folders</td>
</tr>
<tr>
<td>CMSIS</td>
<td>SmartFusion CMSIS-PAL</td>
</tr>
<tr>
<td>demo/Microsemi_SmartFusion/port</td>
<td>FreeModbus porting layer files targeting SmartFusion cSoC device</td>
</tr>
<tr>
<td>demo/Microsemi_SmartFusion/demo.c</td>
<td>Reference design slave implementation program file containing main(), default slave firmware configuration #defines, Modbus register and callback implementations etc.</td>
</tr>
<tr>
<td>drivers</td>
<td>Various SmartFusion firmware drivers</td>
</tr>
<tr>
<td>drivers/mss_ace</td>
<td>SmartFusion MSS ACE Driver</td>
</tr>
<tr>
<td>drivers/mss_gpio</td>
<td>SmartFusion MSS GPIO Driver</td>
</tr>
<tr>
<td>drivers/mss_i2c</td>
<td>SmartFusion MSS I2C Driver</td>
</tr>
<tr>
<td>drivers/mss_rtc</td>
<td>SmartFusion MSS RTC Driver</td>
</tr>
<tr>
<td>drivers/mss_timer</td>
<td>SmartFusion MSS Timer Driver</td>
</tr>
<tr>
<td>drivers/mss_uart</td>
<td>SmartFusion MSS UART Driver</td>
</tr>
<tr>
<td>drivers_config/mss_ace</td>
<td>MSS ACE driver configuration code generated from the SmartFusion MSS configurator based on the MSS ACE configuration</td>
</tr>
<tr>
<td>modbus</td>
<td>The core FreeModbus communication stack</td>
</tr>
<tr>
<td>oled</td>
<td>MSS I2C based OLED driver for SmartFusion development/eval boards</td>
</tr>
</tbody>
</table>
Slave Firmware Configuration #defines

The following manifest constants control various aspects of the firmware operation and can be modified by specifying new values in the SoftConsole project properties (Properties > C/C++ Build > Settings > GNU C Compiler > Symbols) or by editing the #defines directly before recompiling the firmware, in Modbus_MSS_MSS_CM3_0_app/Microsemi_SmartFusion/demo.c.

<table>
<thead>
<tr>
<th>Manifest Constant</th>
<th>Description – Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODBUS_SERIAL_MODE</td>
<td>FreeModbus communication stack mode of serial operation</td>
</tr>
<tr>
<td></td>
<td>• MB_RTU – RTU mode</td>
</tr>
<tr>
<td></td>
<td>• MB_ASCII – ASCII mode</td>
</tr>
<tr>
<td></td>
<td>• Default: MB_RTU</td>
</tr>
<tr>
<td></td>
<td>Note that in RTU/ASCII mode the Modbus master serial communications must be configured for 8/7 data bits respectively</td>
</tr>
<tr>
<td>MODBUS_SLAVE_ADDR</td>
<td>Modbus slave address.</td>
</tr>
<tr>
<td></td>
<td>• 1 – 247 (0x01 – 0xF7)</td>
</tr>
<tr>
<td></td>
<td>• Default: 1 (0x01)</td>
</tr>
<tr>
<td>MODBUS_PORT</td>
<td>Serial port used</td>
</tr>
<tr>
<td></td>
<td>• 0 = MSS UART_0/RS-232</td>
</tr>
<tr>
<td></td>
<td>• 1 = MSS UART_1/RS-485*</td>
</tr>
<tr>
<td></td>
<td>• Default: 0</td>
</tr>
<tr>
<td>MODBUS_BAUD_RATE</td>
<td>Baud rate</td>
</tr>
<tr>
<td></td>
<td>• Default: 19200</td>
</tr>
<tr>
<td>MODBUS_PARITY</td>
<td>Parity</td>
</tr>
<tr>
<td></td>
<td>• MB_PAR_EVEN</td>
</tr>
<tr>
<td></td>
<td>• MB_PAR_ODD</td>
</tr>
<tr>
<td></td>
<td>• MB_PAR_NONE</td>
</tr>
<tr>
<td></td>
<td>• Default: MB_PAR_EVEN</td>
</tr>
<tr>
<td>MODBUS_SLAVEID</td>
<td>Modbus slave id; one byte ID followed by an optional number of bytes of device specific data</td>
</tr>
<tr>
<td></td>
<td>• Default: 0x55 0xC0 0xFF 0xEE</td>
</tr>
<tr>
<td>REG_DISCRETE_START</td>
<td>Offset (from Modbus register address 10000) of first discrete input register implemented</td>
</tr>
<tr>
<td></td>
<td>• Default: 1</td>
</tr>
<tr>
<td>REG_DISCRETE_NREGS</td>
<td>Number of discrete input registers implemented</td>
</tr>
<tr>
<td></td>
<td>• Default: 2</td>
</tr>
<tr>
<td>REG_COILS_START</td>
<td>Offset (from Modbus register address 0) of first coil register implemented</td>
</tr>
<tr>
<td></td>
<td>• Default: 1</td>
</tr>
<tr>
<td>REG_COILS_NREGS</td>
<td>Number of discrete input registers implemented</td>
</tr>
<tr>
<td></td>
<td>• Default: 1</td>
</tr>
<tr>
<td>REG_INPUT_START</td>
<td>Offset (from Modbus register address 30000) of first input register implemented</td>
</tr>
<tr>
<td></td>
<td>• Default: 1</td>
</tr>
</tbody>
</table>

Note: *A2F500-DEV-KIT only – not supported on A2F200-EVAL-KIT*
SoftConsole Firmware Project

By default, the reference design SoftConsole firmware project is configured to use the following Modbus and serial settings:

- Modbus serial RTU mode
- Modbus slave address 0x01
- Modbus slave id 0x55 with three optional data bytes 0xC0 0xFF 0xEE
- MSS UART_0/RS-232 physical layer communications (via the SmartFusion board's Silicon Laboratories CP2102 USB to UART bridge)
- 19200 baud
- 8 data bits (as required by Modbus RTU mode; Modbus ASCII mode uses 7 data bits)
- Even parity
- 1 stop bit

By default, the project is set up to use the following CMSIS-PAL sample linker scripts:

- Debug target: Modbus_MSS_MSS_CM3_0_hw_platform/CMSIS/startup_gcc/debug-in-actel-smartfusionesram.ld
- Release target: Modbus_MSS_MSS_CM3_0_hw_platform/CMSIS/startup_gcc/debug-in-actel-smartfusionenvm.ld

The debug target supports downloading to and debugging from SmartFusion MSS Embedded SRAM (ESRAM). The release target supports downloading to and debugging from SmartFusion MSS Embedded NVM (ENVM). Once the release target has been downloaded, it will persist in ENVM and will run from the board reset/power cycle. If you prefer to download the firmware via FlashPro, the release target can be modified to use the CMSIS CMSIS/startup_gcc/production-execute-in-place.ld linker script and the Intel HEX file resulting from the build process can be imported into an MSS ENVM Data Storage Client configured to load at offset 0x00000000 of ENVM so that the firmware runs from ENVM out of reset.

As with any SmartFusion firmware project, other build/link and memory configurations are possible, such as booting from ENVM, copying/relocating to ESRAM or external RAM and continuing to run from there, or more sophisticated “scatter loading” of portions of the firmware image to disparate memory regions. These configurations are beyond the scope of this document.

### Default Configuration

<table>
<thead>
<tr>
<th>Manifest Constant</th>
<th>Description – Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>REG_INPUT_NREGS</td>
<td>Number of input registers implemented</td>
</tr>
<tr>
<td></td>
<td>• Default: 2</td>
</tr>
<tr>
<td>REG_HOLDING_START</td>
<td>Offset (from Modbus register address 40000) of first holding register implemented</td>
</tr>
<tr>
<td></td>
<td>• Default: 1</td>
</tr>
<tr>
<td>REG_HOLDING_NREGS</td>
<td>Number of holding registers implemented</td>
</tr>
<tr>
<td></td>
<td>• Default: 38</td>
</tr>
</tbody>
</table>

Note: *A2F500-DEV-KIT only – not supported on A2F200-EVAL-KIT

### Linker Scripts

By default, the project is set up to use the following CMSIS-PAL sample linker scripts:

- Debug target: Modbus_MSS_MSS_CM3_0_hw_platform/CMSIS/startup_gcc/debug-in-actel-smartfusionesram.ld
- Release target: Modbus_MSS_MSS_CM3_0_hw_platform/CMSIS/startup_gcc/debug-in-actel-smartfusionenvm.ld

As with any SmartFusion firmware project, other build/link and memory configurations are possible, such as booting from ENVM, copying/relocating to ESRAM or external RAM and continuing to run from there, or more sophisticated “scatter loading” of portions of the firmware image to disparate memory regions. These configurations are beyond the scope of this document.
FreeModbus Configuration Options

See the FreeModbus API documentation [Reference 7] for information about manifest constants (in SmartFusion_demo/modbus/include/mbconfig.h) that control the configuration of the FreeModbus communications stack itself.

Reference Design Slave Modbus Register Map

The reference design slave firmware supports the Modbus registers shown in Table 2-3.

<table>
<thead>
<tr>
<th>Modbus Address</th>
<th>Physical Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coils Registers – Single Bit Read/Write</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>LED D1</td>
</tr>
<tr>
<td>2</td>
<td>LED D2</td>
</tr>
<tr>
<td>3</td>
<td>LED D3</td>
</tr>
<tr>
<td>4</td>
<td>LED D4</td>
</tr>
<tr>
<td>5</td>
<td>Not connected – reads as 0, writes ignored</td>
</tr>
<tr>
<td>6</td>
<td>Not connected – reads as 0, writes ignored</td>
</tr>
<tr>
<td>7</td>
<td>Not connected – reads as 0, writes ignored</td>
</tr>
<tr>
<td>8</td>
<td>Not connected – reads as 0, writes ignored</td>
</tr>
<tr>
<td><strong>Discrete Input Registers – Single Bit Read Only</strong></td>
<td></td>
</tr>
<tr>
<td>10001</td>
<td>Push-button SW1</td>
</tr>
<tr>
<td>10002</td>
<td>Push-Button SW2</td>
</tr>
<tr>
<td>10003</td>
<td>Push-button SW3</td>
</tr>
<tr>
<td>10004</td>
<td>Push-button SW4</td>
</tr>
<tr>
<td>10005</td>
<td>Push-button SW5</td>
</tr>
<tr>
<td>10006</td>
<td>Not connected – reads as 0</td>
</tr>
<tr>
<td>10007</td>
<td>Not connected – reads as 0</td>
</tr>
<tr>
<td>10008</td>
<td>Not connected – reads as 0</td>
</tr>
<tr>
<td>10009</td>
<td>DIP switch A2F_DIP 1</td>
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<tr>
<td>10010</td>
<td>DIP switch A2F_DIP 2</td>
</tr>
<tr>
<td>10011</td>
<td>DIP switch A2F_DIP 3</td>
</tr>
<tr>
<td>10012</td>
<td>DIP switch A2F_DIP 4</td>
</tr>
<tr>
<td>10013</td>
<td>Not connected – reads as 0</td>
</tr>
<tr>
<td>10014</td>
<td>Not connected – reads as 0</td>
</tr>
<tr>
<td>10015</td>
<td>Not connected – reads as 0</td>
</tr>
<tr>
<td>10016</td>
<td>Not connected – reads as 0</td>
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</tbody>
</table>

Note that when retargeting the reference design to the SmartFusion A2F200-EVAL-KIT board, some of the board resources mapped to Modbus registers are not available or the relevant chip-level I/O signals are connected to other resources. For example, the A2F200-EVAL-KIT board only has push-buttons SW1 and SW2 available for customer use and does not have the A2F_DIP DIP switches at all.
Adding New Registers

New registers can be added by redefining the relevant `REG_<Modbus-register-class>_NREGS` configuration manifest constant where `<Modbus-register-class>` is one of DISCRETE, COILS, INPUT or HOLDING. Once defined, the slave allocates sufficient buffer memory for storing the registers.

Connecting these registers up to hardware board resources requires the modification of the relevant FreeModbus register access handler callback functions `eMBRegDiscreteCB()`, `eMBRegCoilsCB()`, `eMBRegInputCB()`, or `eMBRegHoldingCB()` as well as the possible modification of the Libero SoC hardware project to support the necessary hardware resources.

Adding Support for Additional Modbus Function Codes

By default, the reference design slave provides support for the following Modbus function codes:

- Read Input Register (function code 0x04)
- Read Holding Registers (0x03)
- Write Single Register (0x06)
- Write Multiple Registers (0x10)
- Read/Write Multiple Registers (0x17)
- Read Coils (0x01)
- Write Single Coil (0x05)
- Write Multiple Coils (0x0F)
- Read Discrete Inputs (0x02)
- Report Slave ID (0x11)

See the FreeModbus API documentation [Reference 7] for information about adding support for other Modbus functions by adding callbacks to handle the relevant function codes.
A Libero SoC v10.0 SPB project using the SmartFusion MSS v2.5.106 microcontroller subsystem (MSS) is provided which implements the hardware design on which the reference design slave firmware runs.

**MSS Resources Used**

The reference design Libero SoC hardware project uses the following SmartFusion MSS resources by default:

1. Clock configuration: all clocks (FCLK, ACLK, PCLK0, PCLK1) are 50 MHz, derived from the 100 MHz on-chip RC oscillator.
3. Timers:
   - Timer 1: Used to generate a 50 µs timer interrupt required by FreeModbus for Modbus protocol timing.
   - Timer 2: Used in UART_1/RS-485 communications mode to implement an 8 ms delay for MAXIM MAX3430 RS-485 transceiver transmit/receive turnaround timing and to allow for appropriate settling time when toggling the transceiver’s drive enable/receive enable – DE/REN signals. If RS-485 mode is not being used, MSS Timer 2 is freed up for other use.

In addition to the resources above required for the core Modbus functionality, the following resources are used to implement the demo program and reference design slave Modbus registers:

4. ARM® Cortex™-M3 SysTick: Used by the demo program to generate a 100 ms timer interrupt, from which the ISR is used to synchronize board hardware resources and reference design slave Modbus registers.
5. ACE: Used to implement the RV1 3.3 V pot Modbus input register.
6. RTC: Used to implement the RTC Modbus register.
7. I2C_0: Used to interface to the OLED display for displaying the reference design slave holding registers.
8. GPIOs: Used to interface to LEDs (x4), push-buttons (x5) and DIP switches (x4), which are used to implement the reference design slave Modbus discrete input and coil registers.

**Adapting the Hardware Design**

For the most part, the only changes that might need to be made to the hardware design are those required in order to map additional hardware resources to Modbus slave registers. The reference design slave comes with a set of illustrative Modbus registers mapped to specific hardware board resources.
4 – RS-485 Communications

By default, the reference design firmware SoftConsole project is configured to use MSS UART_0/RS-232 communications. To use MSS UART_1/RS-485 communications on the A2F500-DEV-KIT board, the firmware can easily be reconfigured by defining the MODBUS_PORT manifest constant to be 1 instead of 0. This can be done via the project properties (Properties > C/C++ Build > Settings > GNU C Compiler > Symbols), as shown in Figure 4-1, or the manifest constant can be modified as shown in Figure 4-2 by editing Modbus_MSS_MSS_CM3_0_app/demo/Microsemi_SmartFusion/demo.c.

For RS-485 communications, an appropriate RS-485 based master and RS-485 A/B (also known as D+/D-) plus GND differential encoding twisted pair network cabling is required; optionally bus/multi-drop (multiple slaves connected to a single master) rather than point to point (master to single slave). See [Reference 4] and [Reference 10] for more details about RS-485 network cabling.

When using a PC hosted Modbus master to exercise the reference design slave, an RS-232 to RS-485 converter dongle is usually required since PCs normally do not come with an RS-485 port by default. Examples of such dongles used during the development of the reference design include these:

- DealExtreme.com: www.dealextreme.com/p/rs232-to-rs485-converter-6040

When using Modbus over RS-485, appropriate and timely control of the transceiver’s drive/receive enable signals for half duplex transmit/receive turnaround is critical. Refer to this Netrino® article for some background on this in a general (non Modbus specific) context:

www.netrino.com/Embedded-Systems/How-To/RS-485-Transmit-Enable-Signal

In the reference design, the A2F500-DEV-KIT board’s MAXIM MAX3430 RS-485 transceiver transmit/receive (DE/REn –drive/receive enable) signals are managed by the firmware using the MSS UART_1 modem control RTSn (inverted) and DTRn signals and the MSS Timer 2 is used to allow for settling time on these signals. The approach taken to transmit/receive turnaround management corresponds to option 5 in the Netrino article.
A – References

1. Microsemi SoC Products Group (formerly Actel) System Solutions home page: 
2. Microsemi SmartFusion cSoC home page: 
3. FAQ: www.modbus.org/faq.php
   The Modbus Organization home page: http://www.modbus.org
4. Technical resources including specifications and links to free and commercial Modbus tools and resources: www.modbus.org/tech.php
6. FreeModbus home page: freemodbus.berlios.de/
7. API documentation: freemodbus.berlios.de/api/index.html
8. Examples usage using Modpoll: freemodbus.berlios.de/index.php?id=1
9. 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/#MBACTIVE. A 30 day trial demo version is available for download from Automated Solutions Inc.
   www.automatedsolutions.com/products/modbusrtu.asp
10. Modbus tutorials and overviews
    National Instruments™ Introduction to Modbus: zone.ni.com/devzone/cda/tut/p/id/7675
    AutomatedBuildings.com Introduction to the Modbus Protocol
    Part 1:
    Part 2:
B – List of Changes

List of Changes

The following table lists critical changes that were made in each revision of the chapter.

<table>
<thead>
<tr>
<th>Date</th>
<th>Changes</th>
<th>Page</th>
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<tr>
<td>Revision 3 (January 2013)</td>
<td>Added &quot;Board Settings&quot; section (SAR 43469).</td>
<td>8</td>
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<td>Revision 2 (May 2012)</td>
<td>Modified &quot;Installing the Reference Design&quot; section (SAR 38392)</td>
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<td>Replaced Figure 1-1 (SAR 38392)</td>
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<td>Replaced the command in &quot;Read Coils Registers&quot; (SAR 38392)</td>
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<td>Modified Table 2-1 (SAR 38392)</td>
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<td>Modified the &quot;Installing the Reference Design&quot; section (SAR 36029).</td>
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<td>Modified the &quot;Read Holding Registers&quot; section (SAR 36029).</td>
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<td>Modified the &quot;Using Automated Solution's MiniHMI&quot; section (SAR 36029).</td>
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<td>Modified the &quot;Project Layout&quot; section (SAR 36029).</td>
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<td>Modified the &quot;Slave Firmware Configuration #defines&quot; section (SAR 36029).</td>
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<td>Modified the &quot;Linker Scripts&quot; section (SAR 36029).</td>
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<td></td>
<td>Modified the text listed under &quot;RS-485 Communications&quot; section (SAR 36029).</td>
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<tr>
<td></td>
<td>Changed all the references of Libero IDE to Libero SoC (SAR 36029).</td>
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Note: *The part number is located on the last page of the document. The digits following the slash indicate the month and year of publication.
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