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RFS

UserManual



terasic
www.terasic.com

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Content

Chapter 1	Introduction.....	1
1.1	Package Contents	1
1.2	RFS System CD	2
1.3	Assemble the RFS Daughter Card	2
1.4	Getting Help	5
Chapter 2	RFS Daughter Card	6
2.1	Features	6
2.2	Block Diagram of the RFS Daughter Card	7
2.3	Component Layout.....	7
2.5	Interface for FPGA Host	8
Chapter 3	RTL Example Designs	9
3.1	Query Current Time through Wi-Fi	9
3.2	Bluetooth SPP Slave	12
3.3	Sensor Measurement	17
Chapter 4	Nios II Based Example Designs	21
4.1	Wi-Fi Client	21
4.2	Wi-Fi Server.....	24
4.3	Bluetooth Configuration	28
4.4	Bluetooth SPP Master	33
4.5	Sensor Measurement	40
Chapter 5	Appendix A.....	45
5.1	Revision History	45

Chapter 1

Introduction

The RFS (Radio Frequency and Sensor) daughter card is designed for the applications such as wireless control, environment monitor, and IoT (Internet of Things). The daughter card can be linked to the FPGA development kit via the 2x20 Pin GPIO connector.

The daughter card include Wi-Fi and Bluetooth wireless capabilities and includes a lot of sensors. Sensors include ambient light sensor, temperature sensor, humidity sensor, accelerometer, magnetometer, and gyroscope. An UART-to-USB interface also be provided to communication with Host PC.

1.1 Package Contents

Figure 1-1 shows the RFS kit content. It includes

1. RFS Daughter Card
2. CD Download Guide
3. 40-pin IDC to Box Header Cable

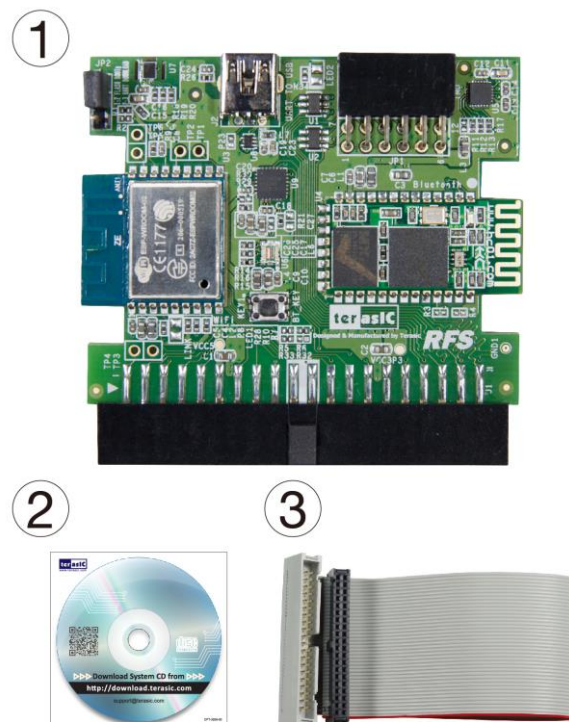


Figure 1-1 The RFS Kit content

1.2 RFS System CD

The RFS System CD contains all the documents and supporting materials associated with the daughter card, including the user manual, reference designs, and device datasheets. Users can download this system CD from the link: <http://rfs.terasic.com/cd>.

1.3 Assemble the RFS Daughter Card

The RFS daughter card can be connected to any FPGA development kit that is equipped with a 2x20 Pin GPIO connector. It can directly connect to the FPGA mainboard or indirectly connect to the FPGA board via a 40-pin IDC Cable. The pictures below show how the RFS daughter card is connected to various Terasic FPGA Boards:

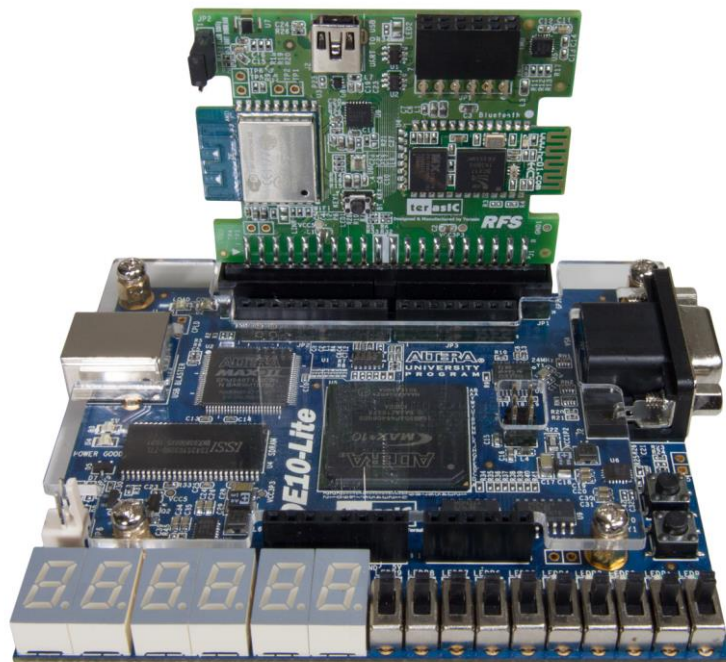


Figure 1-2 Connect the RFS to DE10-Lite directly



Figure 1-3 Connect the RFS to DE10-Lite

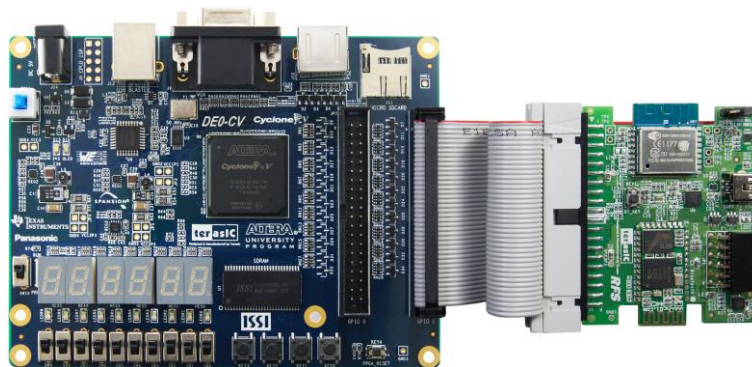


Figure 1-4 Connect the RFS to DE0-CV

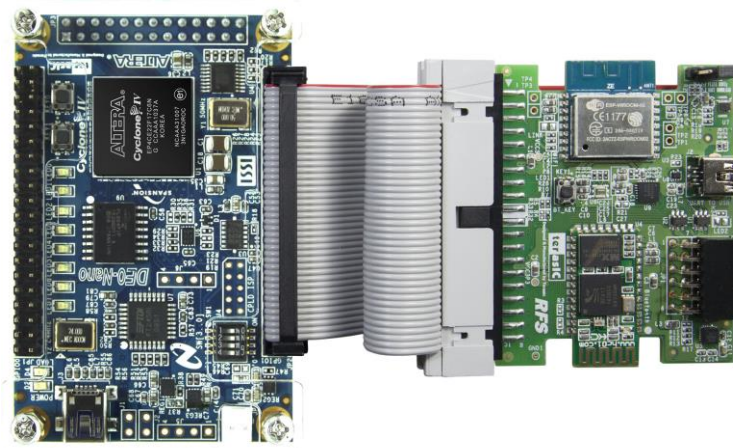


Figure 1-5 Connect the RFS to DE0-Nano

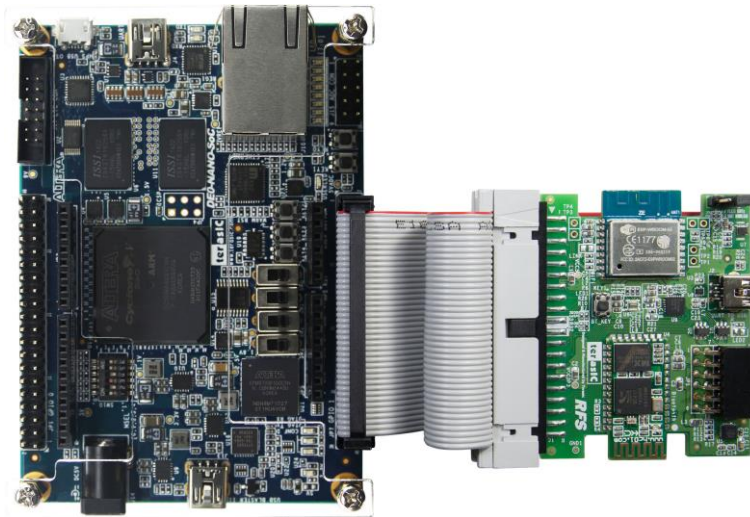


Figure 1-6 Connect the RFS to DE0-Nano-SoC

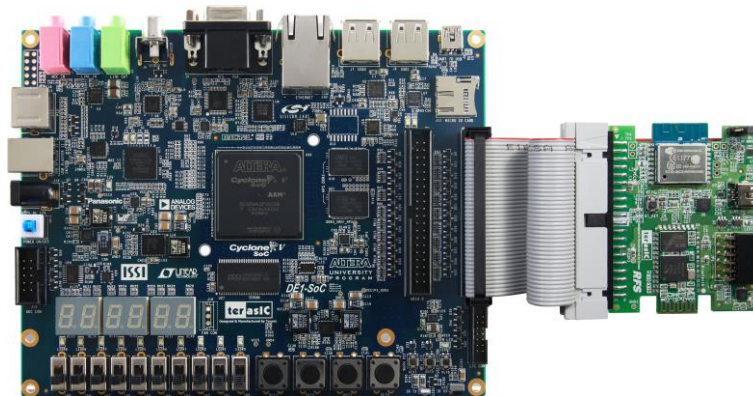


Figure 1-7 Connect the RFS to DE1-SoC

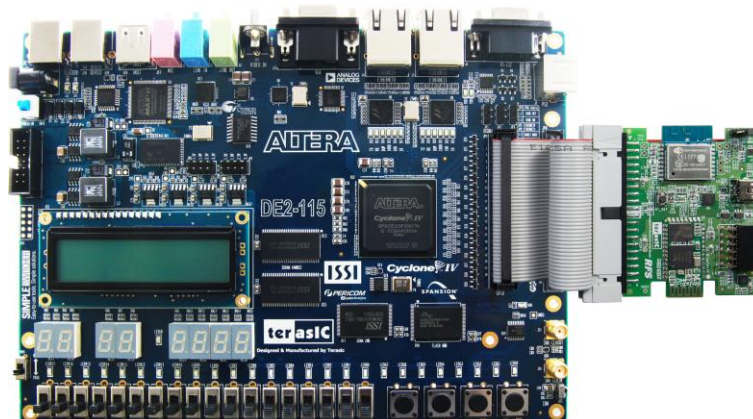


Figure 1-8 Connect the RFS to DE2-115

1.4 Getting Help

Here are the addresses where you can get help if you encounter any problems:

Terasic Technologies

9F., No.176, Sec.2, Gongdao 5th Rd, East Dist, Hsinchu City, 30070. Taiwan

Email: support@terasic.com

Tel.: +886-3-575-0880

Website: <http://rfs.terasic.com>

Chapter 2

RFS Daughter Card

This chapter will introduce the RFS daughter card included in the Kit. The daughter card is interfaced to FPGA mainboard by 2x20 GPIO interface. Except for the uart-to-usb chip, the card is powered from the FPGA mainboard. The 3.3V source in the 2x20 GPIO interface is used to drive this daughter card. The uart-to-sub chip is powered from the USB power which came from host PC.

2.1 Features

Figure 2-1 shows a photograph of the RFS daughter card.

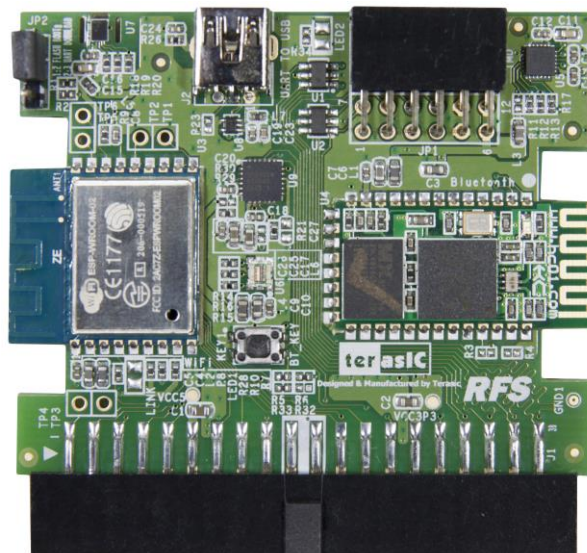


Figure 2-1 RFS Daughter Card

The features of the RFS card are:

- 2x20 GPIO interface
- Wi-Fi, using ESP-WRDDOM-02 module
- Bluetooth SPP, using HC-05 module
- Ambient Light Sensor
- Temperature and humidity sensor
- 9-axis sensor – accelerometer, magnetometer, and gyroscope
- UART to USB
- 2x6 TMD GPIO Header

2.2 Block Diagram of the RFS Daughter Card

Figure 2-2 shows the block diagram of the RFS daughter card. 2x20 GPIO is interface of this daughter card. The sensors can be communicated with I2C interface. Besides I2C, the 9-axis sensor also can be communicated with SPI interface if hi-speed is required. The UART-to-USB interface is 4-pin UART. The Bluetooth module interface is 2-pin UART. The Wi-Fi module interface is 4-pin UART. In the 2x6 TMD header, signals are connected to the 2x20 GPIO header directly.

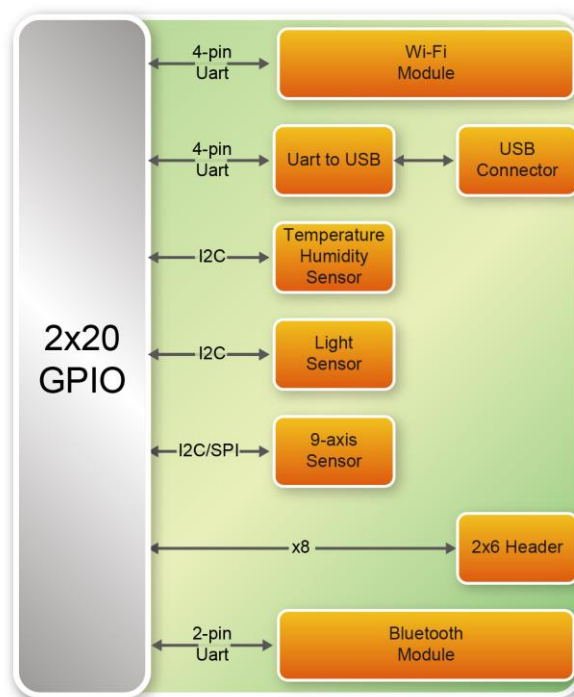


Figure 2-2 Block Diagram of RFS Card

2.3 Component Layout

Figure 2-3 shows the major component layout in the RFS daughter card.

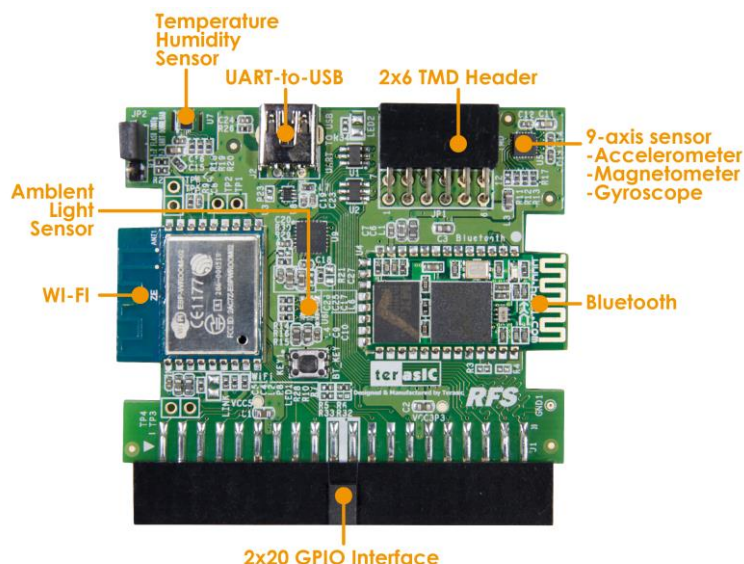


Figure 2-3 Major component layout on the RFS card

2.5 Interface for FPGA Host

The RFS card is connected to the host FPGA through the JP1 - a 2x20 GPIO header as shown in **Figure 2-4**. VCC3P3 power is used to drive this daughter card. BT_UART_CTS and BT_UART_RST is reserved pins. There are total 34 signal pins used.

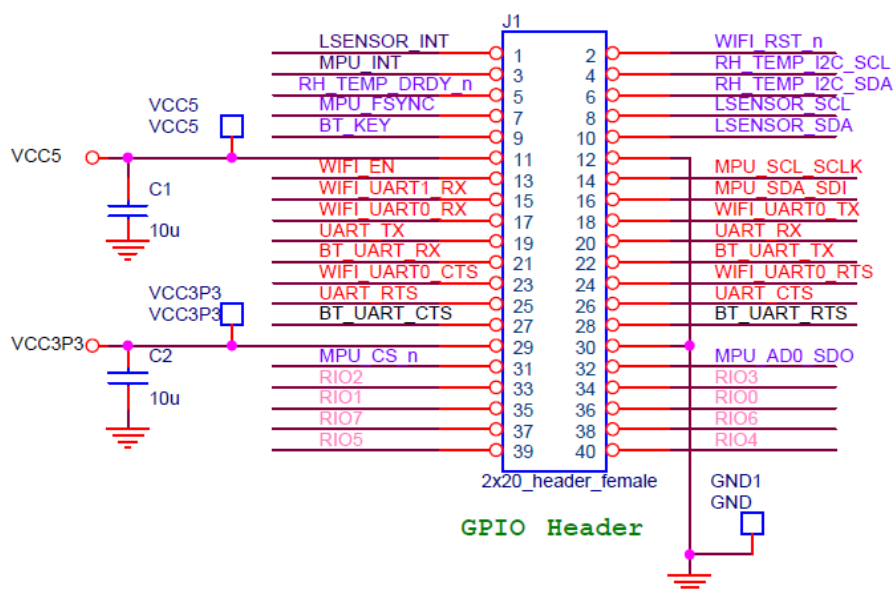


Figure 2-4 2x20 GPIO Pinout

Chapter 3

RTL Example Designs

This chapter will demonstrate how the FPGA to communicate with the RFS daughter card in RTL code.

3.1 Query Current Time through Wi-Fi

This section describe how to the Wi-Fi signal is transmitted via the ESP8266 Wi-Fi module on the RFS daughter card. The command is transmitted from the FPGA to the Wi-Fi module via UART. This demonstration uses the ESP8266 Wi-Fi module to query the current time. If the connection is successful, the current time will be display on the 7-segment of the board in hour:minute:second format.

■ Block Diagram

Figure 3-1 shows the function block diagram of querying current time through Wi-Fi demonstration.

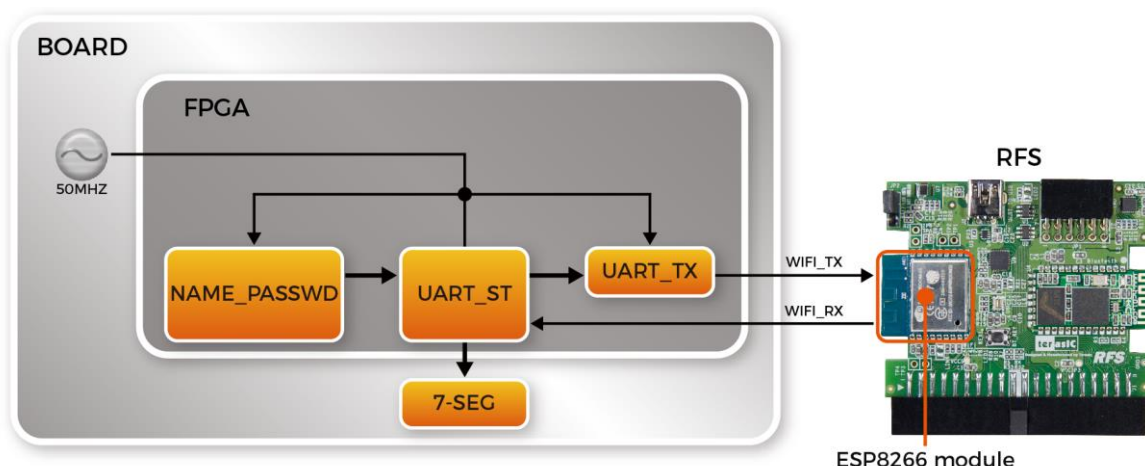


Figure 3-1 Function block diagram of querying current time

NAME_PASSWD: It takes NAME and PASSWORD for the Wi-Fi login. Users can enter up to 20 English, number, or symbol characters for each of them. The module will calculate the length of character in byte automatically.

UART_TX: It is the UART IP from Altera. It is set to Memory mapping with baud-rate at 112500 bps.

UART_ST: It sends a series of command which queries the current time to the ESP8266 Wi-Fi module via the UART IP. The process can be divided to the 7 steps below. If the connection is successful, the current network time in hour:minute:second will be displayed on the 7-segment of

the board.

- Step 1 Reset the ESP8266 Wi-Fi module
- Step 2 Set the ESP8266 Wi-Fi module to the station mode.
- Step 3 Enter the name and password.
- Step 4 Establish the connection
- Step 5 Ready to send out the request.
- Step 6 Send out the request to retrieve the current time.
- Step 7 Read the current time

This demo can be realized on DE2-115 and DE10-Lite. Please follow the steps below for running the demo on these two boards.

■ Quartus Project Information

For DE2-115 Mainboard

Tool	Quartus Prime Standard Edition V16.1.1
Project Directory	Demonstrations\DE2_115_WIFI_TIME_RTL
Demo Batch File	Demonstrations\DE2_115_WIFI_TIME_RTL\demo_batch

For DE10-Lite Mainboard

Tool	Quartus Prime Standard Edition V16.1.1
Project Directory	Demonstrations\DE10_LITE_WIFI_TIME_RTL
Demo Batch File	Demonstrations\DE10_LITE_WIFI_TIME_RTL\demo_batch

■ Demonstration Setup for DE2-115

Please follow the procedures below to setup the demonstration, as shown in **Figure 3-2**.

1. Connect the RFS daughter card to the GPIO of DE2-115 board.
2. Plug in 12 V DC to DE2-115
3. Connect the host PC to the USB connector (J9) on DE2-115 via USB cable.
4. Please make sure Quartus Prime has been installed on the host PC.
5. Search for the key string assign NAME="" and assign PASSWORD="" in DE2_115_WIFI_TIME_RTL.v. Insert user name and password in "", respectively. After the compilation is successful, copy the generated .sof file to \demo_batch.
6. Execute the batch file “ test.bat” under the demo_batch folder of DE2_115_WIFI_TIME_RTL project.
7. Press KEY0 and wait for 15 ~ 20 seconds. The current network time will be displayed on the 7-segment of DE2-115 in decimal hour:minute:second.

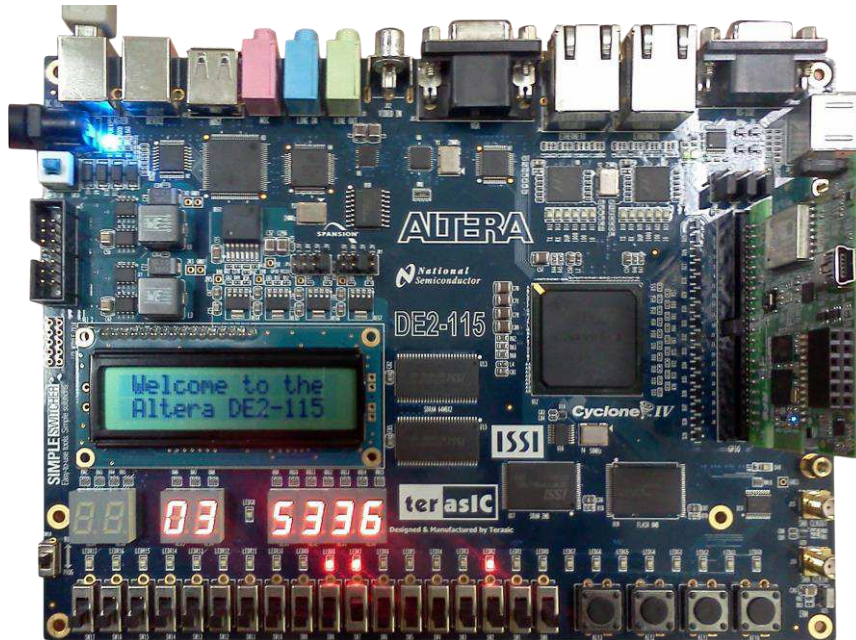


Figure 3-2 Wi-Fi Time setup with DE2-115

■ Demonstration Setup for DE10-Lite

Please follow the procedures below to setup the demonstration, as shown in Figure 3-3

1. Connect the RFS daughter card to the GPIO of DE10-Lite board
2. Connect the host PC to the USB connector (J9) on DE10-Lite via USB cable.
3. Please make sure Quartus Prime has been installed on the host PC.
4. Search for the key string assign NAME="" and assign PASSWORD="" in DE10_LITE_WIFI_TIME_RTL.v. Insert user name and password in "", respectively. After the compilation is successful, copy the generated .sof file to **demo_batch**.
5. Execute the batch file " test.bat" under the demo_batch folder of DE10_LITE_WIFI_TIME_RTL project.
6. Press KEY0 and wait for 15 ~ 20 seconds. The current network time will be displayed on the 7-segment of DE10-Lite in decimal hour:minute:second.

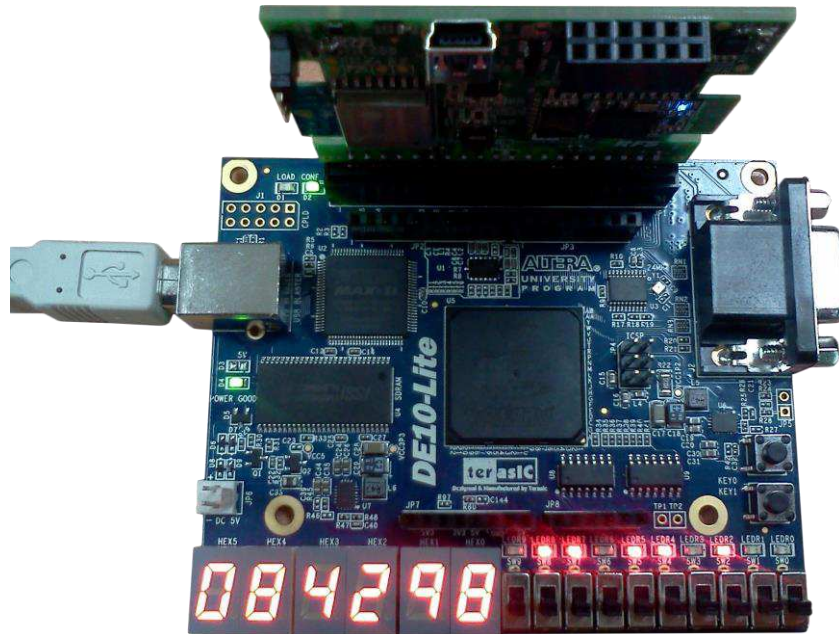


Figure 3-3 Wi-Fi Time Demo setup for DE10-Lite

3.2 Bluetooth SPP Slave

This demonstration shows how to make the HC-05 module in the RFS board to work as a SPP slave. When the SPP slave is launched, it is in standby mode for waiting a SPP connection request from a SPP master. When it accepts a SPP connection from an Android phone, it will be waiting for receiving command from Android phone and interpret the command to control the LED on the FPGA main board.

In this demonstration, Terasic Android TerasicRFS App is used to test the SPP Master. Users also can use other third party Bluetooth SPP APP which is able to send character '0' to '9' to test this demonstration.

■ Block Diagram

Figure 3-4 shows the System Block Diagram of the Bluetooth SPP slave demonstration. In the FPGA board, a **UART Controller** is used to communicate with the HC-05 Bluetooth module. The **Decoder** module is designed to parsing the received command string and control the LEDs on the FPGA main board. The Bluetooth App running on the Android Phone is designed by Terasic. It can discovery the HC-05 device, connect it, and send command string to it.

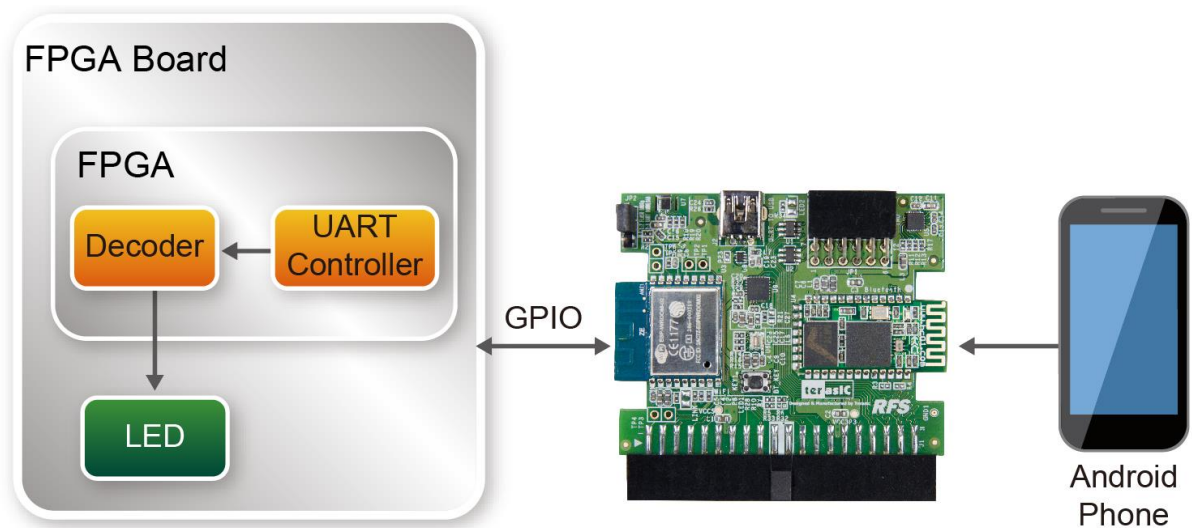


Figure 3-4 Function Block Diagram

■ Communication Protocol

A simple communication protocol is used in this demonstration. One way communication is used in the protocol. The **Decoder** only receive commands from the Android device. It does not response or send any message to the Android device. The command is fixed one-byte length. The valid value is from 0x30(ASCII code of character '0') to 0x39(ASCII code of character '9'). **Figure 3-5** shows the command parsing statement in **Decoder** module. For examples, when 0x30 is received, the LED0 will be turn on. When 0x34 is received, the LED0 will be turn off.

```

case(uart_data)
10'h30:LEDR <= LEDR | 8'd1;
10'h31:LEDR <= LEDR | 8'd2;
10'h32:LEDR <= LEDR | 8'd4;
10'h33:LEDR <= LEDR | 8'd8;
10'h34:LEDR <= LEDR & 8'he;
10'h35:LEDR <= LEDR & 8'hd;
10'h36:LEDR <= LEDR & 8'hb;
10'h37:LEDR <= LEDR & 8'h7;
10'h38:LEDR <= LEDR | 8'hf;
10'h39:LEDR <= LEDR & 8'h0;
default : LEDR <= LEDR;
endcase

```

Figure 3-5 UART data decoder

For SPP mater side, users also can use other third party Bluetooth SPP software to send the commands defined in this demonstration to control the LED on the FPGA main board.

If necessary, designers can expand the one-way communication to two-way communication. Designers can use the `uart_tx` port of the UART Controller to send command to the Android device.

■ Quartus Project Information

For DE10-Lite Mainboard

Tool	Quartus Prime Standard Edition V16.1.1
Project Directory	Demonstrations\DE10_LITE_BluetoothSPP_Slave
Demo Batch File	Demonstrations\DE10_LITE_BluetoothSPP_Slave\demo_batch

For DE2-115 Mainboard

Tool	Quartus Prime Standard Edition V16.1.1
Project Directory	Demonstrations\DE2_115_BluetoothSPP_Slave
Demo Batch File	Demonstrations\DE2_115_BluetoothSPP_Slave\demo_batch

■ Android Project Information

Android project directory: Demonstrations\Android_Project\RFS.

Android APP Installer: <http://www.terasic.com/downloads/demo/rfs/RFS.apk>

■ Demonstration Setup for DE10-LITE

Please follow the procedures below to setup the demonstration as shown in **Figure 3-6**.

1. Power off the DE10-LITE board.
2. Connect the RFS daughter card to the GPIO connector of the DE10-Lite board.
3. Power on the DE10-LITE board.
4. Execute the batch file “ test.bat” under the demo_batch folder of DE10_LITE_BluetoothSPP_Slave project.
5. In your Android device, download the Android TerasicRFS App from the QR code shown **Figure 3-7**.
6. Install TerasicRFS on your Android device and Launch it.
7. For first time to connect HC-05 Bluetooth module, in the TerasicRFS App, click ZOOM icon to discover the **HC-05** and pair it with pin-code “1234” as shown in **Figure 3-8**.
8. Click the ZOOM icon and connect the paired **HC-05** device.
9. In the TerasicRFS App GUI, click the LED0/LED1/LED2/LED3 and ON/OFF icons to control the LED on DE10-Lite.

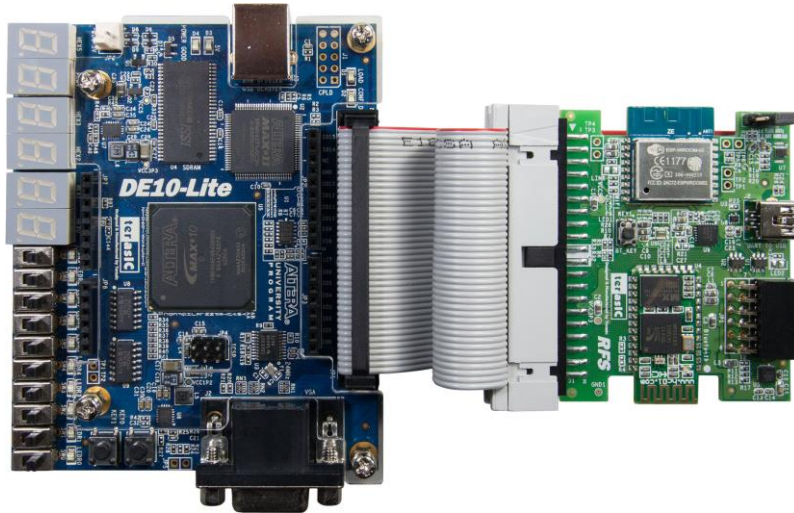


Figure 3-6 Demo setup to DE10-Lite

Note, the QR code link to:

<http://www.terasic.com/downloads/demo/rfs/RFS.apk>



Figure 3-7 Android QR Code



Figure 3-8 TerasicRFS Application UI

■ Demonstration Setup for DE2-115

Please follow the procedures below to setup the demonstration as shown in **Figure 3-9**

1. Power off the DE2-115 board.
2. Connect the GPIO0 output of the DE2-115 board to the RFS board.
3. Power on the DE2-115 board.
4. Connect a USB cable between the host PC and the USB BLASTER (J9) on the DE2-115.
5. Execute the batch file “ test.bat” under the demo_batch folder of DE2-115_BluetoothSPP_Slave project.
6. In your Android device, download the Android TerasicRFS App from the QR code shown **Figure 3-7**.
7. Install TerasicRFS on your Android device and Launch it.
8. The first time connecting to the HC-05 Bluetooth module, in the TerasicRFS App, click ZOOM icon to discover the **HC-05** and pair it with pin-code “1234” as shown in **Figure 3-8**.
9. Click the ZOOM icon and connect the paired DE2-115 device.
10. In the TerasicRFS App GUI, click the LED0/LED1/LED2/LED3 and ON/OFF icons to control the on the DE2-115.

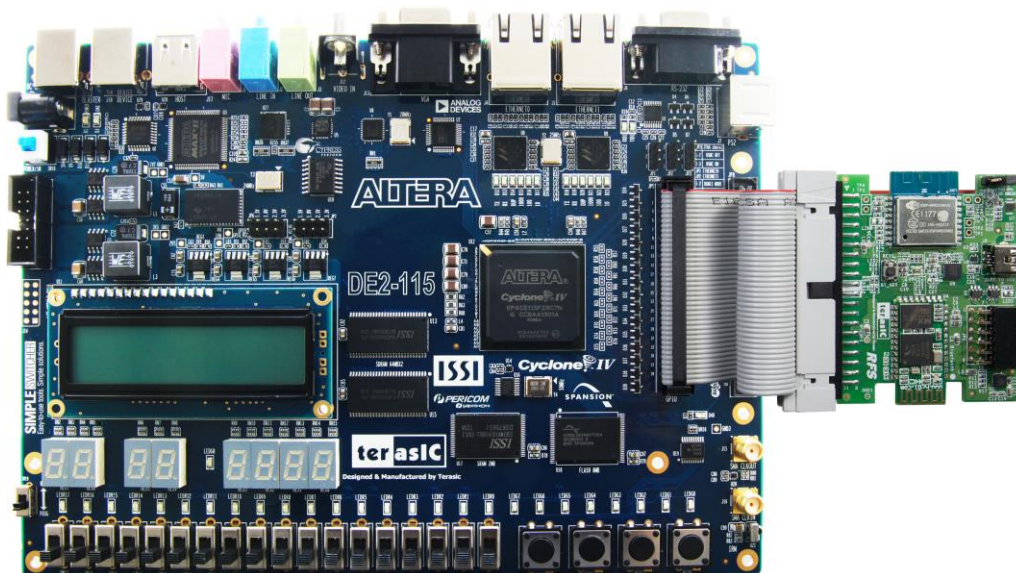


Figure 3-9 Demo Setup for DE2-115

3.3 Sensor Measurement

This part consists of three independent I2C controllers. Each of the I2C controllers is responsible for retrieving the measurement of corresponding sensor on RFS daughter card. The three sensors include humidity, temperature, light photo sensor, and 9-axis sensor which is the combination of 3-axis gyroscope, 3-axis accelerometer, and 3-axis magnetometer. The measurements of these three sensors can be displayed on the 7-segments onboard by the selection of switch settings.

■ Block Diagram

Figure 3-10 shows the function block diagram of Sensor Measurement demonstration.

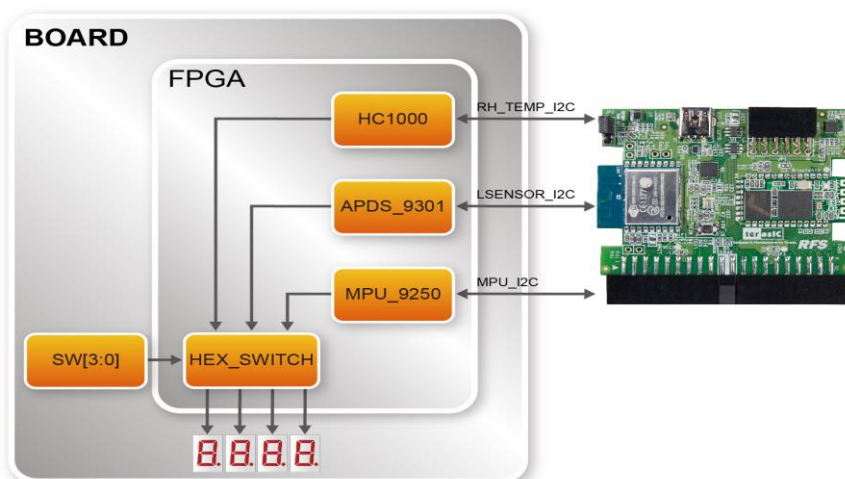


Figure 3-10 Function block diagram of sensor measurement

HC1000: It controls the HDC1000 IC on RFS daughter card via I2C bus. It can retrieve the measurement of humidity and temperature from the slave address 0x80. The values of humidity and temperature can be represented in decimal after conversion in percentage and degrees, respectively.

APDS_9301: It controls the APDS9301 IC on RFS daughter card via I2C bus. It can retrieve the measurement of light photo sensor from ADC0 and ADC1 via slave address 0x52. The length of these two sets are 16-bit.

MPU_9250: It controls the MPU9250 IC on RFS daughter card via I2C bus. There are two ICs integrated into a single MPU9250 chip. One is the accelerometer, which can be accessed from slave address 0xD0 or DxD2 when the pin AD0_SDO = 1, and the other one is AK8963 as magnetometer, which can be accessed from slave address 0x18, provided the register 0x37 of MPU9250 is set to 0x02 (I2C bypass mode). The usage is similar to several I2C slave devices in parallel for the three measurements of MPU9250 (accelerometer, gyroscope, and magnetometer). Each one has x-y-z axis and each axis can be represented in 16-bit in 2's complement for positive and negative values. This module integrates the total of 9 sets of 16-bit data and outputs these values simultaneously.

HEX_SWITCH: This module takes total of 12 sets of data (one for humidity and temperature, another two for light photo sensor, and the last nine from 9-axis sensor) from the three independent modules above. The values can be represented on the 7-segments onboard separately by the SW[3:0] onboard, as shown in Table 3-1.

Table 3-1 The Settings of SW[3:0] and Corresponding Values

SW[3:0]=	Description	Format of HEX[3:0]
0	Humidity and temperature	HEX[3:2] for humidity (positive) in decimal HEX[1:0] for temperature (positive) in decimal
1	Light Sensor ADC0 (DATA0)	hexadecimal (positive)
2	Light Sensor ADC1 (DATA1)	hexadecimal (positive)
3	Accelerometer X	hexadecimal (positive/negative)
4	Accelerometer Y	hexadecimal (positive/negative)
5	Accelerometer Z	hexadecimal (positive/negative)
6	Gyroscope X	hexadecimal (positive/negative)
7	Gyroscope Y	hexadecimal (positive/negative)
8	Gyroscope Z	hexadecimal (positive/negative)
9	Magnetometer X	hexadecimal (positive/negative)
10	Magnetometer Y	hexadecimal (positive/negative)
11	Magnetometer Z	hexadecimal (positive/negative)

This demo can be realized on DE2-115 and DE10-Lite. Please follow the steps below for running the demo on these two boards.

■ Quartus Project Information

Tool: Quartus Prime Standard Edition V16.1.1.

Project directory: Demonstrations\DE2_115_RFS_SENSOR_RTL

Demo batch file folder: Demonstrations\DE2_115_RFS_SENSOR_RTL\demo_batch

■ Demonstration Setup for DE2-115

Please follow the procedures below to setup the demonstration, as shown in **Figure 3-11** Demo setup with DE2-115

1. Connect the RFS daughter card to the GPIO of DE2-115 board.
2. Plug in 12 V DC to DE2-115
3. Connect the host PC to the USB connector (J9) on DE2-115 via USB cable.
4. Please make sure Quartus Prime has been installed on the host PC.
5. Execute the batch file “ test.bat” under the demo_batch folder of DE2_115_RFS_SENSOR_RTL project.
6. Set SW[3:0] to the corresponding positions, as shown in **Table 3-1**, for the measurement. .

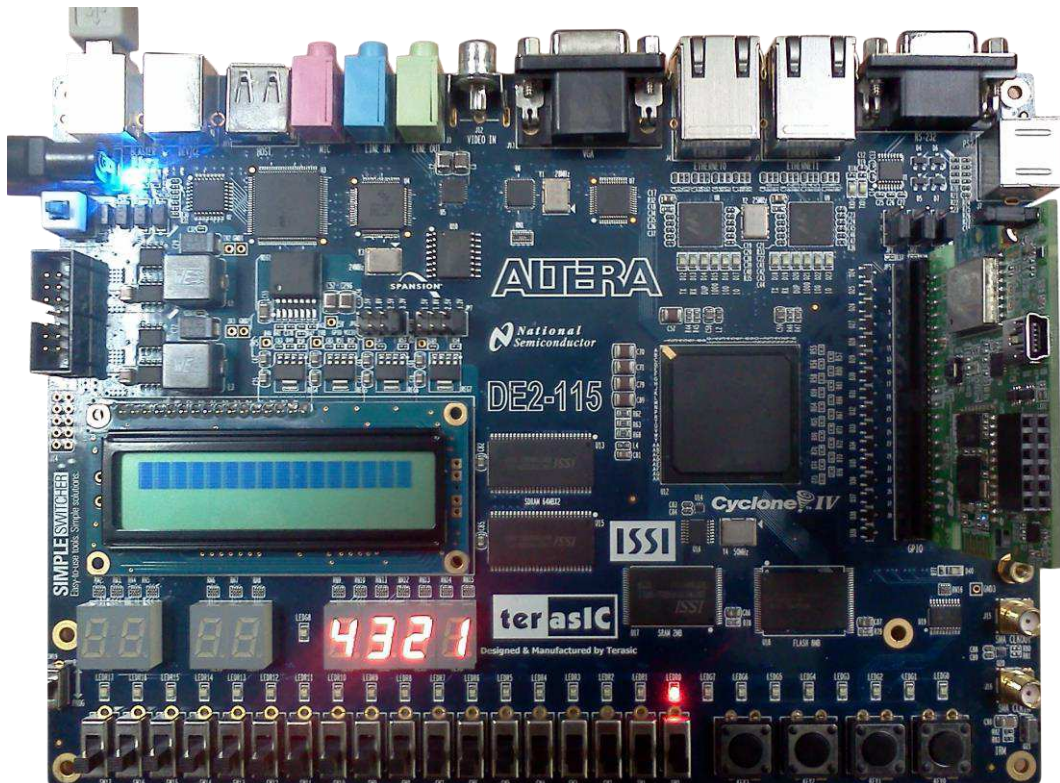


Figure 3-11 Demo setup with DE2-115

■ Demonstration Setup for DE10-Lite

Please follow the procedures below to setup the demonstration, as shown in **Figure 3-12**.

1. Connect the RFS daughter card to the GPIO of DE10-Lite board
2. Connect the host PC to the USB connector (J3) on DE10-Lite via USB cable.
3. Please make sure Quartus Prime has been installed on the host PC.
4. Execute the batch file “ test.bat” under the demo_batch folder of DE10_LITE_RFS_SENSOR_RTL project.
5. Set SW[3:0] to the corresponding positions, as shown in **Table 3-1**, for the measurement. .

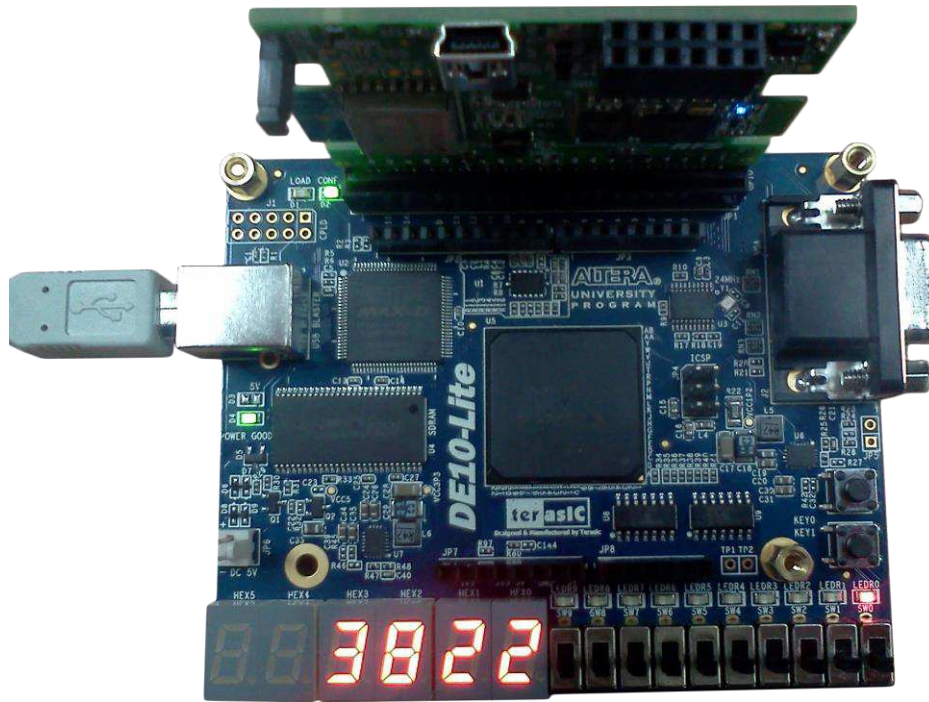


Figure 3-12 Demo setup for DE10-Lite

Chapter 4

Nios II Based Example Designs

This chapter will demonstrate how the FPGA to communicate with the RFS daughter card based on Nios II processor.

4.1 Wi-Fi Client

This demonstration shows how clients use timing web server and query the internet time through the Wi-Fi module on the RFS daughter card. The time information will be shown on the 7-segment with the format HH:MM:SS.

In this demonstration, a Wi-Fi AP is required so the demo program can connect to the internet through the Wi-Fi module. Before accessing the Wi-Fi AP, users need to input the SSID and password for the Wi-Fi AP.

■ Block Diagram

Figure 4-1 shows the function block diagram of the Wi-Fi Client demonstration. The **UART Controller** is used to communicate with the Wi-Fi module on RFS daughter card. The **7-Seg Controller** is used to control the six 7-segment to display time information. These controllers are controlled by the Nios II processor through the Avalon memory-mapped bus. The Nios II program is running on on-chip memory.

First, the Nios II program sends “http get” request to the timing web server through the **UART Controller**. Then, the Nios II program receives responded data from the timing web server. Finally, the Nios II program parsing the responded data to extract the timing information, and display the information on the 7-segment display.

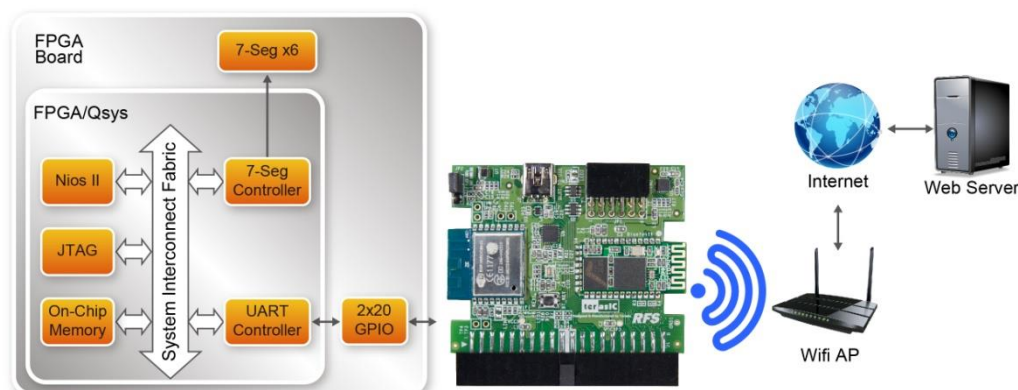


Figure 4-1 Function Block Diagram

■ How to Query Internet Time

The internet time information is available on the web <http://www.timeapi.org>. Sending URL <http://www.timeapi.org/utc/now?\\I:\\M:\\S> to the web server, it will response current time in format HH:MM:SS.

■ Quartus Project Information

For DE10-Lite Mainboard

Tool	Quartus Prime Standard Edition V16.1.1
Project Directory	Demonstrations\DE10_LITE_WiFi_Network_Time
Demo Batch File	Demonstrations\DE10_LITE_WiFi_Network_Time\demo_batch

For DE2-115 Mainboard

Tool	Quartus Prime Standard Edition V16.1.1
Project Directory	Demonstrations\DE2_115_WiFi_Network_Time
Demo Batch File	Demonstrations\DE2_115_WiFi_Network_Time\demo_batch

■ Demonstration Setup for DE10-Lite

Please follow the procedures below to setup the demonstration as shown in **Figure 4-2**.

1. Connect the RFS daughter card to the GPIO connector of the DE10-Lite board.
2. Make sure the jumper is located at pin 1-2 on the JP2 of RFS daughter card.
3. Connect a USB cable between the host PC and the USB connector (J3) on the DE10-Lite.
4. Execute the batch file “test.bat” under the demo_batch folder of DE10_LITE_WiFi_Network_Time project. A Nios II terminal will appear.
5. Input SSID of your WiFi AP according to the prompt in Nios II terminal. The terminal will not display the SSID.
6. Input password of your WiFi AP according the prompt in the Nios II terminal. The terminal will not display the password.
7. The UTC(Universal Time Coordinated) time will be display on the six 7-segement as shown in **Figure 4-3**.



Figure 4-2 Setup ESP8266 Client Demo

```
nios2-terminal: connected to hardware target using JTAG UART on cable
nios2-terminal: "USB-Blaster [USB-0]", device 1, instance 0
nios2-terminal: (Use the IDE stop button or Ctrl-C to terminate)

Hello from Nios II!
Network Name (SSID) List:
AT+CWLAP
+CWLAP:("Terasic")

OK
Enter the Network Name (SSID):
Enter the Password of Network Name (SSID):
Connecting to WiFi AP (SSID: Terasic)
Connect to WiFi AP successfully
time: 07:54:33
time: 07:54:33
time: 07:54:34
time: 07:54:34
```

Figure 4-3 WiFi_Network_Time Demo

■ Demonstration Setup for DE2-115

Please follow the procedures below to setup the demonstration as shown in **Figure 4-4**.

1. Connect the RFS daughter card to the GPIO connector of the DE2-115 board.
2. Make sure the jumper is located at pin 1-2 on the JP2 of RFS daughter card.
3. Connect a USB cable between the host PC and the USB connector (J9) on the DE2-115.
4. Execute the batch file "test.bat" under the demo_batch folder of DE2_115_WiFi_Network_Time project.
5. Input SSID of your WiFi AP according to the prompt in the Nios II terminal. The terminal will not display the SSID.
6. Input the password for your WiFi AP according to the prompt in the Nios II terminal. The terminal will not display the password.
7. The UTC(Universal Time Coordinated) time will be displayed on the six 7-segement as shown in **Figure 4-3**.