Introduction to Mechatronics (ME/AE 6705)

Lab Assignment 4

Serial Communication Using UART

Objective

The main objective of this lab is to write a program that establishes 2-way serial communication between the MSP432 and a PC/laptop via UART. The lab makes use of the Driverlib library, although you are welcome to use direct register access instead if desired.

Deliverables and Grading

To get credit for this lab assignment you must:

1. Submit a typed report as a PDF file to Canvas, answering the questions at the end of the lab (2 pages max, can be shorter). This is due at the beginning of class on the due date specified on Canvas. (40 points)

2. Demonstrate proper operation of your code to TAs or instructor during the office hours or demo hours. You must write your own code for this lab – no lab groups are allowed. (40 points)

3. Submit the commented final version of your code on Canvas *(single .c file containing your main() function, do not submit header files, etc. You should only submit a single file)*. (Pass/Fail)

Setup

This lab requires Code Composer Studio, a SSH terminal (Putty for Windows and Linux, Terminal for MacOS) and the MSP432 LaunchPad. The lab uses only the onboard electronics of the MCU and a USB cable. The MSP432 LaunchPad contains two Enhanced Universal Serial Communication Interface (eUSCI) modules: eUSCI_A and eUSCI_B. The A module supports UART and SPI mode whereas the B module supports SPI and I2C modes. The MSP can be used with up to eight serial communication channels. This lab focuses on configuring and using the MSP432 in the Universal Asynchronous Receiver Transmitter (UART) mode.

Note: To create a new CCS project for the MSP432P401R target device, and include the DriverLib library in the project, follow the procedure described in Lab Assignment 2. The driverlib folder is available on Canvas.

Problem Statement

Write a program to transmit and receive data between the PC and MSP432 over UART. The program should receive data from the SSH terminal console, and then echo it back. Specifically, the MSP432 should receive data from the SSH terminal, storing all data in a character buffer. When a carriage return character is received (generated on the keyboard by the "enter" or return key), it should transmit the entire buffer back to the SSH terminal terminal (this is called "echoing"). It should then clear the buffer and wait for the next line of text to come in. This echoing process is repeated in an infinite loop.

You must use either a receive interrupt or transmit interrupt, or both. If you choose to use only one, you should use polling for the other functionality.

Your buffer should hold at least 200 characters. When data is echoed back to the terminal (upon hitting return or enter), your data should append a carriage return and newline character at the end to move to the next line in the SSH terminal.

Background

UART:

Communication between two devices can be serial or parallel. In serial communication, data is transferred one bit at a time, as opposed to multiple bits in parallel communication. Serial communication is typically used in applications where I/O pins are limited and clock synchronization requirements make parallel communication difficult.

Serial communication can be further subdivided into two categories: Synchronous communication and Asynchronous communication. Synchronous communication uses a data channel to transmit data and a clock channel to maintain synchronism. In asynchronous mode, only a data channel is used and data is transmitted at a certain baud rate. The clock channel is absent in asynchronous communication – rather, clock signals and baud rate are separately generated on each individual device. Synchronous communication is used in applications that require continuous communication between two devices whereas asynchronous communication is used when intermittent communication is acceptable or required.

UART is a hardware device that implements asynchronous communication. The communicating devices first agree on a baud rate. Data is transmitted in groups of 8 bits with parity (optional) and other optional bits as available on the communicating devices. The data packet also consists of one start bit and one or two stop bits. All of these settings are matched for both devices during their respective configurations.

Once configured, data can be transmitted by writing to the `TXBUF` register or by using the function `UART_transmitData(EUSCI_A0_BASE)` from the Driverlib library. Similarly, received data is accessed by reading `RXBUF` or using the function:

`UART_receiveData(EUSCI_A0_BASE).`

Flags are raised when transmission or reception of data are complete. The transmission complete flag `TXIFG` is raised when all the data is transmitted and there is no more data in `TXBUF`. This flag is cleared by writing data to be transmitted to the `TXBUF`. Similarly, the receive complete flag `RXIFG` is raised when a complete character (8 bits) is received. This flag is cleared by reading the `RXBUF` register. When these flags are raised, if enabled, corresponding interrupts are also triggered. The interrupt subroutine can then be used to either transmit new data or to read the received data.

Note: All received data from the SSH terminal console will be encoded in ASCII format, since it will be typed at the keyboard. To determine the hex equivalent of an ASCII character, consult the ASCII encoding table found at: http://www.asciitable.com/

Steps:

The program has to establish successful communication between microcontroller and computer. Initialize the UART module using the functions from the driverlib library as discussed in class. First select a baud rate to use (standard baud rates are 9600, 38400, or 57600). The configuration parameters (clock divider and other register values) can be computed from

http://software-dl.ti.com/msp430/msp430_public_sw/mcu/msp430/MSP430BaudRateConverter/index.html

Use a clock rate of 3 MHz, which is the default clock rate of the MSP432. Your UART configuration should use the above baud rate configuration parameters, the SMCLK source, no parity, LSB first, UART A mode, and one stop bit.

At the beginning of your main function you should configure the clock. Use the following commands to set up the clock:

```
void main()

{

    unsigned int dcoFrequency = 3E+6;

    MAP_CS_setDCOFrequency(dcoFrequency);

    MAP_CS_initClockSignal(CS_SMCLK,CS_DCOCLK_SELECT,CS_CLOCK_DIVIDER_1);

    // do stuff

}
```

Note: Don't forget to stop the watchdog timer as the first step in your main function.

Follow the rest of the steps from the lecture to set up and initialize the UART. Also consult the Driverlib reference manual and MSP432 technical reference manual for guidance as you set up your code.

Recommended SSH terminals for different operating systems

Putty Configuration (for Windows):

Download Putty (which is free). In the Connection Type field on the home screen, select "Serial". Place the baud rate in the Speed window. After plugging in the MSP432, go to Device Manager and look for "XDS110 Class Application/User UART". The COM port listed (COM1, COM4, COM5, etc) is the COM port where the UART is found. Type this COM port in the Putty Serial line field.

Then go to the Serial window on the left. Match the data bit, stop bit, and parity configurations you used in your code. Turn Flow control to XON/XOFF. You can then save this configuration by going back to the Session window, typing a name in the Saved Sessions field, and clicking Save. To load the configuration, click on it and select Load.

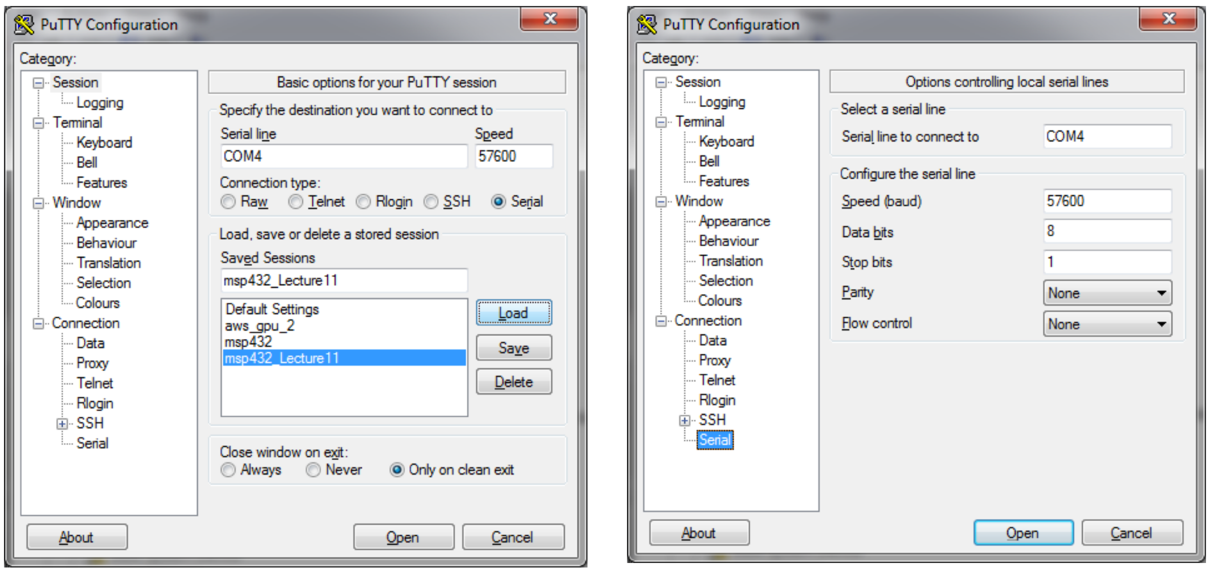
To connect to the MSP432, you must do the following:

The shorter approach:

- Start Putty and open your session as described above
- Start Code Composer Studio and program the MSP432 using the debug button
- Once the code hits its initial breakpoint, terminate the Debug session in Code Composer Studio by hitting the red square “stop” button
- You should then be able to communicate with the MSP via the Putty console

If that doesn’t work, follow the longer approach:

- After programming the MSP432, close both Putty and Code Composer Studio
- Unplug the board
- Plug the MSP432 back in
- Start Putty and Open your session without starting Code Composer Studio
- You should then be able to communicate with the MSP via the Putty console


PuTTY Configuration

Basic options for your PuTTY session

Specify the destination you want to connect to

Serial line: COM4

Speed: 57600

Connection type: Raw Telnet Rlogin SSH [✓ Serial]

Load, save or delete a stored session

Saved Sessions: msp432_Lecture11

Default Settings
aws_gpu_2
msp432
msp432_Lecture11

Close window on exit: Always Never [✓ Only on clean exit]

PuTTY Configuration

Options controlling local serial lines

Select a serial line

Serial line to connect to: COM4

Configure the serial line

Speed (baud): 57600

Data bits: 8

Stop bits: 1

Parity: None

Flow control: None

Figure 1: Putty Configuration in Windows

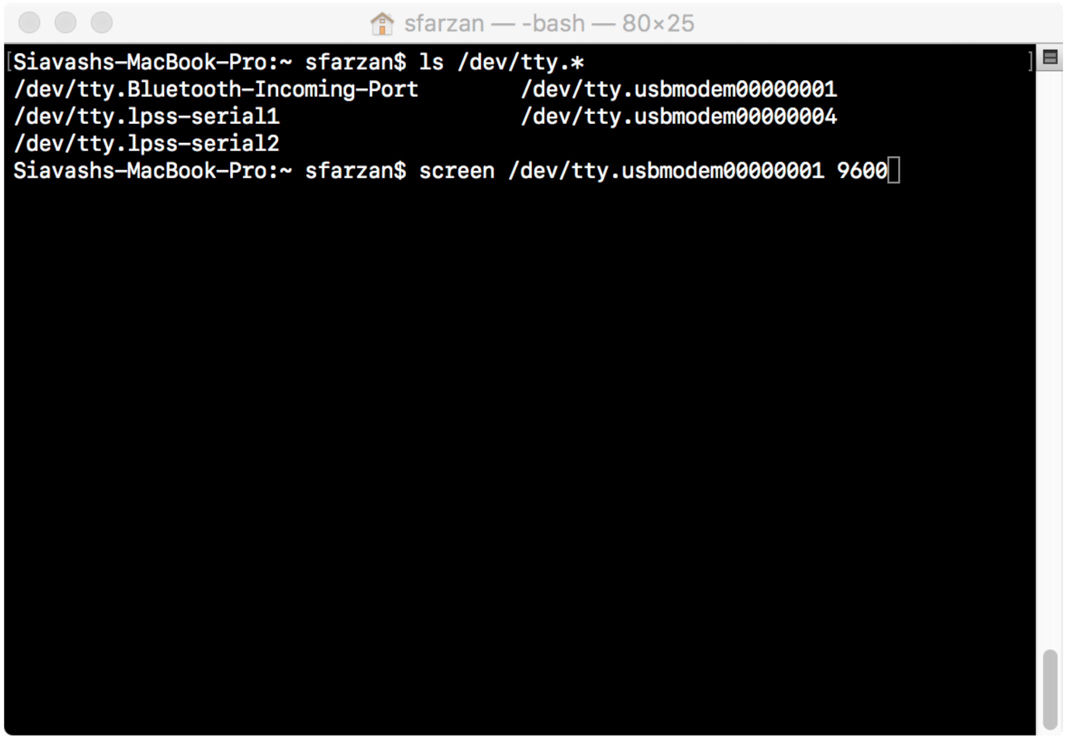
Terminal Configuration (for MacOS):

Terminal app is a terminal emulator included in the macOS operating system by default.

To start Terminal, go to your Mac’s Applications folder, click on the Utilities folder, and then click on Terminal.

- Connect the MSP432 Dev board to a USB port of your Mac
- Type **ls /dev/tty.*** to list the serial devices on your Mac and find the one you want to connect with (it starts with /dev/tty.usbmodem).
- Type **screen /dev/tty.usbmodem00000001 9600**

(replace **/dev/tty.usbmodem00000001** with the right one listed on your Mac and also replace **9600** with the baud rate you have selected) to start the connection to the serial port of the MSP432 dev board.



```
Siavashs-MacBook-Pro:~ sfarzan$ ls /dev/tty.*
/dev/tty.Bluetooth-Incoming-Port        /dev/tty.usbmodem00000001
/dev/tty.lpss-serial1                   /dev/tty.usbmodem00000004
/dev/tty.lpss-serial2
Siavashs-MacBook-Pro:~ sfarzan$ screen /dev/tty.usbmodem00000001 9600
```

Figure 2: Terminal Configuration

- You should then be able to communicate with the MSP432 LaunchPad via the Terminal console.
- To stop the communication, close the session by: **control+a**, then **k**, then **y**.

Requirements

1. Successfully demonstrate your program and all the required functionalities to TAs or instructor.

2. Submit the commented final version of the code on Canvas.

3. Answer the below questions and submit the typed report to Canvas.

Questions

1. Suppose you are using a baud rate of 38400. How far off can the clock rate of your two devices be before you start reading data incorrectly? Do not use the 5% approximation, but rather compute the answer exactly. How does it compare to the 5% approximation?

2. Suppose your clock signals differ by more than the amount in Question 1. What error flag would you expect to see, in what register? Why would this error flag get triggered in this situation?

3. How could you solve the above problem (i.e., by changing the baud rate)? What is the inherent performance penalty associated with this solution?