CSE466 LAB 3 – Electric field sensing, Phase 1

AUTUMN 2011

OBJECTIVES

In this lab you will DO the following:

- Develop a software UART implementation
- Develop a multichannel electric field sensor

In this lab you will LEARN the following:

- Asynchronous serial communication methods
- How to use the ADC10 peripheral
- Basics of electric field sensing
- Code division multiplexing methods

DELIVERABLES

Lab 3 is split into two phases spanning two lab weeks. The deliverables for each phase are due at the beginning of the lab period in the specified week.

PHASE 1, DUE OCT 25TH

- Demo of single-channel electric field sensor.
- Demo of UART transmit functionality.

PHASE 2, DUE NOV 1ST

- Demo of multiple channel electric field sensing, using CDM technique for channel separation.
- Demo of PC-side GUI for your multichannel electric field sensor.
- A PDF containing answers to all questions posed in this lab prompt.
- Your fully commented and neatly presented code, in a zipped format.

RESOURCES

These documents and web resources will be useful in completion of the lab and/or in answering the questions posed.

- MSP430F2012 Datasheet
- MSP430F20XX Family User's Guide
- MSP430 Code Examples
- MSP430 Software Coding Techniques
- MSP430 Optimizing C/C++ Compiler User's Guide

PART 1 (PHASE 1): TALKING TO THE PC

Before building the electric field sensor, you will implement a communication link between the MSP430 and desktop PC. This will allow for simple debugging while constructing the electric field sensor.

SOFTWARE UART

The most common type of serial interface found on desktop computers is a RS-232 compatible Universal Asynchronous Receiver/Transmitter (UART) port, which allows for asynchronous (no clock signal) communication between the computer and peripherals. This interface can be implemented by as little as two signal wires, one for received data and one for transmitted data.

The Universal Serial Interface (USI) is a peripheral on the F2012/F2013 which provides several modes of synchronous serial data transfer for communication between the MSP and external peripherals or other processors. Unfortunately, the USI (unlike the "USCI" peripheral on larger MSP430 devices) does not support asynchronous serial communication. So in order to communicate with the PC, you will need to **write your own software UART** implementation for the MSP430.

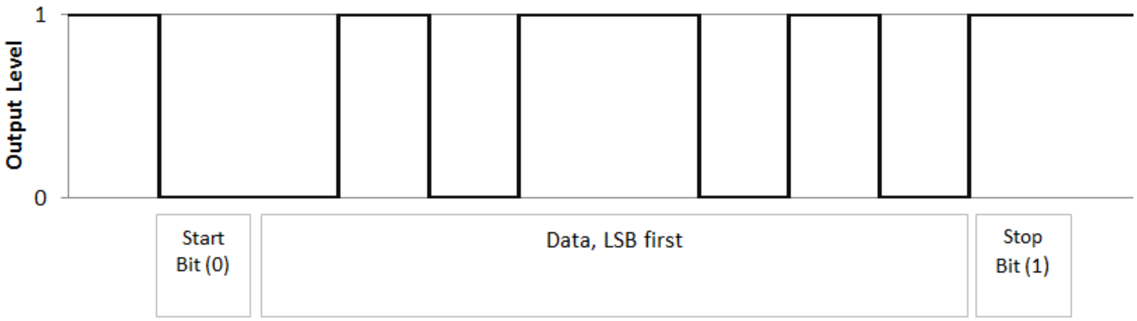

Figure 1. Transmitting the byte 0x5A using the common "8 N 1" asynchronous mode.

TEXT FORMATTING

In addition to simply communicating with the PC, a method of producing readable ASCII text to display on the user's terminal will need to be developed. There are three sprintf() implementations provided by TI, but they either don't work well or won't fit on the F2012. No itoa() function is implemented in the MSP430 libraries. You will therefore need to write your own string formatter.

<u>HINTS:</u>

- The USB debugger includes a virtual COM port for UART communication. Its maximum baud rate is 9600 bps.
- Producing a parity bit is not required, but will decrease the chance of corrupt data or framing errors.
- Packaging your UART functionality into its own set of source files (with a public interface) will make life easier.
- The native instruction set of the MSP includes binary-coded decimal (BCD) instructions.

Question 2.1: Describe your method for producing the asynchronous serial waveform (1-2 paragraphs).

PART 2 (PHASE 1): SINGLE-CHANNEL E-FIELD SENSING

In this section you will construct the electric field sensor hardware and characterize its operation with a single transmitter channel.

THEORY OF OPERATION

An electric field sensor measures minute variations in capacitance between two open plate terminals due to the effects of a nearby conductive body (your hand). In the form of E-field sensing which you will implement in this lab, the method used to measure capacitance of the plate terminals involves measuring the magnitude of the current between the receive plate and the ground node when the transmitting plate voltage is switched abruptly (from “hi” to “lo” or vice versa. The magnitude of the current spike at the receiver indicates the capacitance value, which in turn can be used to determine the position of your hand above the sensor plates.

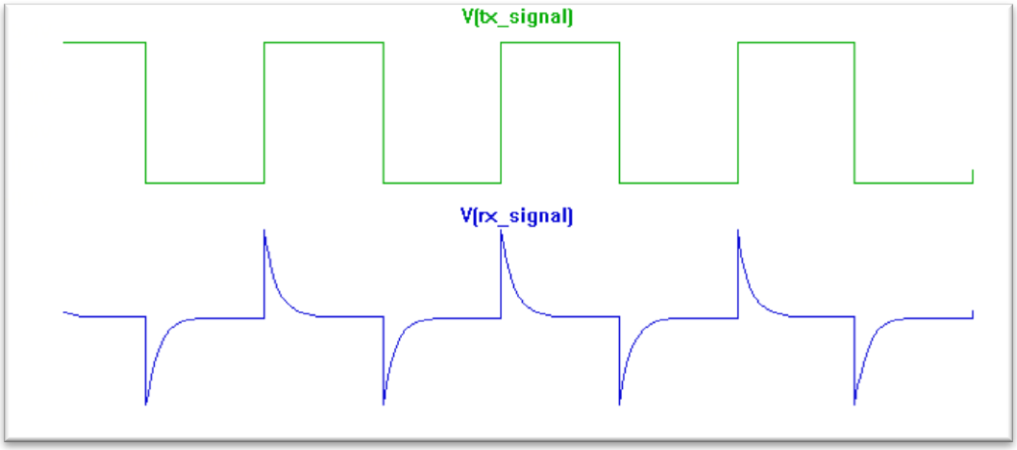

Figure 2. Transmitted (top) and received (bottom) electric field sensor signals

IMPLEMENTATION DETAILS

You will need to sample the value of the received signal directly after the transmitter switches from LO to HI or from HI to LO. The difference between the positive peak voltage and the negative peak voltage should be accumulated (summed) over many cycles of the transmit waveform in order to get an accurate reading:

$$\text{Sensor Value} = \sum_{t=0}^{N} (1.0)S_{2t} + (-1.0)S_{2t+1}$$

In addition to accumulating the values over many cycles, you will also need to run the acquired signal through a low-pass filter. A simple formula used to produce a discrete IIR (infinite impulse response) low-pass filter is shown below:

$$y[t] = (1-a)x[t] + ay[t-1]$$

The MSP430F2012 (not the F2013) will be used in this lab because it includes the ADC10 peripheral. This successive approximation register (SAR) ADC has a much higher maximum sampling rate than the SD16 ADC used in the MSP430F2013. A higher sampling rate will be advantageous in this sensor application, as it allows the received signal to be sampled very quickly after the transmitted signal edge, leading to a better signal-to-noise ratio (SNR). As an additional benefit, the ADC10 may be triggered by the TIMER_A module if desired which could free the CPU for other tasks.

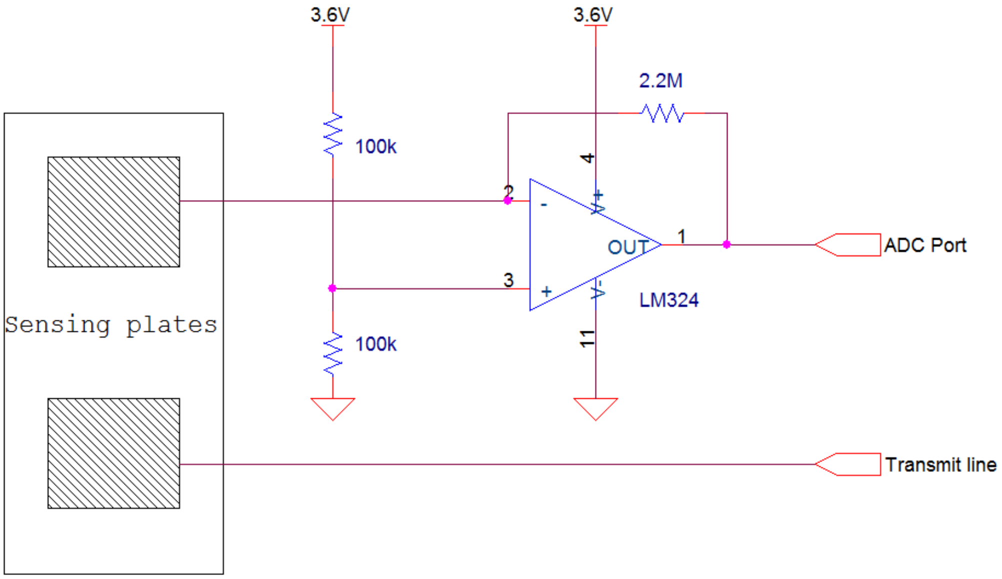

Figure 3. Electric field sensing analog hardware

HINTS:

- The electric field sensor is sensitive to conductive objects. Be aware of the metal framework under the lab benches.
- Division/multiplication by a power of two will be implemented as a bitwise shift and therefore is very fast.

Question 1.1: What value did you choose for "a" in the low-pass filter design, and why?

Question 1.2: How did the numeric value produced by your e-field sensor vary with the distance of your hand from the sensing plates (i.e., was this a linear relationship or something else)?