2.017 Design of Electromechanical Robotic Systems, Fall 2009

Lab 2: Sensors and Signals

1 Overview

The goal of this lab is to learn how to take sensor measurements and to process the acquired data using the Arduino microcontroller board. Specifically you will experiment with analog sensors such as photo resistors and temperature sensors.

You will also design and build a simple security system using a digital sensor as a trigger for sounding an alarm and flashing some LED's. Next we will use the Arduino board as a low cost data acquisition device to digitize a sine wave from a function generator. We will stream the digitized data to the host PC and determine the appropriate sampling frequency for the signal.

After we have completed the above tasks, we will spend an hour assembling the GPS logger shield for Lab 3. We will spend the last half hour of the lab for project discussion.

2 Part 1: The Arduino Kit Experiments

First each group will complete the following 3 circuits in the Arduino Experimenter's Guide:

- {CIRC09} Light - (Photo Resistors)
- {CIRC10} Temperature - (TMP36 Temperature Sensor)
- {CIRC11} Larger Loads - (Relays)

We ask you to modify your code so that the input and the output signals can be monitored through the serial monitor function of the Arduino software. Verify the range and resolution of both the ADC (analog to digital converter) and the PWM (pulse width modulation) output. Use a multi-meter to measure the voltages if necessary.

Put the following line in your setup(){…} to setup a serial communication at 9,600 bps:

```
Serial.begin(9600);
```

Put the following line in your loop(){…} to print values of the variable val:

```
Serial.println(val);
```

3 Part 2: Arduino Mini-Project

In this part of the lab you are asked to design a simple security system using the Arduino board. The objective of this mini-project is to design a system that can trigger an alarm when a door or a window is opened. In a commercially available home security system the trigger event is detected by using a magnetic switch. Here we will use a Reed switch and a permanent magnet to accomplish this.

The Reed switch is a digital sensor that is normally open. The switch will close when it is exposed to a strong magnetic field. The sensitivity of a reed switch is typically quantified by a number called AT (Ampere*Turn) that is related to the magnetic field strength in Tesla or Gauss. Typical applications of reed switches include Reed relays, security, limit switching, and telephone hook switch.

Figure 1 below shows the schematic of the Arduino security system that you will design and build.
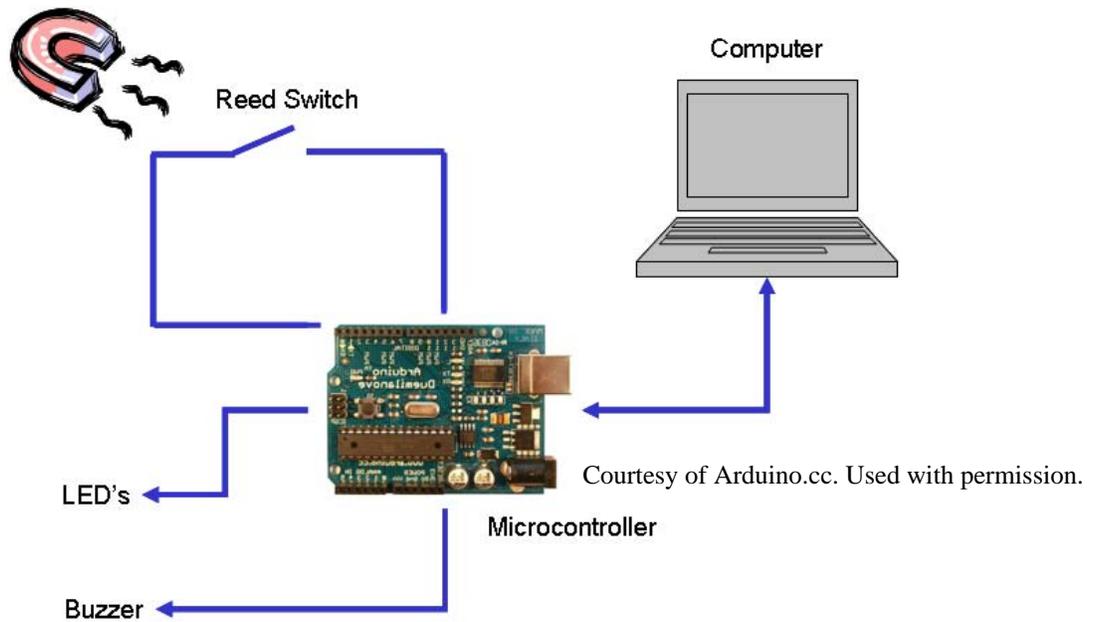

Courtesy of Arduino.cc. Used with permission.

Figure 1. Schematic of the Arduino security system

Write code to implement the logic and try out different scenarios (such as using a pushbutton to enable/disable the circuit). You are free to use other sensors in the lab for your system to enhance its capability.

Show your system to the teaching staff once you are done. Print out your code (with comments) as part of today's deliverables.

4 Part 3: Data Acquisition

In this part of the lab we will use the Arduino board as a low cost data acquisition device. For this we will send a known sine wave generated by a function generator to one of the analog input pins on the Arduino board and stream the digitized data to the host PC for visualization and analysis. We will also learn how to use an oscilloscope to monitor the sine wave signal.

Here are the steps to accomplish this part of the lab:

- Grab a PB-503 protoboard (see Figure 2), an oscilloscope, and a BNC cable from the cabinets.
- Use the scope to monitor the function generator output signal on the protoboard.
- Use the function generator to generate a 10 Hz sine wave with a peak-to-peak of 4v centered at 2.5v.
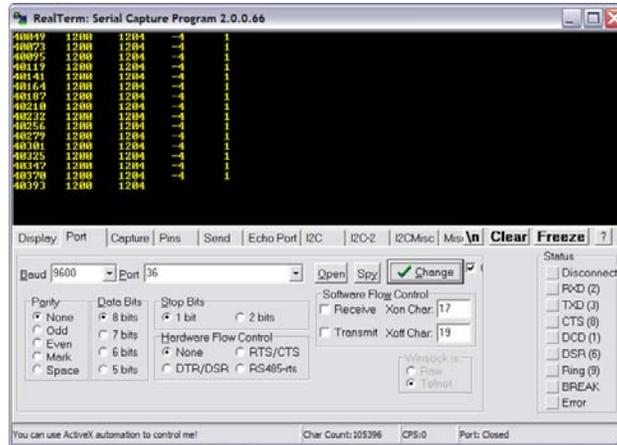- Send the signal to one of Arduino's analog input pins.

Courtesy of Global Specialties. Used with permission.

Figure 2. PB-503 protoboard

- Write code to read the signal and send it to the PC via the USB serial port (set it to 115,200 bps) at a sampling frequency of 15 Hz, 20 Hz, 100 Hz, and 1,000 Hz, respectively. Put the following line in your loop(){…} to set up the sample rate:

```
delay(10);  // delay for 10 milliseconds (i.e., 100 Hz)
```

- Use "RealTerm" to capture about two second worth of data for each sample rate (see Figure 3).
- Load the data into MATLAB. You need to open the data file with a text editor like *notepad* to remove the first and the last lines before you load it into MATLAB. Take
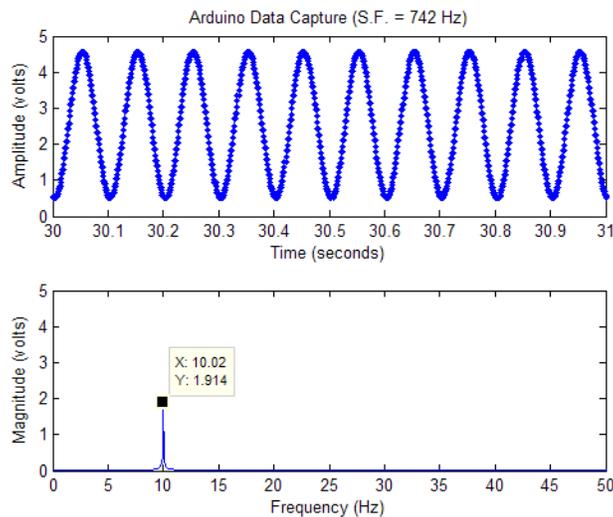
note of any discrepancy between the configured data rate in the code and the actual sample rate.

Courtesy of Simon Bridger. Used with permission.

Figure 3. RealTerm serial capture program

- Use the scaling factor (V/ADC) you found earlier to convert the digitized values to volts.
- Plot the time history of the data and compute the RMS (root-mean-square) value and the first four statistical moments (i.e., mean, variance, skewness, and kurtosis).
- Plot the spectrum of the data. See Figure 4 for an example plot. When plotting the time history, use *stairs* instead of *plot* command in MATLAB to better show the digitization effect.

Figure 4. Time history and spectrum plots of the captured sine wave

5 Part 4: Assemble The GPS Logger Shield

We ask each group to assemble a GPS logger shield in preparation for next week's GPS lab.

- Grab a soldering iron and solder.
- Power the soldering iron and set the temperature to 4.
- Follow the on-line instructions on http://www.ladyada.net/make/gpsshield/solder.html to assemble the board.
- Also solder the 9v battery holder.
- We will test and use the board next week.

Soldering guidelines:

- Wear safety glasses when soldering.
- Do not touch a hot iron.
- Never leave your iron turned on while unattended.
- Never set the soldering iron down on anything other than an iron stand.
- Use needle nose pliers, heat resistant gloves, or a third hand tool to hold small pieces.
- Practice a few times if you have not done soldering recently.
- Do not use excess amount of solder.
- Double check the part you want to solder before you actually do it.
- When done soldering, tinning the iron is required to protect the tip from oxidation thereby dramatically increasing its life.

6 Part 5: Project Discussion

- Try out the vehicle.
- Generate a rough plan (or task list).
- Identify project needs.

7 Deliverables

- Show and explain each completed circuit to the teaching staff.
- Print out a graph showing the relationship between the input voltages and the ADC values, and write down the scaling factor (V/ADC) you found.
- Show your security system to the teaching staff once you are done. Hand in your code (with comments) and a simple description of your system.
- Plots of time history and spectrum of the captured sine wave data at each sample rate. Write down the computed RMS value and the values of the first four statistical moments (i.e., mean, variance, skewness, and kurtosis).
- Assembled GPS logger shield and battery holder.
- Show the teaching staff your lab notebook.

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