BioE 101 – Lab 3

Objectives:

- Learn about sensors
- Implement and analyze voltage dividers and Wheatstone bridges for unknown resistances
- Find Thevenin equivalent circuits
- Design logic in LabView to calibrate and output pressure levels
- Determine the unknown pressure

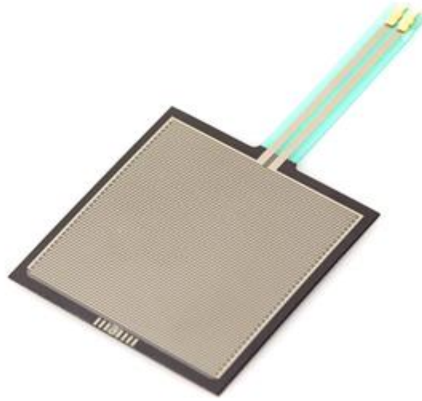
Teams will each turn in one list of answers to the questions in this lab. List all partners' names and section numbers.

1. **Schedule and lab reports**
    a. Week 1: Commercial force sensor with MyDAQ
    Sections 3 - 5 (Questions 1 - 10) due at the start of the second week of Lab #3
    b. Week 2: DIY homemade pressure sensor
    Section 6 (Questions 11 - 13) due the following week electronically to your lab GSI or in person during class on 2/23.

2. **Setup**
    a. You and your partner should have the following items: Pressure sensor, breadboard and jumper wire kit, two banana cables (red and black), two alligator clips (red and black), and items of known and unknown weight.

3. **Using the pressure sensor**
    a. A force-sensing resistor (FSR) is made of conductive polymer, which changes its conductance in a predictable manner when pressure is being applied on the surface. Typically, when we apply pressure on the active surface of a FSR, it exhibits a decrease in resistance. Sometimes, a FSR is designed for use in touch screens or panels on electronic devices.

    The following page gives a brief explanation of how conductive polymer works
    http://en.wikipedia.org/wiki/Conductive_polymer



The specsheet of the FSR we use today can be found at
https://www.sparkfun.com/products/9376

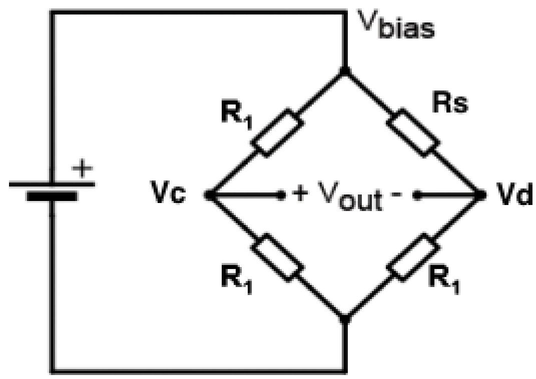
Question 1: What type of sensor is this? Does it give a voltage or current (or neither) output signal?

b. You will now calculate the nominal sensing resistance of your sensor. Note: Do not use the sensing/load resistance values from the datasheet in the next sections. Instead, calculate it empirically as follows.

c. Use your breadboard and the MyDAQ's DGND and 5V output terminals to build a voltage divider with your sensor and a 51kΩ resistor. Wire the 5V and ground terminals to the red/blue rails on the board, and then use those rails for powering your circuit. Configure your voltage divider so the FSR is connected to GND, and use the Digital Multimeter from the NI ELVISmxInstrument launcher.

Question 2: What is the resistance of your FSR with an empty falcon tube placed on the sensor? With a 100g mass? Show your work. Sketch and label your circuit, and write down what weight you used.
Pro-Tip: To help with consistency of your measurements, tape down the FSR and let the measurement 'settle' for 2-3 min to reach steady-state before recording.

4. **Building matched resistance Wheatstone bridges**
   a. Build a matched Wheatstone bridge with your sensor, choosing resistor values for R1 (in the diagram below) that are as close as possible to the steady-state resistance of your FSR with no load, as determined in Question 2. It's OK if the resistances don't match perfectly—just try to get them as close as you can.



Question 3: Imagine that the Wheatstone bridge is actually two different voltage dividers in parallel. Calculate the voltage at Vc and Vd. Then, assuming that zero current passes between Vc and Vd, find an equation that describes Vout.

Question 4: Find an equation that describes Rs as a function of R1, Vbias, and Vout.

5. **Labview Data Analysis and Analog Output**
   a. Connect Vc and Vd of your voltage divider to the two analog inputs (AI 0+ and 0-) of the MyDAQ. Leave all other circuit elements connected as before—do *not* switch the ground from DGND (as in the previous section) to AGND. Create a LabView VI to continuously acquire differential measurements between the two terminals and output the result to a Waveform Graph.

Question 5: What is the steady state differential voltage between the two input terminals? Remember you may have to let the voltage differential 'settle' for many minutes before it reaches steady-state.

   b. Standard objects (50 mL Falcon tubes containing different materials) have different weights. Determine the voltage differentials that correspond to these weights. Place the objects on your FSR one at a time, cap facing down, and record the differential voltage from your Wheatstone bridge. Assuming that the weight-differential voltage relationship is linear (in reality it isn't, but we'll just approximate it in a piecewise linear fashion), find the slope (change in voltage/change in weight) and y-intercept (voltage differential with no load).

Question 6: What did you find as the equation of your weight-resistance plot? Plot it in R, Excel, etc. or draw it below. Note that answers may vary between groups.

Question 7: Using the linear model from above, calculate the weight of the mysterious object.

c. Make a physical LED light up according to the amount of force detected by the sensor. To do this, you can use an Analog Output port of the MyDAQ (terminal AO0). This terminal can be directly plugged into a LED through a current-limiting resistor to ground. Try to limit the total current through the LED to no more than 20mA. ProTip: You might need to multiply or manipulate the voltage sent to AO0 within LabView to make the LED light up, as a small voltage (of e.g. 0.1V) is likely insufficient to power an LED and the voltage can't be negative. Remember that LEDs are diodes and must be connected in the proper orientation to function.

d. In LabView, create a DAQAssist module and set it to Analog Output. The input into this output DAQ Assistant is the same waveform that you acquired from the AI 0+ and 0-. You will need to place boundaries on the signal from 0-5V first, as the analog out of the MyDAQ cannot produce negative voltages. Verify that the brightness of the LED changes with varying pressure or weight sensed.
    i. **Hint**: If you are getting timing related errors, refer to the MyDAQ spec sheet, pg. 32 (Audio example) on how to setup a DAQ Assistant Vis for simultaneous analog input and analog output. Although the example uses the audio input and output ports, the way the VI is designed is similar. Pay special attention to how the samples are acquired (number of samples, rate).

Question 8: Attach a screenshot of your VI and block diagram here.

Question 9: Find another method to communicate pressure, and write down your approach. Some possible ideas to get you started: (1) create a series of Digital Output LEDs that light up sequentially with increasing pressure (2) play a sine wave in the computer's speakers, where the frequency is determined by pressure. Be creative! Attach a screenshot of your VI/block diagram and circuit board here if you had time to implement your method. Otherwise, a description is fine.

Question 10: Find one biomedical application of force sensor, and briefly describe how it works.

You can keep your set up for next week to test your homemade pressure sensor.

6. **<u>Build a homemade pressure sensor</u>**

   You will use two copper plate electrodes and a piece of conductive foam.

   a. First, cut two 2 x 2 cm electrodes from the copper plate, then solder wire leads on to each piece.
   b. Sandwich a 2 x 2 cm piece of conductive foam between the two electrodes, then glue in place with a hot glue gun.
   c. The following questions will use the same techniques you applied in the first week.

Question 11: What is the steady-state resistance with no load?

Question 12: Experimentally make a weight vs. resistance curve by measuring a few objects of different weights. How does the resistance of the sensor change when pressure/weight is applied?

Question 13: How sensitive is your device as compared to a commercial FSR? What is the smallest detectable weight of the commercial device, and your device?