BioE 101 Lab 3 - Physical Sensors, Sensing Circuits and Calibration

Objectives:

- Learn about sensors
- Implement and analyze voltage dividers and Wheatstone bridges for unknown resistances
- Find Thevenin equivalent circuits
- Design logic in Python 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.

Schedule and lab reports

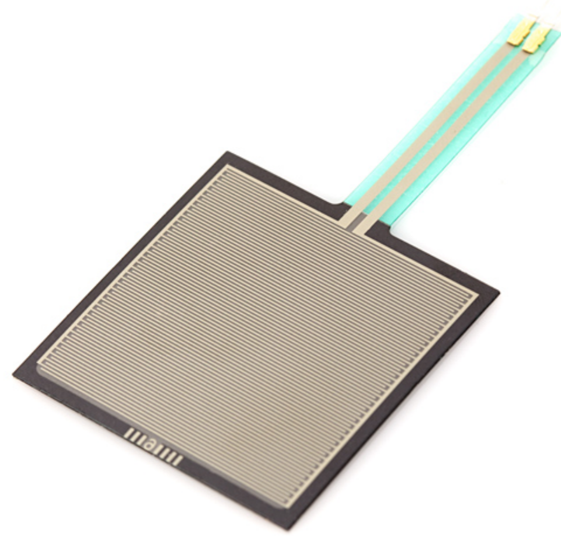
- Week 1: Commercial force sensor with Arduino Sections 3 - 5 (Questions 1 - 9) should be done by 1st week.
- Week 2: DIY homemade pressure sensor Section 6 (Questions 10 - 12) should be done by 2nd week. Lab Report due by end of week.

Part 1. Setup

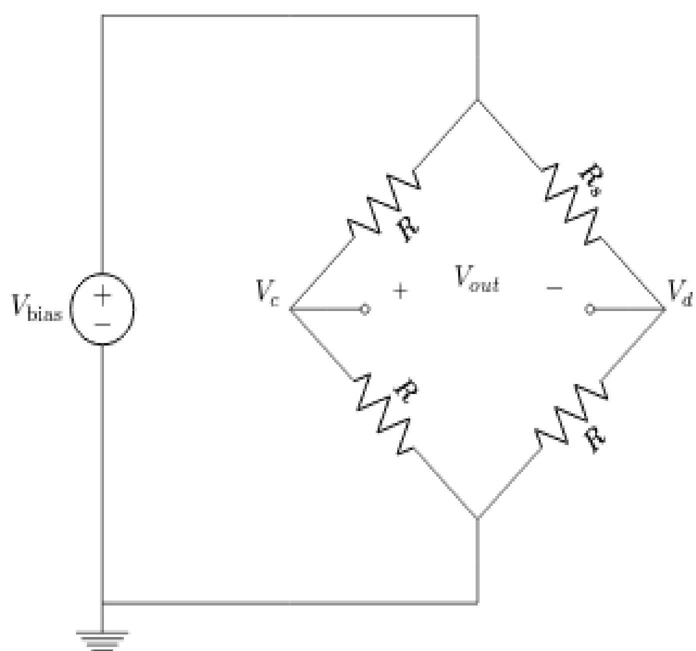
- You and your partners should have the following items: Pressure sensor, breadboard, jumper wires, two banana cables (red and black), two alligator clips, multimeter and items of known and unknown weight.

Part 2. Using the pressure sensor

- 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 (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 (https://www.sparkfun.com/products/9376)



Wheatstone Bridge

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

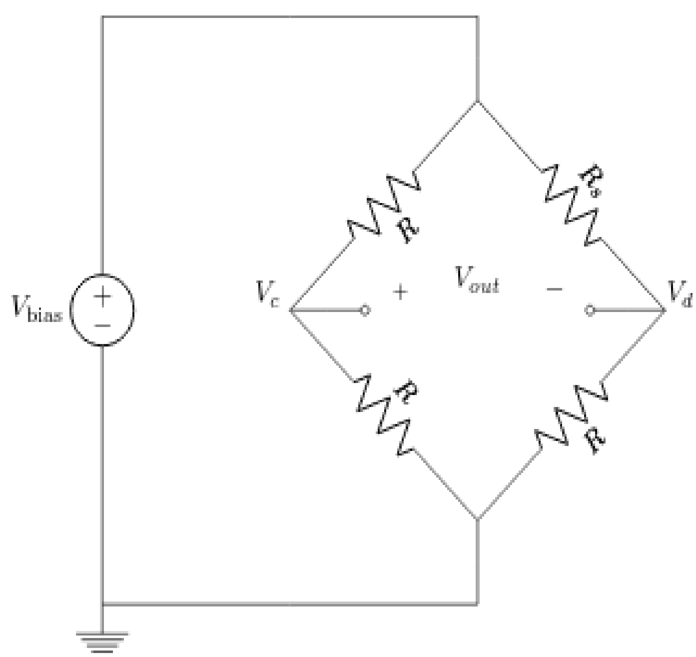
- You will now calculate the nominal sensing resistance of your sensor. Note: Do not use the sensing/load resistance values from the datasheet in the next sections. Instead, calculate it empirically as follows:

- Use your breadboard and the power supply to build a voltage divider with your sensor and a 680kΩ resistor (anywhere from 100kΩ to 1MΩ should be fine). 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 a multimeter.

Question 2: What is the resistance of your FSR with an empty falcon tube placed on the sensor (~13g)? With a ~30 g mass? 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. Remember from homework 2 that you can improve accuracy by waiting for your signal to settle before taking a measurement.

Part 4. Building matched resistance Wheatstone bridges

- 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 the Falcon tube (~13 g), 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.



Wheatstone Bridge

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 R, Vbias, and Vout.

Part 5. Data Analysis and Analog Output

- To read out voltages between Vc and Vd, you can continue using a multimeter or use the Arduino serial monitor. To use the Arduino, connect Vc and Vd of the Wheatstone bridge to the A1 and A0 pin of the Arduino, respectively, and connect the ground of your circuit to GND of the Arduino. Leave all other circuit elements connected as before.

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.

- 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 Falcon tube only (~13 g)).

Question 6: What did you find as the equation of your weight-resistance plot? Plot it in R, Excel, etc. or use a PyPlot cell below. The Python code below uses a 2nd degree fit, and has options to try others, but use the linear fit in your final lab report.

In [ ]:

```
# Run this cell first to import the necessary packages

# allows plots to be plotted right below the cell when run
%matplotlib inline
import serial # the library for reading from serial com ports
import numpy as np # naming convention for numpy library
import matplotlib.pyplot as plt # naming convention for matplotlib
```

In [ ]:

```
### ENTER YOUR VALUES HERE ###
weights = np.array([13.48, 38.77, 45.45, 52.68, 76.31, 100]) # Fill in weights he
voltages = np.array([4, 1, 0.6, 0.5, 0.3, 0.01]) # Fill in output voltages here, 
degree = 2 # if you change this from 2 you have to change the equation for y deta

# Make sure both lists have the same length!

plt.figure()
"""
this creates a list of polynomial coefficients using a least squares regression m
"""
c = np.polyfit(weights, voltages, degree) # array of coefficients, make sure to e
x = np.linspace(0,100, 100) # creates variable weight to iterate over
"""
this is y = anx^n + bx^(n-1) + ... + cx + d, change according to number of degree
right now it's y = a*x^2 + b*x + c because deg = 2
"""
y = c[0]*(x**2) + c[1]*x + c[2] # c[0] is coefficent for x^n, c[1] for x^n-1, ...

actual, = plt.plot(weights, voltages , label="actual")
estimate, = plt.plot(x, y, label="estimate")
plt.legend(handles=[actual, estimate], loc=1)
plt.xlabel("weight (g)"); plt.ylabel("voltage (V)")
```

Question 7: Using your linear fit, calculate the weight of one of mysterious objects (labeled A-E).

In [ ]:

```
# If you used the above cell, you can run this code to find the value

### ENTER UNKNOWN WEIGHT VOLTAGE HERE ###
unknown_val = 2 # enter voltage of unknown weight

### DON'T MODIFY THIS CODE, read comment for explanation on what it does ###
unknown_weight = x[np.abs(y - unknown_val).argmin()] # finds closest weight corre
print(str(unknown_weight) + ' grams' )
```

Question 8: Find one biomedical application of force sensors, and briefly describe how it works.

6. Build a homemade pressure sensor

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

- First, cut two 2 x 2 cm electrodes from the copper plate, then solder wire leads on to each piece. Please ask for guidance if you have not previously soldered to copper. The trick is to apply a lot of heat to the plate to get it to stick.
- Sandwich a 2 x 2 cm piece of conductive foam between the two electrodes, then glue in place with a hot glue gun.
- The following questions will use the same techniques you applied in the first week.

Question 9: What is the steady-state resistance with no load?

Question 10: 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 11: How sensitive is your device as compared to a commercial FSR? What is the smallest detectable weight of the commercial device, and your device?

Please wash your hands after class as the solder we use contains lead!