ECE 321 - Solution to Homework #2

Sensors. Due Monday, April 8th

Temperature Sensors

Problem 1-2) Design a circuit to measure temperature from 10C to +30C.

- Input: Temperature from 10C to +30C
- Output: -10V to +10V, capable of driving a 1k resistor (10mA)
- Relationship:
  - At 10C, the output is -10V
  - At +30C, the output is +10V
  - Proportioanl inbetween

Assume a thermistor with a resistance - temperature relationship of

$$R = 1000 \cdot \exp\left(\frac{3905}{T} - \frac{3905}{298}\right)\Omega$$

Problem 1) Design a linearizing circuit so that the resistance is approximately linear from 10C to +30C

- Plot the resulting resistance vs. temperature relationship using Matlab (or similar program)

Write a routine to find Ra and Rb

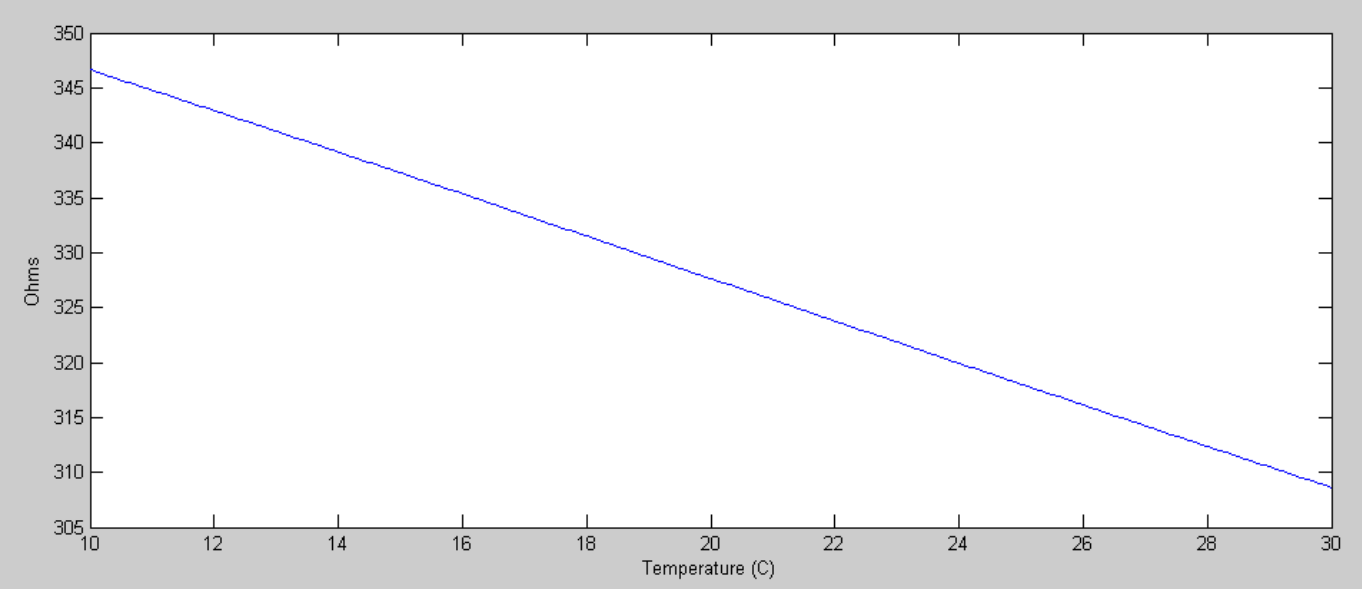
```
function [ J ] = Thermistor( Z )
    Ra = Z(1);
    Rb = Z(2);
    R10 = 1000*exp(3905/283 - 3905/298);
    R20 = 1000*exp(3905/293 - 3905/298);
    R30 = 1000*exp(3905/303 - 3905/298);
% Z = R1 R2 / (R1 + R2)
    Z10 = (R10 + Rb)*(Ra) / (R10 + Ra + Rb);
    Z20 = (R20 + Rb)*(Ra) / (R20 + Ra + Rb);
    Z30 = (R30 + Rb)*(Ra) / (R30 + Ra + Rb);
    E = Z20 - (Z10 + Z30)/2;
    J = E*E;
    end
```

Solve using fminsearch() (takes several tries)

```
[z,e] = fminsearch('Thermistor',[500,500])

z =  401.6296  527.4601

e =  0
```

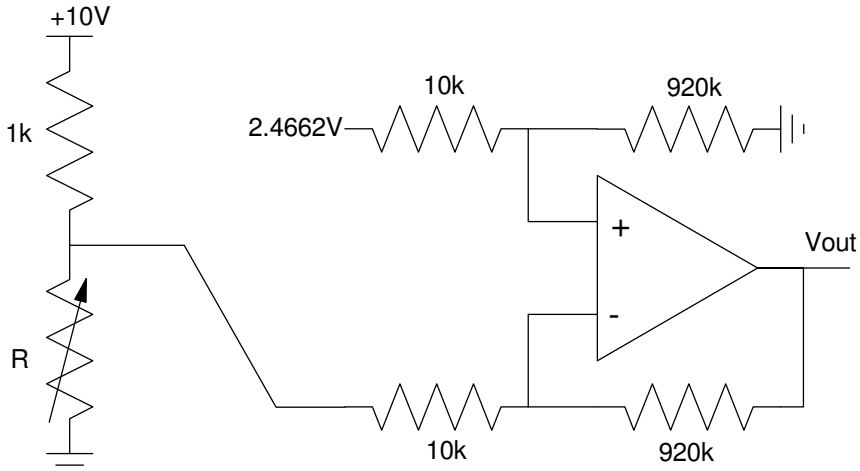
Plotting the resulting resistance vs. temperature:

```
Ra = z(1);
Rb = z(2);
T = [10:0.1:30]';
K = T + 273;
R = 1000*exp(3905 ./ K  -  3905/298);
Z = (R + Rb)*Ra ./ (R + Ra + Rb);
plot(T,Z);
xlabel('Temperature (C)');
ylabel('Ohms');
```

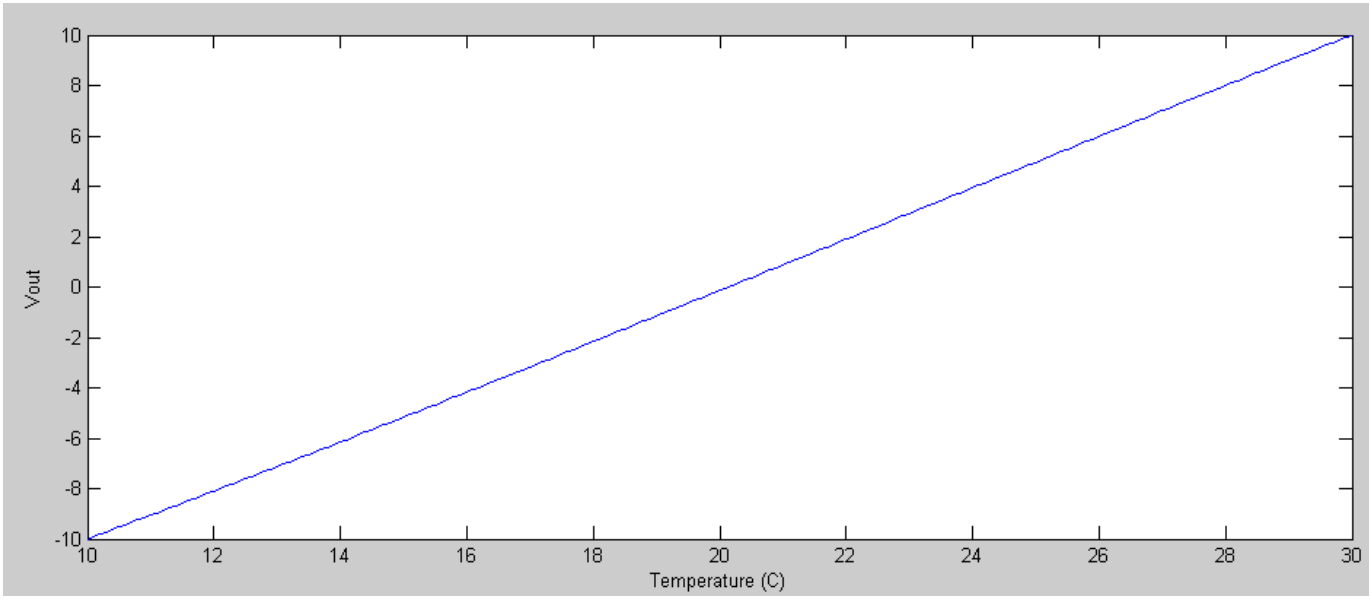

350
345
340
335
330
325
320
315
310
305
Ohms
10
12
14
16
18
20
22
24
26
28
30
Temperature (C)

Problem 2) Using this linearizing circuit, design a circuit which ouputs -10V to +10V as temperature goes from 10C to +30C.

```
Va = Z ./ (1000 + Z)*10;
gain = 20 / ( max(Va) - min(Va) )

gain =   92.8118

Offset = 10/gain + min(Va)

Offset =   2.4662

Vout = gain*( Offset - Va );

plot(T, Vout)
xlabel('Temperature (C)');
ylabel('Vout');
```

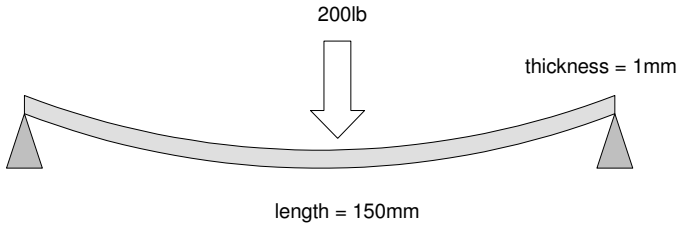


Plot the resulting voltage vs. temperature relationship using Matlab (or similar program)



Strain Sensors

Problem 3) Assume a bathroom scale uses a steel beam to measure weight, and the beam deflects 5mm with a weight of 200 lb (889N)



Design a circuit which output

- 0V at 0lb (0N), and
- +10V at 200lb (889N)

Assume a strain sensor:

$$R = 120(1 + 2.14\varepsilon)$$

The center line radius is

$$R^2 = (R-5)^2 + 75^2$$

$$R = 565mm$$

The arc length is then

$$\theta = \arctan\left(\frac{75mm}{565mm}\right) = 7.56^0 = 0.1320rad$$

The length of the center line is

$$L = r\theta = 565mm \cdot \theta$$

The strain on the inner and outer edges is

$$\varepsilon_{inner} = \left(\frac{-0.5mm}{565mm}\right) = -0.00088496$$

$$\varepsilon_{outer} = \left(\frac{+0.5mm}{565}\right) = 0.00088496$$

The resistance is then

$$R_{inner} = 120(1 + 2.14\varepsilon) = 119.7727\Omega$$

$$R_{outer} = 120(1 + 2.14\varepsilon) = 120.2272\Omega$$

Place this in a Whetstone bridge. The voltage is then

- Vab(0 lb) = 0V
- Vab(200 lb) =

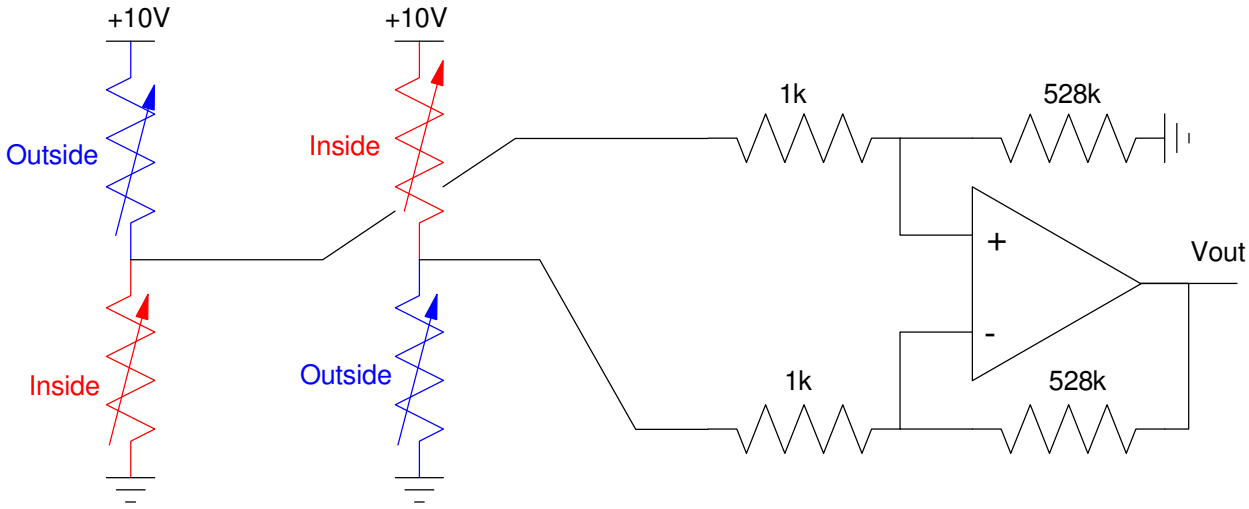
$$V_a = \left(\frac{120.22}{120.22+119.77}\right) 10V = 5.00946V$$

$$V_b = \left(\frac{119.77}{120.22+119.77}\right) 10V = 4.99053V$$

$$V_{ab} = 0.01893V$$

To amplify this to +10V, you need a gain of 528

$$gain = \left(\frac{10V}{0.01893V}\right) = 528.037$$



ECE 321 Project: Section (1)

Problem 4) Specify the requirements for an amplifier circuit. Some suggestions are:

Audio Mixer: Mix two signals together

Input: Two analog signals (A and B)

- -10V to +10V
- Capable of up to 10mA each

Output: One analog signal (Y)

- -10V to +10V
- Capable of up to 10mA

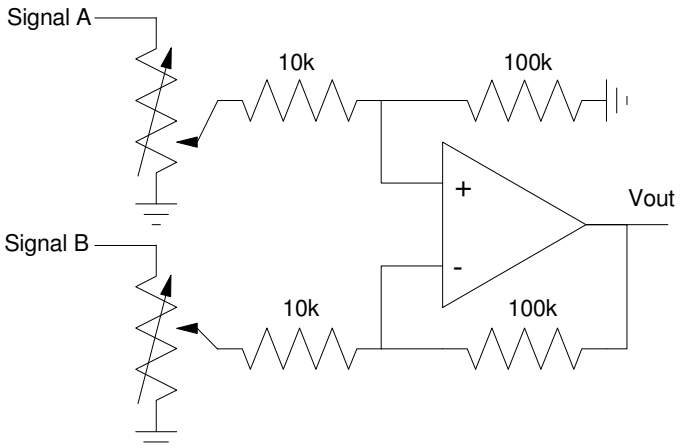
Relationship:

$$Y = aA - bB$$

$$0 < a < 10$$

$$0 < b < 10$$

Problem 5) Design a circuit to meet these requirements.



Problem 6) Build your circuit in lab and verify it operates correctly. Check the endpoints and one or two points inbeweeen.

Problem 8) Demo. Demonstrate your amplfier

Note: Save your circuit. You'll use it again in the following homework sets