ECE 321 - Homework #2

Tmperature and Strain Sensors. Due Wednesday, April 15th

Please make the subject "ECE 321 HW#2" if submitting homework electronically to Jacob_Glower@yahoo.com (or on blackboard)

Temperature Sensors

1) Assume you are using a thermistor where the temperature - resistance relationship is

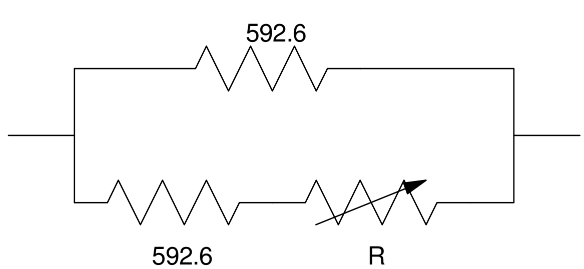
$$R = 1000\ \exp\left(\frac{3905}{T} - \frac{3905}{298}\right)\ \Omega$$

where T is the temperature in degrees Kelvin.

1) Design a linearizing circuit so that the resistance is approximately linear from 0C to +30C. Plot the resulting resitance vs. temperature relationship.

Using Matlab setting Ra = Rb

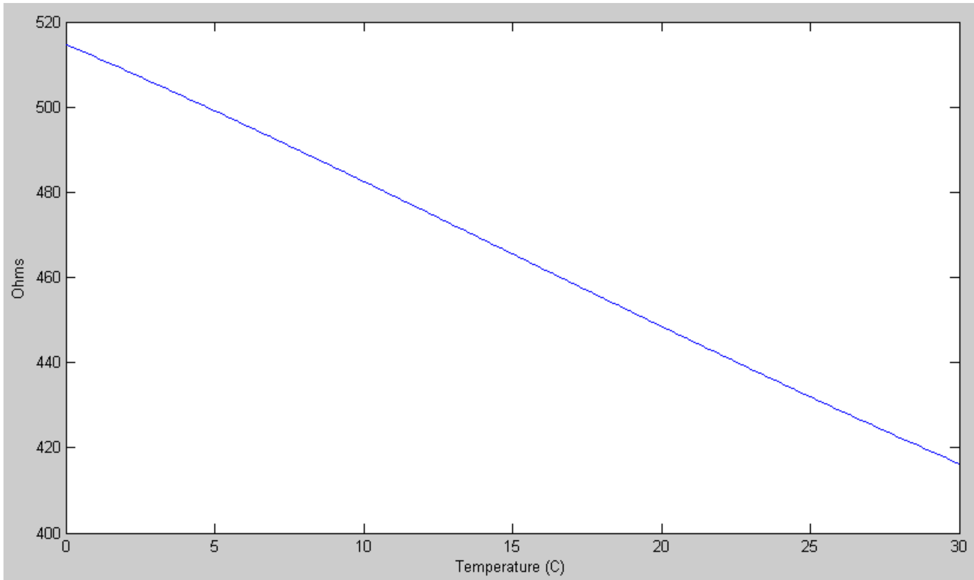
```
function [ J ] = costR( Z )

   a = Z(1);
   b = Z(2);

   R0  = 1000 * exp(3905/273 - 3905/298);
   R15 = 1000 * exp(3905/288 - 3905/298);
   R30 = 1000 * exp(3905/303 - 3905/298);

   Z0  = (R0 + a)*b / (R0 + a + b);
   Z15 = (R15 + a)*b / (R15 + a + b);
   Z30 = (R30 + a)*b / (R30 + a + b);

   e1 = Z0 + Z30 - 2*Z15;
   e2 = a - b;

   J = e1^2 + e2^2;

   end

[Z,e] = fminsearch('costR',[1000,1000])

Z =  592.6961  592.6961
```



Checking in Matlab

```
T = [0:0.1:30]';
R = 1000 * exp(3905 ./ (T+273)  -  3905/298);
a = Z(1);
Ra = Z(1);
Rb = Z(2);
```

```
Z = (R + Ra)*Rb ./ (R + Ra + Rb);
plot(T,Z)
xlabel('Temperature (C)');
ylabel('Ohms');
```



2) Using the linearizing circuit from part 1, design a circuit which outputs

- -10V at 0C
- +10V at +30C
- Proportional in between.

Plot the resulting output voltage vs. temperature.

Use a voltage divider. For the top resistor, pick it close to the average of Z

```
>> mean(Z)

ans =  465.5036
```

Assume a 500 Ohm resistor. Then, the voltages at 0C and 30C are

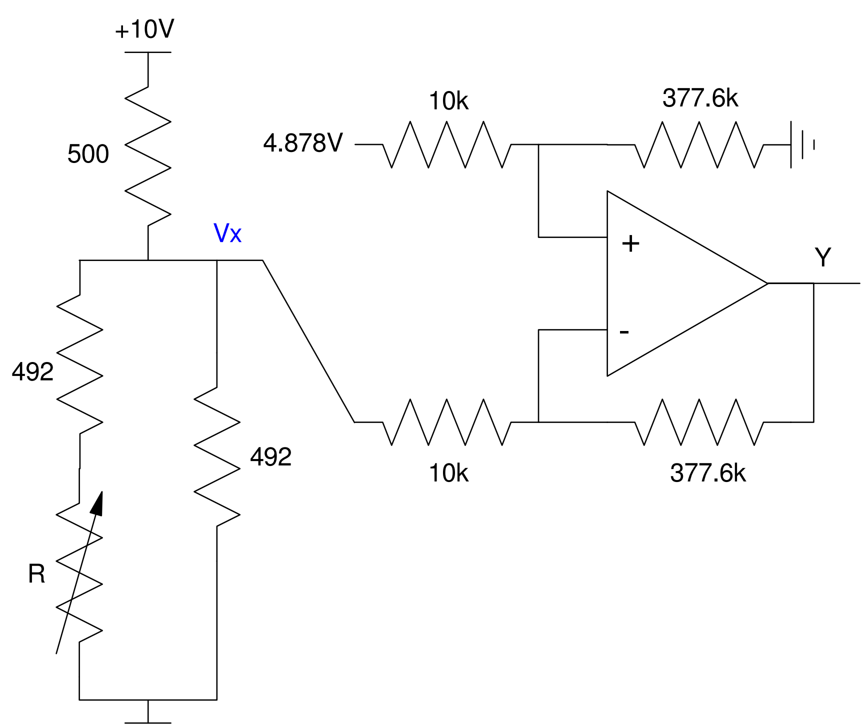
```
V0 = Z(1) / (Z(1) + 500) * 10

V0 =   5.0726

V30 = Z(301) / ( Z(301) + 500 ) * 10

V30 =    4.5430
```

The gain you need is

```
gain = 20 / (V30 - V0)

gain =  -37.7656
```

The offset voltage is

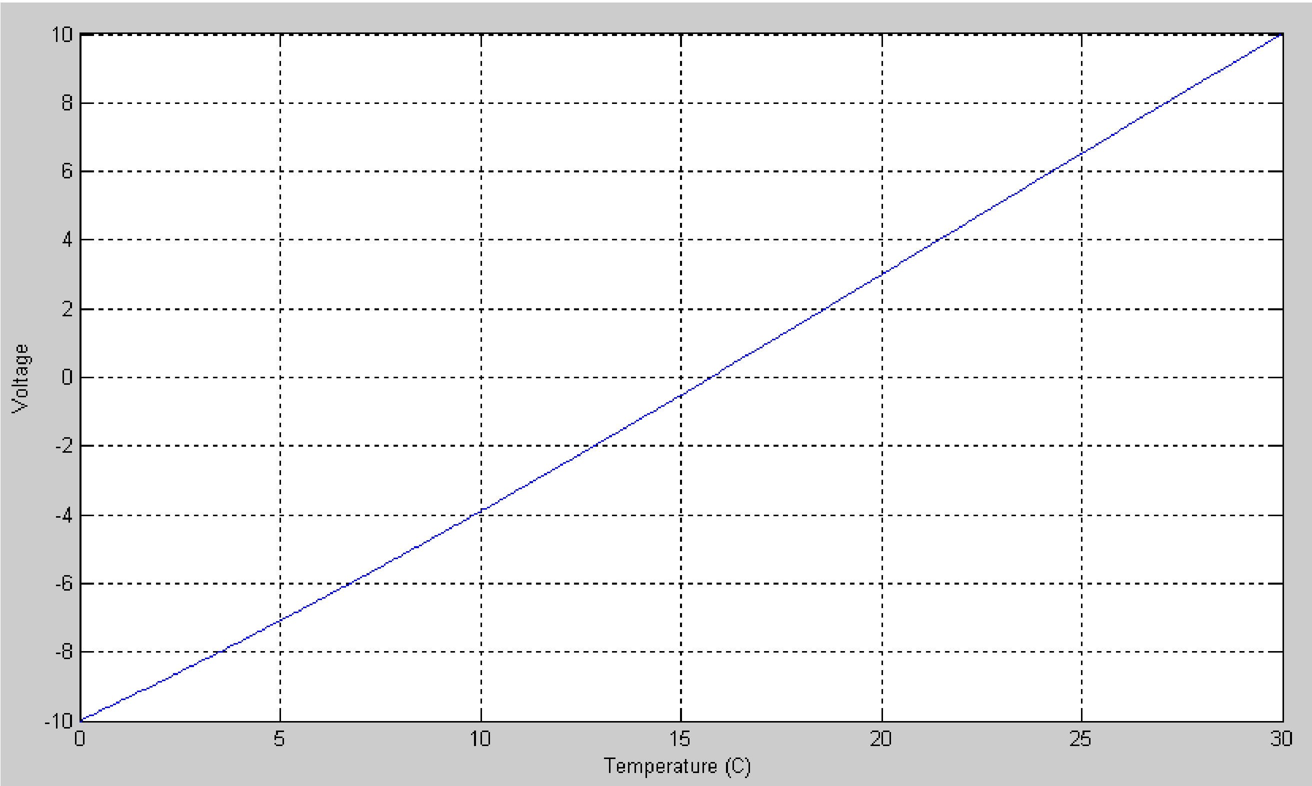
```
offset = (V30 + V0)/2

offset =   4.8078
```



Plotting the resulting voltage vs. temperature

```
Vx = Z ./ (500 + Z) * 10;
Y = abs(gain) * (offset - Vx);
plot(T,Y)
xlabel('Temperature (C)');
ylabel('Voltage');
grid
```

Note that this is still slightly nonlinear (it should pass through 0V at 15C). This is due to the nonlienarity of the voltage divider. If you optimize the circuit with the voltage divider taken into account, you could get it to pass through (15C, 0V)



Audio Sensors and Envelope Detectors:

3) Design a circuit which conerts a 1Vpp, 20-20kHz audio signal to a DC signal

Input: Cell Phone

- 1Vpp capable of driving 1mA
- 20-20kHz

Output: 0 - 10VDC capable of driving 1kOhms (i.e. 10mA @ 10V)

Relationship:

- 1Vpp input produces 10VDC output
- Ripple = 0.5Vpp @ 1kHz

To convert 0.5Vp to 10Vp, you need a gain of 20x.

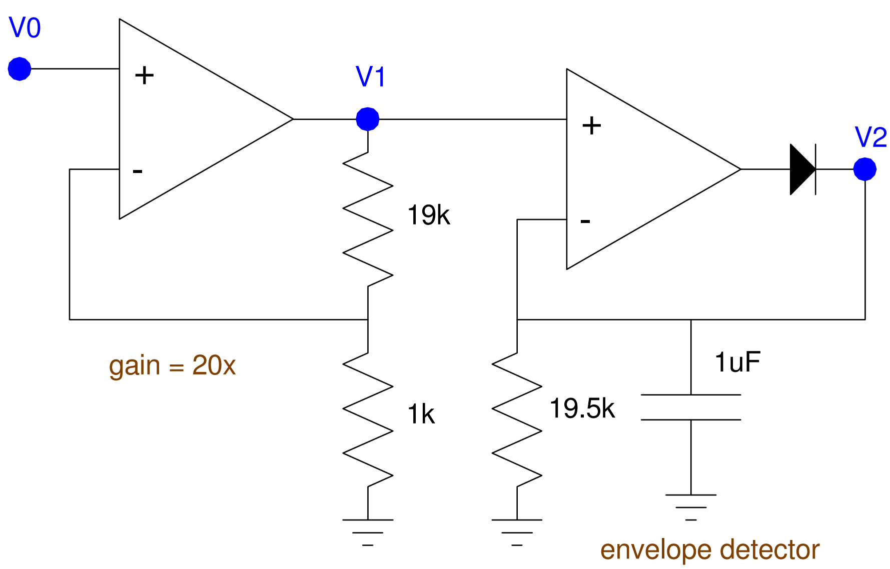
Add an envelope detetor. For the ripple to be 0.5V @ 1kHz

$$V = V_0 \exp\left(\frac{-t}{RC}\right)$$

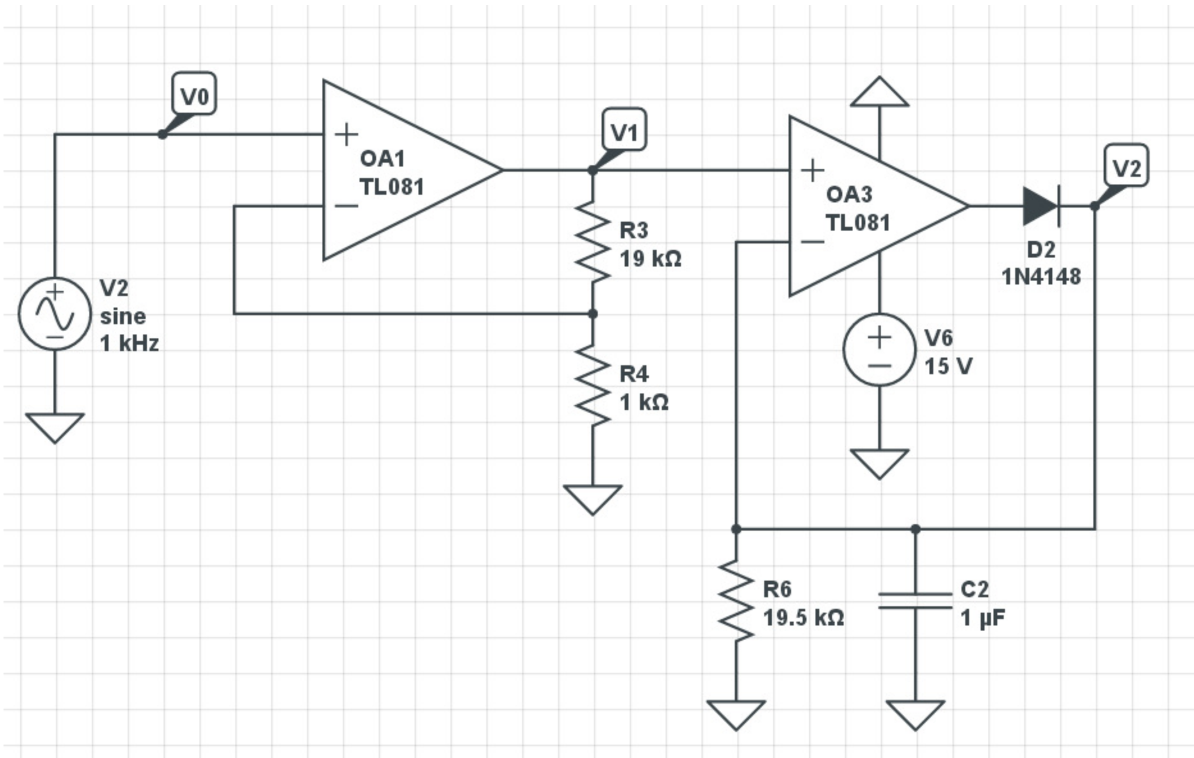
Assume C = 1uF

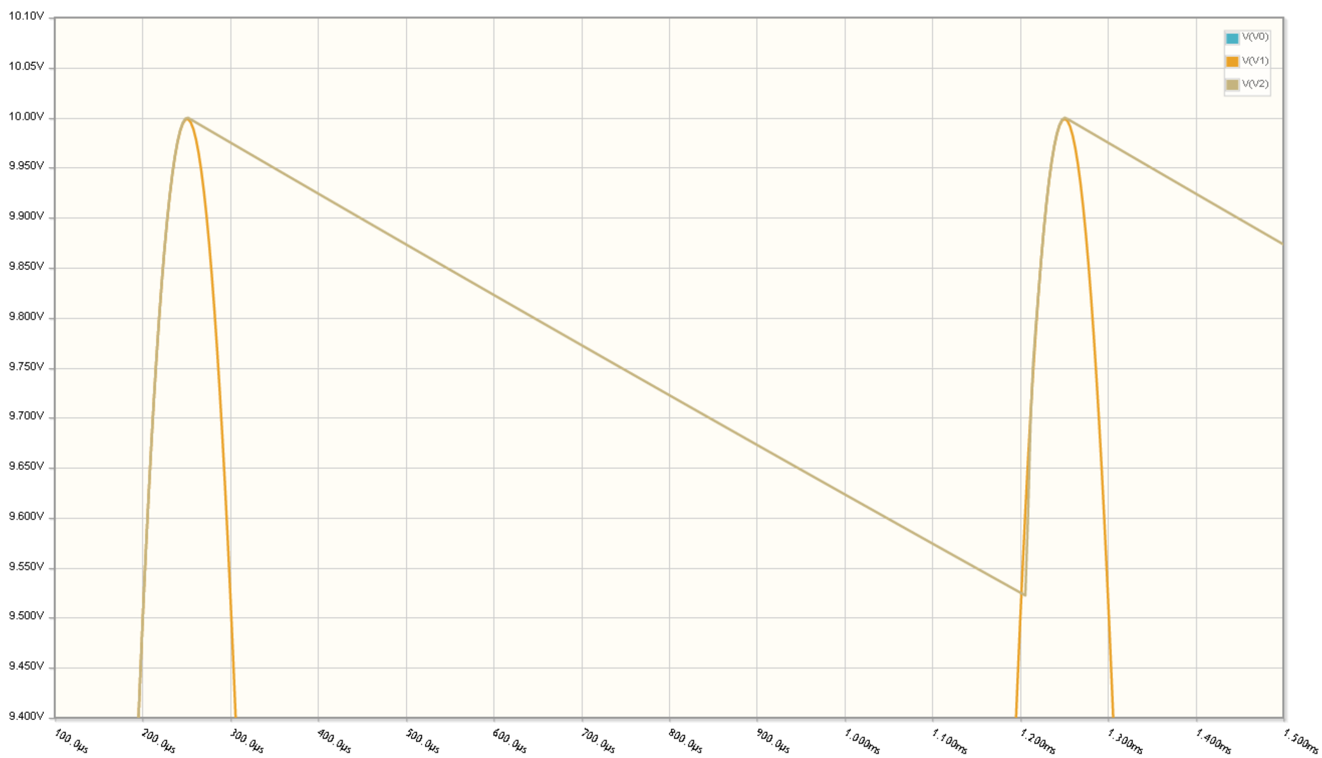
$$9.5V = 10V \cdot \exp\left(\frac{-0.001}{R \cdot 1\mu F}\right)$$

$$R = 19.5k\Omega$$



4) Check your design in CircuitLab using a 0.5Vp, 1kHz sine wave for the input.





Strain Sensors

5) Assume a metal beam deflects 5mm when 200lb is placed on the beam. Design a circuit which outouts

- 0V at 0lb
- 10V at 200lb

Assume

- Length of beam = 5cm
- Thickness of beam = 0.5mm
- Strain Gage relationship is

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

The radius of the circle the beam traces out is

$$R^2 = (R-5)^2 + 25^2$$

$$R = 65mm$$

The strain is proportional to the change in radius to

- the inner edge (minus 1/2 thickness)
- the outer edge (plus 1/2 thickness)

$$\varepsilon = \left(\frac{65.25-65}{65}\right) = 0.00384$$

$$\varepsilon = \left(\frac{64.75-65}{65}\right) = -0.00384$$

The resistance is then

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

$$R = 120.98769\Omega \quad \text{outer edge}$$

$$R = 119.01231\Omega \quad \text{inner edge}$$

Assume

- Two strain gagues (one inner edge, one outer edge)
- 10V power

The voltage across the voltage divider is

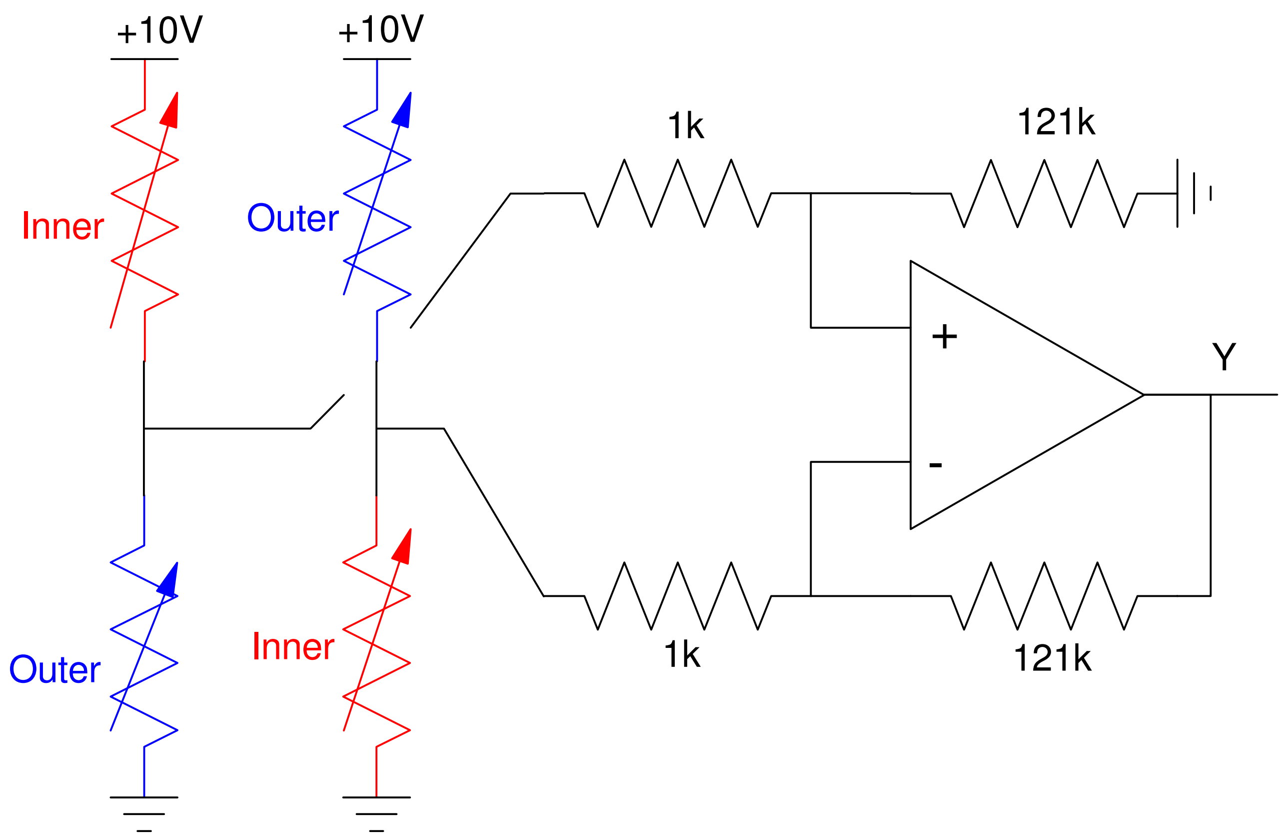
$$V = 5.0000V \qquad \text{strain = 0}$$

$$V = \left(\frac{120.9807}{120.9807+119.01231}\right)10V = 5.04115V \qquad \text{strain = +/- 0.00384}$$

The gain needed is then

$$gain = \left(\frac{10V-0V}{5.04115V-5.000V}\right) = 242.99$$

If you use two more strain gagues, you only need half the gain (121.5) at 4x the cost



4x Strain Gagues