ECE 321 - Quiz #2 - Name ____________________

Sensors & Filters

Calculators, internet, Matlab permitted.

1) A thermistor has a temperature-resistance relationship of (Digikey part number 495-75201-ND) where T is the temperature in degrees C.

$$R = 10,000 \cdot \exp\left(\frac{3980}{T+273} - \frac{3980}{298}\right)\ \Omega$$

Design a circuit which outputs

- 0V at 25C and
- 10V at 100C

Note: A linearizing circuit isn't required.

Let R = 2500

25C (Y = 0V)

- R = 10k Ohms
- X = 8.000V

100C: (Y = 10V)

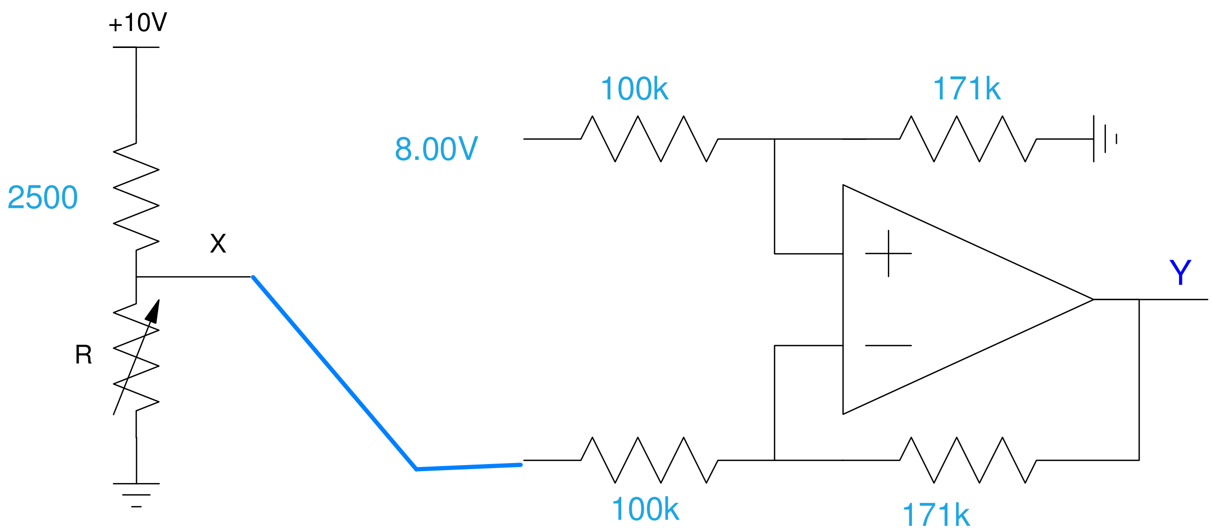
- R = 681.9 Ohms
- X = 2.168V

As X goes down, Y goes up. Connect to the minus input

$$gain = \left(\frac{10V-0V}{8V-2.168V}\right) = 1.715$$

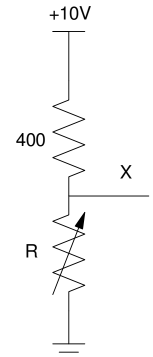
Y = 0V when X = 8.00V

Offset = 8.00V



2) A thermistor has a temperature-resistance relationship of

$$R = 10,000 \cdot \exp\left(\frac{3980}{T+273} - \frac{3980}{298}\right)\ \Omega$$



where T is the temperature in degrees C. Assume the thermistor is used with a voltage divider so that

$$X = \left(\frac{R}{R+400}\right) 10V$$

2a) Determine the least sqares curve fit for temperature as

$$T = aX + b$$

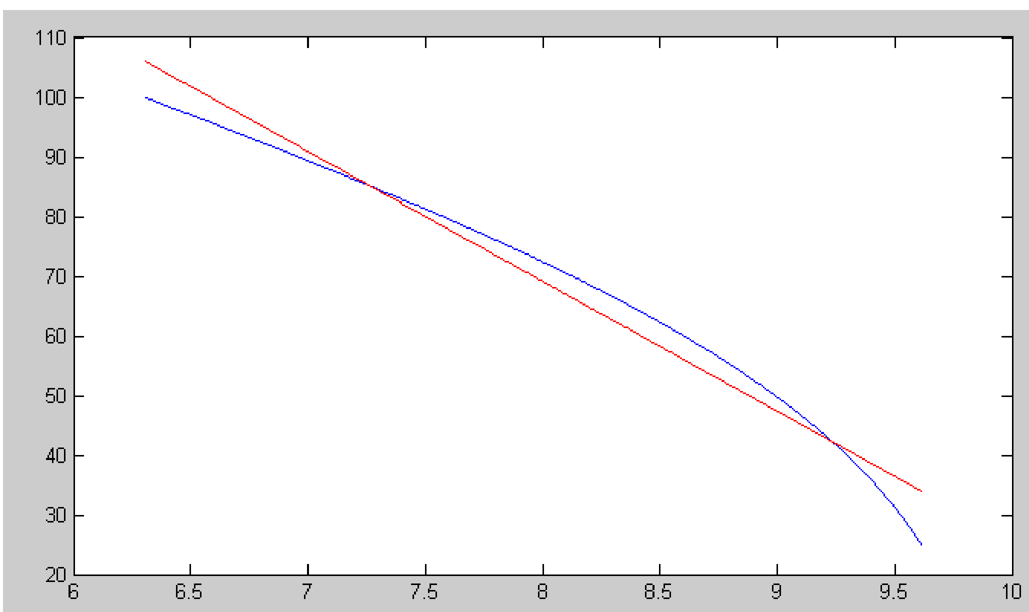
Assume the same temperature range as problem #1 (your answers will vary depending upon what temperature range you choose)

```
T = [25:0.1:100]';
R = 10000 * exp(3980 ./ (T+273)  -  3980/298);
X = R ./ (R+400)*10;
B = [X, X.^0];
A = inv(B'*B)*B'*T

   -21.7887
   243.4206

 plot(X,T,X,B*A,'r')
```

$$T = -21.7887X + 243.42$$



2b) Determine the least sqares curve fit for temperature as

$$T = aX^3 + bX^2 + cX + d$$

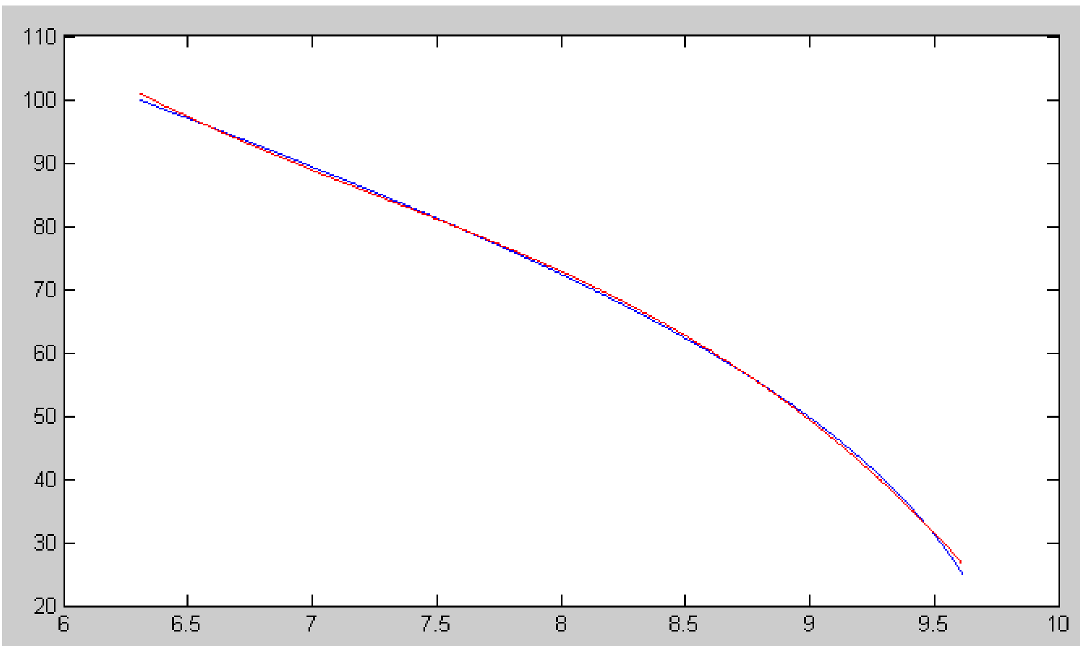
Again, assuming (25C, 100C), (answers vary depending upon the temperature range)

```
>> B = [X.^3, X.^2, X, X.^0];
>> A = inv(B'*B)*B'*T

   -1.7333
   37.8345
 -290.5995
  863.6654

>> plot(X,T,X,B*A,'r')
```

$$T \approx -1.733X^3 + 37.82X^2 - 280.599X + 863.66$$



3) X and Y are related by the following transfer function

$$Y = \left(\frac{50}{(s+5)(s+7)}\right) X$$

3a) What is the differential equation relating X and Y?

$$(s+5)(s+7)Y = (50)X$$

$$(s^2 + 12s + 35)Y = 50X$$

$$y'' + 12y' + 35y = 50x$$

3b) Determine y(t) assuming

$$x(t) = 4 + 5\cos(6t) + 7\sin(6t)$$

Use superposition and phasor analysis

x(t) = 4

$$s = 0$$

$$X = 4 + j0$$

$$Y = \left(\frac{50}{(s+5)(s+7)}\right)_{s=0} (4 + j0)$$

$$Y = 5.714$$

$$y(t) = 5.714$$

x(t) = 5 cos(6t) + 7 sin(6t)

$$s = j6$$

$$X = 5 - j7$$

$$Y = \left(\frac{50}{(s+5)(s+7)}\right)_{s=j6} (5 - j7)$$

$$Y = -4.908 - j3.404$$

$$y(t) = -4.908\cos(6t) + 3.404\sin(6t)$$

The total answer is DC + AC

$$y(t) = 5.714 - 4.908\cos(6t) + 3.404\sin(6t)$$

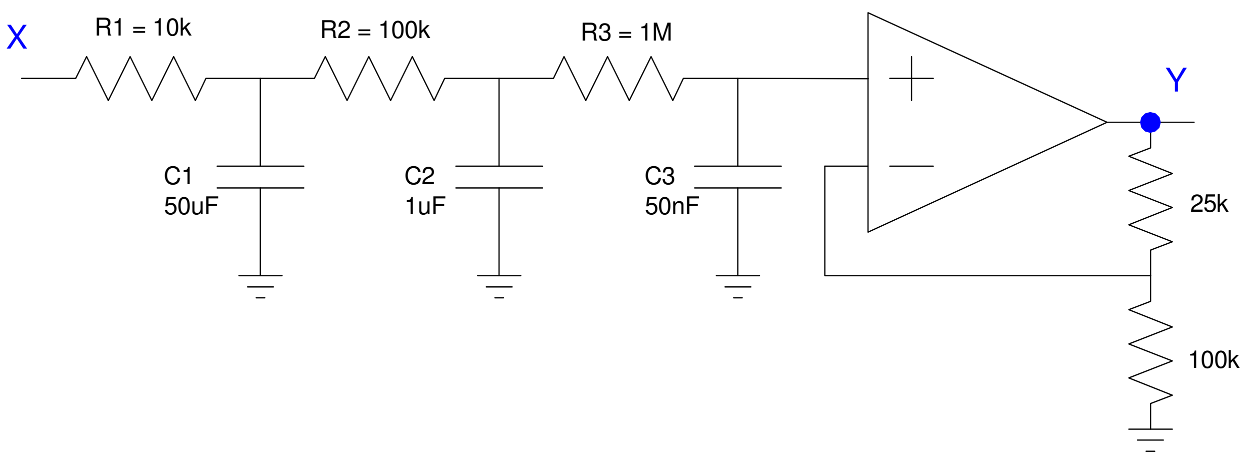
4) Design a circuit to implement the following filter:

$$Y = \left(\frac{500}{(s+2)(s+10)(s+20)}\right)X$$

Use a 3-stage RC filter with a gain

$\frac{1}{R_1C_1} = 2$	R1 = 10k	C1 = 50uF
$\frac{1}{R_2C_2} = 10$	R2 = 100k	C2 = 1uF
$\frac{1}{R_3C_3} = 20$	R3 = 1M	C3 = 50nF

The DC gain is 1.25. Add an amplifier with a gain of 1.25



5) Design a circuit to implement the following filter:

$$Y = \left(\frac{500}{(s+2)(s+3+j10)(s+3-j10)}\right)X$$

Express as

$$Y = \left(\frac{2}{s+2}\right)\left(\frac{250}{s+10.44\angle\pm 73.3^0}\right)$$

$$\frac{1}{R_1 C_1} = 2$$ Let R1 = 10k C1 = 50uF

$$\frac{1}{R_2 C_2} = 10.44$$ Let R2 = 100k C2 = 958nF

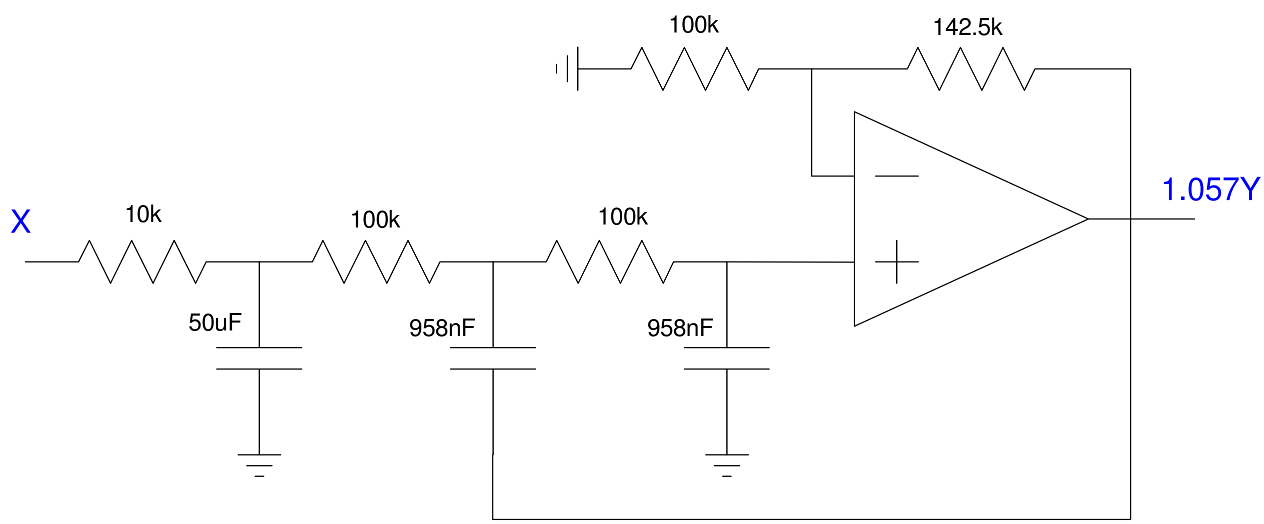
$$3 - k = 2\cos(73.3^0)$$

$$k = 2.425$$

The resulting DC gain is 2.45

The DC gain is supposed to be 2.294

Call the output 1.057Y (or reduce it by 5.7%)



6) Give the transfer function for a 6th order Butteworth filter with

- A DC gain of 1.000
- A corner at 20 rads/c

The amplitude of the poles is 20 rad/sec

The angle between poles is

$$\theta = \frac{180^0}{6} = 30^0$$

$$G(s) = \left(\frac{20^6}{\left(s+20\angle\pm15^0\right)\left(s+20\angle\pm45^0\right)\left(s+20\angle\pm75^0\right)} \right)$$