ECE 321 - Homework #3

Calibration, Filter Circuits, and Frequency Response. Due Monday, April 19th

Please make the subject "ECE 321 HW#3" if submitting homework electronically to Jacob_Glower@yahoo.com (or on blackboard)

Calibration

Problem 1 & 2) Assume you are using a thermistor where the temperature - resistance relationship is

$$R = 1000\ \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right)\ \Omega$$

where T is the temperature in degrees C. Assume this is used along with a voltage divider (5V source, 2k resistor:

$$V = \left(\frac{R}{R+2000}\right) \cdot 5V$$

1) Determine a calibration function of the form

$$T \approx aV + b$$

to estimate temperature over the range of (+10C .. +30C). What is the maximum error in this calibration function?

In matlab

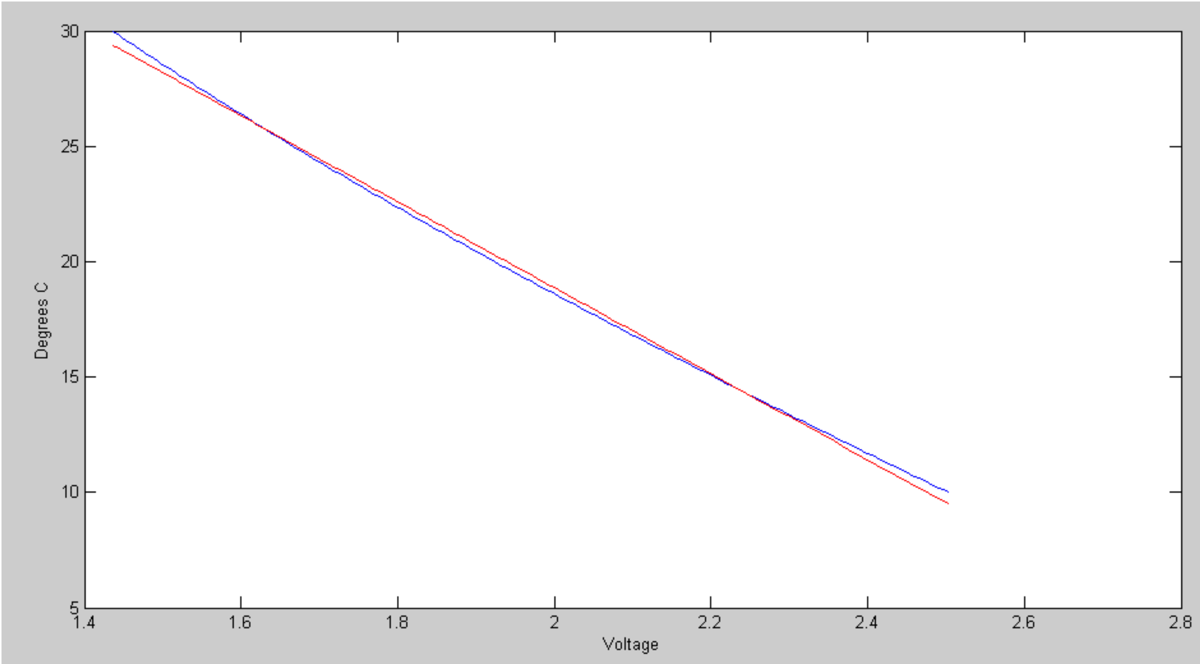
```
>> T = [10:0.1:30]';
>> R = 1000 * exp(3905 ./ (T+273)  -  3905/298);
>> V = R ./ (R+2000) * 5;

>> B = [V, V.^0];
>> A = inv(B'*B)*B'*T

  -18.6498
   56.1622

>> plot(V,T,'b',V,B*A,'r')
>> xlabel('Voltage');
>> ylabel('Degrees C');

>> mean(T - B*A)
 -3.4679e-014

>> std(T - B*A)
    0.2555

>> max(abs(T - B*A))
    0.6120
```

Curve Fit:

$$T \approx -18.6498V + 56.1622$$

maximum error:

0.6120 degrees



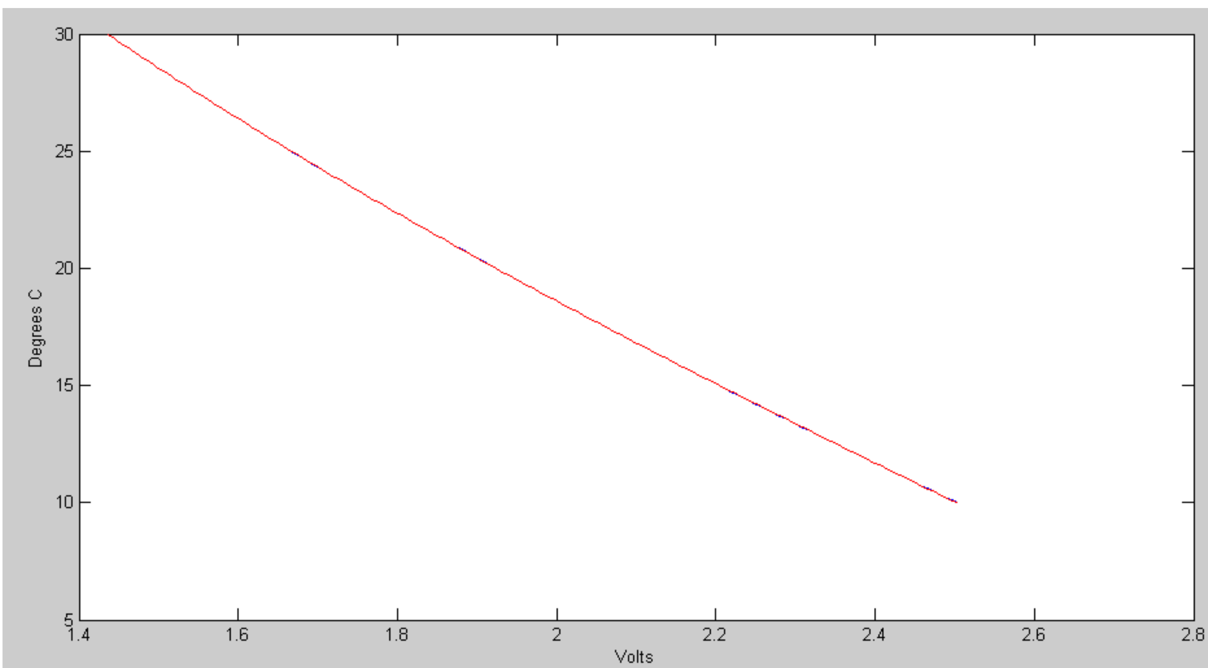
Lienar Curve Fit: Actual Temperature (blue) and Estimated (red)

2) Determine a calibration function of the form

$$T \approx aV^3 + bV^2 + cV + d$$

to estimate temperature over the range of (+10C .. +30C). What is the maximum error in this calibration function?

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

a   -1.5830
b   12.2536
c  -48.1492
d   78.5430

>> plot(V,T,'b',V,B*A,'r')
>> mean(T - B*A)
  2.9552e-010

>> std(T - B*A)
    0.0034

>> max(abs(T - B*A))
    0.0102
```



Cubic Curve Fit: Actual Temperature (blue) and Estimated (red)

Filters

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

$$Y = \left(\frac{40}{(s+2)(s+7)}\right) X$$

a) What is the differential equation relating x and y?

Cross multiply

$$(s^2 + 9s + 14)Y = 40X$$

'sY' means 'the derivative of Y'

$$\boxed{y'' + 9y' + 15y = 40x}$$

b) Determine y(t) assuming

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

Use superposition

x(t) = 4

s = 0

X = 4

$$Y = \left(\frac{40}{(s+2)(s+7)}\right)_{s=0} \cdot (4)$$

$$Y = 11.428$$

meaning

$$y(t) = 11.428$$

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

s = j7

X = 5 - j6

$$Y = \left(\frac{40}{(s+2)(s+7)}\right)_{s=j7} \cdot (5 - j6)$$

$$Y = 4.2588 - j0.8086$$

meaning

$$y(t) = 4.2588\cos(7t) + 0.8086\sin(7t)$$

The total answer is DC + AC

$$\boxed{y(t) = 11.4288 + 4.2588\cos(7t) + 0.8086\sin(7t)}$$

Filter Design using *fminsearch()*

4) Design a filter of the form

$$Y = \left(\frac{ace}{(s+a)\left(s^2+bs+c\right)\left(s^2+ds+e\right)} \right) X$$

to give a gain vs. frequency as close to Gd(s) as possible over the range of (0, 10) rad/sec.

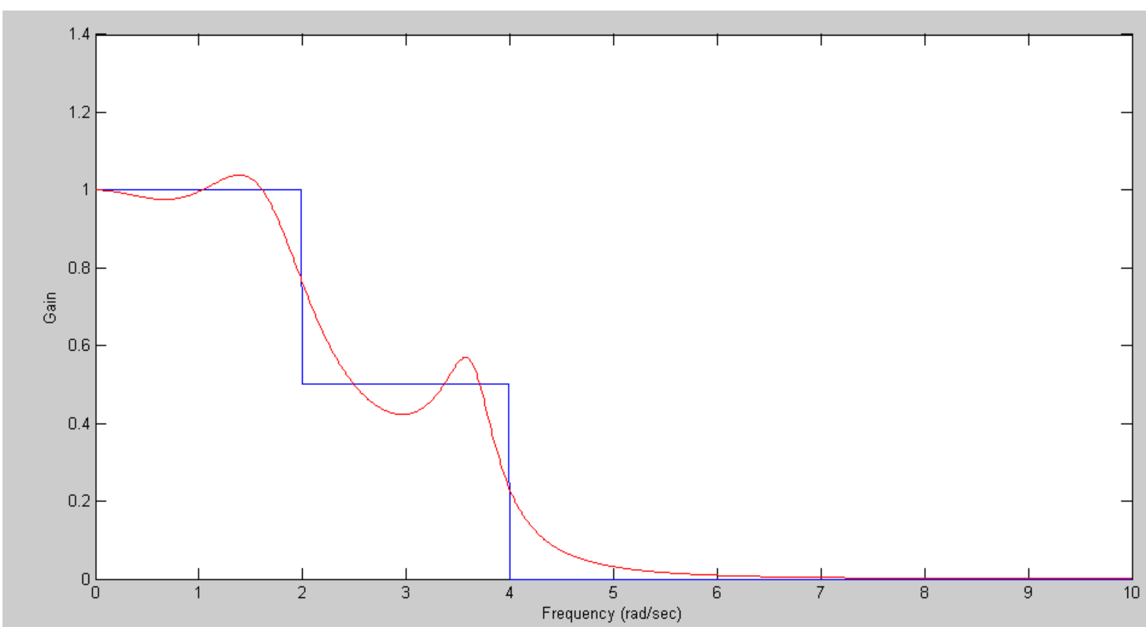
$$G_d(j\omega) = \begin{cases} 1 & 0 < \omega < 2 \\ 0.5 & 2 < \omega < 4 \\ 0 & \omega > 4 \end{cases}$$

Plot your filter's actual frequency response vs. it's ideal response (given by Gd).

In Matlab:

```
>> [Z,e] = fminsearch('costF',[1,2,3,4,5])

Z =     1.0704    1.2733    3.0809    0.5159   13.3705
e =     3.9449

>> [Z,e] = fminsearch('costF',Z)
Z =     1.0704    1.2733    3.0808    0.5159   13.3705
e =     3.9449
```

$$G(s) = \left(\frac{44.0932}{(s+1.0704)\left(s^2+1.2733s+3.0809\right)\left(s^2+0.5159s+13.3704\right)} \right)$$



Filter's ideal response (blue) and actual response (red)

5) Design circuit to implement the filter you designed in problem #4

Build this in three stages

$$G(s) = \left(\frac{a}{s+1.0704}\right)\left(\frac{b}{\left(s^2+1.2733s+3.0809\right)}\right)\left(\frac{c}{\left(s^2+0.5159s+13.3704\right)}\right)$$

Stage 2: $G_2 = \left(\frac{b}{\left(s^2+1.2733s+3.0809\right)}\right) = \left(\frac{b}{s+1.7552\angle\pm 68.73^0}\right)$

$$\frac{1}{RC} = 1.7552$$

C = 1uF

R = 570k

$$3 - k = 2\cos(68.73^0)$$

$$k = 2.2745$$

R1 = 100k

R2 = 127.45k

Stage 3: $G_3 = \left(\frac{c}{s^2+0.5159s+13.3704}\right) = \left(\frac{c}{s+3.6566\angle\pm 85.95^0}\right)$

$$\frac{1}{RC} = 3.6566$$

C = 1uF

R = 273k

$$3 - k = 2\cos(85.95^0)$$

$$k = 2.8587$$

R1 = 100k

R2 = 185.87k

Stage 1: $G_1 = \left(\frac{a}{s+1.0704}\right)$

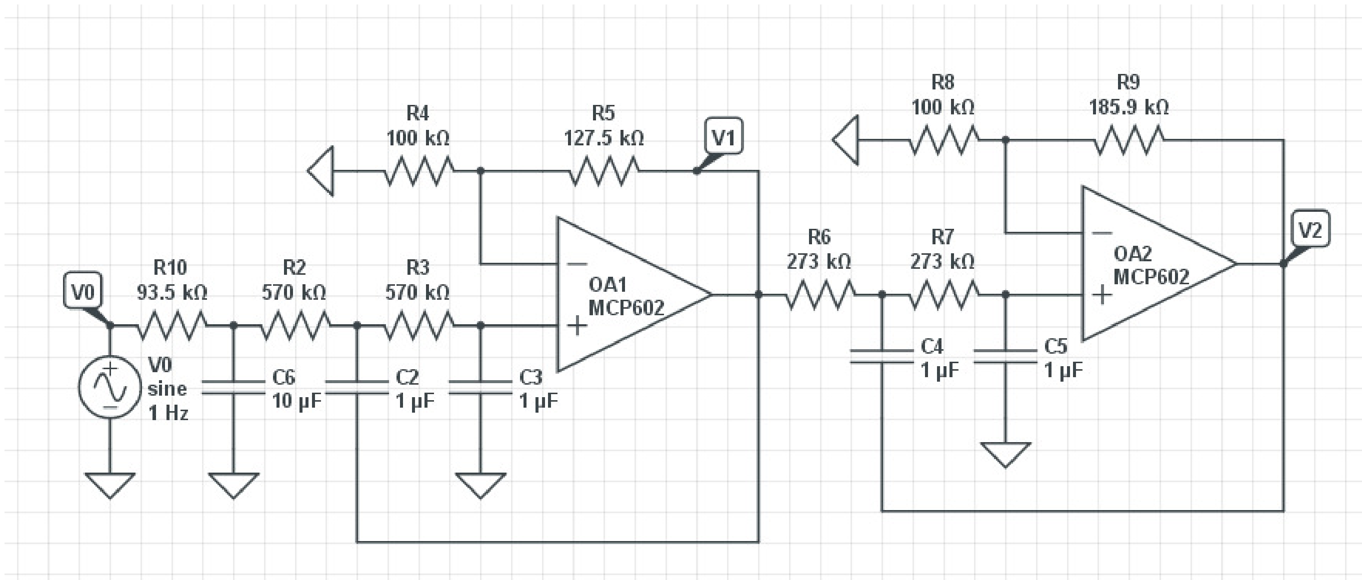
$$\frac{1}{RC} = 1.0704$$

R = 93.4k (<< R(Stage 2))

C = 10uF

The resulting DC gain is k*k = (2.2745)(2.8587) = 6.5021

call the output 6.5021Y



6) Check your filter using CircuitLab