ECE 321 - Homework #3

Calibration, Filter Circuits, and Frequency Response. Due Monday, April 20th

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

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

along with a voltage divider (10V source, 2k resistor:

$$V = \left(\frac{R}{R+2000}\right) \cdot 10V$$

1) Determine a calibration function of the form

$$T \approx aV + b$$

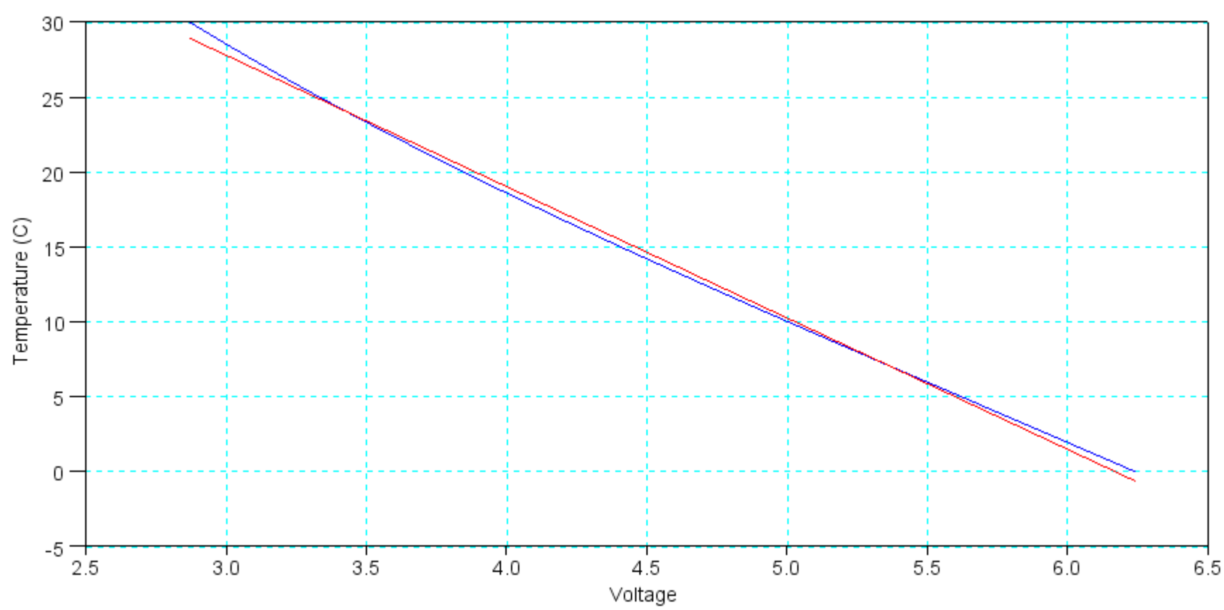
to estimate temperature over the range of (0C, +30C). What is the maximum error in this calibration function?

```
T = [0:0.1:30]';
R = 1000 * exp(3905 ./ (T + 273)  -  3905/298);
V = R ./ (R + 2000) * 10;
B = [V, V.^0];
A = inv(B'*B)*B'*T

  - 8.7698745
    54.106726

max(T - B*A)
 ans  =   1.0738336     maximum error on the high side

min(T - B*A)
 ans  = - 0.4660400     maximum error on the low side
```



2) Determine a calibration function of the form

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

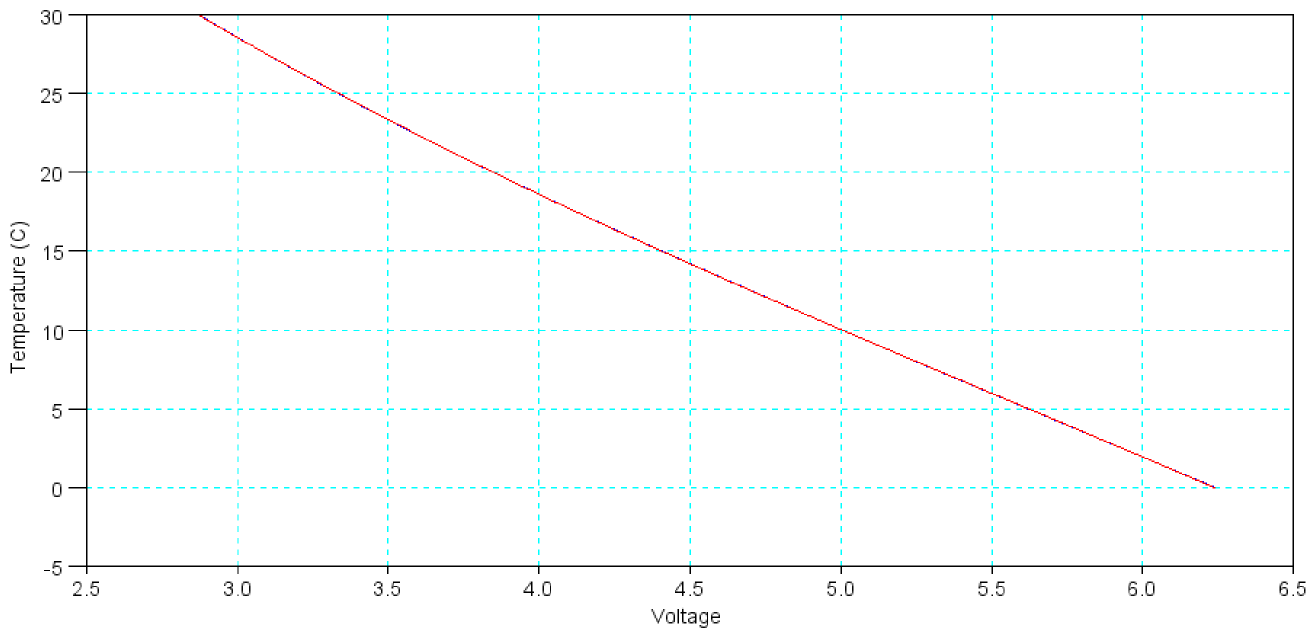
to estimate temperature over the range of (0C, +30C). What is the maximum error in this calibration function?

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

  - 0.1489113
    2.4763568
  - 21.769242
    75.579249

max(T - B*A)
 ans  =    0.0353359

min(T - B*A)
 ans  =  - 0.0151326
```



Filters

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

$$Y = \left(\frac{30}{(s+3)(s+8)}\right)X$$

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

$$(s^2 + 11s + 24)Y = 30X$$

$$\frac{d^2y}{dy^2} + 11\frac{dy}{dt} + 24y = 30x$$

b) Determine y(t) assuming

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

Use superposition

x(t) = 5

s = 0

X = 5 + j0

$$Y = \left(\frac{30}{(s+3)(s+8)}\right)_{s=0}(5 + j0)$$

$$Y = 6.25$$

$$y(t) = 6.25$$

x(t) = 6 cos(4t)

s = j4

X = 6 + j0

$$Y = \left(\frac{30}{(s+3)(s+8)}\right)_{s=j4}(6 + j0)$$

$$Y = 0.720 - j3.960$$

$$y(t) = 0.720\cos(4t) + 3.960\sin(4t)$$

The total answer is then

$$y(t) = 6.25 + 0.720\cos(4t) + 3.960\sin(4t)$$

Filter Design using *fminsearch()*

4) Design a filter of the form

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

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

$$G_d(j\omega) = \begin{cases} 1 & 0 < \omega < 6 \\ 0 & otherwise \end{cases}$$

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

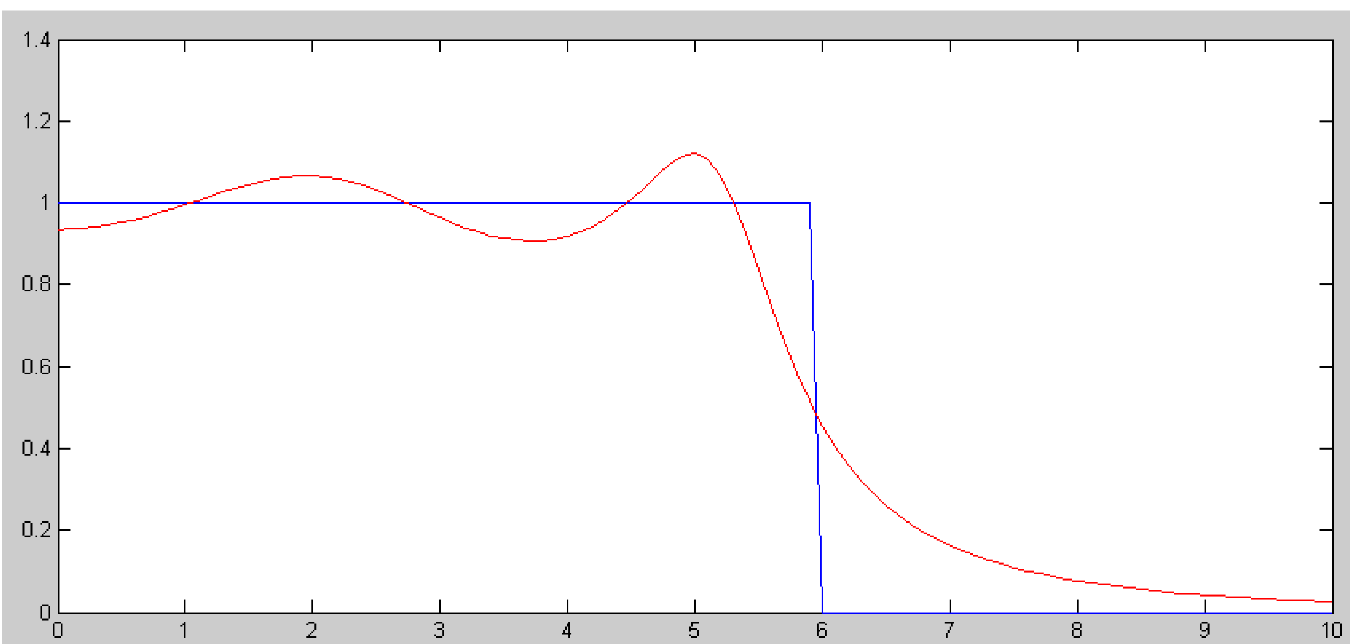
```
Z,e] = fminsearch('costF',[130,2,5,2,26])

Z =   181.1933     3.2716     7.0623     1.2414    27.4180

e =   1.9369
```

meaning

$$G(s) = \left(\frac{181.1933}{(s^2+3.2716s+7.0623)(s^2+1.2414s+27.4180)} \right)$$



Code:

```
function [ J ] = costF( z )

    a = z(1);
    b = z(2);
    c = z(3);
    d = z(4);
    e = z(5);

    w = [0:0.1:10]';
    s = j*w;

    Gd = 1 .* (w < 6);

    num = a;
    den = (s.^2 + b*s + c).*(s.^2 + d*s + e);

    Gs = num ./ den;

    e = abs(Gd) - abs(Gs);

    J = sum(e.^2);

    plot(w,abs(Gd),'b',w,abs(Gs),'r');
    pause(0.01);

    end
```

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

$$G(s) = \left(\frac{181.1933}{(s^2+3.2716s+7.0623)(s^2+1.2414s+27.4180)} \right)$$

Put in polar form

$$G(s) = \left(\frac{181.1933}{(s+2.657\angle\pm 52.01^0)(s+5.2362\angle\pm 83.19^0)} \right.$$

Stage 1:

$$\left(\frac{1}{RC}\right) = 2.657$$

$$C = 1\mu F$$

$$R = 376k\Omega$$

$$3 - k = 2\cos(52.01^0)$$

$$k = 1.769$$

Stage 2

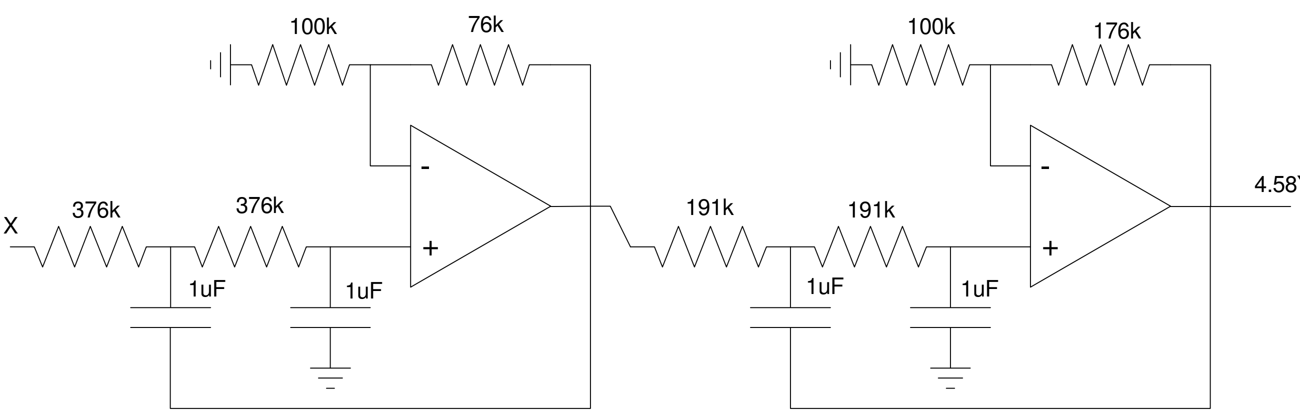
$$\left(\frac{1}{RC}\right) = 5.2362$$

$$C = 1\mu F$$

$$R = 191k\Omega$$

$$3 - k = 2\cos(83.19^0)$$

$$k = 2.763$$



Note: The DC gain of this filter is 4.58.

- Reduce the gain (add a voltage divider) to make the DC gain match, or
- Label the output as 4.58Y

The latter is better: you're probably going to add gain somewhere. This filter provides a DC gain of 4.58. The rest of the circuit adds the rest.

6) Check your filter using CircuitLab