ECE 321 - Homework #3

Filter Design. Due Monday, April 16th, 2018

(Option 1): Design a filter to meet the following requirements

- Input: +/- 10V analog signal, 0 - 10kHz, capable of driving 10mA (1k resistor)
- Output: +/- 10V analog signal, 0 - 10kHz, capable of driving 10mA (1k resistor)
- Relationship

$0.9 < \text{Gain} < 1.1$	$0 < f < 200$ Hz
$\text{Gain} < 0.1$	$f > 600$ Hz

1) (Analysis): Give the transfer function for a filter which meets these requirements

First, determine the number of poles you need

$$\left(\frac{200Hz}{600Hz}\right)^n < 0.1$$

$$n > 2.09$$

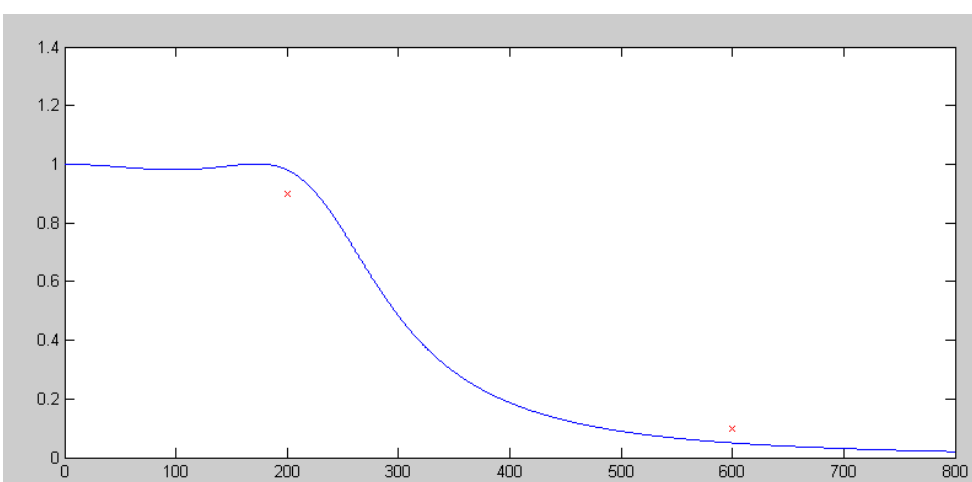
Let n = 3

Choose a Chebychev filter. With a corner at 1 rad/sec,

$$G(s) = \left(\frac{1.2445}{(s+0.85)(s+1.21\angle 69.5^0)(s+1.21\angle -69.5^0)}\right)$$

Scale this in Matlab to meet the requirements (gain > 0.9 at 200Hz)

```
>> w = [0:0.001:4]';
>> f = w / (2*pi);
>> s = j*w;
>> s1 = 0.85;
>> s2 = 1.21*exp(j*69.5*pi/180);
>> s3 = conj(s2);
>> G = 1.2445 ./  ( (s+s1) .* (s+s2) .* (s+s3) );
>> plot(f*400*pi,abs(G),[200,600],[0.9,0.1],'rx')
>> xlabel('Frequency (Hz)');
```



This meets the requirements so

$$G(s) = \left(\frac{1.244}{\left(\frac{s}{400\pi}+0.85\right)\left(\frac{s}{400\pi}+1.21\angle 69.5^0\right)\left(\frac{s}{400\pi}+1.21\angle -69.5^0\right)} \right)$$

$$G(s) = \left(\frac{1.244(400\pi)^3}{(s+1068)\left(s+1520\angle 69.5^0\right)\left(s+1520\angle -69.5^0\right)} \right)$$

2) (Analysis): Design an op-amp circuit to implement this transfer function

RC Filter:

Let R = 10k

1/RC = 1068

C = 93nF

2-Stage Filter

Let R = 100k

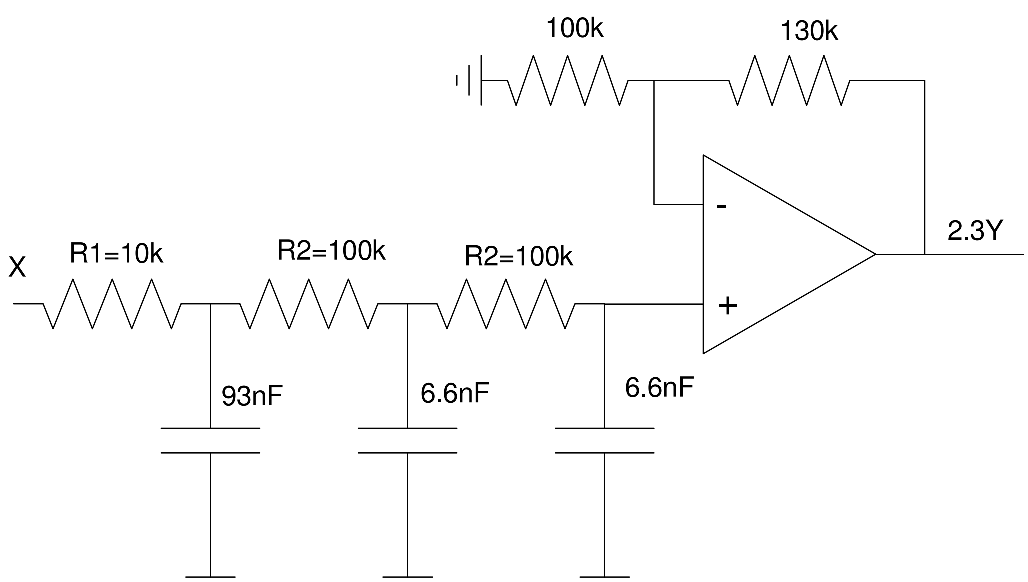
1/RC = 1520

C = 6.6nF

3 - k = 2 cos(69.5)

k = 2.3

R1 = 100k. R2 = 130k

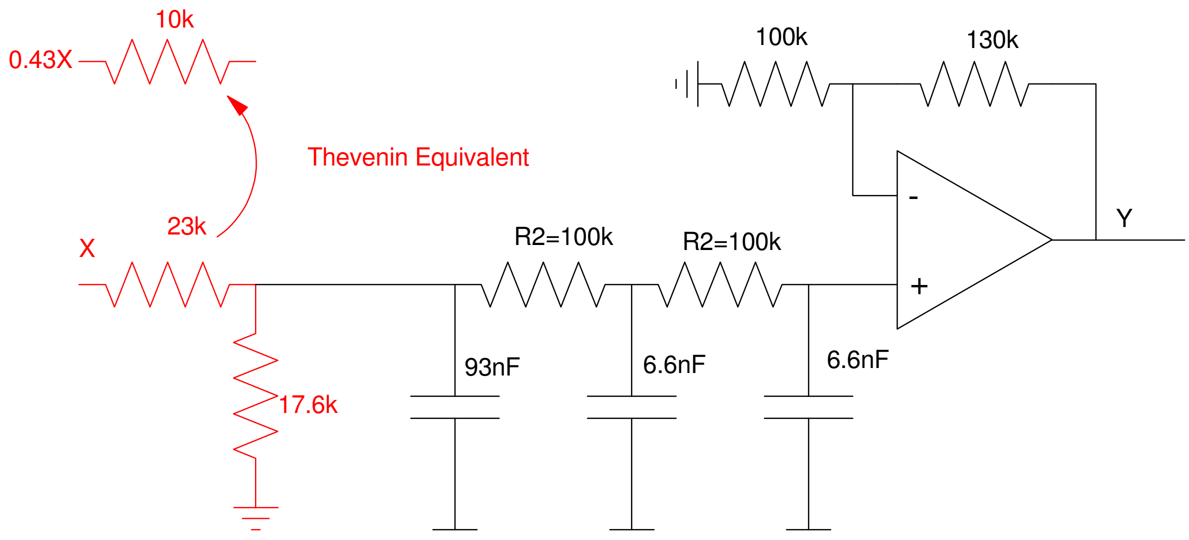


Note: This filter has a DC gain of 2.3

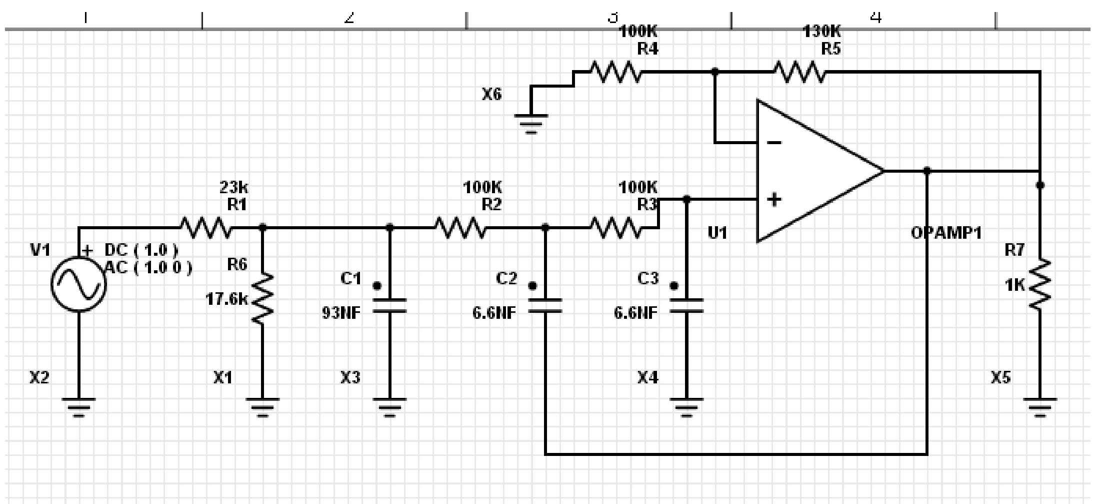
- Live with it and call the output 2.3Y (the extra gain means some other amplifier doesn't need as much), or
- Reduce the gain by a factor of 1/2.3 (0.4335)

Think Thevenin: Change the 10k resistor to a voltage divider with

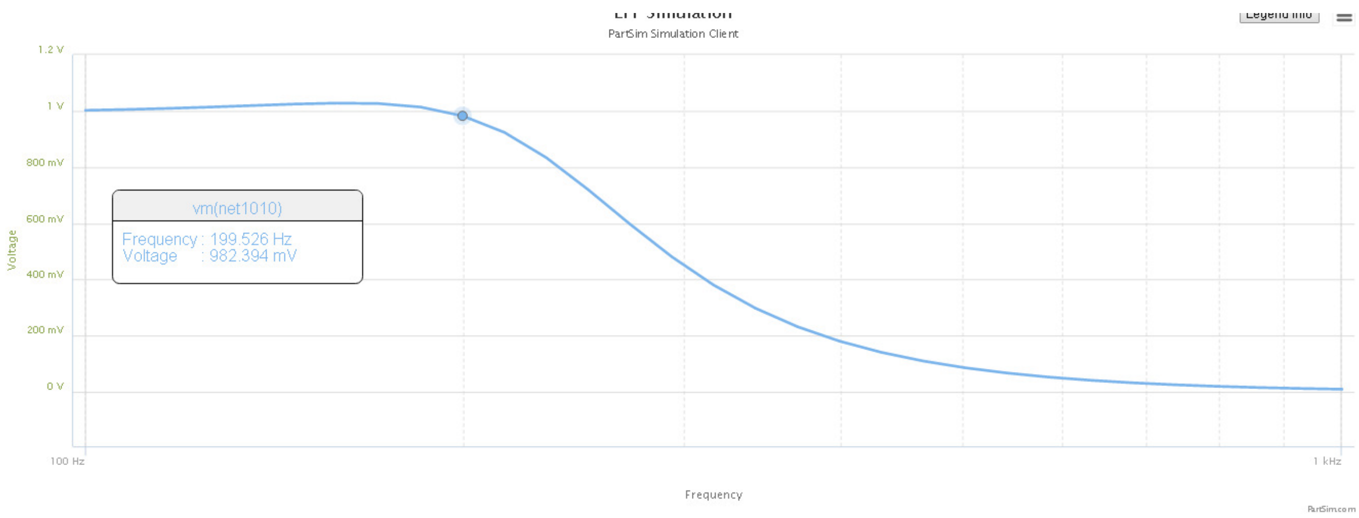
- A gain of 0.4335
- A Thevenin resistance of 10k



3) (Simulation): Test your design in simulation with PartSim (or similar software)



Frequency	Calculated Gain	Simulated Gain	Measured Gain (Lab)
100 Hz	0.9814	1.002	
200Hz	0.9813	0.982	
600Hz	0.0502	0.0484	
1000Hz	0.0103	0.010	



4) (Validation): Build your circuit and test it in lab to verify it meets your requirements.