ECE 321 - Homework #4

Butterworth & Chebychev filters, Analog Computers. Due Monday, April 26th

Please make the subject "ECE 321 HW#4" if submitting homework electronically to Jacob_Glower@yahoo.com (or on blackboard)

Analog Computers

1) Design an analog computer to implement

$$Y = \left(\frac{20(s^2+4)}{(s+3)\left(s^2+4s+15\right)} \right) U$$

Rewrite as

$$X = \left(\frac{1}{(s+3)\left(s^2+4s+15\right)} \right) U$$

$$Y = (20s^2 + 80)X$$

Multiply out

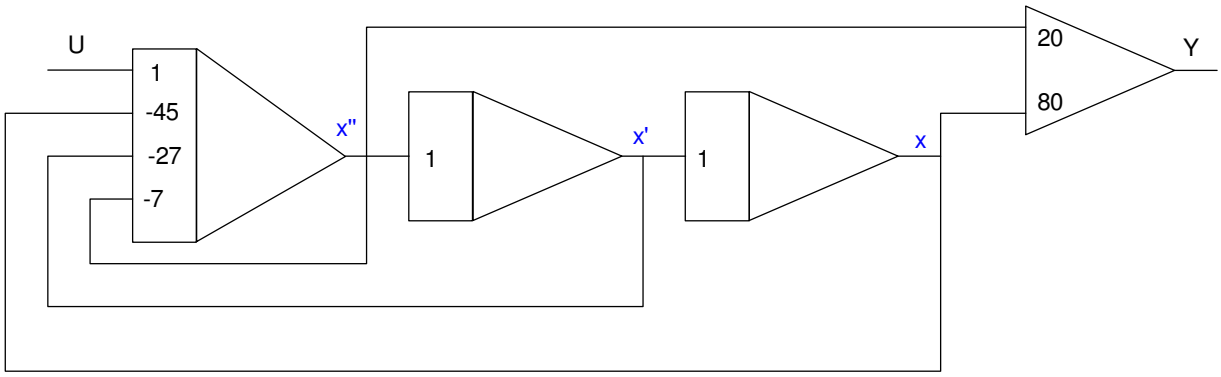
$$x''' + 7x'' + 27x' + 45x = u$$

Solve for the highest derivative

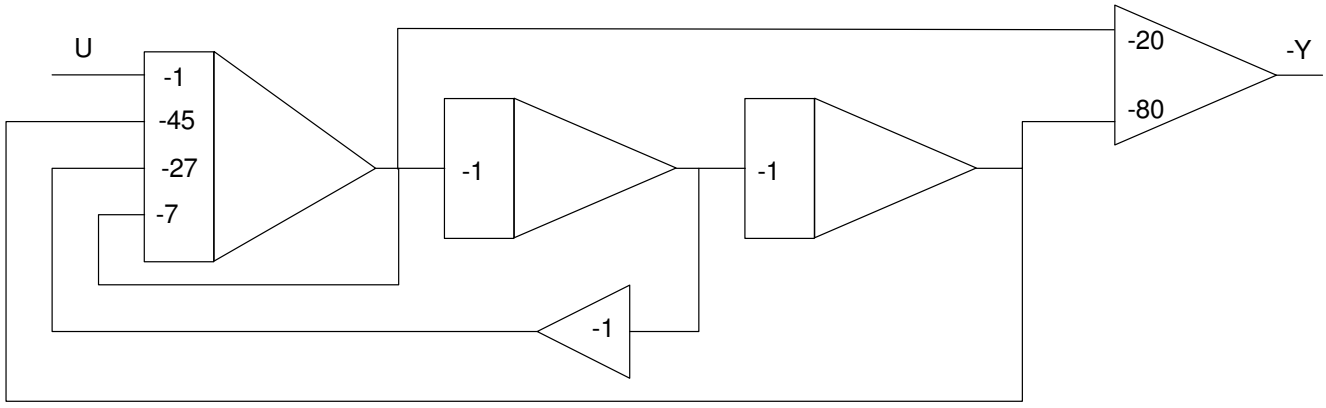
$$x''' = -7x'' - 27x' - 45x + u$$

$$y = 20x'' + 80x$$

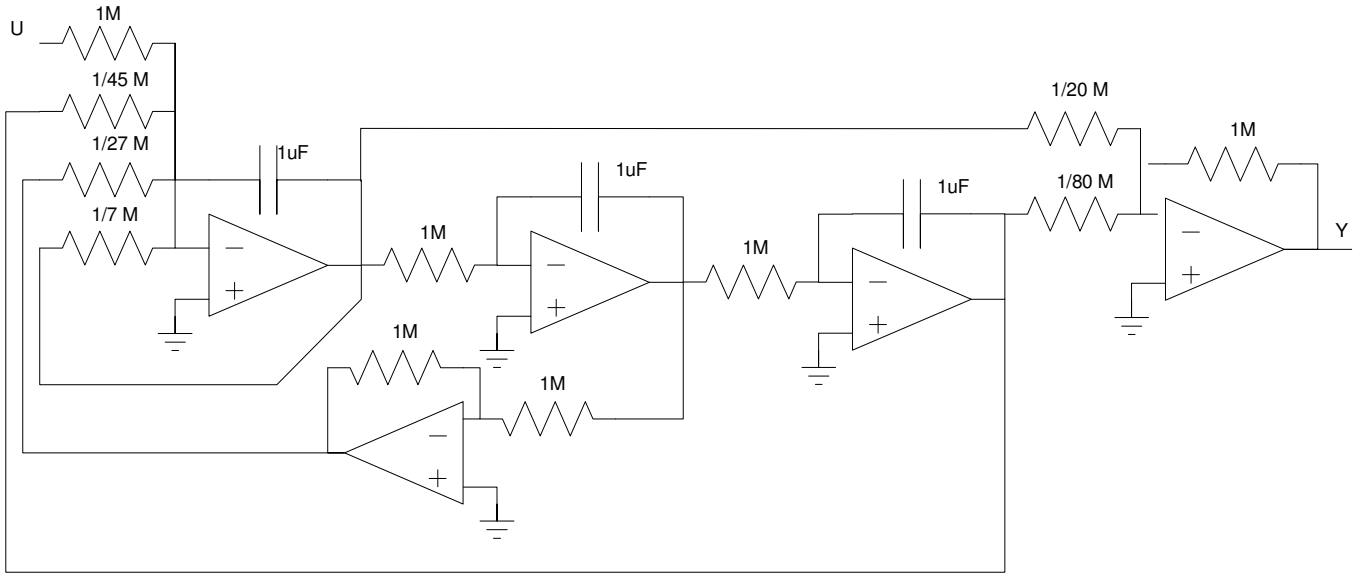
Implement as an analog computer



Adjust the gains so that they are all negative. Add an inverter (gain = -1) if needed

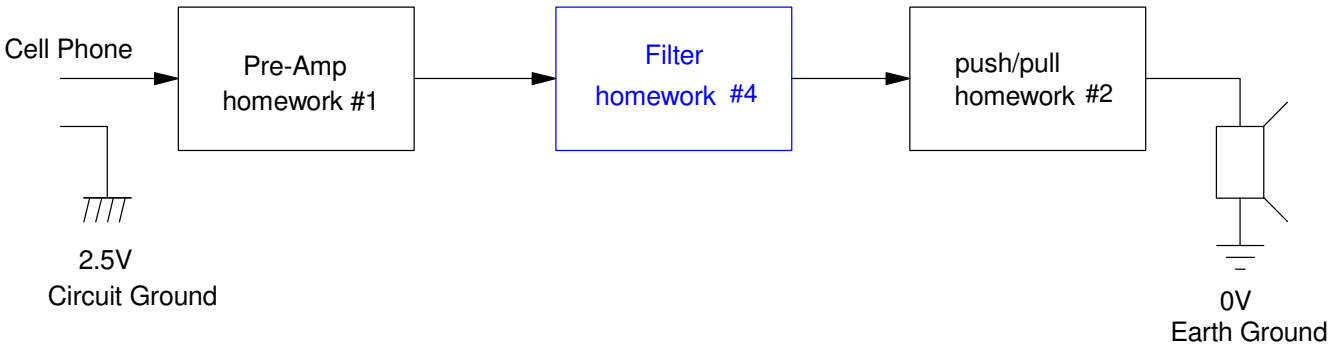


Implement with an op-amp circuit



Design a filter for your cell-phone to speaker circuit. Some suggestions are...

- Subwoofer Crossover. Pass frequencies below 250Hz. Reject frequencies above 500Hz.
- Cow-Bell Filter: Pass frequencies between 590 and 630Hz. Reject frequencies below 500Hz or above 700Hz.
- Middle-C Filter: Pass frequencies between 220Hz and 440Hz. Reject frequencues below 150Hz and above 650Hz.
- Other...



2) Requirements.

- gain < 0.3 for f < 400hz
- 0.8 < gain < 1.2 for 580 Hz < f < 620 Hz
- gain < 0.3 for f > 800hz

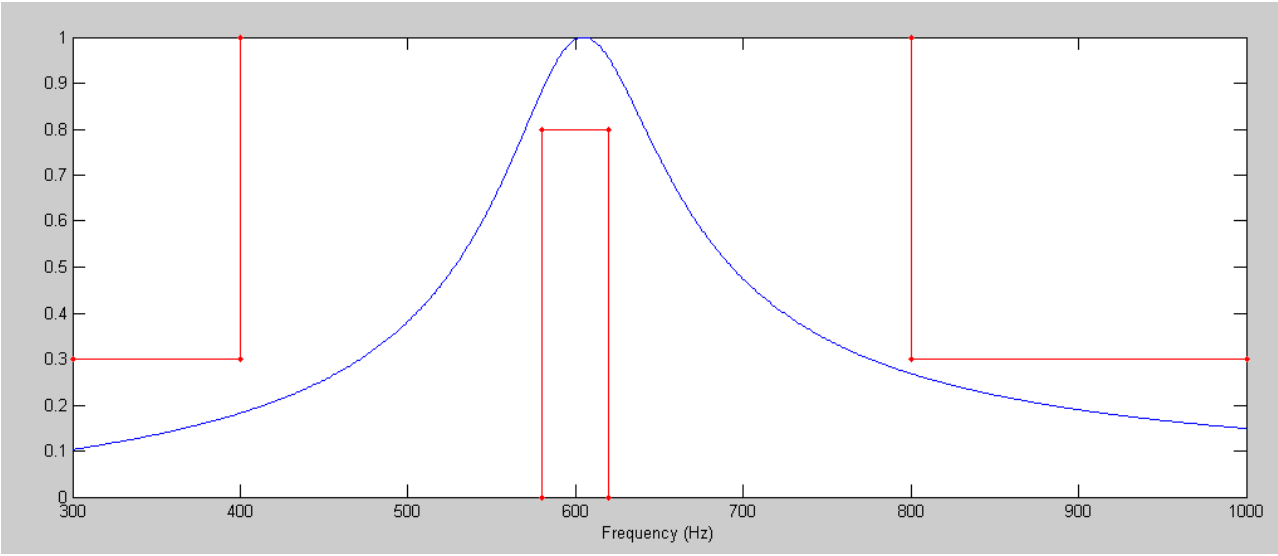
3) Filter design:

Pass 600Hz +/- 50hz

- complex part of pole = 600hz = 3770 rad/sec
- real part of pole = 50hz = 300 rad/sec

Let

$$G(s) = \left(\frac{600s}{(s+300+j3770)(s+300-j3770)}\right) \approx \left(\frac{600s}{s^2+600s+3800^2}\right)$$



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>> f = [300:1000]';
>> w = 2*pi*f;
>> s = j*w;
>> Gs = 600*s ./ ( s.^2 + 600*s + 3800^2);
>> plot(w,abs(Gs))

>> s = j*2*pi*600;

>> abs(evalfr(G, j*2*pi*400))
ans =    0.1825

>> abs(evalfr(G, j*2*pi*580))
ans =    0.8835

>> abs(evalfr(G, j*2*pi*620))
ans =    0.9539

>> abs(evalfr(G, j*2*pi*800))
ans =    0.2684
```

>>

freq	400hz	580hz	600hz	620hz	800hz
requirement	< 0.3	> 0.8	< 1.2	> 0.8	< 0.3
gain (calc)	0.1825	0.8835		0.9539	0.2684
meet req?	yes	yes		yes	yes

4) Simulation: Simulate your filter in CircuitLab to verify that it meets your requirements

- 0.9 < gain < 1.1 in the pass-band region, and
- gain < 0.2 in the band-reject region

The target is

$$G(s) = \left(\frac{600s}{s^2+600s+3800^2}\right) = \left(\frac{\left(\frac{1}{R_1C}\right)s}{s^2+\left(\frac{2}{R_3C}\right)s+\left(\frac{R_1+R_2}{R_1R_2}\right)\left(\frac{1}{R_3C^2}\right)}\right)$$

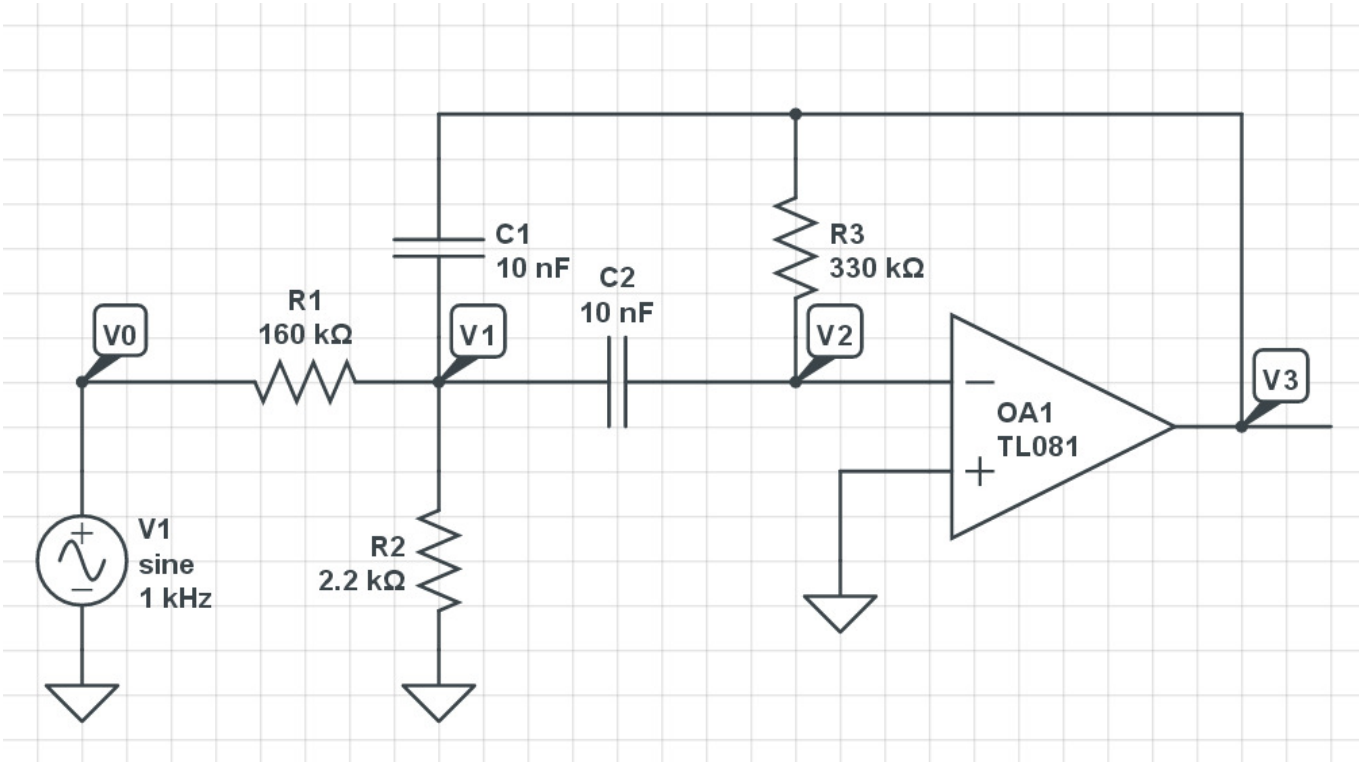
Let C = 0.01uF (somewhat arbitrary)

$$\left(\frac{1}{R_1C}\right) = 600 \quad \Rightarrow \quad \text{R1 = 167k}$$

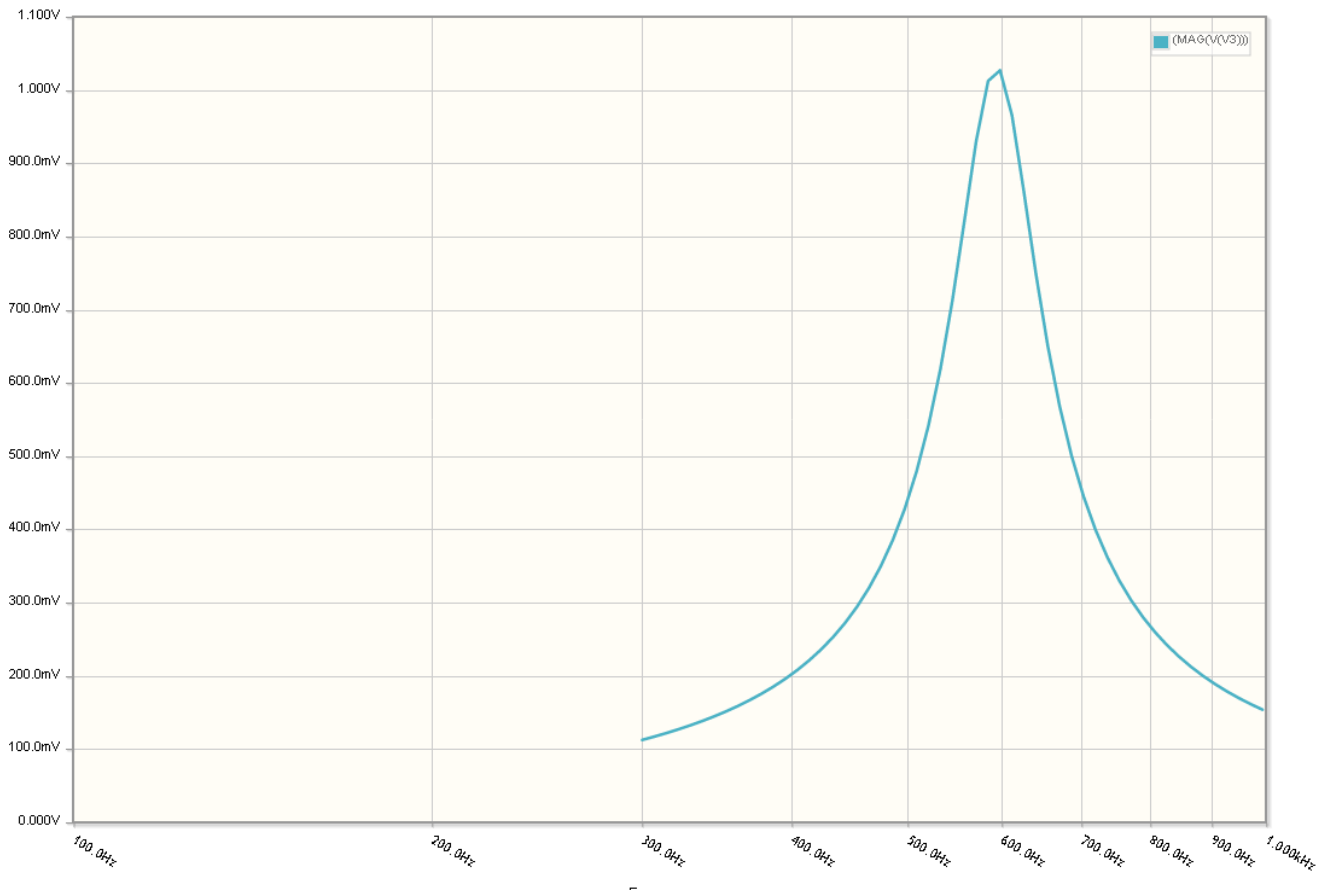
$$\left(\frac{2}{R_3C}\right) = 600 \quad \Rightarrow \quad \text{R3 = 333k}$$

$$\left(\frac{R_1+R_2}{R_1R_2}\right)\left(\frac{1}{R_3C^2}\right) = 3800^2 \quad \Rightarrow \quad \text{R2 = 2105}$$

Adjusting the values for common resistor / capacitor values



Doing a frequency sweep



freq	400hz	580hz	600hz	620hz	800hz
requirement	< 0.3	> 0.8	< 1.2	> 0.8	< 0.3
gain (sim)	0.2079	0.930	1.02	0.860	0.259
meet req?	yes	yes	yes	yes	yes

5) Hardware: Build your filter and verity it meets your requirements.

- 0.9 < gain < 1.1 in the pass-band region, and
- gain < 0.2 in the band-reject region
- input = 1.736Vac

296hz	401hz	580hz	604hz	708hz	776hz	919hz
0.1999	0.119	0.218	0.240	0.440	0.619	0.412

6) Demo: Demonstrate your pre-amp - filter - power amp circuit.