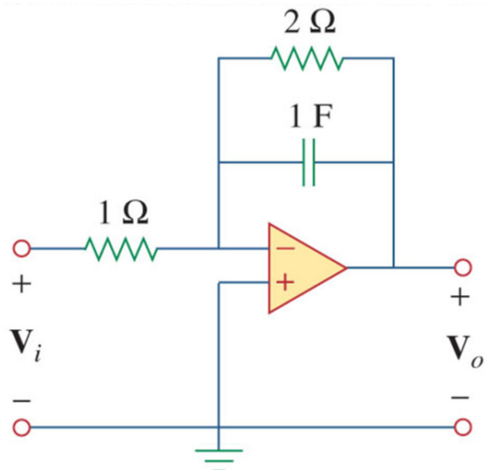
IUPUI ECE 202 Spring 2015:
Homework #6 (SOLUTIONS)   Name:

1. (**10 pts:** Prob. 14.82 in text) Scale the **lowpass** active filter shown below so that its corner frequency increases from 1 rad/s to 200 rad/s. (Use a 1 μF capacitor).



Solution from the Author's Solution manual:

$$C' = \frac{C}{K_m K_f}$$

$$K_f = \frac{\omega_c'}{\omega} = \frac{200}{1} = 200$$

$$K_m = \frac{C}{C'} \cdot \frac{1}{K_f} = \frac{1}{10^{-6}} \cdot \frac{1}{200} = 5000$$

$R' = K_m R = 5\ \mathbf{k\Omega}$, thus, $R_f' = 2R_i = 10\ \mathbf{k\Omega}$

However, this results in a corner frequency of 100 rad/s not 200 rad/s !!

The "error" is that the original corner frequency is actually 0.5 rad/s.

$$\omega_c = \frac{1}{R_f C_f} = \frac{1}{(2)(1)} = 0.5$$

Using this instead we get:

$$C' = \frac{C}{K_m K_f}$$

$$K_f = \frac{\omega_c'}{\omega_c} = \frac{200}{0.5} = 400$$

$$K_m = \frac{C}{C'} \cdot \frac{1}{K_f} = \frac{1}{1 \times 10^{-6}} \cdot \frac{1}{400} = 2500$$

$$R_f' = K_m R_f = (2500) \times (2) = \boxed{5\ \text{k}\Omega}$$

$$R_i' = K_m R_i = (2500) \times (1) = \boxed{2.5\ \text{k}\Omega}$$

Another solution:

To scale the circuit to result in a corner frequency of 200rad/s and use a 1 uF capacitor:

$$\omega_c' = \frac{1}{R_f' C_f'}$$

$$R_f' = \frac{1}{C_f' \omega_c'}$$

$$R_f' = \frac{1}{(1 \times 10^{-6}) \times 200} = \boxed{5\ \text{k}\Omega}$$

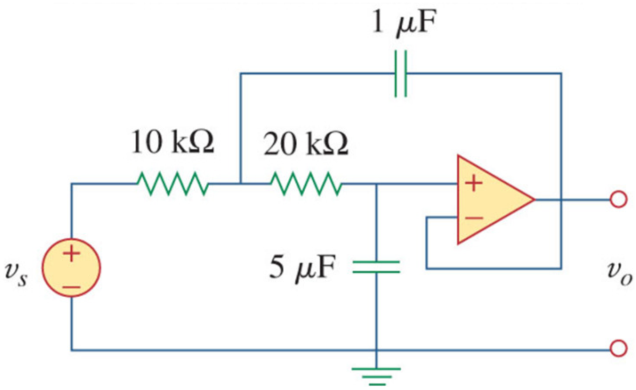
To find R_i to keep the same gain:

$$Gain = \frac{R_f}{R_i} = \frac{2}{1} = 2 = \frac{R_f'}{R_i'}$$

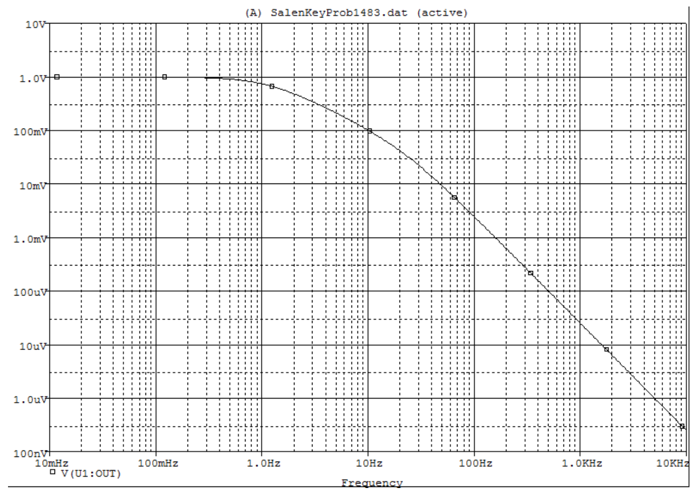
$$R_i' = \frac{R_f'}{2} = \boxed{2.5\ \text{k}\Omega}$$

2. (**10 pts**: Prob. 14.83 from Text) The op amp circuit in the figure below is to be magnitude-scaled by 100 and frequency-scaled by 105. Find the resulting element values. (If Possible, use Pspice to verify)

Note: This is actually a fairly significant circuit, it's called a Sallen-Key filter and is a commonly used active filter design.



From PSpice



$1\mu F \longrightarrow C' = \frac{1}{K_m K_f} C = \frac{10^{-6}}{100 x 10^5} = \underline{0.1\,pF}$

$5\mu F \longrightarrow C' = \underline{0.5\,pF}$

$10\,k\Omega \longrightarrow R' = K_m R = 100 x 10\,k\Omega = \underline{1\,M\Omega}$

$20\,k\Omega \longrightarrow R' = \underline{2\,M\Omega}$

From website:
http://sim.okawa-denshi.jp/en/OPstool.php

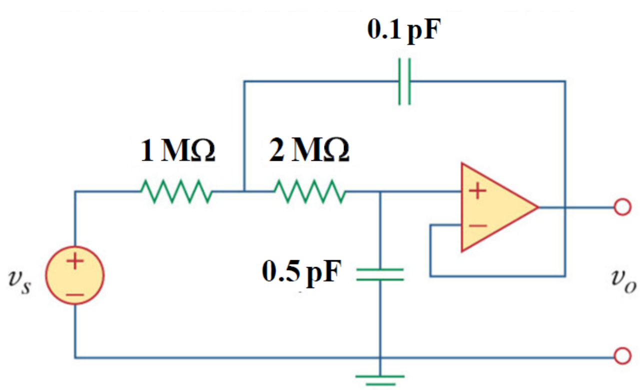
Transfer Function

$$G(s) = \frac{1000}{s^2 + 150s + 1000}$$

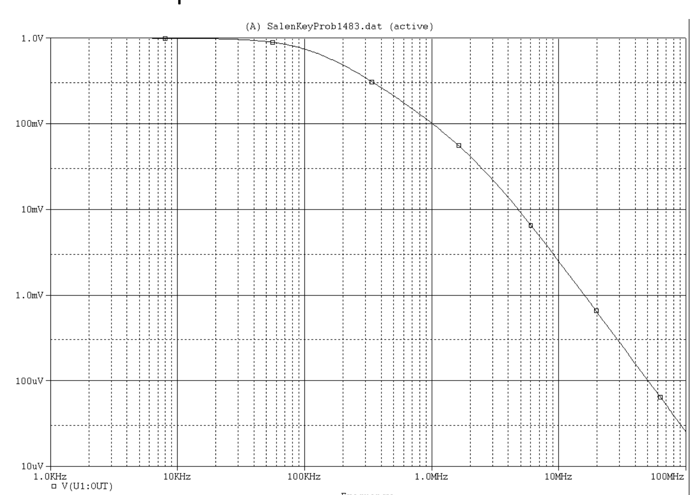
Sallen-Key Low-pass Filter

Cut-off frequency
fc = 5.03292121045[Hz]

Quality factor
Q = 0.210818510678



From PSpice



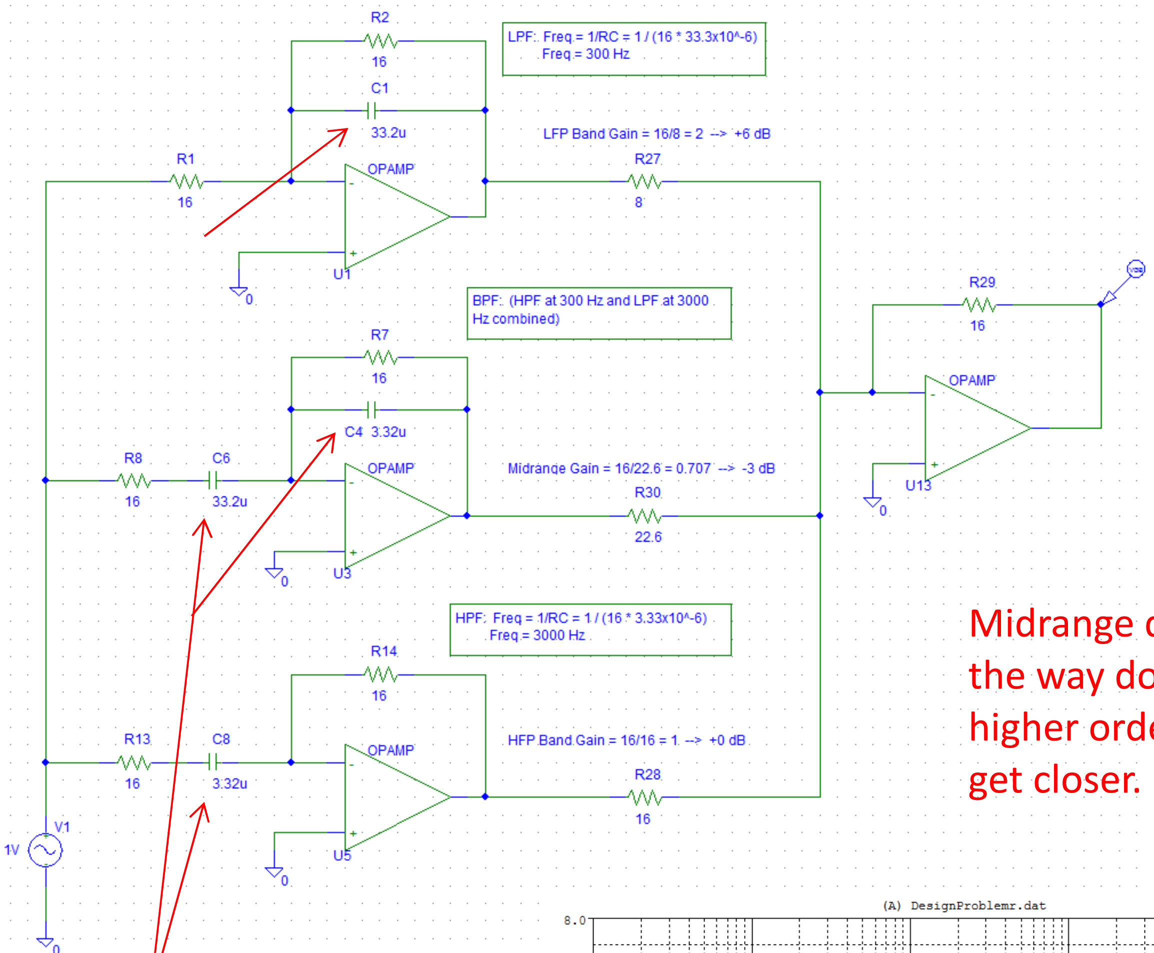
Sallen-Key Low-pass Filter

Cut-off frequency
fc = 503292.121045[Hz]

Quality factor
Q = 0.210818510678

Damping ratio
ζ = 2.37170824513

3. (**20 pts:** Design Problem) Design a circuit to control the Base, Midrange, and Treble. Use 300 Hz as the crossover between the Base and Midrange and 3 KHz as the crossover between Midrange and Treble. Select resistor values to set the Base to +6 dB, the Midrange to -3 dB, and the Treble to +0dB Gain.



Midrange doesn't go all the way down to -3dB, higher order filter would get closer.

Time constants (Using 16 ohm resistor)

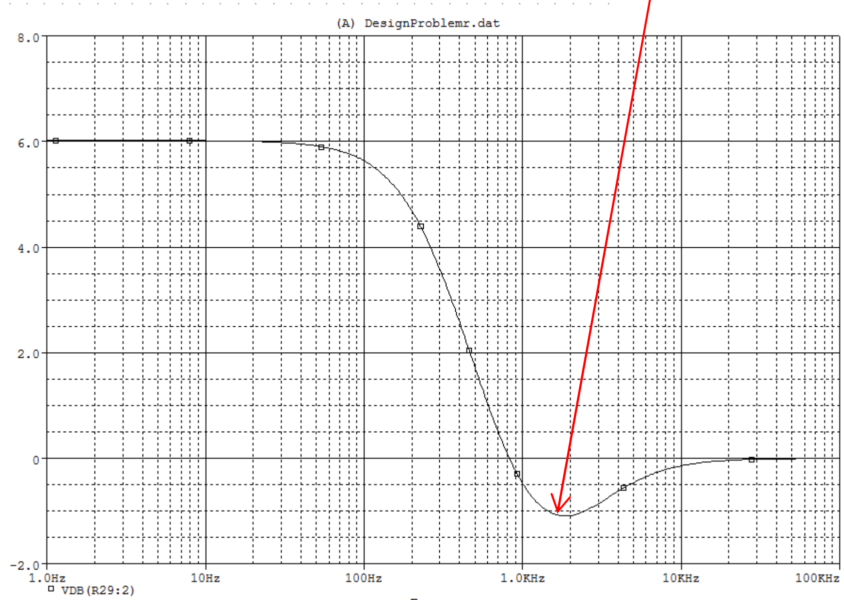
$$\omega_c = \frac{1}{RC}$$

$$R = 16 \ \ \Omega$$

$$C = \frac{1}{16 \times 2\pi f_c}$$

$$C_{LPF} = \frac{1}{(16) \times 2\pi \times 300} = 33.2 \ \ \mu\text{F}$$

$$C_{HPF} = \frac{1}{(16) \times 2\pi \times 3000} = 3.32 \ \ \mu\text{F}$$



Another Solution: