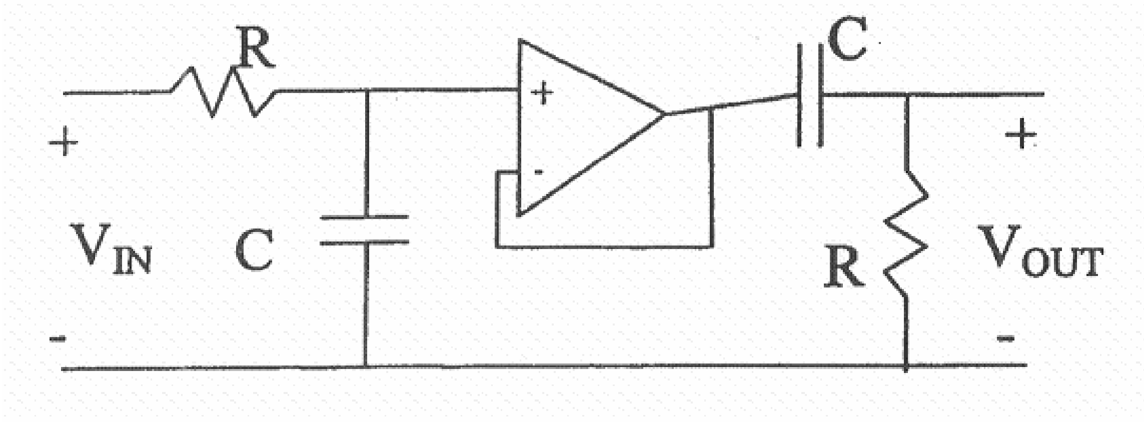
ENG 100 PreLab for Lab #5

The Operational Amplifier in Filters

One application of op amps is in filters.

A. Second-order bandpass filter using a voltage buffer:



For the 2nd-order RC circuit with one op amp shown above:

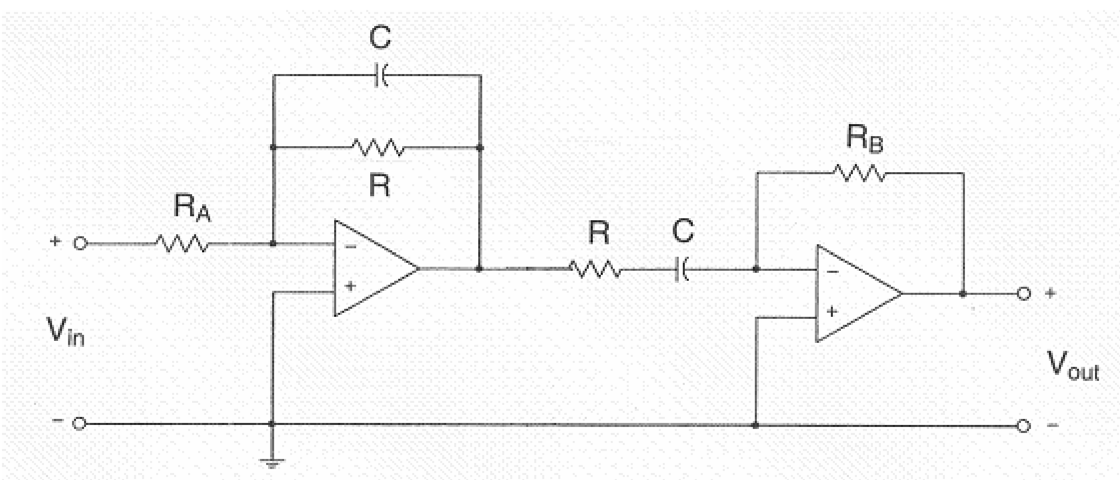
Let R = 1500 Ω = 1.5 kΩ, and let C = 0.01 μF.

1. Derive the transfer function, and find ω_o and Q. The transfer function has the form:
   $H(s) = V_{out}(s)/V_{in}(s) = Ks / (s^2 + s(\omega_o/Q) + \omega_o^2)$. (1)

2. Calculate the magnitude, phase and time delay of the transfer function at each of the frequencies in Table 1. Fill in the 'expected' values in Table 1.

Notice that this circuit is similar to the circuit in Lab #3, only with a buffer isolating the two RC sections. The buffer simplifies the circuit analysis and leads to a different transfer function.

B. Second-order bandpass filter using 2 op amps:



For the 2nd-order RC circuit with two op amps shown above:

Let R = 1500 Ω = 1.5 kΩ, and let C = 0.01 μF.

1. Derive the transfer function, and find ω_o and Q. The transfer function has the form:
   $H(s) = V_{out}(s)/V_{in}(s) = Gs / (s^2 + s(\omega_o/Q) + \omega_o^2)$. (2)

2. Determine a resistor ratio for R_B / R_A that makes $|H(j\omega_o)| = 5 = 14\text{dB}$. (This will give more gain and larger output voltages in the second circuit compared to the first circuit.)

3. Calculate the magnitude, phase and time delay of the transfer function at each of the frequencies in Table 2. Fill in the 'expected' values in Table 2.

NOTE: The TA may ask to look at your pre-lab calculations and plots by coming to your station while you work. Points may be given. <u>Don't leave until the TA has seen your pre-lab.</u>

Updated: 5/1/07

Table 1 – First Circuit: Filter using an opamp as a voltage buffer

f (Hz)	$\omega=2\pi f$ (rad/s)	Expected $\|H\|$	Expected $\|H\|$ (dB)	Expected phase = ang(H) (deg)	Expected delay t_d (sec)	Measured ampl. of V_{OUT} (Vpp)	Measured delay t_d (sec)	$\|H\|$ (dB) [from measured ampl. of V_{OUT}]	Phase = ang(H) (deg) [from measured delay t_d]
100									
1 000									
3 000									
5 000									
10 000									
30 000									
50 000									
100 000									
300 000									
500 000									

Fill the above table up to and including the **Expected delay** column; you should do this from calculations before your lab period.

Get the expected phase from methods given in class, then calculate expected delay, t_d, using the formula t_d = phase / $(-360^o \cdot f)$.

Example: If the expected phase at 17800 Hz is -23^o, then the expected delay is $-23^o / (-360^o \cdot 17800\text{ Hz}) = 3.59\ \mu s$.

Example: If the expected phase at 3160 Hz is $+61^o$, then the expected delay is $+61^o / (-360^o \cdot 3160\text{ Hz}) = -53.6\ \mu s$.

Notice that a positive phase (an "advance" in phase) results in a <u>negative</u> delay!

When you get to lab, measure and then fill in the first two "Measured" columns with your measurements, then calculate the last two columns.

Using the measured delay, calculate phase shift using the formula: phase (deg) = $-360^o \cdot f \cdot t_d$.

Plot your amplitude in dB vs. f (Hz), <u>**not** vs. ω</u> (radians/s). Plot your phase in degrees (^{o}) vs. f (Hz), <u>**not** vs. ω</u>.

Table 2 – Second Circuit: Filter using 2 opamps

f (Hz)	$\omega=2\pi f$ (rad/s)	Expected $\lvert H\rvert$	Expected $\lvert H\rvert$ (dB)	Expected phase = ang(H) (deg)	Expected delay t_d (sec)	Measured ampl. of V_{OUT} (Vpp)	Measured delay t_d (sec)	$\lvert H\rvert$ (dB) [from measured ampl. of V_{OUT}]	Phase = ang(H) (deg) [from measured delay t_d]
100									
1 000									
3 000									
5 000									
10 000									
30 000									
50 000									
100 000									
300 000									
500 000									

Fill the above table up to and including the **Expected delay** column; you should do this from calculations before your lab period.

Get the expected phase from methods given in class, then calculate expected delay, t_d, using the formula t_d = phase / ($-360^o \cdot f$).

Example: If the expected phase at 17800 Hz is -23^o, then the expected delay is $-23^o / (-360^o \cdot 17800\text{ Hz}) = 3.59\ \mu s$.

Example: If the expected phase at 3160 Hz is $+61^o$, then the expected delay is $+61^o / (-360^o \cdot 3160\text{ Hz}) = -53.6\ \mu s$.

Notice that a positive phase (an "advance" in phase) results in a <u>negative</u> delay!

When you get to lab, measure and then fill in the first two "Measured" columns with your measurements, then calculate the last two columns.

Using the measured delay, calculate phase shift using the formula: phase (deg) = $-360^o \cdot f \cdot t_d$.

Plot your amplitude in dB vs. f (Hz), **<u>not</u>** <u>vs. ω</u> (radians/s). Plot your phase in degrees (^{o}) vs. f (Hz), **<u>not</u>** <u>vs. ω</u>.