Laboratory IV: Filter

Reading:	Simpson	Chapter 11.1 - 11.6
	Simpson	Chapter 3.3 for a refresher on Fourier Analysis (if needed)
	Handout	

1 Laboratory Experiments

1.1 Low Pass Filters

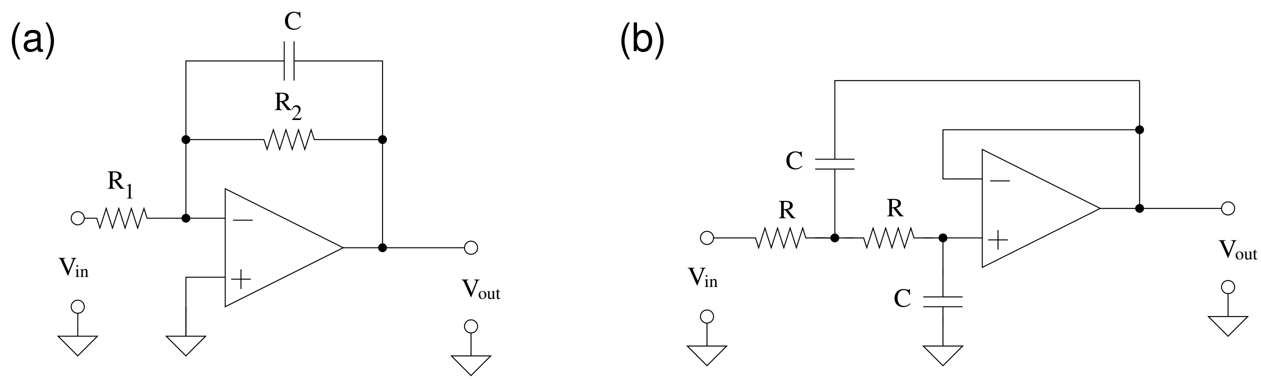

Figure 1: (a) First order active low-pass filter. (b) Sallen-Key second order low-pass filter.

Construct both a unity-gain first-order low-pass RC active filter [Fig. 1(a)] and a second-order Sallen-Key low-pass filter [Fig. 1(b)] side-by-side on your breadboard. Choose component values so that both filters have a 3 dB-frequency at 1600 Hz. Then input the same sine-wave signal into each filter and simultaneously observe both outputs on the two channels of your scope. You may wish to input the function generator's SYNC OUT squarewave signal into a third channel and use this signal to trigger the scope. This square wave is in phase and has the same frequency as the sine wave from MAIN OUT. Because one of the filters is inverting, it may also be convenient to use the scope's INVERT option on one of the channels.

(a) Frequency Response: With a sine-wave input, map the gain as a function of frequency for each filter. Find the 3 dB-frequencies. How do these values match your theoretical predictions? Measure and plot the rolloff in each case. The asymptotic roll-off value is generally not achieved until frequencies well above the 3 dB-frequency (for example, until the output is reduced by 10 to 20 dB from the low-frequency plateau value), so make sure you take data to sufficiently high frequencies. If you'd like to try a more sophisticated analysis, curve-fit your data to the theoretical relations for the gain.

(b) Step Response: To see how quickly each filter is able to switch its output to a new voltage-level use a square-wave input. Inputting a square-wave from MAIN OUT to both filters, simultaneously observe the rising portion of each filters output. Is the network time constant τ_{RC} =RC about what you would expect from the R and C values that you have chosen? Does the measured rise time match the 3 dB-frequency measurement? [See the handout for a discussion on τ_{RC}, $\tau_{63\%}$, R.T., and F_{3dB}.] Which filter is able to “acquire” the new voltage level quickest? Does either filter produce an overshoot or ringing (Simpson, Section 11.5) in the output?

1.2 Band Pass Filter

Construct the Active Inductor Bandpass Filter pictured below in Fig. 2

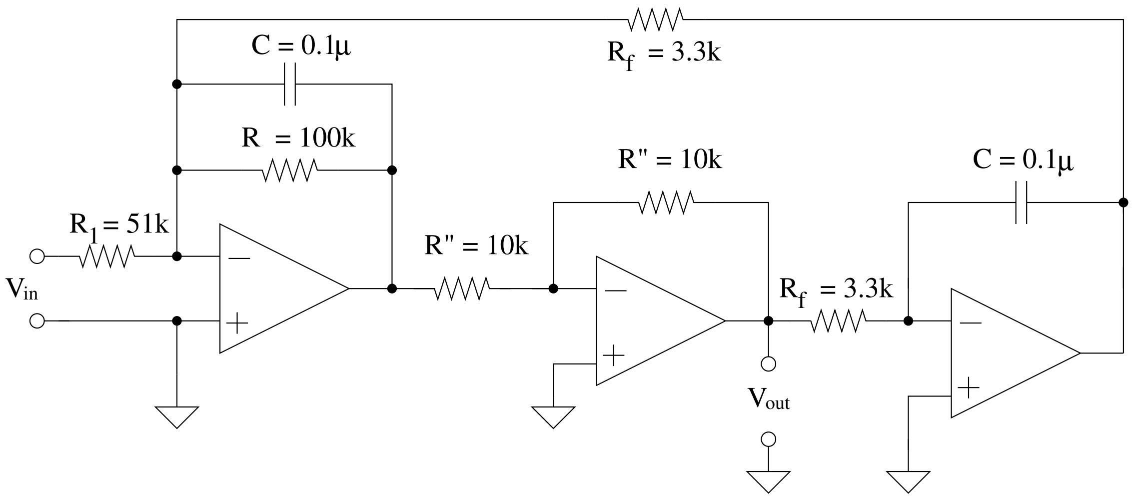

Figure 2: Active inductor band-pass filter as discussed in Simpson pp. 502–504

(a) Frequency Response: With a sine-wave input, map the gain as a function of frequency for this filter. Are the resonant frequency f_0, bandwidth $\Delta f = \Delta\omega/2\pi$, quality factor $Q \equiv \omega_0/\Delta\omega$, and gain at the peak $|H(\omega_0)|$ (see p. 504) what you expect? The bandwidth is defined as the difference in frequencies at the half-power points (see pg. 101), i.e., the difference in frequencies where the gain is $|H(\omega_0)|/\sqrt{2}$.

(b) Spectrum Analysis: Input a square-wave with frequency f_0 and measure the amplitude of the filters sine-wave output. Without changing the input square-wave, tune the filter to the frequency $2f_0$ by proper substitution of the R_f resistor-value (Note: R_f can be easily changed to the appropriate value by putting two resistors in parallel). Measure the amplitude of the input square-waves second harmonic. Repeat this process to measure the amplitude of the square-wave's third, fourth and fifth harmonic. Do the ratios of these measured amplitudes compare favorably to your expectations based on the Fourier Series representation of a square-wave (see pg. 113)? Discuss this in your report.