

Laboratory 6: Low-Pass and High-Pass Filter Circuits

The response of a circuit as a function of frequency may be classified by the way that it “passes” signals with different frequencies. For example, a circuit that has a larger output amplitude for low frequencies compared with high frequencies is a *low-pass* filter. A circuit that has a larger output amplitude for high frequencies is a *high-pass* filter (it “passes” the high frequency signals). What are the characteristics of *band-pass* and *band-stop* filters?

1. Simulate the circuits shown in Figure 1 using PSpice. (In Simulation Settings, set the Analysis type to AC Sweep/Noise.) Plot the magnitude of the voltage ratio as a function of frequency on a semi-log scale, with the log of frequency on the x -axis. Print the plots and discuss them with Prof. Kozick.
 Find the frequency at which the voltage V_{OUT} is 0.707 times V_{IN} .
2. Build the circuit shown in Figure 1(a). Measure the true value of your resistor, and use the *measured* value in calculations.
3. Using the oscilloscope, measure the magnitudes of V_{OUT} and V_{IN} at several different frequencies. (Set the function generator for sine-wave output with an amplitude of 2V peak-to-peak.) Connect Channel 1 of the scope to measure the output of the function generator (V_{IN}) and connect Channel 2 to measure the voltage across the capacitor (V_{OUT}). Set the scope to trigger from Channel 1. Determine the frequency range of interest from your Pspice plot. Take enough data to graph a curve of the voltage ratio (V_{OUT}/V_{IN}) vs. frequency on a semi-log scale. Find the frequency at which the voltage V_{OUT} is 0.707 times V_{IN} . Compare it with your Pspice simulation and the following formula for the “cutoff frequency” that we will study in ELEC 226:

$$f = \frac{1}{2\pi RC} \text{ (Hz)}$$

Also check the *phase shift* at the cutoff frequency and compare it with the value that is expected from phasor/impedance analysis. Is the output *leading* or *lagging* the input?

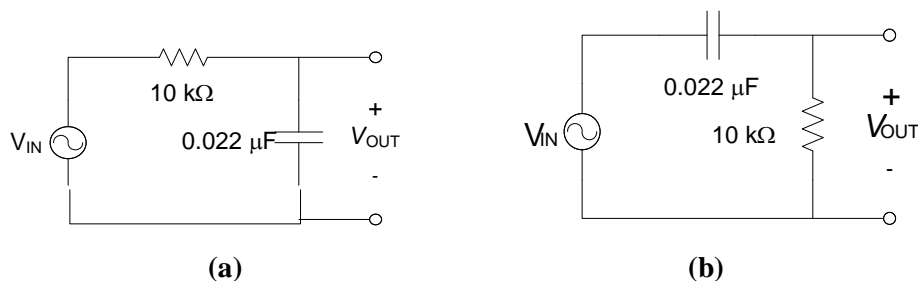


Figure 1 – (a) Low-Pass Filter Circuit (b) High-Pass Filter Circuit

4. Build the circuit shown in Figure 1(b), and measure the magnitudes of V_{OUT} and V_{IN} for a range of frequencies and produce a semi-log plot as in step 3.
 Why is this a high-pass filter?
5. For this circuit, find the frequency at which the voltage V_{OUT} is 0.707 times V_{IN} . Compare it with the “cutoff frequency” formula. Is the prediction reasonably close to the frequency where the “amplitude gain” is 0.707? Also check the phase shift at the cutoff frequency.

- Review Lab 5 and test your filters using the soundcard and headphones. Use 741 op amp buffer circuits before and after the filters. Can you hear the effect of the filters on music?
- When you finish the previous activities, display the input and output sine waves on the oscilloscope for the circuits in Figure 1 at frequencies below and above the cutoff frequency. Use phasor/impedance analysis to explain the amplitude and phase shift of the output waveform.

If you finish the previous activities with the RC circuits in Figure 1, repeat with the RLC circuit in Figure 2 and follow the steps below.

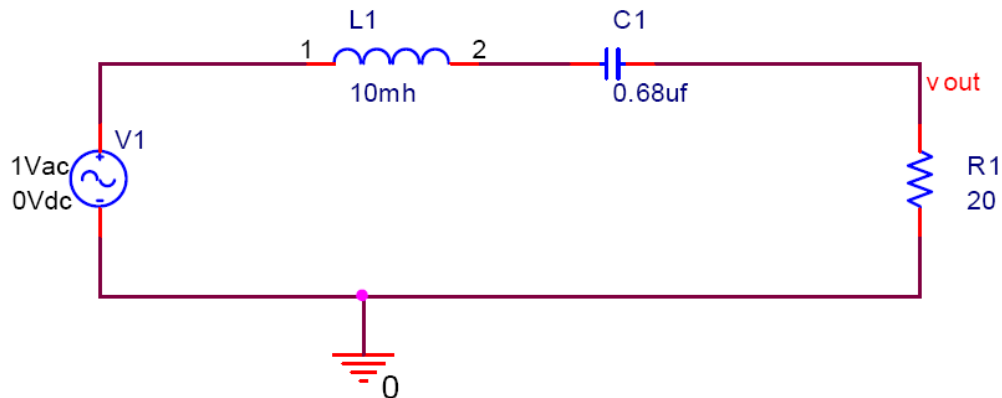


Figure 2 –Band-Pass Filter Circuit

- Build the circuit and measure the gain of the circuit at about 20 different sinusoidal frequencies from 100 Hz to 10,000 Hz. Use the function generator and the oscilloscope, and be sure to measure the amplitudes of the input and output signals at each frequency. (Why would the *input* amplitude change with frequency? What is the Thevenin equivalent of the function generator source?) Plot the gain in dB = $20 \log_{10} (v_{out}/v_{in})$ versus frequency.

- We will learn in class that the maximum gain of this circuit should occur at the “resonant frequency”

$$f = \frac{1}{2\pi\sqrt{LC}} \text{ (Hz)}$$

How well do your PSpice simulations and measured results agree with this value?

- The inductor is a coil of wire, so it has a resistance. Measure the DC resistance of the inductor and include it as a series resistor in your PSpice simulation. How does including the resistance of the inductor change the plot of dB gain versus frequency?
- Add op amp circuits to apply a gain and buffer the input and output of the RLC circuit.
- Play music through the RLC bandpass filter with different values for L (1 or 2 mH, 10 mH, 100 mH) and listen to the effects. How do the different values for L affect the resonant frequency and what you hear?