

## First-order filters

In this lab, we measure frequency response plots of several different types of first-order filters. We will do some of the measurements using old-fashioned (and tedious) manual point-by-point methods. For the others, we will use a “quick-and-dirty” method to extract the important parameters of the first-order filters with a minimal number of measurements.

### Prior to Lab

1. Review the transfer functions for low- and high-pass first order filters.
2. Calculate the transfer function for each circuit in parts A-D, including values for the corner frequencies and pass-band gains.
3. Make preliminary design for the circuits of parts E and F.
4. Make sure that you have a flash drive or some other means for saving data.

### A. RC low-pass — complete frequency response

Build the RC low-pass circuit shown in Fig. 1. For the source, use a sinusoid with an amplitude of  $2.5 \text{ V}_{\text{RMS}}$  ( $= 3.54 \text{ V}$  amplitude  $= 7.07 \text{ V}$  peak-to-peak).

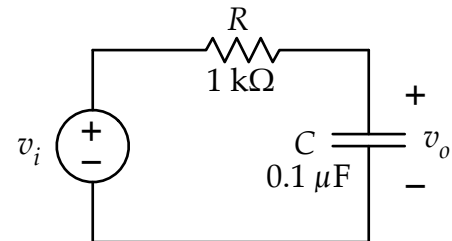


Figure 1.

- Calculate the expected corner frequency. Set the source to the expected corner frequency and observe the input and output together on the oscilloscope using channels 1 and 2.
- Use the DMM and the oscilloscope to measure the magnitude and phase frequency response curves over the range of 10 Hz to 100 kHz. Measure at 5 points in each decade of frequency. Here is a suggested distribution of frequencies: 10, 15, 25, 40, 65; 100, 150, 250, 400, 650; and repeating the pattern for subsequent decades. There will be a total of 21 measurements and there will be a reasonably smooth distribution of points within each decade. (You can use a more dense distribution of measurement points if you'd like.)
- At each frequency, use the DMM to measure the magnitude of the source voltage and the capacitor voltage. (You probably need to measure the source voltage only once, but you should measure *at least once* to make certain that the input amplitude is what you think it is.)
- At each frequency, use the oscilloscope to measure the phase difference between capacitor voltage and the source voltage.
- Use an Excel spreadsheet (download from the lab web page or make your own) to plot the magnitude and phase of the frequency response.

**B. *RL* low-pass — quick and dirty frequency response**

Build the *RL* low-pass active filter shown in Fig. 2. For the source, use a sinusoid with an amplitude of  $2.5 V_{\text{RMS}}$  ( $= 3.54 V$  amplitude  $= 7.07V$  peak-to-peak).

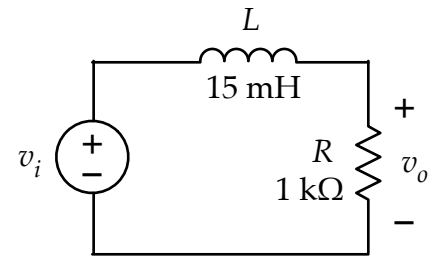


Figure 2.

Calculate the expected corner frequency and the expected magnitude of the transfer function for frequencies *well below* the corner frequency. Now, use a “quick-and-dirty” approach to measure the two most important parameters of a first-order filter.

- First, set the source frequency to a value a well below the expected corner – say 1 kHz. Use the multi-meter to measure the source and resistor voltages and calculate magnitude of the transfer function at this low frequency. (Note that it might be a bit smaller than what you expected – this is due to the parasitic resistance of the inductor.)
- Divide the low-frequency value of the measured resistor voltage by the square-root of two, which is the expected voltage at the corner frequency. Then, while keeping the source amplitude the same, increase the frequency of the source until the resistor voltage matches the value that you just calculated. The frequency at which this occurs is the corner frequency of the filter. With these two parameters – low-frequency magnitude and corner frequency, you can construct a transfer function that will accurately reflect the real properties of the filter circuit.

**C. Active low-pass filter.**

Build the second-order low-pass filter circuit shown in Fig. 3. Use a 660 op amp with  $\pm 8\text{-V}$  power supplies. For the source, use a sinusoid with an amplitude of  $0.25 V_{\text{RMS}}$  ( $= 0.354 V$  amplitude  $= 0.707 V$  peak-to-peak).

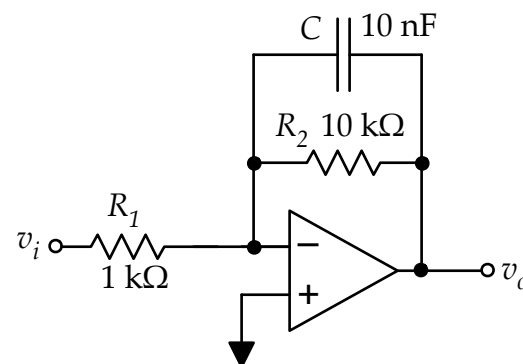


Figure 3.

Calculate the expected low-frequency gain and the expected corner frequency. Use the DMM to measure the frequency response plot of the *magnitude* of the transfer function. (No phase this time.) Measure from 10 Hz to 100 kHz, with the same distribution of measurement points used in part A. Make a plot of the result using a fresh copy of the Excel spreadsheet. Even though you are not measuring phase, you should observe the output at each frequency to make certain that the amp is not clipping.

### D. RC high-pass

Build the RC high-pass circuit shown in Fig. 4. For the source, use a sinusoid with an amplitude of  $2.5 V_{\text{RMS}}$  ( $= 3.54 V$  amplitude  $= 7.07V$  peak-to-peak).

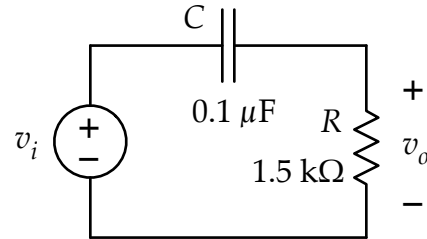


Figure 4.

Repeat the steps outlined in part A above to manually obtain a set of frequency and phase frequency response plots. Use the same frequency range and the same distribution of measurement points.

### E. Design a passive low-pass

Design, build, and test a passive first-order low-pass filter. Use resistors and the 15-mH inductor from your kit. (No capacitor.) The corner frequency should be 10 kHz ( $\pm 10\%$ ) and the passband gain should be 0.5 ( $\pm 10\%$ ). You may want to ask a lab instructor to check your design before you build and test. (The instructors may also be able to provide hints about components choices to meet the specifications.)

Build your design on a breadboard. Use a sinusoidal source for the input. Be sure to observe the output on the oscilloscope as well as measuring the magnitude with the DMM.

Test your circuit using the quick-and-dirty method described above. Confirm that the circuit is working according to the specifications. Take a screen shot of the oscilloscope showing the input and output waveforms together *at the corner frequency*.

### F. Design an active high-pass

Design, build, and test an active first-order high-pass filter. Use a 660 op amp with  $\pm 8V$  supplies along with resistors and capacitors from your kit. (No inductors.) The corner frequency should be 1 kHz ( $\pm 10\%$ ) and the passband gain should be  $-10$  ( $\pm 10\%$ ). You may want to ask a lab instructor to check your design before you build and test. (The instructors may also be able to provide hints about components choices to meet the specifications.)

Build your design on a breadboard. Use a sinusoidal source for the input. Be sure to adjust the amplitude to reasonable value and observe the output on the oscilloscope to ensure that it is not clipping.

Test your circuit using the quick-and-dirty method described above. Confirm that the circuit is working according to the specifications. Take a screen shot of the oscilloscope showing the input and output waveforms together *at the corner frequency*.



**Reporting**

Prepare and submit a report after you have finished the lab. A report template is available. Each lab group is required to submit one report (i.e. one report for two people). Be sure to include all calculations and graphs and answer all questions specified in the template. The report is due in one week at your normal lab time