# Lab 5: Poles and Zeroes in AC circuits (v 1.2)

WARNING: Use electrical test equipment with care! Always double-check connections before applying power. Look for short circuits, which can quickly destroy expensive equipment.

Note: The experiments in this lab are performed with the Elvis board and software on the computer. No external scope, function generator, or power supply are used.

Build the following 1-pole low-pass circuit on the breadboard. Choose values of R and C to provide a cutoff frequency of your choice: $f_c = 1/(2\pi RC)$. Use the Elvis board functions described in Labs 3 and 4 to measure all component values. Record them in your notes.
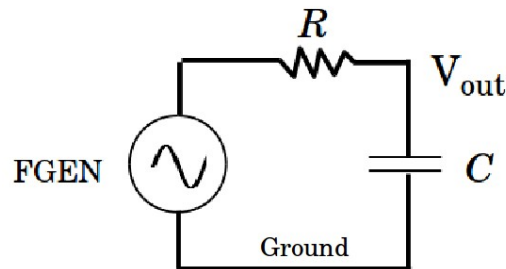

The sinusoidal input voltage is supplied by the function generator (FGEN) on the Elvis board. Refer to Lab 4 for instructions on how to set this up. Determine that your circuit is working properly with the Elvis SCOPE. Test with the FGEN frequency initially set well below cutoff and then increase it to verify low-pass operation. At this point, stop both FGEN and SCOPE. Following Lab 4, run the BODE analyzer and record data for amplitude and phase (LOG button) to display the low-pass filter function of the circuit.

Add a second pole by modifying the circuit as shown:
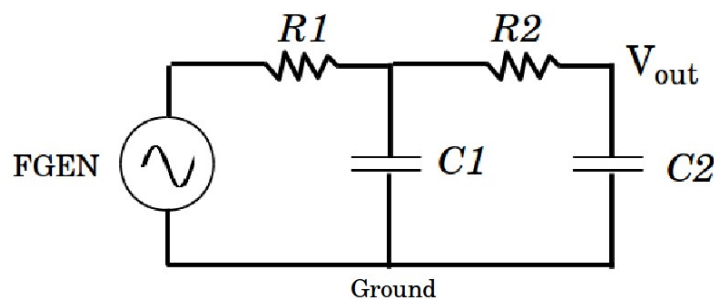
where the second cutoff frequency $f_c = 1/(2\pi R2C2)$ should be about an order of magnitude greater than the frequency established by $R1C1$. Collect amplitude and phase data for this two-pole filter using the BODE analyzer over a suitable range of frequencies. Next, modify the circuit so that $R1=R2$ and $C1=C2$. This will establish both poles at the same frequency and thus sharpen the response of the filter. Repeat the BODE measurement and log the data to a file.

The following circuit has one zero and one pole:
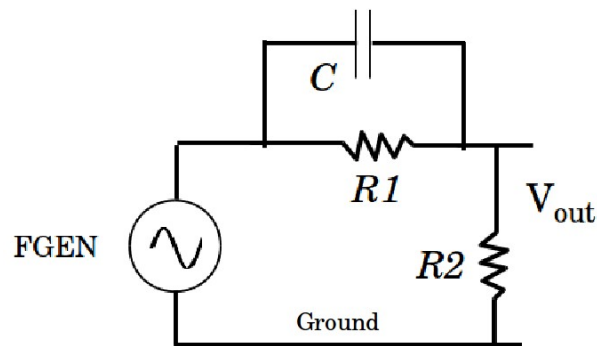
The zero frequency is $f_{ZERO} = 1/(2\pi R1C)$ and the pole frequency is $f_{POLE} = 1/[2\pi C R1R2/(R1+R2)]$. Set $R1 = R2$ so that $f_{POLE} = 2 f_{ZERO}$ and the amplitude response spans about 6 dB. Record BODE data over an appropriate range of frequencies and LOG data to a removable storage device.

Analysis and Writeup

You are required to analyze the amplitude and phase data for the above four circuits. The relation for the single-pole low pass filter can be found in Lab 3. For the double-pole low pass filter, the following approximation can be used **if** the frequencies of the two poles are sufficiently separated:

$$\frac{V_{OUT}}{V_{IN}} \approx \left[\frac{1}{1 + j\omega R_1 C_1}\right]\left[\frac{1}{1 + j\omega R_2 C_2}\right]$$

When the poles are identical (*R1=R2, C1=C2*), the output and input voltage are related as follows:

$$\frac{V_{OUT}}{V_{IN}} = \frac{1}{1 - (\omega RC)^2 + j\omega 3RC}$$

Also plot the approximation that assumes the two poles are uncoupled:

$$\frac{V_{OUT}}{V_{IN}} \approx \left[\frac{1}{1 + j\omega RC}\right]^2$$

Provide a separate plot that compares the single-pole filter data to the double-pole filter data with two identical poles. This plot should show a steeper cutoff when two poles are present at the same frequency.

The zero-pole circuit is modeled with the following equation:

$$\frac{V_{\text{OUT}}}{V_{\text{IN}}} = \left[\frac{R2}{R1+R2}\right]\left[\frac{1+j\omega R1C}{1+j\omega C\frac{R1R2}{R1+R2}}\right]$$

Recall the definitions for amplitude (dB) and phase (radians) in the Bode data:

$$\text{Amplitude (dB)} = 20\log_{10}|G|$$

$$\text{Phase (rad)} = \text{atan}\left[\frac{\text{Im}(G)}{\text{Re}(G)}\right]$$

where G = $V_{\text{OUT}}/V_{\text{IN}}$. You will need to use a program such as MatLab, Scilab, Octave, or LabView for the complex algebra associated with the above equations. All 4 circuits should be analyzed for amplitude and phase and compared to experimental data. Send as a single file (.pdf preferred) to the instructor before the next class meeting.