11.4.2: Non-inverting Low Pass Filter

Overview:

Bode plots are a convenient way to represent frequency responses. In particular, straight-line approximations to Bode plots are extremely easy to generate. In this lab assignment, we will generate a straight line approximation to the Bode plot for an active low-pass filter. We will then measure the frequency response of the circuit at several discrete frequencies and compare these to our straight-line approximation. Finally, we will use the Analog Discovery's Bode Transfer Function instrument to automatically generate a Bode plot for the circuit.

Before beginning this lab, you should be able to:

- Generate straight line approximations to the Bode plot for a first order circuit
- Determine the DC gain, high frequency gain, and cutoff frequency of a first order filter
- Measure the magnitude and phase responses of first order filter circuits (Labs 11.3.1, 11.3.2)

After completing this lab, you should be able to:

- Measure the magnitude and phase responses of an active electrical circuit at discrete frequencies
- Use the Bode Transfer Function instrument to automatically measure the Bode plot for a circuit
- Design an active filter to provide a desired DC gain and cutoff frequency

This lab exercise requires:

- Analog Discovery module
- Digilent Analog Parts Kit
- Digital multimeter (optional)

Symbol Key:

DEMO — Demonstrate circuit operation to teaching assistant; teaching assistant should initial lab notebook and grade sheet, indicating that circuit operation is acceptable.

ANALYSIS — Analysis; include principle results of analysis in laboratory report.

SIM — Numerical simulation (using PSPICE or MATLAB as indicated); include results of MATLAB numerical analysis and/or simulation in laboratory report.

DATA — Record data in your lab notebook.

General Discussion:

The circuit of Figure 1 is a non-inverting low pass filter. The DC gain of the circuit of Figure 1 is:

$$\omega_c = \frac{1}{R_3 C} \tag{1}$$

and the DC gain of the circuit is:

$$DCgain = \frac{R_2}{R_1} \tag{2}$$

In this assignment, we will choose values of R_1, R_2, and C in the circuit of Figure 1 to meet design requirements set on the cutoff frequency and DC gain.

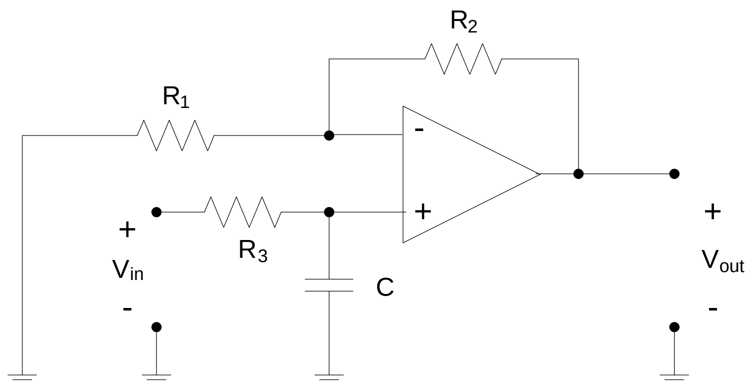

Figure 1. Non-inverting low-pass filter circuit.

Pre-lab:

ANALYSIS Design the circuit of Figure 1 (e.g. choose values for R_1, R_2, R_3, and C) to meet the following design requirements:

- DC gain = 3 ± 10%
- Cutoff frequency = 1.5kHz ± 10%

ANALYSIS Sketch a straight-line approximation to the Bode Plot for your design.

Lab Procedures:

a. Construct the circuit you designed in the pre-lab.

   i. Be sure to measure and record the actual values for R_1, R_2, and R_3. If your DMM has a capacitance measurement, record the actual value for C; if you do not have the ability to measure capacitance, assume that the nominal value of your capacitor is correct.

   ii. Measure the magnitude response of the circuit at frequencies approximately equal to $\omega_c/8$, $\omega_c/4$, $\omega_c/2$, ω_c, $2\omega_c$, $4\omega_c$, and $8\omega_c$, where ω_c is the cutoff frequency of the circuit[1].

   iii. Demonstrate operation of your circuit to the TA and have them initial the appropriate page(s) of your lab notebook and the lab worksheet.

b. Use the Bode Transfer Function instrument to automatically generate a Bode plot for the circuit. To do this, follow the steps below:

   i. Click on the 

icon on the WaveForms main window. Select **Network Analyzer** from the resulting drop-down menu. A window will open, which will allow you to automatically create a Bode plot for the system.

   ii. Bode plot parameters are set using the options shown in Figure 2 below. The available options are:

   - Start and Stop: provide the range of frequencies which will be plotted. Generally, a range of frequencies from about an order of magnitude below the cutoff frequency to about an order of magnitude above the cutoff frequency is a good starting point.
   - AWG Offset and Amplitude: The offset and amplitude of the input voltage. Use the offset and amplitude that you used to measure the response in part (a).
   - Steps: The number of data points that will be used to generate the plot and the maximum gain that can be measured. More points will result in a smoother curve, but will take longer to generate.
   - Max-Gain: Make sure the Max-Gain parameter is large enough to display the entire Bode plot.
   - Bode Scale: The drop-down menus here allows you to choose the scale on both the magnitude and phase responses.
   - Scope Channels: Choose the channels to be displayed.

   Example parameters for this lab project are shown in Figure 2. Record an image of the Network Analyzer window. Also save the data to a .csv file for later processing by selecting the **File** option on the menu bar and clicking on **Export**.

[1] Keep in mind that the units of ω are radians/second, while the design requirement on the cutoff frequency is given in Hz.

Figure 2. Example parameters for this lab project.

Post-lab Exercises:

SIM **ANALYSIS**

Use your favorite mathematical software package (MATLAB, Octave, Excel,…) to plot the frequency response data (gain and phase vs. frequency) acquired by the Bode Transfer Function instrument in part (b) of the lab procedures. Overlay on this plot the data you acquired in part (a) of the lab procedures. Compare the responses from parts (a) and (b) and comment on any differences.

ANALYSIS

Compare the data you acquired in parts (a) and (b) of the lab procedures with your expectations from the pre-lab. Especially provide an assessment as to whether the original design requirements were met by your design.

