11.3.1: Passive RL Filter

Overview:

This assignment concerns a passive filtering circuit consisting of a series combination of a resistor and an inductor. If the voltage across the inductor is taken as the filter output, the circuit will act as a high-pass filter. However, if we take the voltage across the resistor as the filter output, the circuit acts as a low-pass filter[1]. We will measure both the high-pass and low-pass characteristics of this circuit and compare them to our expectations based on the analytically determined frequency response.

Before beginning this lab, you should be able to:

- Calculate the frequency response of a passive electrical circuit
- Calculate the magnitude and phase responses of a passive electrical circuit
- Determine the DC gain, high frequency gain, and cutoff frequency of a passive first order filter

After completing this lab, you should be able to:

- Measure the magnitude and phase responses of first order filter circuits

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.

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[1] If the energy in the input does not appear in the inductor voltage, it must be somewhere else (it can't simply disappear). Thus, if the inductor voltage stops low frequencies, the energy in these frequencies must show up somewhere else – in this case, it will be apparent in the resistor voltage (or, equivalently, the inductor current.

General Discussion:

This lab assignment concerns the circuit shown in Figure 1. We will measure the response of both the voltages $v_R(t)$ and $v_L(t)$ to the input voltage $v_{IN}(t)$ and plot the frequency response – both magnitude and phase – of both voltages. Obviously, since we are interested in the frequency response of the circuit, the input voltage will consist of sinusoids.

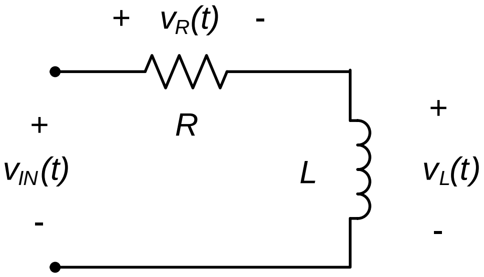

Figure 1. RL circuit.

Pre-lab:

ANALYSIS Determine the frequency responses of both $v_L(t)$ and $v_R(t)$ in the circuit shown in Figure 1, as a function of R and C. Use the voltage $v_{IN}(t)$ as the input in both cases[2]. Calculate the cutoff frequency of the circuit (both outputs share the same cutoff frequency). Also calculate the DC gain and high frequency gain of both outputs.

ANALYSIS Sketch the magnitude and phase responses of both outputs in the circuit of Figure 1. Label your sketches with the DC gain, high frequency gain, and cutoff frequency.

Lab Procedures:

a. Construct the circuit of Figure 1, using R = 100Ω and L = 1mH.

DATA

  i. Use your oscilloscope to measure both $v_{IN}(t)$ and $v_R(t)$.

  In order to measure the frequency response (amplitude and phase) of your circuit, use the function generator to apply sinusoidal inputs to the circuit. Apply inputs for at least the following frequencies: $\omega_c/10$, $\omega_c/8$, $\omega_c/4$, $\omega_c/2$, ω_c, $2\omega_c$, $4\omega_c$, $8\omega_c$, and $10\omega_c$, where ω_c is the cutoff frequency of the circuit, as determined in the pre-lab.. For each frequency, record the frequency, the input voltage amplitude, the output voltage amplitude, and the time difference between the input and output sinusoids.

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[2] If the phasor representation of $v_{IN}(t)$, $v_L(t)$, and $v_R(t)$ are $\underline{V}_{IN}$, $\underline{V}_L$, and $\underline{V}_R$, respectively, we are calculating $\underline{V}_L / \underline{V}_{IN}$ and $\underline{V}_R / \underline{V}_{IN}$.

DEMO

ii. 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. Repeat the procedures of part (a):

DATA

i. Except use your oscilloscope to measure $v_{IN}(t)$ and $v_L(t)$. (In this case, the inductor voltage, $v_L(t)$, is our output.) Again, for each of the frequencies listed in part (a), record the frequency, the input voltage amplitude, the output voltage amplitude, and the time difference between the input and output sinusoids.

DEMO

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

Post-lab Exercises:

SIM

a. Use your favorite mathematical analysis software package (MATLAB, Octave, Excel…) to plot the theoretical frequency response determined in the pre-lab, with R = 100Ω and L = 1mH. Use $v_R(t)$ as your output, and plot <u>both</u> magnitude and phase vs. frequency. Use a range of frequencies from $\omega_c/10$ to $10\omega_c$. Overlay the data you acquired in part (a) of the lab procedures on your plot. Comment on the agreement between the data and the theoretical response. Does the circuit behave as a high-pass or low-pass filter when the output is the resistor voltage?

SIM

b. Use your favorite mathematical analysis software package (MATLAB, Octave, Excel…) to plot the theoretical frequency response determined in the pre-lab, with R = 100Ω and L = 1mH. Use $v_L(t)$ as your output, and plot <u>both</u> magnitude and phase vs. frequency. Use a range of frequencies from $\omega_c/10$ to $10\omega_c$. Overlay the data you acquired in part (b) of the lab procedures on your plot. Comment on the agreement between the data and the theoretical response. Does the circuit behave as a high-pass or low-pass filter when the output is the inductor voltage?