8.5.2: Parallel RLC Circuit Response

Overview:

This lab will emphasize modeling and testing of a parallel second order circuit containing two resistors, a capacitor, and an inductor. In this assignment, the step response of the given circuit is analyzed and tested. The measured response of the circuit is compared with expectations based on the damping ratio and natural frequency of the circuit.

Before beginning this lab, you should be able to:

- Model practical inductors as an ideal inductor in series with a resistance (Lab 6.4.2)
- Determine natural frequency and damping ratio for second order circuits
- State the relationship between damping ratio and maximum overshoot for underdamped systems
- State the relationship between natural frequency and rise time for underdamped systems
- Use the Analog Discovery to apply and measure time-varying waveforms

After completing this lab, you should be able to:

- Measure the step response of a second order electrical circuit
- Estimate the damping ratio and natural frequency of an underdamped second order circuit from measured step response data

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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General Discussion:

In this lab assignment, we will analyze the circuit of Figure 1 to estimate the maximum overshoot, rise time, and DC gain of the circuit step response. The circuit will then be tested, these parameters measured, and the measurements compared with expectations from the analysis.

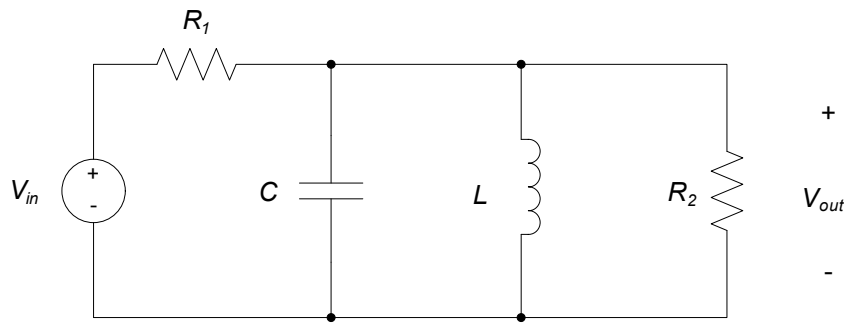

Figure 1. Circuit schematic.

Pre-lab:

ANALYSIS

a. Write the differential equation relating V_{out} and V_{in} for the system shown in Figure 1 in the form:

$$\frac{d^2V_{out}(t)}{dt^2} + 2\varsigma\omega_n \frac{dV_{out}(t)}{dt} + \omega_n^2 V_{out}(t) = K \cdot V_{in}(t)$$

ANALYSIS

b. From your differential equation, estimate the damping ratio and natural frequency of the circuit if $R_1 = 47\Omega$, $R_2 = 1k\Omega$, $C = 10\mu F$, and $L = 1mH$.

ANALYSIS

c. Estimate the rise time (t_r), overshoot (M_p), and frequency of any oscillations you would expect to see in the step response of the circuit.

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Lab Procedures:

DATA

Construct the circuit shown in Figure 1 using the component values provided in part (b) of the pre-lab. Record measured values of R_1, R_2, and C (if your DMM has the ability to measure capacitance). Also measure the resistance of the inductor; you may assume that the nominal inductance of the inductor value is correct.

DATA

a. Use your arbitrary waveform generator to apply a 2V step input to the circuit, at a low enough frequency so that the circuit can reach steady-state between pulses. Use your oscilloscope to measure both the input and output voltages (V_{out} and V_{in}) for the circuit.

DEMO

b. Demonstrate operation of your circuit to the TA and have them initial your lab notebook and the lab checklist.

DATA

c. Record an image of the oscilloscope window, showing the signals $V_{in}(t)$ and $V_{out}(t)$. Save the data to a file for later plotting.

ANALYSIS

d. Estimate the damping ratio and natural frequency of the circuit <u>from your data</u>. Express the difference between the measured values and those expected from your pre-lab analysis <u>as a percentage of the expected value</u>. Comment on the measured response relative to your expectations from the pre-lab analysis.

ANALYSIS

e. Re-do the calculations of part (c) of the pre-lab, including the measured inductor resistance. Compare the results of this analysis to the measured damping ratio and natural frequency of the circuit. Express the differences as a percentage of the expected values. Comment on the differences between the measured response and the results of this analysis.

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