Lab 3: RLC Circuits & Resonance

Physics 327

Spring 2025

Goals

Explore more complex *RLC* circuits, studying their behavior and the occurrence of resonances and ringing. Learn about filters by constructing a notch filter.

Pre-Laboratory Exercises

To prepare for this laboratory:

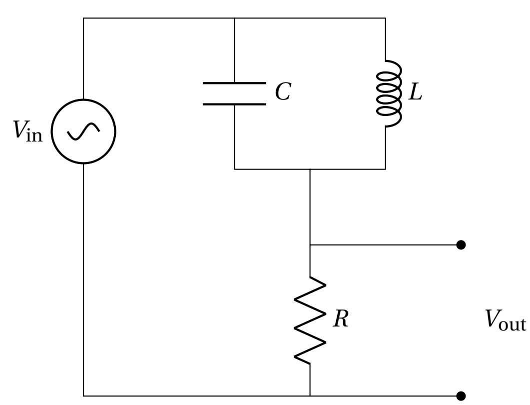
1. Read about RC and RLC circuits in Chapters 8–12 of the Faissler textbook.
2. Construct the circuit described in Part B below in a SPICE simulation program, such as `LTspice`. Use $R = 10\,\Omega$ and set up the voltage source as a pulse with Von = 1, Ton = 500 μs, and Tperiod = 1 ms. Draw (or include a screenshot of) the ringing displayed. What is the frequency of the ringing?
3. Answer Question 1 below.

Introduction

Both parallel and series RLC circuits exhibit resonance in their response to AC inputs. This behavior can be exploited to construct many useful circuits, for example selectively amplifying or attenuating a particular frequency range (e.g., for noise reduction or an audio equalizer). In this lab, you will use both types of RLC circuit as filters and use the frequency response as a way to understand their behavior. You will also investigate the response of the RLC circuits to step function inputs. When the output involves oscillation, this is known as *ringing*.

A Notch Filters

First, you will construct a notch filter as shown below, by placing an inductor L in parallel with a capacitor C, and putting that pair in series with a resistor R. V_{out} will be measured across the resistor.



Build this circuit using $L = 1$ mH, $C = 0.1$ μF, and $R = 1$ kΩ.

Question 1: Calculate the notch (resonance) frequency for the circuit.

Adjust the function generator for a sine wave driving frequency with an amplitude of about 1 V. By adjusting the frequency, determine the amplitude of the V_{out} for the following *angular* frequencies ω: 100 Hz, 1 kHz, 10 kHz, 100 kHz, and 1 MHz. To achieve these angular frequencies, set the function generator frequency $f = \omega/(2\pi)$. Use these measurements to identify the notch point, and take additional data near that frequency (at least 10 more data points around the resonance frequency) so that you have determined the behavior and the width of the resonance well. Make a Bode plot of your data (i.e., power gain in dB vs. $\log f$) and compare to theory predictions for the gain. Discuss this in your lab report. Include theoretical derivation of the gain for this circuit in your report.

Next, replace the 1 kΩ resistor with a 100 Ω resistor and repeat these measurements.

Question 2: Describe and explain any differences you see when changing R.

B Series RLC Circuits

Next, construct a series RLC circuit, placing a capacitor $C = 0.1$ μF, an inductor $L = 1$ mH, and a resistor $R = 10$ Ω in series. Measure V_{out} across the *capacitor*.

Using a sine wave input from the function generator, measure V_{out} at several angular frequencies between 100 Hz and 1 MHz, as above. Take additional data points (at least 10) near the resonance frequency to ensure it is well-characterized.

Now, change R to 100 Ω and repeat these measurements. Create plots of your data for both values of R, and include this in your report along with the relevant calculations. Also, include theoretical derivation of the gain of this circuit.

Question 3: Compare the data and calculations. Describe the dependence on resistance.

Next, for both $R = 10$ Ω and $R = 100$ Ω, measure V_{out} across the *resistor* for different frequencies between 100 Hz and 1 MHz, again with dense data points near the resonance frequency. Create plots of your data for both values of R, together with the relevant calculations of the gain (magnitude) as a function of frequency.

C Ringing

Finally, keeping your series RLC circuit and using $R = 10$ Ω, adjust the function generator to input a low-frequency square wave. Carefully examining the spikes in V_{out} (across the resistor), you should see an exponentially-damped sine wave, i.e. *ringing* behavior. Include a picture or drawing of the ringing waveform, being sure to note the time and voltage scales.

Question 4: What is the frequency of the ringing sine wave? How does this compare to the calculated value of the resonance frequency?

Change R from 10 Ω to 200 Ω. If you have extra time, try additional intermediate values of R.

Question 5: How does the ringing change for different values of R?