PHYS 361 - Electronics Lab

Lab 5: RC, RL, and RLC Circuits - Frequency Domain Response

Jordan Ashley, Quintinne Madsen

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1 Introduction

This lab explores the frequency response of RC, RL, and RLC circuits, focusing on how these circuits modify the amplitude and phase of sinusoidal input signals. By analyzing their behavior over a range of frequencies, we aim to characterize their filtering properties, identify key parameters such as characteristic and resonant frequencies, and compare experimental results with theoretical predictions. The study of AC circuits is essential in understanding signal processing, resonance phenomena, and impedance effects, all of which are fundamental in electrical engineering and physics. Through systematic measurements and Bode plot analysis, this experiment provides insight into how reactive circuit elements influence signal behavior and how circuits can be designed for specific frequency-dependent applications.

- Ohm's Law
$$V = IR \tag{1}$$
- Power dissipation
$$P = I^2V \tag{2}$$
- Resistors in series
$$R = R_1 + R_2 \tag{3}$$
- Resistors in parallel
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \tag{4}$$

- Shockley Formula

$$I = I_s(e^{V/nV_T} - 1) \tag{5}$$

- Power Dissipation

$$P = VI \tag{6}$$

- Voltage Divider

$$V_{\text{out}} = V_{\text{in}}(\frac{R_2}{R_1 + R_2}) \tag{7}$$

2 Methods

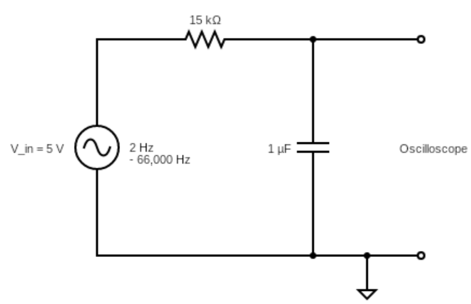

Figure 1: A diagram of the RC low pass circuit

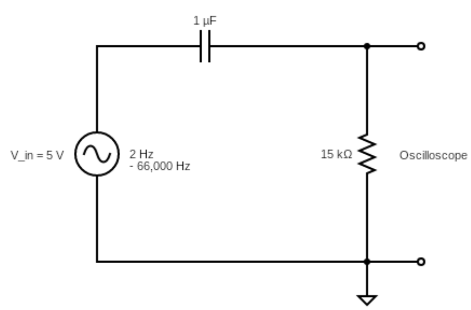

Figure 2: A diagram of the RC high pass circuit

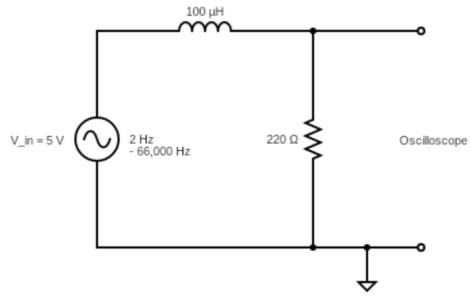

Figure 3: A diagram of the RL low pass circuit

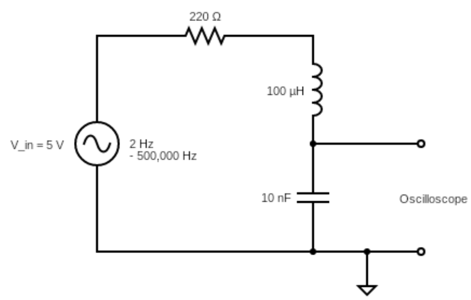

Figure 4: A diagram of the RLC resonance circuit

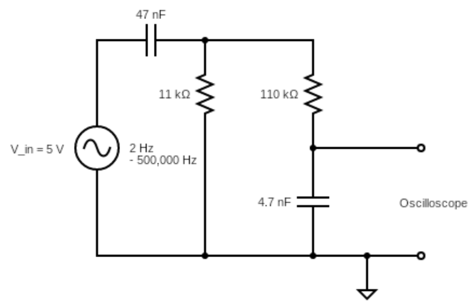

Figure 5: A diagram of the RC bandpass circuit

3 Results

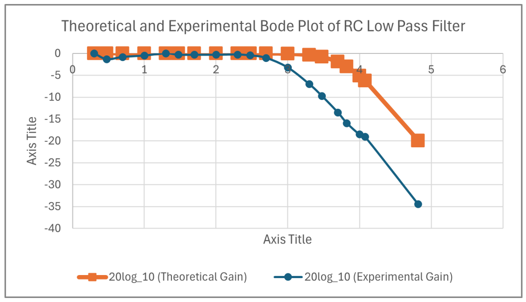

Figure 6: A bode plot of the RC low pass circuit

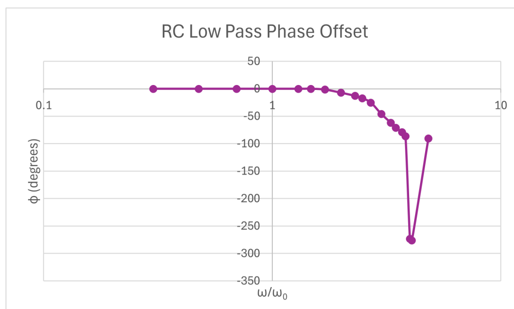

Figure 7: A phase offset plot of the RC low pass circuit

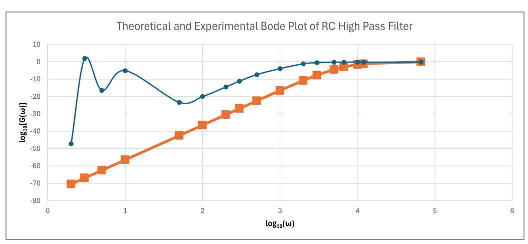

Figure 8: A bode plot of the RC high pass circuit

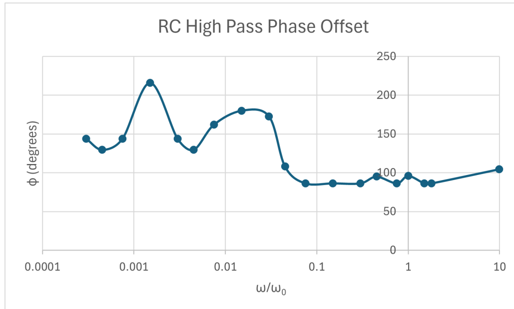

Figure 9: A phase offset plot of the RC high pass circuit

4 Discussion and Conclusion

4.1 Discussion

Integrating and differentiating circuits are two types of filters that modify the frequency-dependent behavior of signals based on how capacitors and resistors are arranged.

Integrating Circuit (Low-Pass Filter):
An integrator outputs the time integral of the input signal, meaning that lower-frequency components pass through with minimal attenuation, while higher frequencies are significantly reduced. This occurs in an RC circuit when the resistor is placed in series and the capacitor is in parallel with the output. At high frequencies, the capacitor has low impedance, diverting most of the current away from the output, thereby attenuating high-frequency components.

Differentiating Circuit (High-Pass Filter):
A differentiator outputs the time derivative of the input signal, amplifying rapid changes (high-frequency components) while attenuating lower frequencies. This is achieved when the capacitor is in series and the resistor is in parallel with the output. At high frequencies, the capacitor dominates, allowing rapid voltage changes to appear at the output, whereas low frequencies are blocked due to the increasing impedance of the capacitor.

In summary, an integrator smooths out rapid variations, making it useful for averaging signals over time, while a differentiator emphasizes rapid changes, highlighting edges and transients in a signal.

4.2 Conclusion

In this lab, we investigated the frequency response of RC, RL, and RLC circuits by measuring amplitude and phase shifts as functions of frequency. By constructing these circuits and analyzing their behavior, we confirmed theoretical predictions regarding their filtering properties, characteristic frequencies, and resonance. Our experimental results closely matched calculated expectations, with minor deviations likely due to component tolerances and measurement uncertainties. The use of Bode plots allowed for a clear visualization of gain and phase relationships, reinforcing key concepts such as low-pass and high-pass filtering, resonance, and impedance effects. Additionally, the exploration of circuit coupling demonstrated the importance of impedance matching when designing functional circuit systems. Overall, this experiment provided valuable hands-on experience in AC circuit analysis, bridging theoretical knowledge with practical implementation.