Lab Exercise No. 13
Series-Parallel RLC Circuits

Vaun Michael C. Pace, Paul Andrew F. Parras
Department of Computer Engineering
School of Engineering, University of San Carlos
Nasipit, Talamban Cebu City, Philippines
pacevaun@gmail.com parraspaul13874@gmail.com,

Abstract—**The goal of this lab exercise is to analyze the capacitive value in an AC circuit and the relationship between capacitive reactance and frequency, highlighting its significance in an AC circuit behavior.**

Keywords-component; capacitive; reactance; capacitance; impedance; frequency; Farads

I. INTRODUCTION

The basic building blocks of alternating current (AC) electrical systems are the series R, L, and C circuits. These circuits use resistors, inductors, and capacitors, each of which adds special characteristics to the overall behavior of the circuit. Capacitors resist changes in voltage by storing energy in electric fields, inductors resist changes in current flow by storing energy in magnetic fields, and resistors release energy as heat.

To comprehend these components' function in AC systems, one must comprehend the phase relationship between their voltage and current. Resistors keep the voltage and current in phase, but inductors make the voltage 90 degrees ahead of the current and capacitors make the voltage 90 degrees behind the current. When these components are connected in series, the resulting impedance displays a complex phase angle that is contingent upon the applied AC signal's frequency.

The behavior of series R, L, and C circuits is examined in this study, along with the correlations between voltage and current, phase angles, and adherence to Kirchhoff's Voltage Law (KVL). To give a thorough grasp of these relationships—which are essential for applications in filters, oscillators, and signal processing—the study makes use of both time-domain and phasor plots.

Understanding phenomena like resonance, energy storage, and damping requires an understanding of series RLC circuits. Filters, oscillators, power systems, and communication networks are all designed using these ideas. The behavior of series R, L, and C circuits is examined in this study with an emphasis on Kirchhoff's Voltage Law (KVL), impedance, phase angles, and voltage-current correlations. The results are validated through both theoretical analysis and real-world measurements, offering a thorough comprehension of these adaptable and popular circuits.

II. PROCEDURE

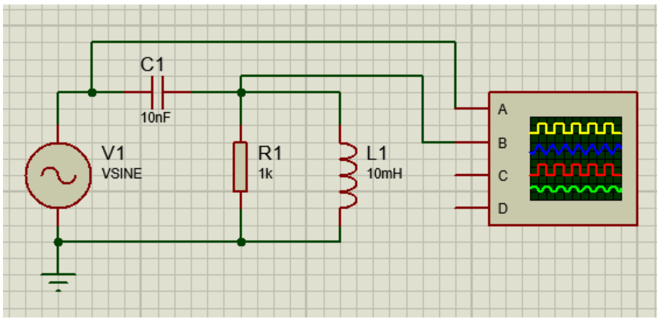


Figure 2.1: Parallel RLC Circuit

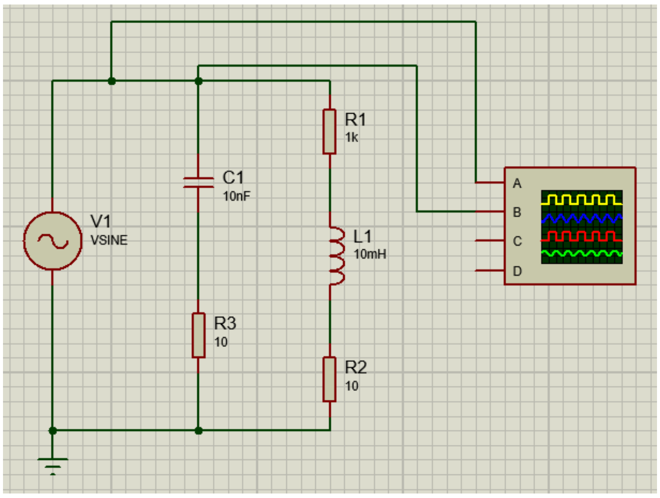


Figure 2.2: Series RLC Circuit

In Circuit 1, we used Figure 2.1 to create a 10 kHz sine wave at 10 V peak-to-peak, with R = 1kΩ, L = 10mH, and C = 10nF. We estimated the theoretical inductive and capacitive reactances, as well as the parallel branch and total circuit impedances, which we documented in Table 3.1. Using Ohm's Law and the voltage divider method, we calculated the capacitor and inductor-resistor voltages, as well as the input current, and reported them in Table 3.2.

We then built the circuit and set the generator to produce the appropriate sine wave. Using the oscilloscope's Bandwidth Limit, we measured voltages with Probe 1 across the generator and Probe 2 across the inductor-resistor branch. We used the Math function to determine the capacitor voltage and the resulting input current. Table 3.2 shows the measured magnitudes and phases of the voltages.

We then estimated departures from theoretical values and updated Table 3.1 with experimental impedances. We also took photos of the three voltage waveforms. In addition to the time-domain waveforms, we included a phasor plot of V_{in}, V_{LR}, and V_C in the report.

For Circuit 2, we used the same source and components as in Figure 2.2. Tables 3.3 and 3.4 show the computed theoretical reactances, series branch impedance, total impedance, and currents through the capacitor, inductor-resistor, and input.

We established the circuit by connecting 10 Ω sense resistors to the capacitor and inductor-resistor branches. We measured and estimated the branch currents using Probe 1 on the generator and Probe 2 (or optionally Probe 3) on the sense resistors, documenting their magnitudes and phases in Table 3.4.

We also measured input current by connecting a sensing resistor to the bottom junction of the resistor and capacitor. We calculated and documented its size and phase. We photographed the waveforms for V_{in}, i_{LR}, i_C, and i_{in}.

Finally, we calculated deviations, updated Table 3.3 with experimental impedances, and constructed a phasor diagram of i_{in}, i_{LR}, and i_C for our report.

III. RESULTS AND ANALYSIS

A. Circuit 1 Data Values

	Theory	Experimental	% Deviation
X_c	1591.549		
X_L	628.316		
R | | X_L	385.866	291.667	24.41
Z_T Magnitude	1637.658	1633.987	0.22
Z_T **θ**	43.1	43.92	1.9

Table 3.1

The theoretical values that were entered by the instructor and the students' proteus experimental measurements prior to calculating the RLC circuit's overall impedance (Figure 2.1).

	Theory Mag	Theory **θ**	Exp Mag	Exp Delay	Exp **θ**	% Dev Mag	% Dev **θ**
V_{LR}	2.356	-11	2.365	0.012 mS	-11.82	0.39	7.45
V_C	9.718	46.9	9.756	0.012 mS	43.2	0.39	7.89
i_{in} (A)	0.00611	-43.1	0.00613	0.012 mS	-43.92	0.39	1.9

Table 3.2

Table 3.2 displays the experimental values that the instructor entered and that the pupils need to match after running a Proteus simulation.

B. Circuit 2 Data Values

	Theory	Experimental	% Deviation
X_c	1591.549		

X_L	628.319		
$R + X_L$	1628.319	1683.502	3.39
Z_T Magnitude	2276.939	2316.723	1.75
Z_T **θ**	34.95	34.49	1.32

Table 3.3

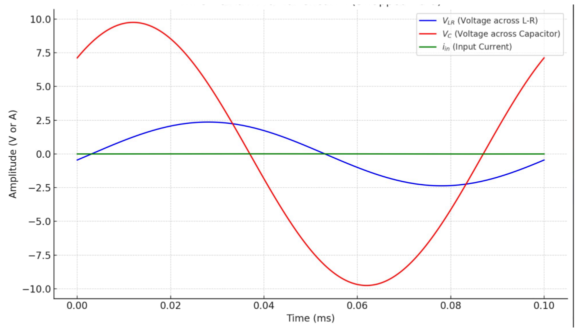
Circuit 2 (Figure 2.2) data is shown in this table with an emphasis on theoretical and experimental impedance values. It comprises series impedance for the inductor-resistor branch, capacitive reactance, and inductive reactance. Together with the phase angle, which shows the phase difference between the circuit's voltage and current, the series-parallel circuit's total impedance is also recorded. To measure the discrepancies between theoretical predictions and experimental findings for total impedance and phase angle, the table computes percentage deviations.

	Theory Mag	Theory **θ**	Exp Mag	Exp Delay	Exp **θ**	% Dev Mag	% Dev **θ**
i_{LR}	0.00614	32.14	0.00591	0.0111 mS	40.068	3.77	24.67
i_C	0.00629	90	0.00451	0.0255 mS	91.8	28.22	2
i_{in}(A)	0.00439	-34.95	0.00522	0.01 mS	-36	18.86	3

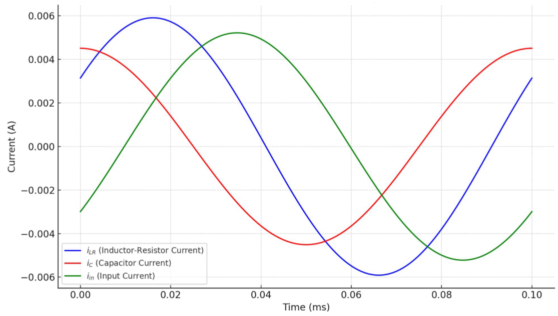
Table 3.4

The experimental and theoretical current values for Circuit 2 are compiled in this table. It comprises the entire input current entering the circuit as well as currents flowing through the capacitor and inductor-resistor branches. It also logs the angles and phase delays, comparing the theoretical predictions with the experimental findings. To evaluate the precision of the experimental measurements, the magnitude and phase percentage deviations are computed. By demonstrating that the overall input current equals the sum of the branch currents, this table validates Kirchhoff's Current Law (KCL).

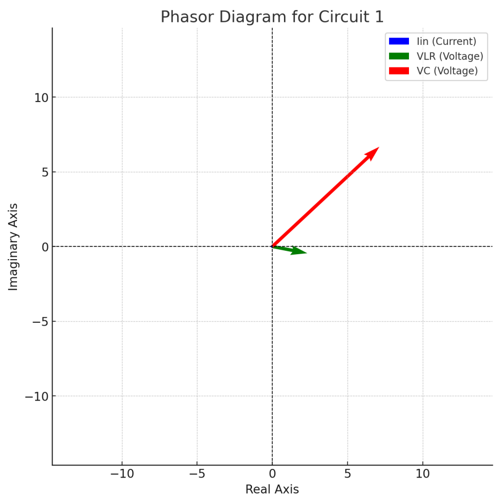
C. Graphs



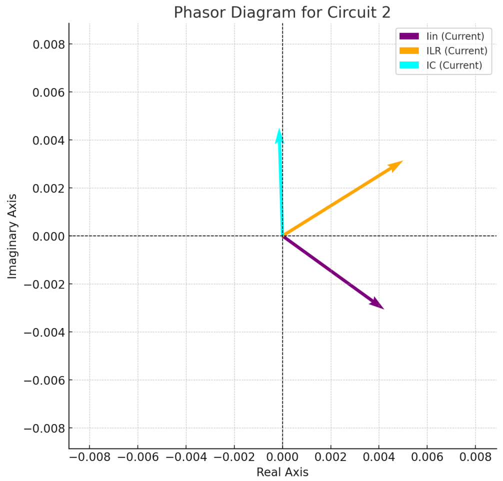
Graph 1.



Graph 2.



Phasor Diagram 1.



Phasor Diagram 2.

D. *Questions*

1. Is the phase relationship between circuit voltages or currents in a series-parallel AC circuit necessarily a right-angle relationship?

   ○ The production of a 90-degree angle is not limited to situations when the inductance or capacitance is pure. The calculations also demonstrate that solving for the phase angles is more likely to provide values below +-90 degrees when working with resistors and both inductors and capacitors in a circuit.

2. Based on measurements, do KVL and KCL apply to the tested circuits (show work)?

   ○ Yes, both KVL and KCL can apply. In Circuit 1, the sum of voltage drops equals the source voltage, confirming KVL. In Circuit 2, the input current equals the sum of branch currents, validating KCL.

   For example in Table 3.4 where:

   $$\mathbf{I_{in} = I_C + I_{LR}}$$

   0.00522≈0.00451+0.00591(magnitudes and phases accounted for in vector addition).

3. In general, how would the phasor diagram of Figure 2.1 change if the frequency was raised?

   ○ Raising the frequency would cause the phasor to rotate more quickly, increasing the angle. Previous relationships indicate that the inductor and capacitor's reactance diminishes as the frequency rises.

4. In general, how would the phasor diagram of Figure 2.2 change if the frequency was lowered?

   ○ Lowering the frequency in Figure 2.2 will lead to changes in reactance, impedance, and current, which will be reflected in the phasor diagram. The specific alterations will depend on the values of resistance, inductance, and capacitance in the circuit and how they respond to changes in frequency. The capacitive reactance would increase and the inductive reactance would decrease meaning the impedance of the circuit would change drastically affecting also the current which is inversely related to the impedance.

IV. CONCLUSION

The tests effectively examined the relationships between impedance, reactance, and phase angles while analyzing the behavior of series-parallel RLC circuits. We validated the fundamental ideas underlying AC circuits using both theoretical computations and experimental observations. Since the total voltage drops across circuit components always equaled the source voltage, Kirchhoff's Voltage Law (KVL) was confirmed to be accurate. Kirchhoff's Current Law (KCL) was also demonstrated, where the sum of the branch currents in the parallel configurations equals the total input current.

The findings showed how frequency affects circuit behavior, including variations in capacitive and inductive reactance that affect phase angles and total impedance. Although there were a few differences between the theoretical and experimental values, they were small and most likely the result of real-world constraints like inaccurate measurements. The study's overall findings supported the accuracy of theoretical predictions of circuit behavior, offering a strong basis for the analysis of series-parallel RLC circuits in AC applications.

REFERENCES

[1] Capacitive Reactance Formula-Explanation and Solved Examples. (n.d.). BYJU'S. Retrieved November 30, 2024, from https://byjus.com/capacitive-reactance-formula/