Series Sinusoidal Circuits

Lab 007

Electrical Networks

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Objective

The objective of this laboratory exercise is to verify the validity of Kirchhoff's Voltage Law (also known as *Kirchhoff's Loop Rule*)when applied to AC circuits consisting of various electrical components placed in series configuration with respect to one another; and understand the underlying behavior of internal impedances interacting with the capacitive and inductive reactances of said components via experimentation. In addition, students will also learn to determine the phase angle (often denoted as ϕ) associated with the corresponding voltages using the dual trace method on the oscilloscope. Upon completion of this exercise students will learn to successfully analyze a network consisting of the three components: resistors, inductors, and capacitors - and apply the voltage divider rule via acquisition of experimental results.

Theory

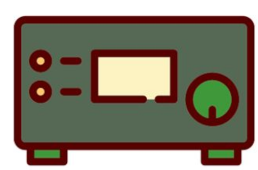
RLC circuits are electrical circuits constructed with three main elements: a capacitor, a resistor and a inductor. The purpose of using these three components in a circuit is to form a harmonic oscillator for current or to creating what is also called "damping". The resistor helps reduce the resonant frequency. In an Ideal LC circuit, when the supply voltage is reduced, the charge in the capacitor is also diminished, hence, discharging the capacitor. But in an AC circuit the input signal is always changing from positive to negative and with a change rate controlled by the frequency of said supply. This implies that the capacitor receiving an AC signal is either being charged or discharged on a continuous basis at a rate regulated by the frequency of the supply. As the capacitor charges or discharges. There's a current flow being slowed down by the internal impedance of the capacitor. This is what we call as capacitive reactance or Xc, measured in Ohms. however, capacitive reactance does not behave as resistance because its based on the frequency; therefore, any variation in supply frequency will have a notable effect on the capacitive reactance measured value.

Instruments & Materials

Digital Multimeter

Oscilloscope

Function Generator

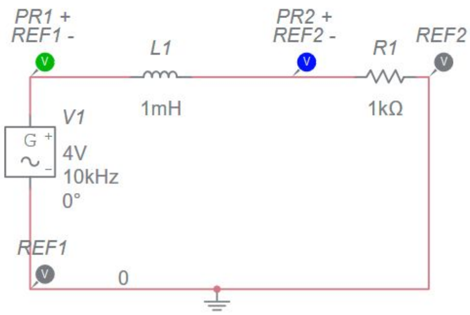


DC Power Supply

Resistors	Capacitors	Inductors
1 kΩ	0.01 μF	10 mH

Procedure

Part 1 Series R-L Circuit



First, we constructed the circuit (shown left) and set the peak to peak voltage of the function generator to (8 Vpp). Then we determined the phase angle θ_1 between $\mathbf{E}$ and $\mathbf{V}_R$ using the dual trace method, as shown below.

Next we determined the I_{pp} from the following: $I_{pp} = V_{R(pp)}/R_{measured}$.

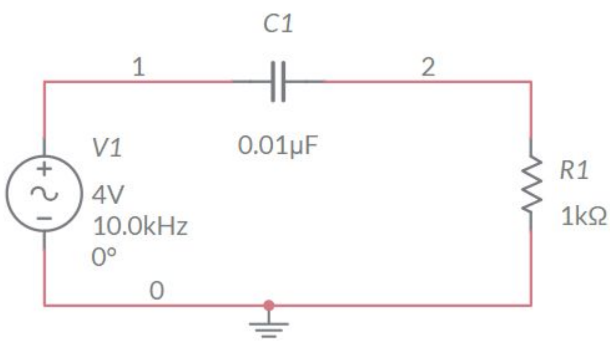
Given, $V_{R(pp)}$ = 6.72 V_{pp} & $R_{measured}$ = 993 Ω - the deduced current was approximately 6.8 mA_{pp}

Afterwards we determined the input impedance using the equation below and recording its value.

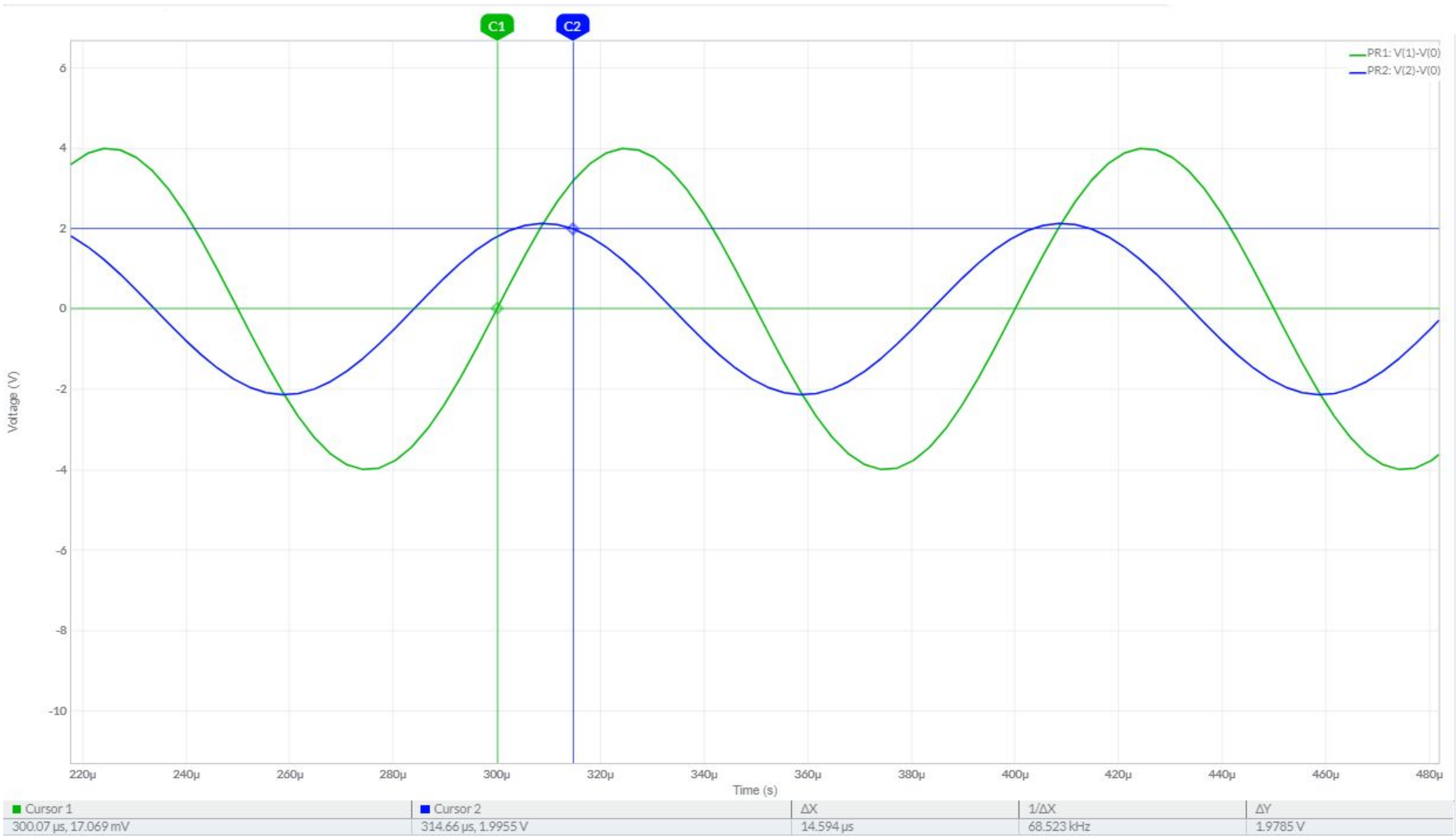
$$Z_T = \frac{E_{pp}}{I_{pp}} = \frac{8V}{6.76} = 1.18\Omega$$

Then, we calculated the total impedance (magnitude and angle) of the circuit and Current I_{pp}

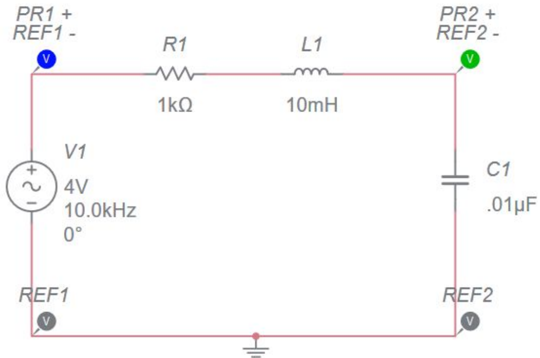
Part 2 Series R-C Circuit



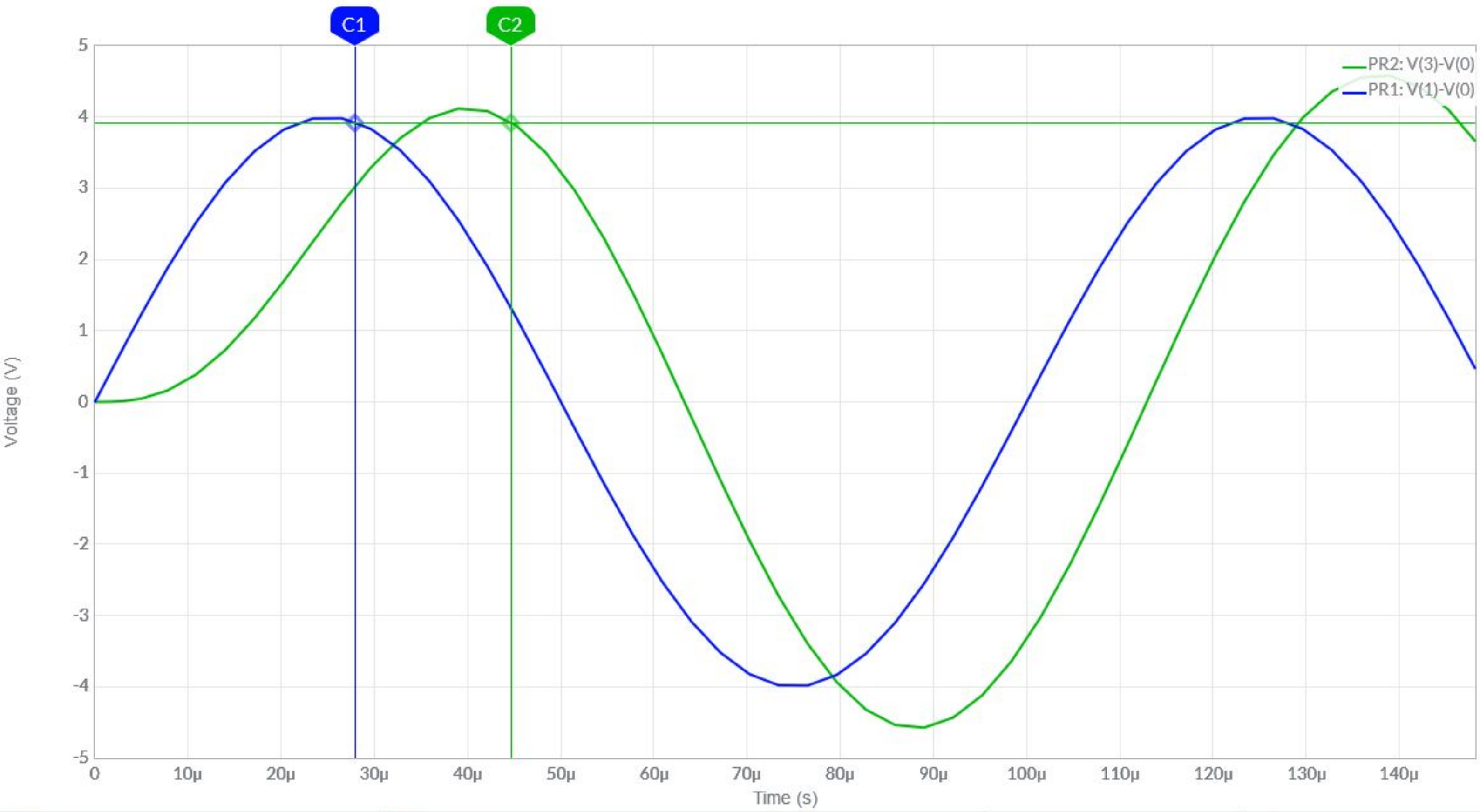
Next, we constructed the circuit (shown left) and set the peak to peak voltage of the function generator to (8 Vpp) determined the phase angle θ_1 between **E** and $\mathbf{V}_R$ using the dual trace method, as shown below. This circuit uses a 0.01uF and 1KΩ resistor.



Part 3 Series R-L-C Circuit



Next, we constructed the circuit (shown left) and set the peak to peak voltage of the function generator to (8 Vpp) determined the phase angle θ_1 between $\mathbf{E}$ and $\mathbf{V}_c$ using the dual trace method, as shown below.



Cursor 1	Cursor 2	ΔX	1/ΔX	ΔY
27.872 µs, 3.9164 V	44.623 µs, 3.9171 V	16.751 µs	59.699 kHz	760.92 µV

Results

Table 8.1

		$V_{R(p-p)}$	D_1	D_2	θ (measured)	θ (calculated)
***R* and θ_1**		6.72	100 µs	8 µs	28.8°	32.142°
		$V_{L(p-p)}$	D_1	D_2	θ (measured)	θ (calculated)
***L* and θ_2**		2.481 V	100 µs	15 µs	54°	57.858°

Table 8.2

Quantity		Measured (Calculated from Measured Values)	Theoretical (Calculated)
E_{pp}		8 V_{pp}	7.16 V_{pp}
$V_{R(pp)}$		6.72 V_{pp}	4.91 V_{pp}
$V_{L(pp)}$		2.481 V_{pp}	3.085 V_{pp}
I_{pp}		6.76 mA_{pp}	5 mA_{pp}
Z_T		1.18 kΩ	1.6 kΩ
θ_T		82.8°	90°

Table 8.3

		$V_{R(p-p)}$	D_1	D_2	θ (measured)	θ (calculated)
***R* and θ_1**		4.56	100 µs	14.2 µs	51.12°	57.96°
		$V_{L(p-p)}$	D_1	D_2	θ (measured)	θ (calculated)
***C* and θ_2**		6.52 V	100 µs	10 µs	36°	-32.04°

Table 8.4

Quantity		Measured (Calculated from Measured Values)	Theoretical (Calculated)
E_{pp}		8 V_{pp}	8 V_{pp}
$V_{R(pp)}$		4.56 V_{pp}	$4\angle 57.96^{\circ} V_{pp}$
$V_{C(pp)}$		6.52 V_{pp}	$6.36\angle -32.04^{\circ} V_{pp}$
I_{pp}		4.59 mA_{pp}	$4\angle 57.96^{\circ}$ mA
Z_T		1.74 kΩ	$1884.72 \angle -57.96^{\circ}$ Ω
θ_T		87.12°	90°

Conclusion

In order for us to further analyze the behavior of RLC circuits, we constructed several electrical circuit arrangements and supplied each of them with an AC signal coming from our function generator. With the help of an oscilloscope, we were able to perform calculations and empirical analysis to determine certain parameters given by the each circuit. The first circuit constructed was a Series R-L circuit, with an AC input signal of 8V peak-to-peak, running at frequency 10-Khz. While the oscilloscope read the voltage across the 1-KΩ resistor. By comparing the input signal and the signal at the output we, were able to observe the distance between the to signals, and calculate the angle between them, which amounted to 28.8 µS.

We decided to use Kirchhoff's voltage law as a tool of verification for our measurements and calculations. By inputting our values into eq.1, which resulted in input voltage being equal to 7.16V. The original value inputted into our circuit was meant to be 8V, therefore, at some point throughout the exercise, there must have been a human error introduced while taking measurements. This can be avoided by confirming the status of our circuits and our input values before recording measurements.

$$E = \sqrt{V_R^2 + V_L^2} = \sqrt{(6.720)^2 + (2.481)^2} = 7.16V\ peak - peak$$

Eq.1

References

- "AC Waveform and AC Circuit Theory of Sinusoids." *Basic Electronics Tutorials*, 24 Apr. 2018, www.electronics-tutorials.ws/accircuits/ac-waveform.html.
- "Inductive Reactance - The Reactance of an Inductor." *Basic Electronics Tutorials*, 25 Sept. 2018, www.electronics-tutorials.ws/inductor/ac-inductors.html.
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- "RLC Circuit." *Wikipedia*, Wikimedia Foundation, 4 Mar. 2019, en.wikipedia.org/wiki/RLC_circuit.