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Objectives

- To examines the voltage and current relationships in series R, L, C networks.
- The phase of the various components and how Kirchhoff's Voltage Law is extended for AC circuits.
- To study Both time domain and phasor plots of the voltages are generated.

Theory Overview

RLC Circuits

An RLC circuit is an electrical circuit consisting of a resistor (R), an inductor (L), and a capacitor (C), connected in series or in parallel. The name of the circuit is derived from the letters that are used to denote the constituent components of this circuit, where the sequence of the components may vary from RLC.

Phasor Diagram

Phasor Diagram is a graphical representation of the relation between two or more alternating quantities in terms of magnitude and direction. In other words, it depicts the phase relationship between two or more sinusoidal waveforms having the same frequency.

RLC Phasor Diagram

The model phasor diagram of the RLC series circuit :

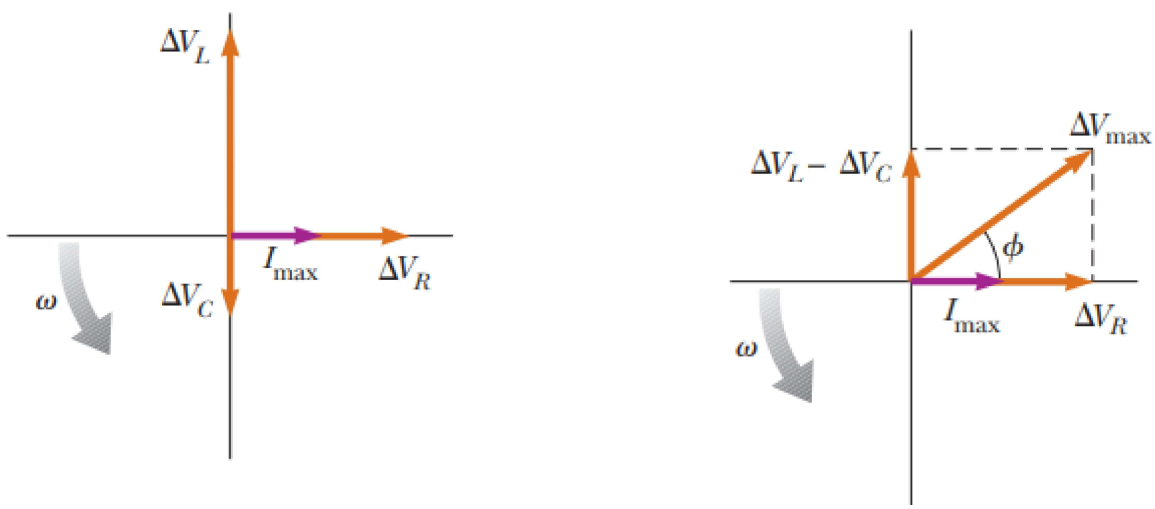

Figure A : Phasor Diagram of RLC Circuit

Each element phasors a unique phase response: for resistors, the voltage is always in phase with the current, for capacitors the voltage always lags the current by 90 degrees, and for inductors the voltage always leads the current by 90 degrees. Consequently, a series combination of R, L, and C components will yield a complex impedance with a phase angle between +90 and -90 degrees. Due to the phase response, Kirchhoff's Voltage Law must be computed using vector (phasor) sums rather than simply relying on the magnitudes. Indeed, all computations of this nature, such as a voltage divider, must be computed using vectors.

Equipment

1. AC Function Generator
2. Oscilloscope

Components

1. 10 nF actual:__10 nF___
2. 10 mH actual:___10 mH__
3. 1 kΩ actual:___1 kΩ___

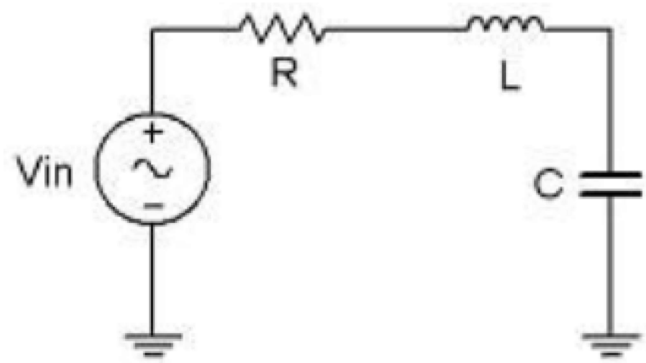

Figure 1

Procedure

1. Using Figure 1 with Vin=2Vp-p sine at 10 kHz, R=1kΩ, L=10mH and C=10nF, determine the theoretical inductive and capacitive reactance and circuit impedance, and record the results in Table 1 (the experimental portion of this table will be filled out in step 4). Using the voltage divider rule, compute the resistor, inductor and capacitor voltages and record them in Table 2.
2. Build the circuit of Figure 1 using R=1kΩ, L=10mH and C=10nF. Set the generator to a 10 kHz sine wave and 2 Vp-p. Using oscilloscope measure the signals. Unfortunately, it is impossible to see the voltages of all the three components simultaneously using only two probes of the oscilloscope. To obtain the proper readings, place one probe on the function generator to see the input signal and the second probe across the last element. This step is repeated three times. The first time the components are so arranged that capacitor is the last component, the second time inductor is connected as the last component and finally resistor is made the last component. The peak-to-peak voltages and phase angles of each one of the three components, relative to the source are thus determined in turn. Thus Vs, VC, VL and VR are measured. Record in Table 2.
3. Compute the deviations between the theoretical and experimental values of Table 2 and record the results in the final columns of this table.

4. Based on the experimental values, determine the experimental Z, XL and XC values via Ohm's Law (i=VR/R, XL=VL/i, XC=VC/i, Z=Vin/i) and record back in Table 1 along with the deviations.
5. Create a phasor plot showing Vin, VL, VC, and VR.
6. Repeat the experiment for 1nF capacitor, 1mH inductor and 1kΩ resistor.

Data Tables

	Theoretical	Experimental	%Deviation
X_C	**628**	**645.71**	**±3**
X_L	**1591**	**1571.43**	**±1**
Z	**1388**	**1428.57**	**±3**
Ɵ	**-43.93**	**-44.74**	**±2**

Table 1

	Theoretical	Experimental	%Deviation
Vc	2.291	2.2	±4
V_L	0.904	0.949	±5
V_R	1.44	1.48	±3
V_S	2	2	0
Ɵ	32.034	33	±3

Table 2

Experiment Pictures

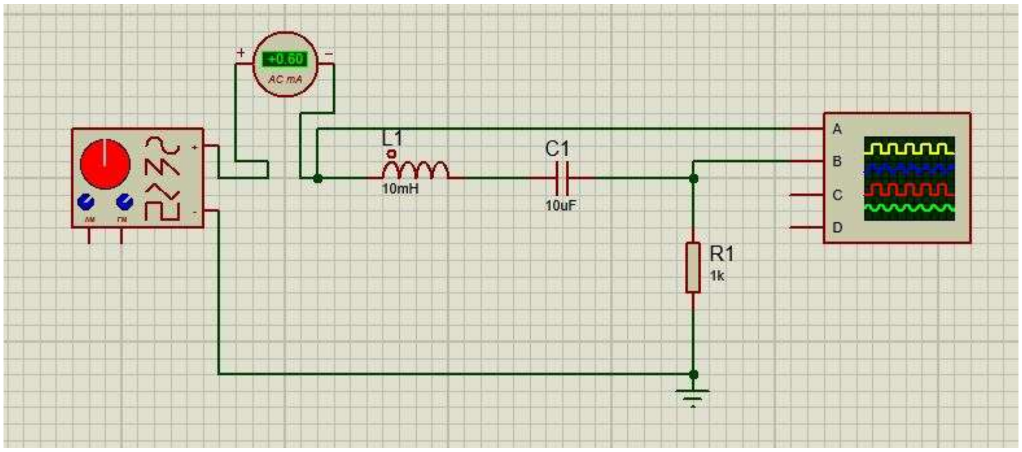

Figure : Proteus

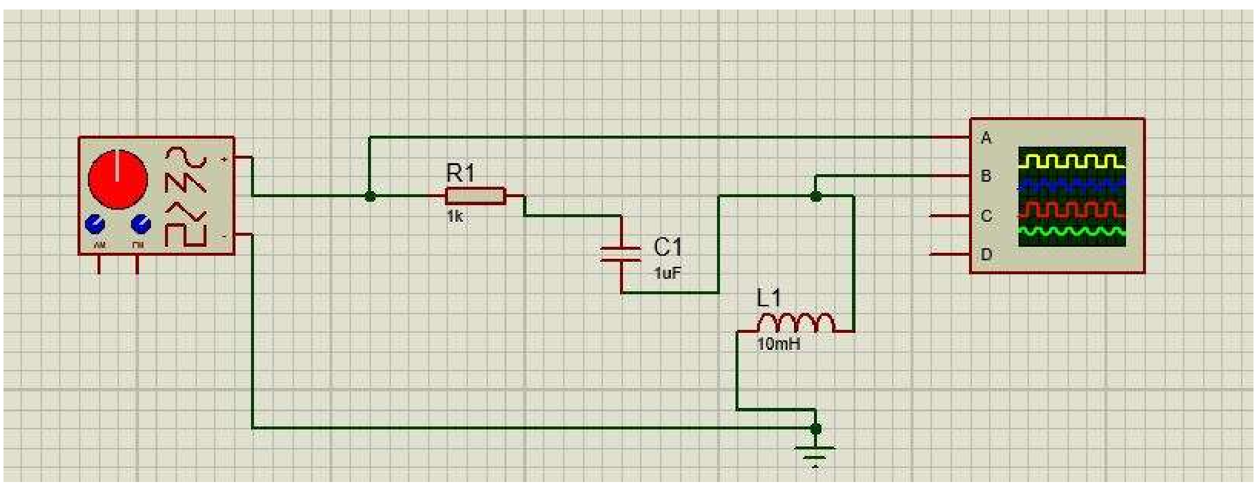

Figure : Proteus

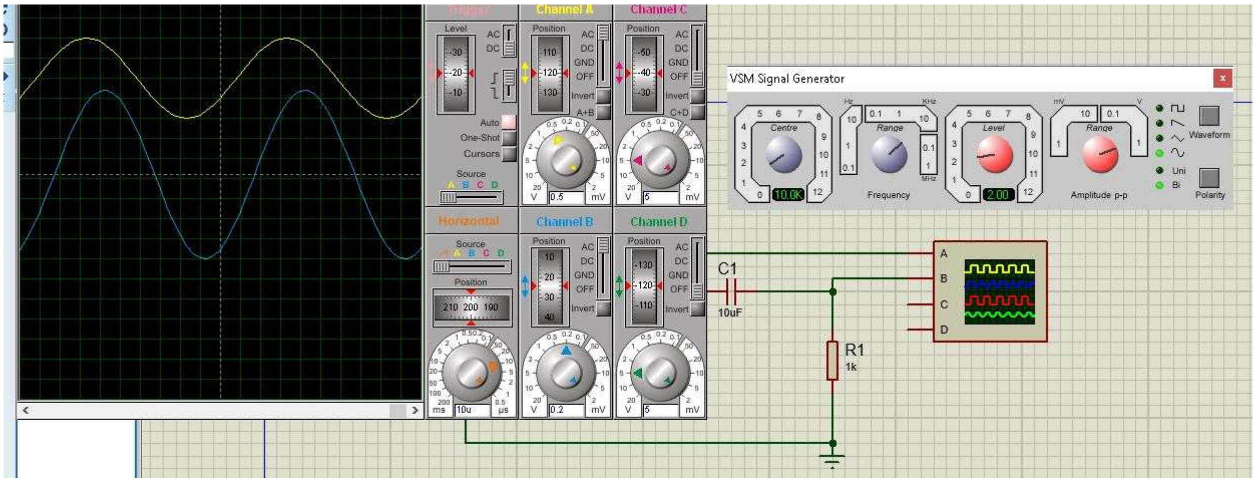

Figure : Proteus

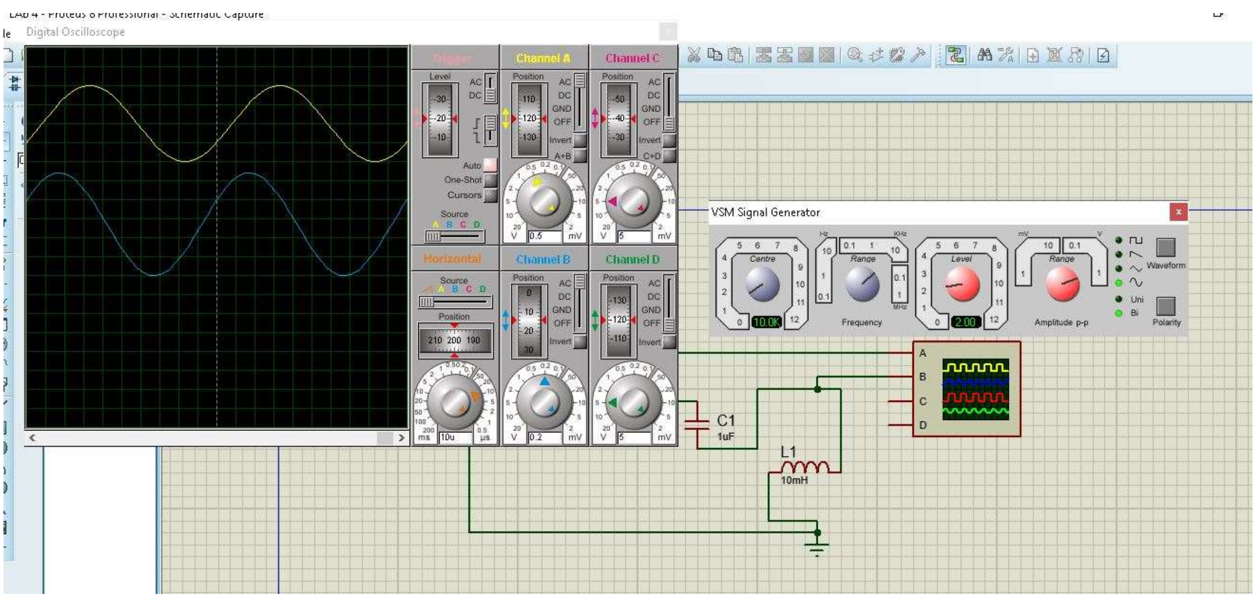

Figure : Proteus

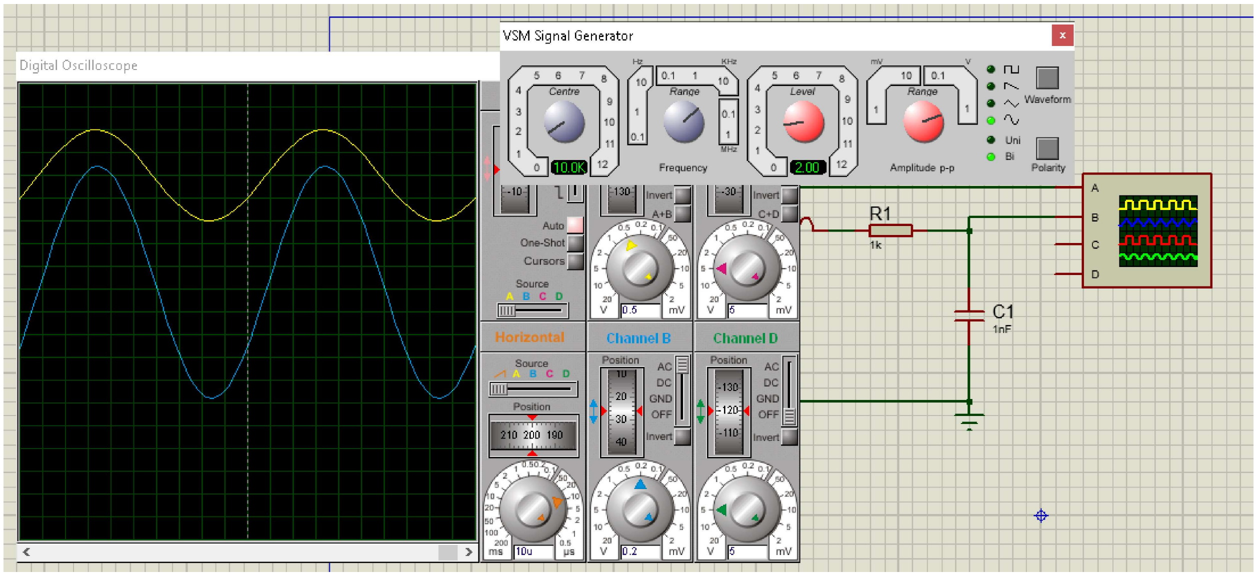

Figure : Proteus Simulation Screen Shot

Questions

1. What is the phase relationship between R, L, and C components in a series AC circuit?

Phase

When capacitors or inductors are involved in an AC circuit, the current and voltage do not peak at the same time. The fraction of a period difference between the peaks expressed in degrees is said to be the phase difference. The phase difference is <= 90 degrees. It is customary to use the angle by which the voltage leads the current. This leads to a positive phase for inductive circuits since current lags the voltage in an inductive circuit. The phase is negative for a capacitive circuit since the current leads the voltage.

Phasor Diagram is a graphical representation of the relation between two or more alternating quantities in terms of magnitude and direction. In other words, it depicts the phase relationship between two or more sinusoidal waveforms having the same frequency.

RLC Phasor Relationship

The specialty of RLC series Circuit is that each element phasors has a unique phase response to frequency. For

Resistor

- The voltage across **resistor is in phase** with Current.

Inductor

- The voltage across **Inductor leads** to current by 90 degree.

Capacitor

- The Voltage across **Capacitor lags** to current by 90 degree.

Accordingly, a series combination of Resistor R, Inductor L, and Capacitor C components will produce a complex impedance with a phase angle between +90 and -90 degrees.

2. Based on measurements, does Kirchhoff's Voltage Law apply to the tested circuits?

Yes. It does apply.

For Circuits involving frequency, the voltages developed across the capacitor and inductor are equal, but 180 degrees out of phase with each other. So, if we add up all the voltages, in phase Vr, -90 degree Vc, and 90 degree Vl, the voltages across the inductor and capacitor cancel and leave only the voltage across the resistor, which equals the driving voltage. Hence, voltages around the loop still sum to zero.

However, due to the phase response, Kirchhoff's Voltage Law computed using vector (phasor) sums rather than simply relying on the magnitudes is better. Indeed, all computations of this nature, such as a voltage divider, must be computed using vectors.

3. In general, how would the phasor diagram of Figure 1 change if the frequency was raised?

From the right triangle in the phasor diagram in Active Figure A, the phase angle phi between the current and the voltage is found as follows:

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

Here,

X_L which is Inductive reactance, is directly proportional to applied frequency.

And Xc which is Capacitive Reactance, is inversely proportional to frequency.

So, increase in frequency will result in a condition where XL > Xc, then **the phase angle is positive and shift upward**, signifying that the current lags the applied voltage. We describe this situation by saying that the circuit is more inductive than capacitive. The phasor Diagram will look generally look like:

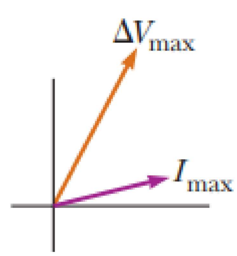

Figure: Phasor

4. In general, how would the phasor diagram of Figure 1 change if the frequency was lowered?

From the right triangle in the phasor diagram in Active Figure A, the phase angle phi between the current and the voltage is found as follows:

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

Here,

X_L which is Inductive reactance, is directly proportional to applied frequency.
And Xc which is Capacitive Reactance, is inversely proportional to frequency.

So, decrease in frequency will result in a condition where XL < Xc, then the **phase angle is negative so it shift downwards,** signifying that the current leads the applied voltage. We describe this situation by saying that the circuit is more capacitive than inductance. The phasor Diagram will look generally look like:

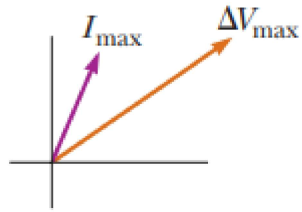

Figure: Phasor