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Assignment Title:	Analysis of RC, RL, RLC series circuits and verification of KVL in RLC series Circuit.
Assignment No: 08	**Date of Submission:** November 27, 2022
Course Title:	Introduction to Electrical Circuits Laboratory
Course Code: COE2102	**Section:** T
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Abstract:

The experiment was conducted to analysis of RC, RL, RLC series circuit and verification of KVL in RLC circuit. The objectives of this experiment are to determine the reactance of the RL and RC circuits and the impedance equation both practically and theoretically, to determine phase relationship between voltage and current in an RLC circuit and also verify the KVL. In this experiment some basic equipment like oscilloscope, function generator, resistor, inductor, capacitor, connecting wire, SPST switch, bread board are used. By observing this experiment we are able to analyze RC, RL and RLC circuit and also we can verify the KVL.

Theory:

RC Series Circuit:

A resistor-capacitor circuit or RC Network, is an electric circuit composed of resitors and capacitor is in series driven by a voltage or current source. A first order RC circuit is composed of one resistor and one capacitor and is the simplest type of RC circuit.

Analysis of a series RC Circuit

Step-1: Calculate the value of, X_C

$$X_C = \frac{1}{2\pi f C}$$

step-2: Calculate the total Impedence Z

$$Z = \sqrt{(X_C^2 + R^2)}$$

step-3: Use Ohm's Law to calculate the total current I_T

$$I_T = \frac{V_T}{Z}$$

Difference between Rectangular and Polar representation of Impedence:

Rectangular Form:

$$Z_{RC} = R - JX_C$$

Polar Form:

$$Z_T = \sqrt{R^2 + (X_C)^2}$$

$$\theta = \tan^{-1}\left(\frac{-X_C}{R}\right) = \tan^{-1}\left(\frac{-1}{\omega RC}\right)$$

Impact of frequency on the value of Capacitance:

Figure-1.1 will shows the impact of frequency by varying the value of capacitance in series resonance.

RL Series Circuit:

A resistor-inductor circuit or RL network in an electric circuit composed of resistors and inductor is in series driven by a voltage or current source. A first order RL circuit is composed of one resistor and one inductor and is the simplest type of RL circuit.

Analysis of a series RL Circuit:

step-1: Calculate the value of X_L:

$$X_L = 2\pi f L$$

step-2: Calculate the total Impedance Z:

$$Z = \sqrt{(X_L^2 + R^2)}$$

step-3: Use Ohm's Law to calculate Current I_T:

$$I_T = \frac{V_T}{Z}$$

Impact of frequency on the value of Inductance:

Figure-2.1 will shows the impact of frequency by varing the value of inductance in series resonance.

RLC Circuit:

Three basic passive components - R, L and C have very different phase relationship to each other when connected to a sinusoidal AC supply. In case of a resistor the voltage waveforms are "in phase" with the current. The phase difference depends upon the reactive value of the components being used. Reactance is zero if the element is resitive, positive if the element is inductive and negative if the element is capacitive.

Instead of analyzing each passive element seperately, we can combine all three together into a series RLC circuit. The analysis of a series RLC circuit is the same as that for the dual series RL and RC circuits we studied in the last experiment except this time we need to take account the magnitudes of both inductive reactance and capacitive reactance to find the overall circuit reactance.

Relevant Equations:

Inductive reactance, $X_L = 2\pi f L$

Capacitive reactance, $X_C = \frac{1}{2\pi f C}$

Net reactance, $X = X_L - X_C$

Total Impedence, $Z = \sqrt{R^2 + X^2}$

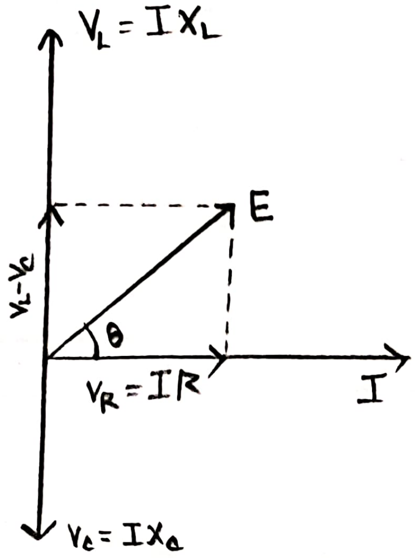
Current, $I = \frac{V}{Z}$

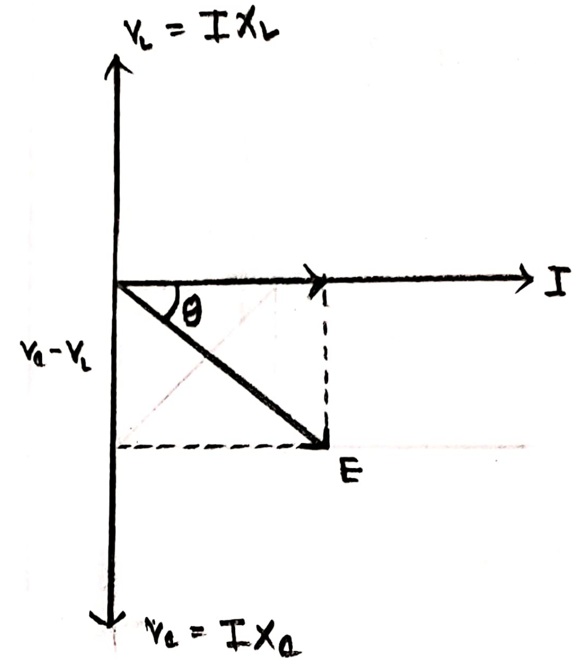
Resistive voltage drop, $V_R = I * R$

Reactive voltage drop $= V_L - V_C$

Total Voltage drop $= \sqrt{V_R^2 + (V_L - V_C)^2}$

Vector Diagram:





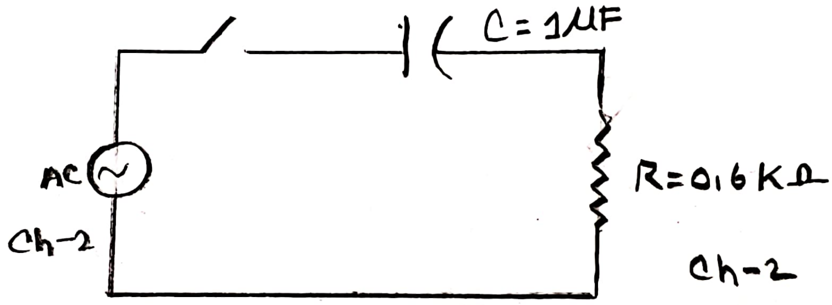


Figure-1

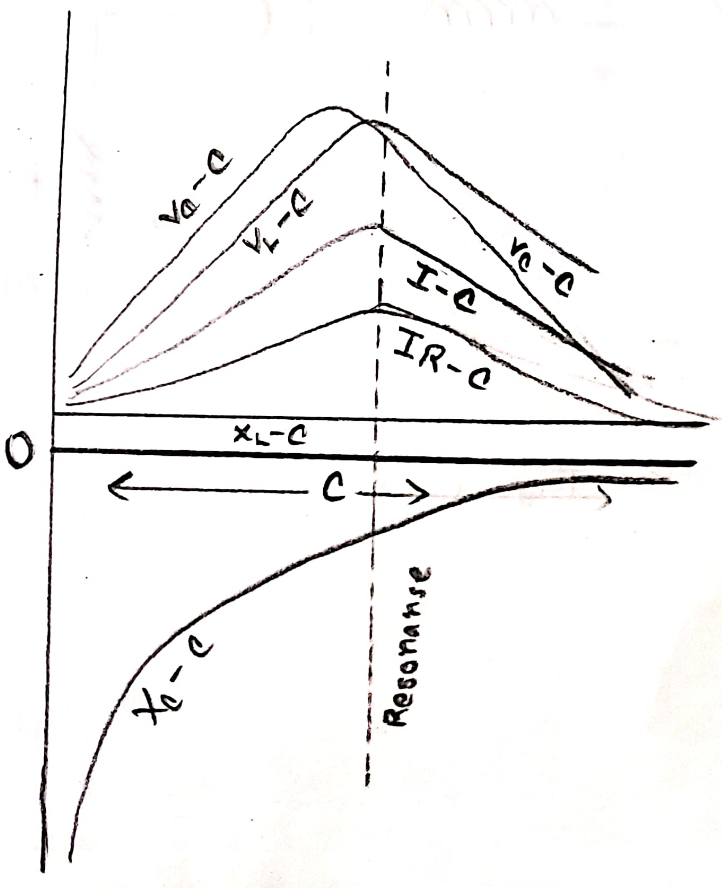


Figure-1.1

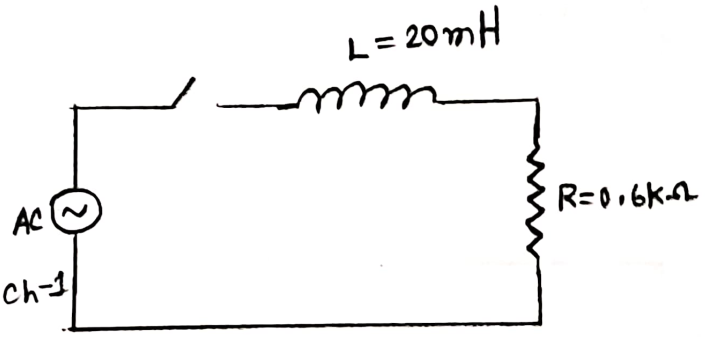


Figure-2

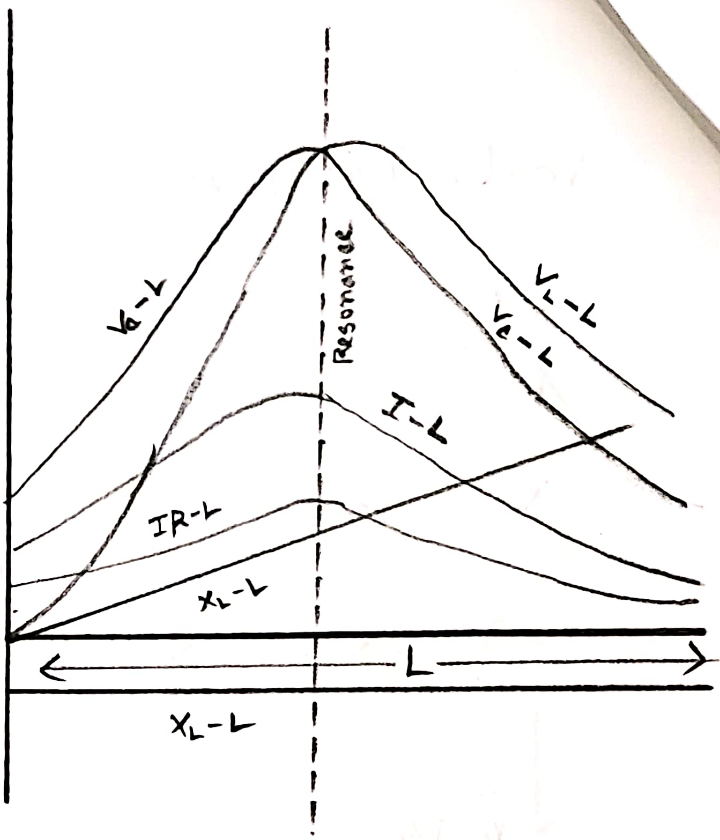


Figure-2.1

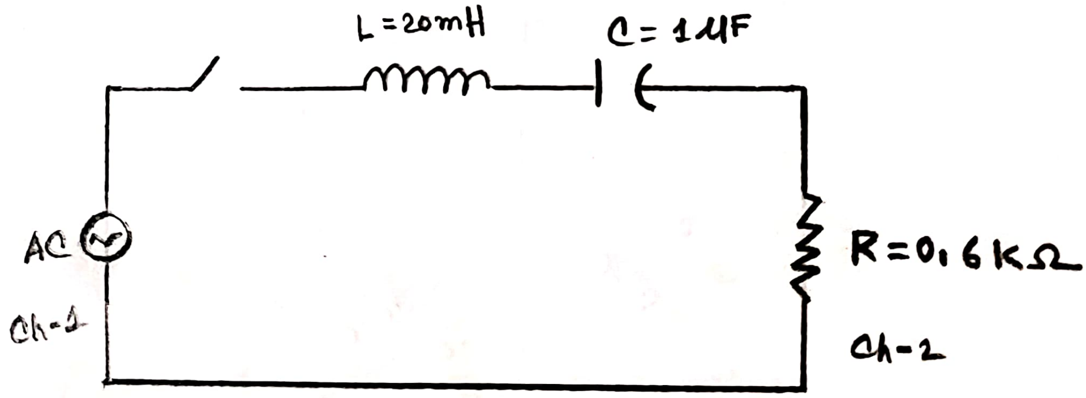


Figure-3

Apparatus:

- Oscilloscope.
- Function Generator.
- Resistor. ($R = 0.6 K\Omega$)
- Inductor. ($L = 20mH$)
- Capacitor. ($C = 1\mu F$)
- SPST switch.
- Connecting wire.
- Bread board.

Precautions:

- Oscilloscopes should be properly calibrated using the information provided at the calibration port before obtaining the wave shapes using the experimental set up.
- Do not short any connections. short connections can produce heat which is harmful for the components.

Experimental Procedure:

For RC and RL series Circuit:

1. Construct the circuit as shown in the fig.1. Connect channel 1 of the oscilloscope across function generator and channel 2 of the oscilloscop across R.

2. Set amplitude of input signal and frequency. Select sinusoidal waveshape.

3. Measure peak value of both wave shapes.

4. Determine phase relationship between the waves.

5. Write down the equations for I and E.

6. Calculate resistance and reactance for the relevant data.

7. Do the same experiment setting input another two frequency

8. Complete the following table:

Table-1: RC Circuit

f (Hz)	E (V)	V_R (V)	I (A)	R (kΩ)	X_C (Ω)	Z (reactangular) (Ω)	Z (polar) (Ω)	V_C (V)	$\sqrt{V_R^2+V_C^2}$ (V)
100	6.29	2.16	3.6×10^{-3}	0.6	1591.54	$600-j1591.54$	$1700.88\angle-69.34^\circ$	5.72	6.11
200	6.13	3.52	5.87×10^{-3}	0.6	795.77	$600-j795.77$	$996.61\angle-52.98^\circ$	4.67	5.84
300	6.02	4.32	7.2×10^{-3}	0.6	530.51	$600-j530.51$	$800.9\angle-41.48^\circ$	3.81	5.76

Table-2: RL Circuit

f (KHz)	E (V)	V_R (V)	I (A)	R (kΩ)	X_L (Ω)	Z (rectangular) (Ω)	Z (polar) (Ω)	V_L (V)	$\sqrt{V_R^2+V^2}$ (V)
5	6.13	3.63	6.05×10^{-3}	0.6	628.32	$600+j628.32$	$868.78\angle46.32^\circ$	3.80	5.25
10	6.24	2.27	3.78×10^{-3}	0.6	1256.64	$600+j1256.64$	$1392.53\angle64.47^\circ$	4.75	5.26
15	6.36	1.59	2.65×10^{-3}	0.6	1884.96	$600+j1884.96$	$1978.14\angle72.34^\circ$	5	5.24

For RLC Series Circuit

1. Constract the circuit as shown in ~~in~~ the figure-3. Connect channel-1 of the oscilloscope accross the ac voltage source and channel 2 of the oscilloscope across R.

2. Set amplitude of input signal.
3. Set the frequency of the signal generator.
4. Measure value of I.

6. Measure value of V_R, V_L and V_C

7. Verify KVL using the experimental data.
~~and draw t~~

8. Complete the following table.

Table:-3 : RLC circuit

f kHz	E (V)	V_R (V)	I (A)	X_L (Ω)	V_L (V)	X_C (Ω)	V_C (Ω)	θ	$V^* = \sqrt{V_R^2 + (V_L^2 - V_C^2)}$ (V)
3	5.91	4.89	8.15×10^{-3}	377	3.072	53.05	0.432	28.36°	5.51
5	6.13	3.97	6.63×10^{-3}	628.32	4.16	31.83	0.21	44.83°	5.60
7	6.24	3.29	5.48×10^{-3}	879.64	4.82	22.73	0.12	55°	5.73

Result and Calculation:

RC Circut:

When frequency = 100 Hz

$$V_p = 4.45\ \cancel{div} \times \frac{2V}{\cancel{div}} = 8.9$$

$$E = V_p \times 0.707 = 8.9 \times 0.707 = 6.29V$$

$$V_p' = 1.53\ \cancel{div} \times \frac{2V}{\cancel{div}} = 3.06$$

$$V_R = V_p' \times 0.707 = 3.06 \times 0.707 = 2.16\ V$$

$$I = \frac{V_R}{R} = \frac{2.16}{0.6 \times 10^3} = 3.6 \times 10^{-3}\ A$$

$$X_c = \frac{1}{2\pi f c} = \frac{1}{2 \times 3.1416 \times 100 \times 1 \times 10^{-6}} = 1591.54\ \Omega$$

$$Z = R - jX_c = 0.6 \times 10^3 - j1591.54 \text{ (rectangular)}$$

$$Z = 1700.88 \angle -69.34^\circ \text{ (polar)}$$ $\boxed{\text{By using Calculator}}$

$$V_c = IX_c = 3.6 \times 10^{-3} \times 1591.54 = 5.72V$$

$$\sqrt{V_R^2 + V_c^2} = \sqrt{(2.16)^2 + (5.72)^2} = 6.11\ V$$

$$\%\,Error = \frac{6.29 - 6.11}{6.11} \times 100 = 2.94\%$$

When Frequency $= 200\ Hz$

$$V_P = 4.34\ div \times \frac{2V}{div} = 8.68\ V$$

$$E = V_P \times 0.707 = 8.68 \times 0.707 = 6.13\ V$$

$$V_P' = 1.49\ div \times \frac{2V}{div} = 4.98\ V$$

$$V_R = V_P' \times 0.707 = 4.98 \times 0.707 = 3.52V$$

$$I = \frac{V_R}{R} = \frac{3.52}{600} = 5.87 \times 10^{-3} A$$

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2 \times 3.1416 \times 200 \times 1 \times 10^{-6}} = 795.77\ \Omega$$

$Z = R - jX_C = 600 - j\,795.77$ (rectangular)

$Z = 996.61 \angle -52.98^\circ$ (polar) $\boxed{\text{By using calculator}}$

$$V_C = I X_C = 5.87 \times 10^{-3} \times 795.77 = 4.67V$$

$$\sqrt{V_R^2 + V_C^2} = \sqrt{(3.52)^2 + (4.67)^2} = 5.84V$$

$$\%\ Error = \frac{6.13 - 5.84}{5.84} \times 100$$

$$= 4.96\%$$

When Frequency = 300 Hz

$V_p = 4.26 \text{ div} \times \frac{2V}{\text{div}} = 8.52V$

$E = V_p \times 0.707 = 8.52 \times 0.707 = 6.02V$

$V_p' = 3.06 \text{ div} \times \frac{2}{\text{div}} = 6.12V$

$V_R = V_p' \times 0.707 = 6.12 \times 0.707 = 4.32V$

$I = \frac{V_R}{R} = \frac{4.32}{600} = 7.2 \times 10^{-3} A$

$X_c = \frac{1}{2\pi f c} = \frac{1}{2 \times 3.1416 \times 300 \times 1 \times 10^{-6}} = 530.51\Omega$

$Z = R - jX_c = 600 - j530.51$ (rectangular)

$Z = 800.9 \angle -41.48^\circ$ (polar) [By using calculator]

$V_c = IX_c = 7.2 \times 10^{-3} \times 530.51 = 3.81 V$

$\sqrt{V_R^2 + V_c^2} = \sqrt{(4.32)^2 + (3.81)^2} = 5.76 V$

$\% \text{Error} = \frac{6.02 - 5.76}{5.76} \times 100$

$= 4.51\%$

RL Circuit:

when frequency = 5 KHz

$V_P = 4.34 \text{ div} \times \frac{2V}{\text{div}} = 8.68 \text{ V}$

$E = V_P \times 0.707 = 8.68 \times 0.707 = 6.136 \text{ V}$

$V_P' = 2.57 \text{ div} \times \frac{2V}{\text{div}} = 5.14 \text{ V}$

$V_R = V_P' \times 0.707 = 5.14 \times 0.707 = 3.63 \text{ V}$

$I = \frac{V_R}{R} = \frac{3.63}{600} = 6.05 \times 10^{-3} \text{ A}$

$X_L = 2\pi f L = 2 \times 3.1416 \times 5 \times 10^3 \times 20 \times 10^{-3} = 628.32 \, \Omega$

$Z = R + jX_L = 600 + j\,628.32$ (rectangular)

$Z = 868.78 \angle 46.32^\circ$ (polar) (By using calculator)

$V_L = IX_L = 6.05 \times 10^{-3} \times 628.32 = 3.80 \text{ V}$

$\sqrt{V_R^2 + V_L^2} = \sqrt{(3.63)^2 + (3.80)^2} = 5.25 \text{ V}$

$\% \text{ Error} = \frac{6.13 - 5.25}{5.25} \times 100$

$= 16.76\%$

When frequency = 10KHz

$V_P = 4.42 \text{ div} \times \frac{2V}{\text{div}} = 8.84V$

$E = V_P \times 0.707 = 8.84 \times 0.707 = 6.24 \text{ V}$

$V_P' = 1.61 \text{ div} \times \frac{2V}{\text{div}} = 3.22V$

$V_R = V_P' \times 0.707 = 3.22 \times 0.707 = 2.27 \text{ V}$

$I = \frac{V_R}{R} = \frac{2.27}{600} = 3.78 \times 10^{-3} A$

$X_L = 2\pi f L = 2 \times 3.1416 \times 10 \times 10^3 \times 20 \times 10^{-3} = 1256.64 \, \Omega$

$Z = R + jX_L = 600 + j\,1256.64$ (rectangular)

$Z = 1392.53 \angle 64.47^\circ$ (polar) [By using Calculator]

$V_L = IX_L = 3.78 \times 10^{-3} \times 1256.64 = 4.75 \text{ V}$

$\sqrt{V_R^2 + V_L^2} = \sqrt{(2.27)^2 + (4.75)^2} = 5.26 \text{ V}$

$\% \text{Error} = \frac{6.24 - 5.26}{5.26} \times 100$

$= 18.63 \%$

When frequency = 15KHz

$V_p = 4.50 \text{div} \times \frac{2V}{\text{div}} = 9V$

$E = \quad V_p \times 0.707 = 9 \times 0.707 = 6.36$

$V_p' = 1.13 \text{ div} \times \frac{2V}{\text{div}} = 2.26V$

$V_R = V_p' \times 0.707 = 2.26 \times 0.707 = 1.59V$

$I = \frac{V_R}{R} = \frac{1.59}{600} = 2.65 \times 10^{-3} A$

$X_L = 2\pi f L = 2 \times 3.1416 \times 15 \times 10^3 \times 20 \times 10^{-3} = 1884.96\Omega$

$Z = R + jX_L = 600 + j\,1884.96$ (rectangular)

$Z = 1978.14 \angle 72.34°$ [By using Calculator]

$V_L = IX_L = 2.65 \times 10^{-3} \times 1884.96 = 5\,V$

$\sqrt{V_R^2 + V_L^2} = \sqrt{(1.59)^2 + (5)^2} = 5.24$

$\% \text{Error} = \frac{6.36 - 5.24}{5.24} \times 100$

$= 21.37\%$

RLC Circuit:

When frequency = 3 kHz

$$V_P = 4.18\,\text{div} \times \frac{2V}{\text{div}} = 8.36V$$

$$E = V_P \times 0.707 = 8.36 \times 0.707 = 5.91V$$

$$V_P' = 3.46\,\text{div} \times \frac{2V}{\text{div}} = 6.92V$$

$$V_R = V_P' \times 0.707 = 4.89\,V$$

$$I = \frac{V_R}{R} = \frac{4.89}{600} = 8.15 \times 10^{-3} A$$

$$X_L = 2\pi f L = 2 \times 3.1416 \times 3 \times 10^3 \times 20 \times 10^{-3} = 377\Omega$$

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2 \times 3.1416 \times 3 \times 10^3 \times 1 \times 10^{-6}} = 53.05\,\Omega$$

$$X = X_L - X_C = (377 - 53.05) = 323.95\,\Omega$$

$$\theta = \tan^{-1}\left(\frac{X}{R}\right) = \tan^{-1}\left(\frac{323.95}{600}\right) = 28.36^{\circ}$$

$$V_L = IX_L = 8.15 \times 10^{-3} \times 377 = 3.072\,V$$

$$V_C = IX_C = 8.15 \times 10^{-3} \times 53.05 = 0.432V$$

$$V^* = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{(4.89)^2 + (3.072 - 0.432)^2}$$

$$= 5.51\,V$$

$$\%\,\text{Error} = \frac{5.91 - 5.51}{5.51} \times 100 = 7.25\%$$

When frequency = 5KHz

$V_P = 4.34 \text{ div} \times \frac{2V}{\text{div}} = 8.68\,V$

$E = V_P \times 0.707 = 8.68 \times 0.707 = 6.13\,V$

$V_P' = 2.81 \text{ div} \times \frac{2V}{\text{div}} = 5.62\,V$

$V_R = 5.62\, V_P' \times 0.707 = 5.62 \times 0.707 = 3.97V$

$I = \frac{V_R}{R} = \frac{3.97}{600} = 6.63 \times 10^{-3} A$

$X_L = 2\pi f L = 2 \times 3.1416 \times 5 \times 10^3 \times 20 \times 10^{-3} = 628.32\,\Omega$

$X_C = \frac{1}{2\pi f C} = \frac{1}{2 \times 3.1416 \times 5 \times 10^3 \times \quad \times 10^{-6}} = 31.83\,\Omega$

$X = X_L - X_C = (628.32 - 31.83) = 596.49$

$\theta = \tan^{-1}\left(\frac{596.49}{600}\right) = 44.83^\circ$

$V_L = I X_L = 6.63 \times 10^{-3} \times 628.32 = 4.16\,V$

$V_C = I X_C = 6.63 \times 10^{-3} \times 31.83 = 0.21\,V$

$V^* = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{(3.97)^2 + (4.16 - 0.21)} = 5.60V$

$\% \text{Error} = \frac{6.13 - 5.60}{5.60} \times 100$

$= 9.46\%$

When frequency = 7 KHz

$V_P = 4.42 \text{ div} \times \frac{2V}{\text{div}} = 8.84 V$

$E = V_P \times 0.707 = 8.84 \times 0.707 = 6.24 V$

$V_P' = 2.33 \text{ div} \times \frac{2V}{\text{div}} = 4.66 V$

$V_R = V_P' \times 0.707 = 4.66 \times 0.707 = 3.29 V$

$I = \frac{V_R}{R} = \frac{3.29}{600} = 5.48 \times 10^{-3} A$

$X_L = 2\pi f L = 2 \times 3.1416 \times 7 \times 10^3 \times 20 \times 10^{-3} = 879.64 \Omega$

$X_C = \frac{1}{2\pi f C} = \frac{1}{2 \times 3.1416 \times 7 \times 10^3 \times 1 \times 10^{-6}} = 22.73 \Omega$

$X = X_L - X_C = (879.64 - 22.73) = 856.91 \Omega$

$\theta = \tan^{-1}\left(\frac{X}{R}\right) = \tan^{-1}\left(\frac{856.91}{600}\right) = 55°$

$V_L = I X_L = 5.48 \times 10^{-3} \times 879.64 = 4.82 V$

$V_C = I X_C = 5.48 \times 10^{-3} \times 22.73 = 0.12 V$

$V^* = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{(3.29)^2 + (4.82 - 0.12)^2} = 5.73 V$

$\% \text{ Error} = \frac{6.24 - 5.73}{5.73} \times 100 = 8.9\%$

Discussion:

First of all, we checked oscilloscope and function generator. After that we build up all necessary circuit. All values were taken carefully. Finally all the data was placed in the data table.

Conclusion:

By completing this experiment we had become familiar with the function generator and oscilloscope. Measuring RC, RL and RLC circuit and verified KVL in RLC series circuit.

References:

[1] "Fundamental of Electric Circuit" by Alekzendresadiku

[2] "Alternating Current Circuit" by George F Corcoran