Lab 3: Series RLC circuits

A. Objectives

- Investigate series RC, RL, and RLC circuits.
- Analyze the peak voltage, current and phase relationships between the circuit components.

B. Background

B.1. Voltage and Current in an AC circuit:

The complex impedance in an AC circuit is represented by Z and expressed in Cartesian form by the formula:

$$Z = R + jX$$

where the real part of impedance is the resistance R and the imaginary part is the reactance X.

Impedance can also be expressed in magnitude and phase form: $|Z|\angle\theta$, where θ is the phase difference between the voltage and the current. The magnitude of the impedance can be expressed as: $|Z| = \sqrt{R^2 + X^2}$and the phase can be expressed as: $\theta = tan^{-1}\frac{X}{R}$.

It follows, then, that since Ohm's Law is true for AC circuits, the current flow caused by a voltage V can be given by:

$$\mathbf{I} = \frac{\boldsymbol{V}}{\boldsymbol{Z}}$$

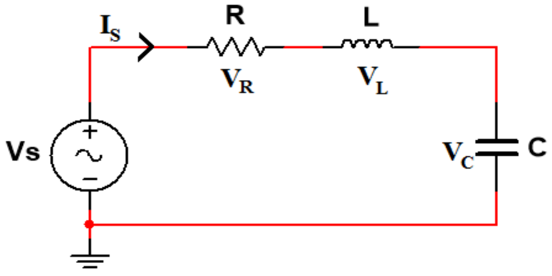

Fig.B.1.1: Series RLC circuit

Consider the circuit in **Figure B.1.1**.
Here, V_S is the source voltage, I_S the source current and V_R, V_L and V_C the voltages across the resistor, inductor and capacitor respectively. The complex voltage across any of the components can be found using the voltage divider rule. The phase relations of the voltages mentioned can be expressed by the phasor diagram in **Figure B.1.2**:

We can see that V_L and V_C are both 90° out of phase with the circuit current I_S, and θ_L° and θ_C°out of phase with the source voltage respectively. We can also see that the voltage across the resistor is always in phase with the current through the resistor, which, in this case, is the source current.

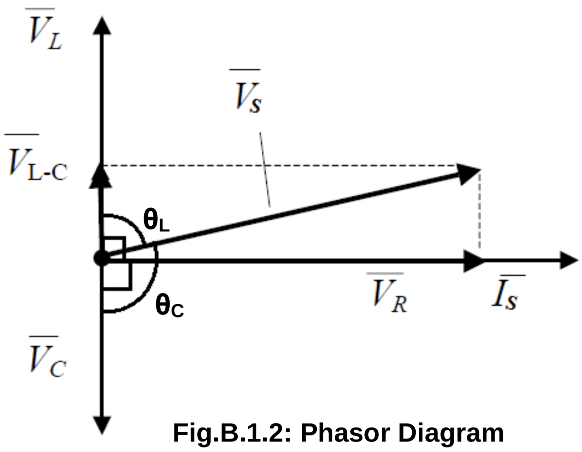

Fig.B.1.2: Phasor Diagram

Experiment 1: Series RC, RL and RLC circuits

A. Apparatus

Components	Instruments
• Resistors: 1×100Ω • Capacitors: 1×1µF • Inductor: 1x330µH	• 1× Bread Board • 1× Function Generator • 1× Digital Storage Oscilloscope(DSO) • Connecting wires and probes

B. Procedure

1. Measure the practical value of the resistor (R) using DMM and note down the value in Tables 1.1, 1.3 and 1.5. Use the measured values in all your calculations.
2. Measure the practical value of the capacitor (C) using an LCR meter and note down the values in Tables 1.1, and 1.5. Do the same for the inductor (L) and note down the values in Tables 1.3 and 1.5.

3. Construct the circuit shown in Fig.B.1.1 on the bread board. Connect Channel 1 of the oscilloscope across the source VS (positive red port to node 'a' and negative black port to node '0' i.e. ground). Connect the channel 2 at node 'b' (positive red port to node 'b' and negative black port to node 0 i.e. ground).
4. To set 3V peak (6V peak to peak) and 10 KHz in the function generator, observe the generated signal on the oscilloscope screen (channel 1) and fine tune the amplitude & frequency of the input signal generated from the function generator to match the nominal values. **Always set the amplitude after setting the frequency because changing the frequency of a non-ideal source might alter the amplitude.**

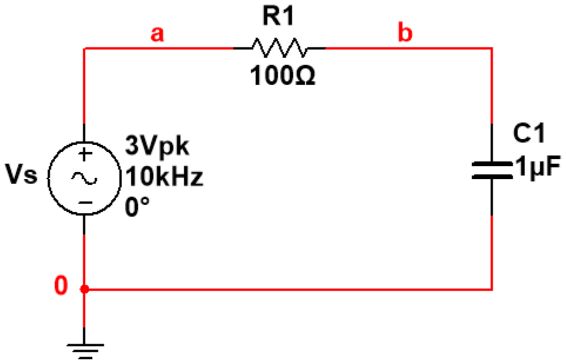

Fig.B.1.1: Series RC circuit

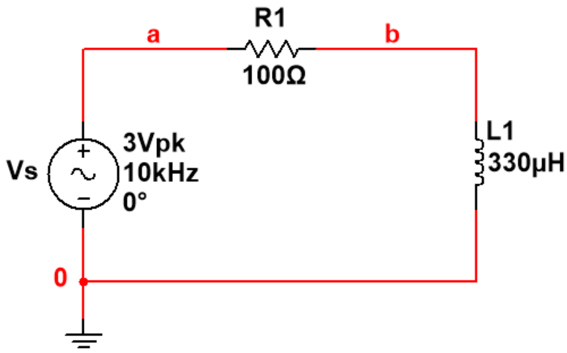

Fig.B.1.2: Series RL circuit

5. Channel 2 of the Oscilloscope will show you the voltage drop across C1 and Channel 1 will show you the source voltage VS. To find out the Voltage drop across R1, use **MATH** function to get a signal CH1-CH2.
6. Use **CURSOR** (**type** should be: **Voltage** & **source** should be **MATH**) on the signal that was generated using MATH function, to find out the peak voltage drop across R1 (V_R). From measurement, find out the peak voltage drop across C1 (V_C) and record them in table 1.2.
7. Use **CURSOR** (type should be: **Time**) to measure the time difference between a peak of the source wave shape (V_S – Channel 1) and the next peak of the voltage across C1 (V_C– Channel 2). Note down the time (Delay) in table 1.2.
8. Use **CURSOR** (type should be: **Time**) to measure the time difference between a peak of the source wave shape (V_S – Channel 1) and the next peak of the voltage across R1 (V_R – Math generated signal). Note down the time (Delay) in table 1.2.

9. Now, replace the capacitor (C1) with the inductor (L1) to construct the circuit shown in **Fig.B.1.2**.
10. Keep the source frequency to 10 kHz and the amplitude to 3V peak (6V peak to peak).
11. Repeat step 6 to find out V_R & V_L and record them in table 1.4
12. Repeat steps 7 & 8 to find out the time difference between V_S(peak) and V_L(peak) and V_S(peak) and V_R (peak)

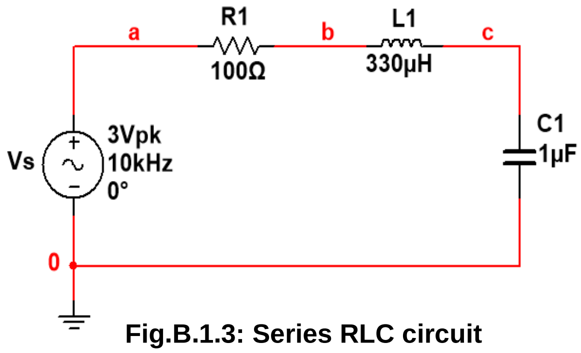

Fig.B.1.3: Series RLC circuit

13. Construct the circuit shown in Fig.B.1.3 on the bread board. Connect Channel 1 of the oscilloscope across the source VS (positive red port to node ‘a’ and negative black port to node ‘0’ i.e. ground). Connect the channel 2 at node ‘c’ (positive red port to node ‘c’ and negative black port to node ‘0’ i.e. ground).
14. To set 3V peak (6V peak to peak) and 10 KHz in the function generator, observe the generated signal on the oscilloscope screen (channel 1) and fine tune the amplitude & frequency of the input signal generated from the function generator to match the nominal values. **Always set the amplitude after setting the frequency because changing the frequency of a non-ideal source might alter the amplitude.**

15. Channel 2 of the Oscilloscope will show you the voltage drop across C1 and Channel 1 will show you the source voltage VS.
16. From measurement, find out the peak voltage drop across C1 (V_C) and record that in table 1.6.
17. Use **CURSOR** (type should be: **Time**) to measure the time difference between a peak of the source wave shape (V_S – Channel 1) and the next peak of the voltage across C1 (V_C– Channel 2). Note down the time (Delay) in table 1.6.

18. Now connect the Channel-2 (red port) to node ‘b’. And to find out the Voltage drop across R1, use **MATH** function to get a signal CH1-CH2.
19. Use **CURSOR** (type should be: **Voltage**) on the signal that was generated using MATH function, to find out the peak voltage drop across R1 (V_R) and record that in table 1.6.
20. Use **CURSOR** (type should be: **Time**) to measure the time difference between a peak of the source wave shape (V_S – Channel 1) and the next peak of the voltage across R1 (V_R – Math generated signal). Note down the time (Delay) in table 1.6.

21. Use **REF** function of the oscilloscope to **save** the output graph of V_S (Channel 1)

22. Now connect the Channel-1 (red port) to node ‘b’ & the Channel-2 (red port) to node ‘c’. The current **MATH** function generated signal will give you the Voltage drop across the inductor L1.
23. Use **CURSOR** (type should be: **Voltage**) on the signal that was generated using MATH function, to find out the peak voltage drop across L1 (V_L) and record that in table 1.6.
24. Use **CURSOR** (type should be: **Time**) to measure the time difference between a peak of the source wave shape (V_S – **REF signal**) and the next peak of the voltage across L1 (V_L – Math generated signal). Note down the time (Delay) in table 1.6.

C. Simulation

1. In MULTISIM, construct the circuit in figure B.1.1, B.1.2 & B.1.3 and do TRANSIENT analysis for showing the time delays between different voltages across all the components.
2. Attach the output graphs in your report.

D. Questions

1. In step 6, what would have happened if the required readings had been obtained by switching the positions of the resistor and the capacitor? Explain your answer.
2. Draw the phasor diagrams for the circuits in Fig B.1.1, Fig B.1.2 and Fig B.1.3.
3. How would each of the phasor diagrams change if the source frequency was raised?
4. In case of the series RLC circuit, do the practical readings confirm the theoretical values? If any of the percentage differences are above 10%, suggest 3 possible reasons for the discrepancy.

E. Data Sheet: Lab 3

Date:	Points:
Remarks:	

Signature of the Instructor

Student Information

Section:	Group:	Status:

E.1 Table 1.1: Reactance and Impedance values (series RC circuit)

R (measured)(Ω)	**C (measured)**(F)	X_C $[\frac{1}{2\pi f C}]$ (Ω)	**|Z|**(Ω) $[\sqrt{R^2+X^2}]$	**Z ∠θ°** $[tan^{-1}(\frac{X}{R})]$

E.2 Table 1.2: Comparing magnitudes and phases of V_C and V_R

	|V_{peak}| (Theory)	**θ** (Theory)	**|V_{peak}|** (Practical)	**Delay ΔT** (Practical)	**θ (Practical)** [ΔT x f x 360]	**% Difference |V|**	**% Difference θ**
V_C							
V_R							

E.3 Table 1.3: Reactance and Impedance values (series RL circuit)

R (measured)(Ω)	**L(measured)**(H)	**X_L (Theory)** $[2\pi f L]$ (Ω)	**|Z|**(Ω) $[\sqrt{R^2+X^2}]$	**Z ∠θ°** $[tan^{-1}(\frac{X}{R})]$

E.4 Table 1.4: Comparing magnitudes and phases of V_L and V_R

	|V_{peak}| (Theory)	**θ** (Theory)	**|V_{peak}|** (Practical)	**Delay ΔT** (Practical)	**θ (Practical)** [ΔT x f x 360]	**% Difference |V|**	**% Difference θ**
V_L							
V_R							

E.5 Table 1.5: Reactance and Impedance values (series RLC circuit)

R (Ω)	**C** (F)	**L** (H)	**X_C (Theory)** $[\frac{1}{2\pi f C}]$ (Ω)	**X_L (Theory)** $[2\pi f L]$ (Ω)	**|Z|**(Ω) $[\sqrt{R^2+X^2}]$	**Z∠θ°** $[tan^{-1}(\frac{X}{R})]$

E.6 Table 1.6: Comparing magnitudes and phases of V_C,V_L and V_R

	|V_{peak}| (Theory)	**θ** (Theory)	**|V_{peak}|** (Practical)	**Delay ΔT** (Practical)	**θ (Practical)** [ΔT x f x 360]	**% Difference |V|**	**% Difference θ**
V_C							
V_R							
V_L							