Lab 4: Parallel RC, RL & RLC circuits

A. Objectives

- Investigate peak voltage, current and phase relationships between the circuit components of parallel RC, RL, and RLC circuits.
- Understand and prove Kirchhoff's Current Law for AC circuits.
- Understand the technique to measure current using a current sense resistor.

B. Background

B.1. Voltage and Current in a parallel AC circuit:

In a parallel RLC circuit, the source voltage V_s is common to all the components and the individual branch currents through each element is different. From our previous experiments we know that for resistors voltage is always in phase with the current, for capacitor voltage lags the current by 90 degrees and for inductors the voltage leads the current by 90 degrees. Because each element has a unique phase response between +90 and -90 degrees, a parallel combination of R, L & C will yield a complex impedance with a phase angle between +90 and -90 degrees. Due to this phase response, Kirchhoff's Current Law must be computed using vector (phasor) sums rather than simply relying on magnitude.

B.2. Measuring current using an Oscilloscope:

We can indirectly determine the magnitude and phase of the current in any branch of a circuit by using a small sense resistor. The phase angle of the current in the branch will be the same as the phase angle of the voltage across the sense resistor.

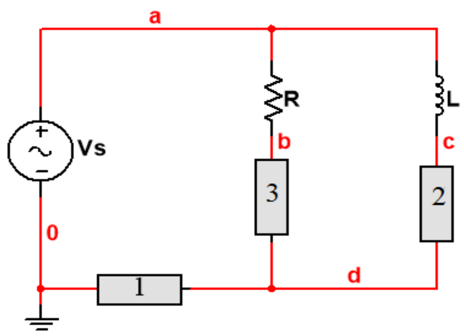

Fig.B.2.1: Sense resistor placement

In the circuit in **Figure B.2.1**, the source current can be measured by adding a resistor 'r1' at Box 1. The resistor chosen must be much smaller than the total circuit impedance so as to have minimal impact on the total current. The phase difference between V_S and V_{r1} will be the phase angle of the circuit current.

Similarly, to find the current through the inductor L, we can add a sense resistor 'r2' at Box 2. The magnitude of the current through L can be determined using Ohm's Law and the phase can be obtained from the phase difference between V_S and V_{r2}.

Experiment 1: Parallel RC, RL and RLC circuits

A. Apparatus

Components	Instruments
• Resistors: 1×10kΩ, 3×1kΩ, 2×3Ω, 3×10Ω • Capacitors: 1×10nF, 1×33nF • Inductor: 1×330µH	• 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 (10nF), and 1.5 (33nF). 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.1.3 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 '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 1 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.**

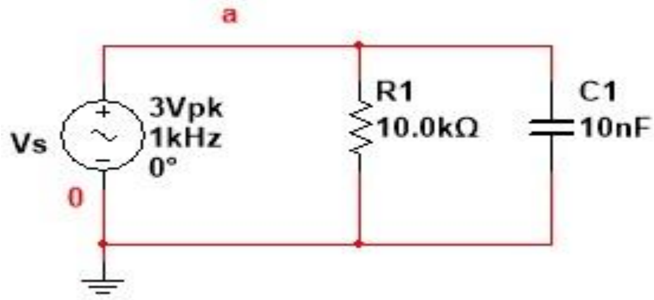

Fig.B.1.1: Parallel RC circuit

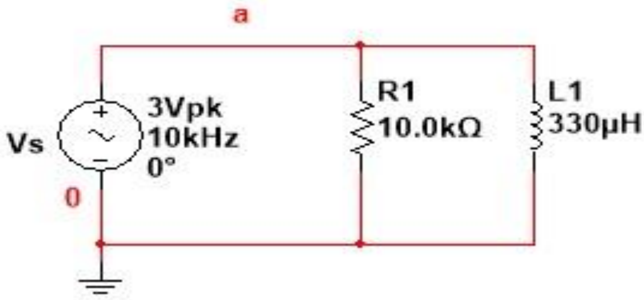

Fig.B.1.2: Parallel RL circuit

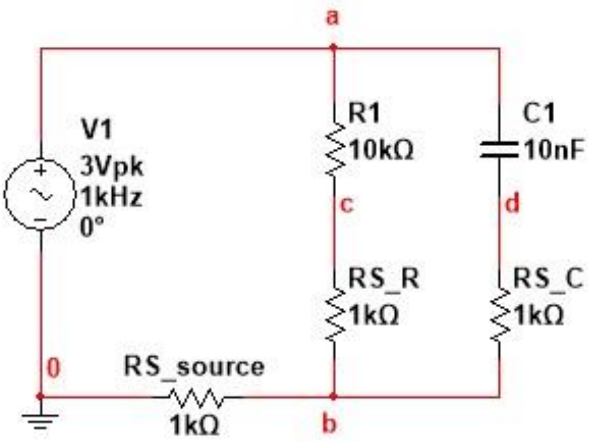

Fig.B.1.3: Parallel RC circuit with sense resistors

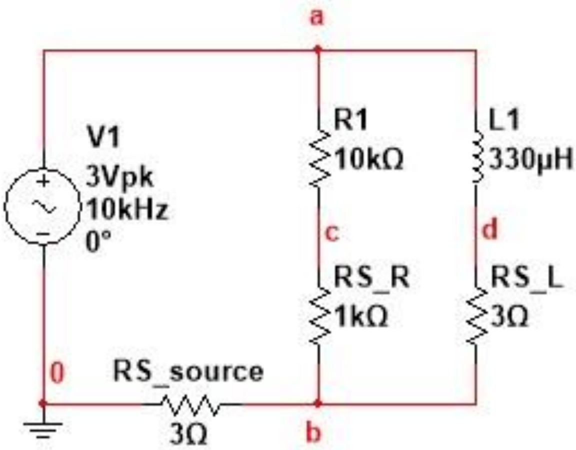

Fig.B.1.4: Parallel RL circuit with sense resistors

5. Channel 2 of the Oscilloscope will show you the voltage drop across RS_source and Channel 1 will show you the source voltage VS. From measurement, find out the peak voltage drop across **RS_source** and record it in table 1.2.
6. 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 **RS_source** (Channel 2). Note down the time (Delay) in table 1.2.

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

8. While keeping channel 2 at node 'b', move channel 1 to node 'c'.
9. Use **MATH** function to get a signal CH1-CH2. This MATH function generated signal will show you the voltage drop across **RS_R**.
10. 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 **RS_R** and record it in table 1.2.
11. 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 **RS_R** (Math generated signal). Note down the time (Delay) in table 1.2.
12. While keeping channel 2 at node 'b', move channel 1 to node 'd'.

13. The MATH function generated signal will now show you the voltage drop across **RS_C**.
14. 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 **RS_C** and record it in table 1.2.
15. 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 **RS_C** (Math generated signal). Note down the time (Delay) in table 1.2.

16. Construct the circuit shown in Fig.B.1.4 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).
17. 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.**

18. Repeat step 5 to step 15 and fill up table 1.4

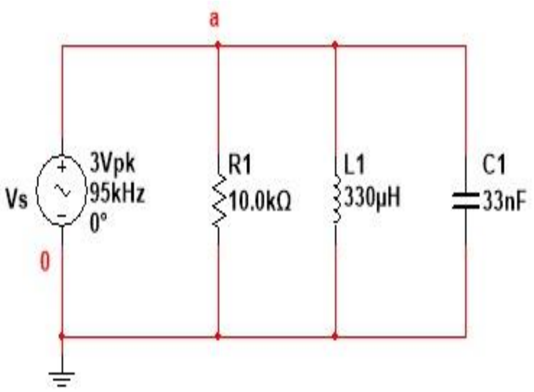

Fig.B.1.5: Parallel RLC circuit

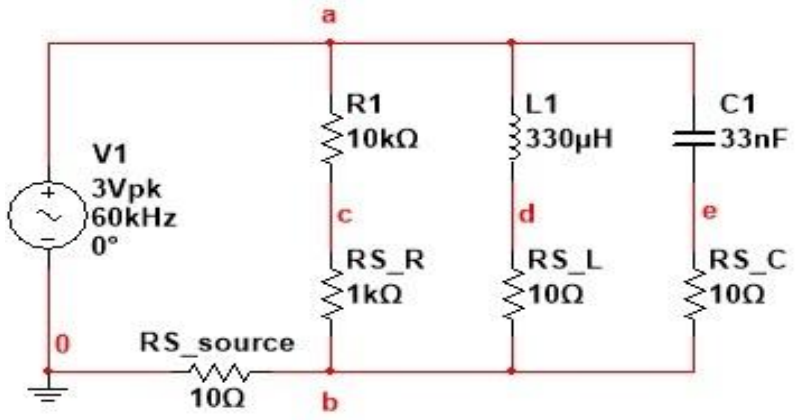

Fig.B.1.6: Parallel RLC circuit with sense resistors

19. 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).
20. To set 3V peak (6V peak to peak) and 60 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.**

21. Follow previous steps to complete table 1.6.

C. Simulation

1. In MULTISIM, construct the circuit in figure B.1.3, B.1.4 & B.1.6 and do TRANSIENT analysis for showing the time delays between different voltages across the components.
2. Attach the output graphs in your report.

D. Questions

1. A 1kΩ sense resistor was used to perform this experiment. Suggest 1 possible advantage and 1 possible disadvantage of using an even smaller (say 10Ω) sense resistor in the first circuit (B.1.3).
2. Draw the phasor diagrams for the circuits in Fig B.1.3, Fig B.1.4 and Fig B.1.6.
3. How would each of the phasor diagrams change if the source frequency was raised?
4. In case of the parallel 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 4

Date:	Points:
Remarks:	

Signature of the Instructor

Student Information

Section:	Group:	Status:

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

R (measured)(Ω)	**C (measured)**(F)	**X_C (Theory)** [$\frac{1}{2\pi fC}$] (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 i_C and i_R

	|i_{peak}| (Theory)	θ (Theory)	**$V_{sense(peak)}$** (Measured)	**|i_{peak}|** (Practical)	**Delay ΔT** (Measured)	**θ (Practical)** [ΔT x f x 360]	**% Difference |i|**	**% Difference θ**
i_S								
i_R								
i_C								

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

R (measured)(Ω)	**L (measured)**(H)	**X_L (Theory)** [$2\pi fL$] (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 i_L and i_R

	|i_{peak}| (Theory)	**θ** (Theory)	**$V_{sense(peak)}$** (Measured)	**|i_{peak}|** (Practical)	**Delay ΔT** (Measured)	**θ (Practical)** [ΔT x f x 360]	**% Difference |i|**	**% Difference θ**
i_S								
i_R								
i_L								

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

R (Ω)	**C** (F)	**L** (H)	**X_C (Theory)** [$\frac{1}{2\pi fC}$] (Ω)	**X_L (Theory)** [$2\pi fL$] (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

	|i_{peak}| (Theory)	**θ** (Theory)	**$V_{sense(peak)}$** (Measured)	**|i_{peak}|** (Practical)	**Delay ΔT** (Measured)	**θ (Practical)** [ΔT x f x 360]	**% Difference |i|**	**% Difference θ**
i_S								
i_R								
i_L								
i_C								