Regular . Session :	Wednesday , Afternoon Session (LB)
Exp. No :	03
Date of Experiment :	02/03/16
Student - 01 :	K.Y.ASHOK (150107027)
Student - 02 :	K. Indramani (150107028)
Table - No :	14

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PRE- EXPERIMENT OBSERVATIONS:-

PART A: For RC Circuit;

Time Constant ; $\tau = RC$

$= 1000\,\Omega \times 10^{-6}\,F$

$= \underline{10^{-3}\,s}$

PART B: For RL Circuit;

Time Constant ; $\tau = \frac{L}{R}$

$= \frac{0.1\,H}{4.7 \times 10^{3}\,\Omega} = \underline{2.12 \times 10^{-5}\,s}.$

PART C: For RLC Circuit;

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2\pi\sqrt{0.1 \times 0.1 \times 10^{-6}}}$$

$$= \frac{1}{2\pi\sqrt{10^{-8}}}$$

$$= \frac{1}{2\pi \times 10^{-4}} = 0.16 \times 10^{4}\,Hz$$

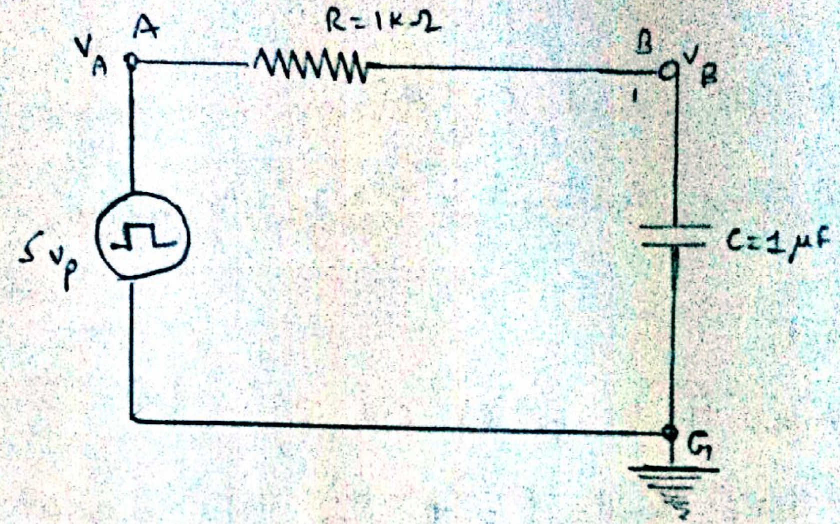
$$= \underline{1.6 \times 10^{3}\,Hz}.$$

$$= \underline{1.6\,KHz}.$$

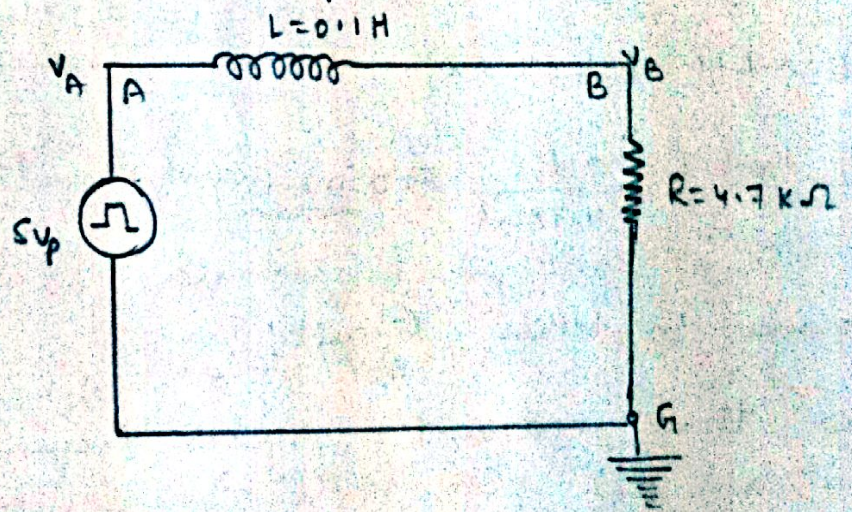
tive → To find the step response of RC & RL Circuits and RLC Circuit resonances in Series Combination.

Diagrams →

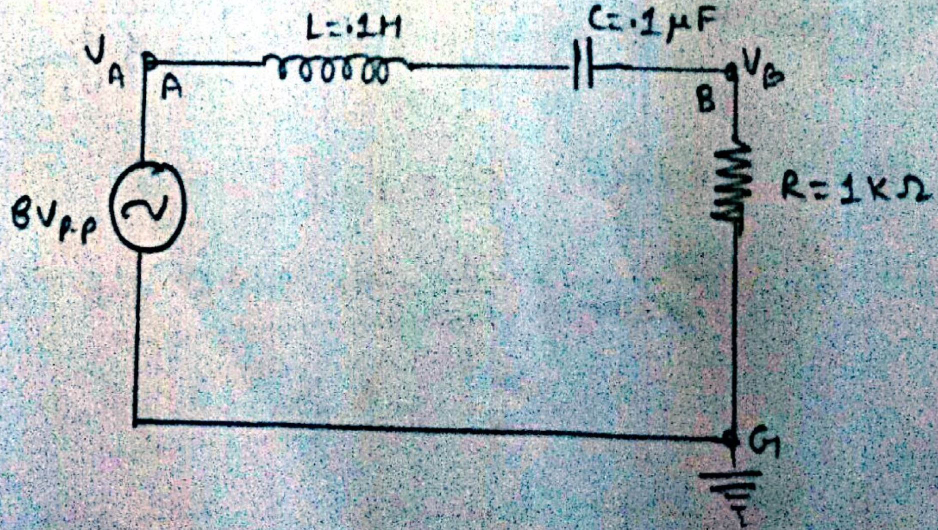
PART A → Step response of RC Circuit



PART B → Step response of RL Circuit.



PART-C → Resonance in Series RLC Circuit.



Pre-experimental Analysis →

→ For RC Circuit;

We know that for RC Circuit;

$$\text{Time Constant} = R \times C = T$$

Here;

$R = 1K$ and $C = 1\mu F$

So, Time Constant $= 10^3 \times 10^{-6} = 10^{-3} = \underline{1ms}$.

→ For RL Circuit;

We know that for RL Circuit;

$$\text{Time Constant} = \frac{L}{R} = T$$

Here;

$L = 0.1H$ & $R = 4.7k$;

So; $T = \dfrac{0.1}{4.7 \times 10^3} \Rightarrow \underline{0.02ms}$.

→ For RLC resonance in Series. Circuit;

We know that resonant Angular frequency;

$$\omega = \frac{1}{\sqrt{LC}}$$

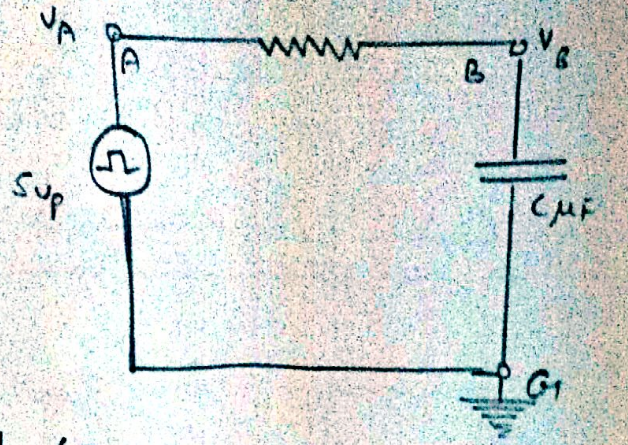
So; resonant frequency $\Rightarrow f_r = \dfrac{1}{2\pi} \times \dfrac{1}{\sqrt{LC}}$.

Here; $L = 0.1H$ & $C = 0.1\mu F$.

$$f_r = \frac{1}{2 \times 3.14} \times \frac{1}{\sqrt{10^{-8}}} \Rightarrow 0.16 \times 10^4 Hz \Rightarrow \underline{1.6 \times 10^3 Hz}.$$

~ERVATIONS →

PART-A:



→ Setting Input (5V, 0.1 KHz) Unipolar Square Wave from the function generator.

In this situation. Capacitor. first gets. charged upto, 5V the remain. charged. for some time. charging takes place as;

$$\boxed{V_C(t) = V_S\left(1 - e^{-t/RC}\right)} \quad [\text{Here } V_S = 5V]$$

- in the voltage Input cycle. when input becomes. 0V Capacitor. starts. discharging. by the equation;

$$V_c(t) = 5\left(e^{-t/RC}\right)$$

- and in charging Condition we can see that after a time $t = T = RC$;

$$V_c = V_S\left(1 - e^{-1}\right) \Rightarrow V_S = (1 - 1/e) = 0.63V.$$

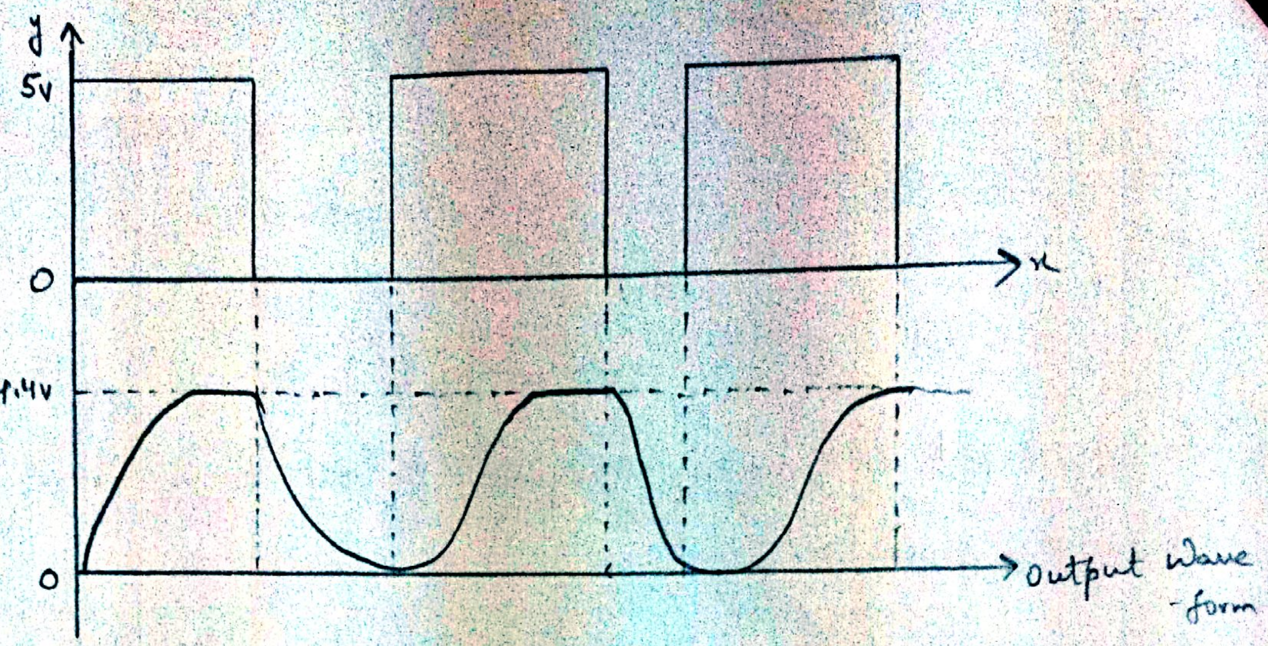
$$V_{max} = 5V.$$

As; Time. Constant $(\tau) = 0.8ms$.

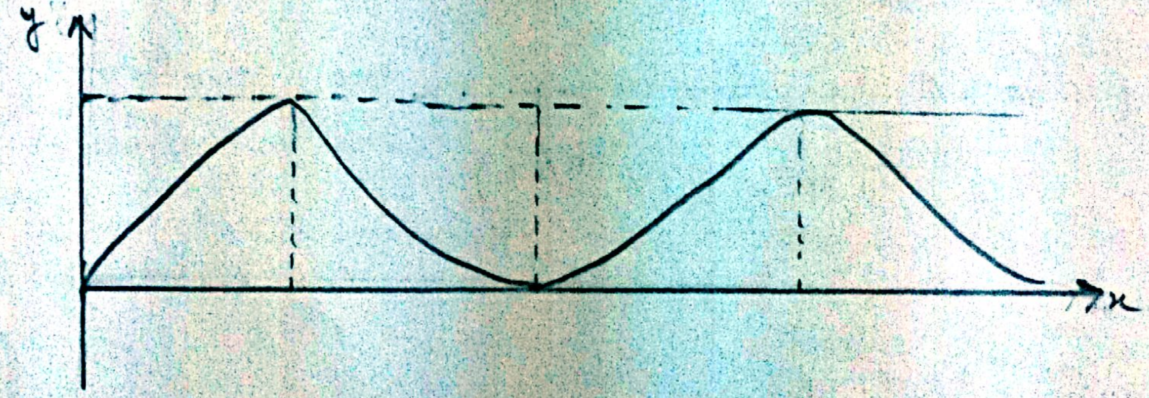
As; 63% of 5V = 3.15V.

And the time taken to be charged upto 63% of 4.4V; i.e; 3.15V was found to be at 0.8ms.

Results (PART-A) →



when frequency of Input signal was changed to get the characteristic such that charging is just done i.e, there is no linear in the characteristic and frequency was found to be 112 KZ.



and; $T = 1/f$;

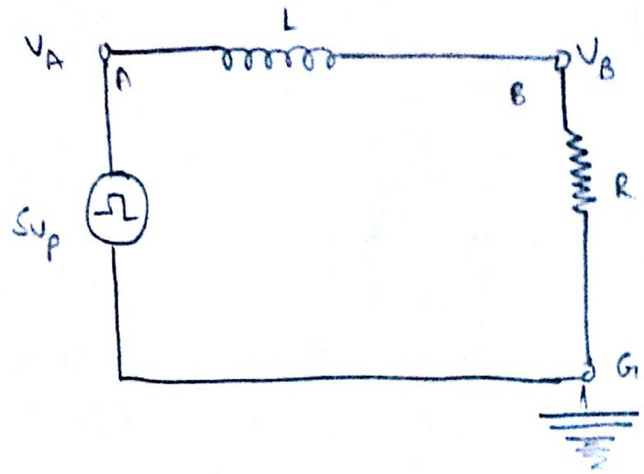
$$T/2 = \frac{1}{f2} = \frac{1}{112 \times 10^{-3} \times 0.8}$$

$$T/2 = \underline{11.6}.$$

$$\boxed{\therefore T/2 = 11.6}$$

~~T-~~ B:

Arranging the given Circuit and again applying (5V, 0.5KHz) Unipolar Square Wave in pot.



In the given RL Circuit. Current Can be Written as;

$$I_L(t) = \frac{V_S}{R}\left(1 - e^{-Rt/L}\right) \qquad V_S = 5V$$

$$\text{Voltage } V_R(t) = V_S\left(1 - e^{-Rt/L}\right)$$

$$\underline{V_R = V_B}.$$

So voltage, In this Case across "R" Varies Similar to Voltage across Capactior in the first Circuit.

→ Time Constant τ Can be given as time table to be charged upto 0.63 times of maximum voltage i.e; 3.15v.

→ But in this Case; the maximum voltage across resistance was found to be 5v as some Internal resistance of Inductor, so τ is time taken to V_B to reach upto 3.15v.

and the time Was found to be 22μs.

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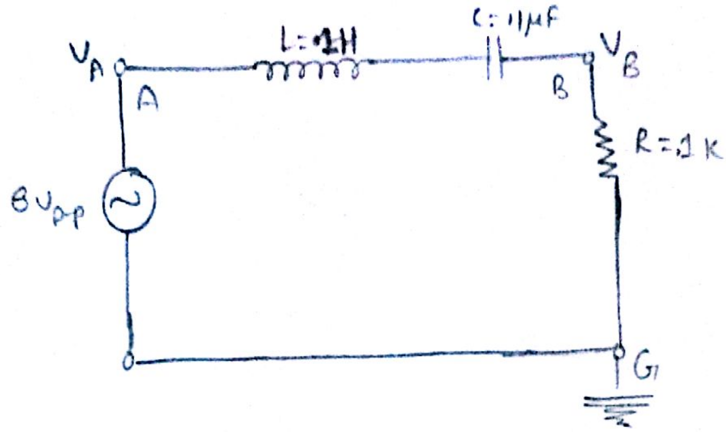
PART-C →

Resistance in RLC Circuit;



First assembling the given Circuit and then giving input of 8$V_{p\text{-}p}$ sinusoidal Wave;

We know that RLC Circuit;

Impedance for Inductor = $\omega L\, j$

Impedance for Capacitor = $\frac{-1}{\omega C}\, j$

Total Impedance; $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$

Phase difference ϕ;

$\tan\phi = \frac{\omega L - \frac{1}{\omega C}}{R}$;

where;

$V_0 = V_0 \sin\omega t$

$I = I_0 \sin(\omega t - \phi)$

$\phi > 0 \rightarrow$ Current lags

$\phi < 0 \rightarrow$ Current leads.

So in resonance Condition, Impedance is minimum, &

Current Amplitudes maximum;

$\omega = \sqrt{\frac{1}{LC}}$

$\tan\phi = 0 \Rightarrow \boxed{\phi = 0}$.

∴ So, at resonance, V & I are in same phase.

our exp. We measured amplitude of $V_{B\,p\text{-}p}$ and;

$$V_B = \frac{R\,V_A}{\sqrt{R^2+\left(\omega L-\frac{1}{\omega C}\right)^2}}$$

By; changing frequency i.e; $\frac{\omega}{2\pi}$; i.e ω.

Frequency (in KHz)	Voltage across B-G
0.1	0.5
0.5	2.4
1.0	4.6
1.5	5.6
2.0	5.4
4.0	3.2
10.0	1.3

And next we changed the frequency to get the frequency at which there is no phase difference b/w Current i.e; V_B & output; i.e V_A.

It was obtained at t ⇒ 1620 Hz.

Theoritically; → 1.6 KHz.

$$(2\pi f \times \omega_0) \quad \left(\omega L-\frac{1}{\omega C}\right)=0$$

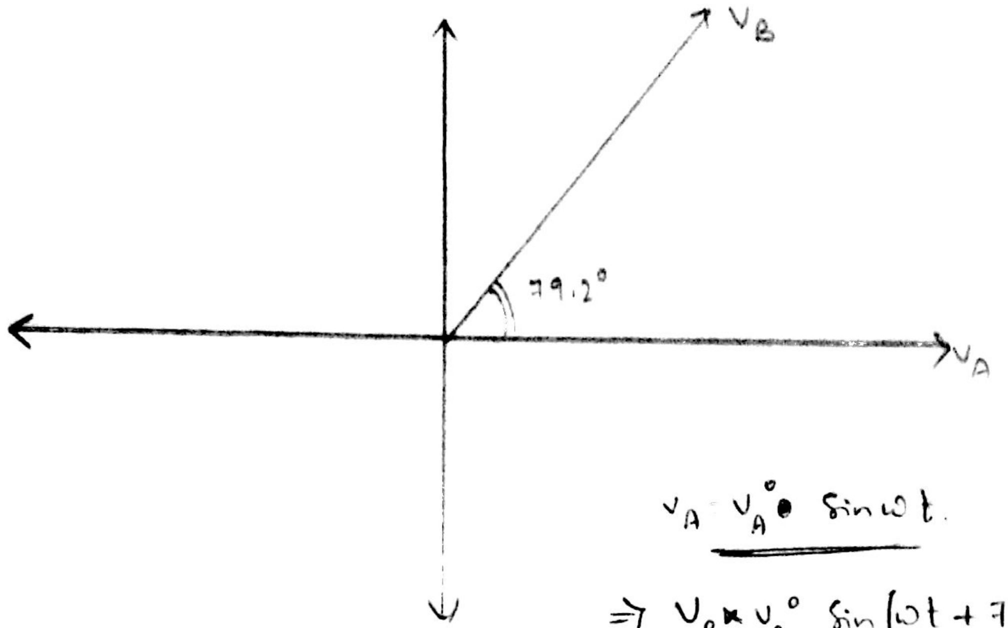
$$\omega > \omega_0 \Rightarrow \phi > 0$$
$$\omega < \omega_0 \Rightarrow \phi < 0$$

f = 1 KHz.

In this case leading V_A;

and phase difference was found to be -79.2°.

PHASOR DIAGRAMS →



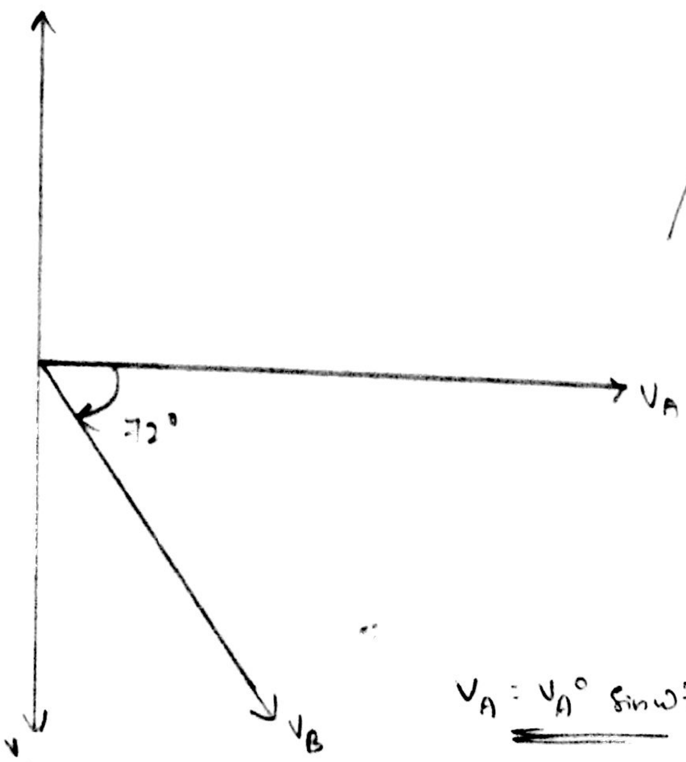
$v_A = V_A^0 \sin \omega t$

$\Rightarrow v_B = v_B^0 \sin(\omega t + 79.2°)$

when $f = 10\,kHz$;

In this v_B is found leading v_A & phase difference

$= 72°$.



$V_A = V_A^0 \sin \omega t$

$V_B = V_B^0 \sin(\omega t - 72°)$.

OBSERVATIONS:

PART - A →

Step Input V_s is applied to an RC Circuit with a Capacitor;

$$V_c(t) = V_s\left[1 - \exp(-t/RC)\right]$$

$$\tau = RC$$

$\therefore V_{max} = \underline{\underline{5V}}$.

when the Capacitor's time has risen to 63% of it's maximum charge voltage;

$\therefore$ 63% of 5V = $\underline{\underline{3.15V}}$.

Time Constant $(\tau) = \underline{0.8\,ms}$.

When the voltage is at maximum; the ratio of T/τ; where $T = 1/f$ is;

$$\left\{ \because T = 1/f = 1/112 \right\}$$

$$T/\tau = \frac{1}{f\tau} = \frac{1}{112 \times 10^{-3} \times 0.8} = \text{[redacted]}\ \underline{\underline{11.6}}.$$

PART-B →

Step Input V_s is applied to an RL Circuit with an Inductor;

$$I_L(t) = (V_s/R)\cdot\left[1 - \exp(-Rt/L)\right]$$

$$\tau = L/R.$$

$\therefore V_{max} = \underline{\underline{5V}}$.

when the resistor's time taken by rising 63% of its maximum voltage;

$\therefore$ 63% of 5V = 3.15V.

Time Constant (τ) = 22 μs.

PART C →

Frequency (in KHz)	Voltage across B-G
0.1	0.5
0.5	2.4
1.0	4.6
1.5	5.6
2.0	5.4
4.0	3.2
10.0	1.3

The resonant frequency of RLC Circuit;

Theoritically; f_r = 1.6 KHz.

Experimentally; f_r = 1.62 KHz.

→ At Input frequency 0.1 KHz;

$$\Delta\phi = \frac{2\pi}{T} \cdot \Delta t = \frac{2\pi}{10\,ms} \times 2.2\times10^{-3}\ \text{rad} = 79.2^\circ.$$

→ At Input frequency 10 KHz;

$$\Delta\phi = \frac{2\pi}{T} \cdot \Delta t$$

$$= \frac{2\pi}{0.1} \times 20\times10^{-6}\ \text{rad} = 72^\circ.$$

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24/02/2016

INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
Department of Electronics & Communication Engineering
EE102: Basic Electronics Laboratory
EXPT. NO 3 : RLC Circuits

OBJECTIVE: To find the step response of RC and RL circuits and RLC series circuit resonance

MATERIALS REQUIRED

- Breadboard
- Equipment : Function Generator, Oscilloscope
- Components : Resistors: One 1 k Ω, One 4.7 kΩ; Inductor: 0.1 H; Capacitors: One 0.1 µF, One 1 µF

PRECAUTIONS AND GUIDELINES

1. Make sure the ground terminals of the oscilloscope probes and function generator are connected together.
2. While switching on the set-up, switch on the oscilloscope first, followed by the function generator.

Pre-experiment observation

Part A: Calculate the value of the time constant for RC circuit given in Fig. 8.1.
Part B: Calculate the value of the time constant for RL circuit given in Fig. 8.2.
Part C: Find the value of the resonant frequency for RLC circuit given in Fig. 8.3 using the formula

$$f_r = \frac{1}{2\pi\sqrt{(LC)}}$$

Part A: STEP RESPONSE OF RC CIRCUIT

When a step input V_S is applied to an RC circuit with no charge on capacitor, the capacitor starts charging towards V_S with time t. The instantaneous voltage across capacitor is given by $V_C(t) = V_S\,(1 - exp(-t/RC))$. The time required by the capacitor to charge up to 63% of full charge voltage is called the time-constant 'τ' of RC circuit and is given by $\tau = RC$.

1. Assemble the circuit shown in Fig. 8.1. Connect Ch1 and Ch2 probes of CRO to node A and node B, respectively. Use the dc coupling mode of CRO for this part of the experiment.
2. Apply a **unipolar** square wave input (5 V; 0.1 kHz) from the function generator.
3. Observe the voltages at node A and node B in CRO and measure the time-constant 'τ' by noting the time taken by the capacitor to rise to 63% of its maximum charge voltage.

$\tau = 1ms$

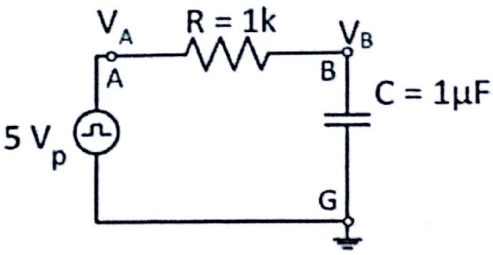

Fig.8.1

4. Now increase the frequency of the input signal and note the frequency 'f' for which the capacitor just gets charged up to maximum possible voltage. Find the ratio of $T\,/\,\tau$, where $T = 1/f$.

75Hz

$\frac{1}{75}$; $\frac{T}{\tau} = 13.33$

Part B: STEP RESPONSE OF RL CIRCUIT

When a step input V_S is applied to an RL circuit with inductor having no stored energy, initially the current through it is zero but increases towards the maximum value of V_S/R with time 't'. The instantaneous value of current through inductor is given by $I_L(t) = (V_S/R)\,(1 - exp(-Rt/L))$. The time required by the voltage across inductor to drop to 37% of maximum voltage or the voltage across resistor to rise up to 63% of maximum voltage is called the time-constant 'τ' of RL circuit and is given by $\tau = L\,/\,R$.

1. Assemble the circuit shown in Fig. 8.2. Connect Ch1 and Ch2 probes of CRO to node A and node B, respectively. Keep using the dc coupling mode of the CRO.
2. Apply a unipolar square wave input (5 V; 0.5 kHz).
3. Observe the voltages at node A and node B in CRO and measure the time-constant 'τ' by noting the time taken by the voltage drop across resistor to rise to 63% of its maximum value.

20 µs

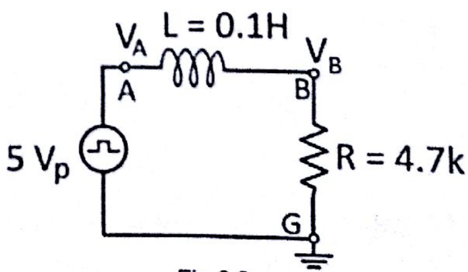

Fig.8.2

Part C: RESONANCE IN SERIES RLC CIRCUIT

The resonance in a series RLC circuit is a state where the current drawn from the source is in phase with the voltage applied. This occurs at a particular frequency which is called the resonant frequency. At resonance, the reactance of the inductor and that of the capacitor cancel each other so the RLC circuit offers minimum impedance and hence the current through the circuit is maximized.

1. Assemble the circuit as shown in Fig. 8.3. Apply a sinusoidal input (8 Vp-p) to the circuit.

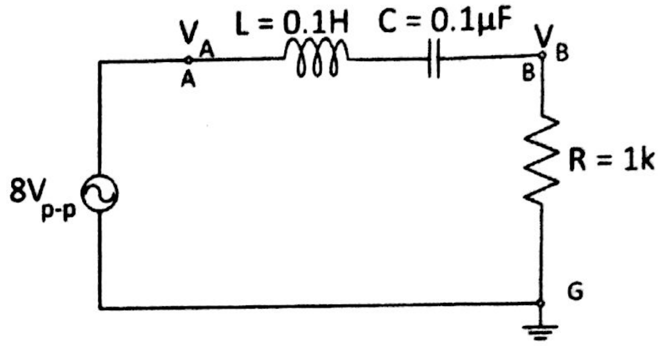

Fig.8.3

2. Using CRO measure the applied input across terminals A-G in Ch1 and the current through RLC circuit through the voltage drop across terminals B-G in Ch2.

3. Vary the frequency of the function generator as suggested below and measure the peak-to-peak amplitude of voltage across terminals B-G (Ch2) which proportional to the current in the circuit. Estimate the coarse resonant frequency of the RLC circuit from these measurements.

Frequency (in kHz)	Voltage across B-G
0.1	0.48
0.5	2.3
1.0	4.2
1.5	5
2.0	4.8
4.0	2.8
10.0	1.16

4. To refine the estimate of resonant frequency, set the function generator again to the coarse estimate of the resonant frequency and now observe the phase difference between the applied input voltage (Ch1) and the circuit current (Ch2). Finely varying the frequency of the function generator till voltages in Ch1 and Ch2 get phase synchronized. The frequency at which synchronization is achieved is a precise estimate of the resonant frequency of the RLC circuit. Compare that with theoretically computed value.

f = 1.4931kHz

2.88 rad (lead)

θ = ~~1.3 rad~~

5. In the same setup, reset input frequency to 0.1 kHz and observe the amount and the nature of the phase difference between Ch1 and Ch2.

6. Repeat step 5 for input frequency of 10 kHz instead of 0.1 kHz. θ = 2.24 rad (lag ~~leading~~)

7. Comment on the cause of the observations made in step 5 and 6, if any. Also draw the phasor diagram of voltages across all three components at resonant frequency using given nominal value of components.

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24/2/16