Federal Urdu University of Arts,Science & Technology

LAB MANUAL

ELECTRICAL NETWORK THEORY

DEPARTMENT OF ELECTRICAL ENGINEERING

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Semester: _____________________________________

Batch: ____

CONTENTS

EXPERIMENT NO: 01

SUPERPOSITION THEOREM

OBJECTIVE:

To Verify Superposition Principle in DC Circuits

REQUIRED:

1- DMM
2- 2 DC Power Supplies,
3- Resistances (1k Ω, 2k Ω, 430k Ω)

THEORY:

The superposition principle states that:

> **"The current through or voltage across, any resistive branch of a multisource network is the algebraic sum of the contribution due to each source acting independently."**

When the effect of one source is considered, the others are replaced by their internal resistances. This principle permits one to analyze circuits without restoring to simultaneous equations.

Superposition is effective only for linear circuit relationship. Non-linear effects, such as power, which varies as the square of the current or voltage, cannot be analyzed using this principle.

FIGURE:

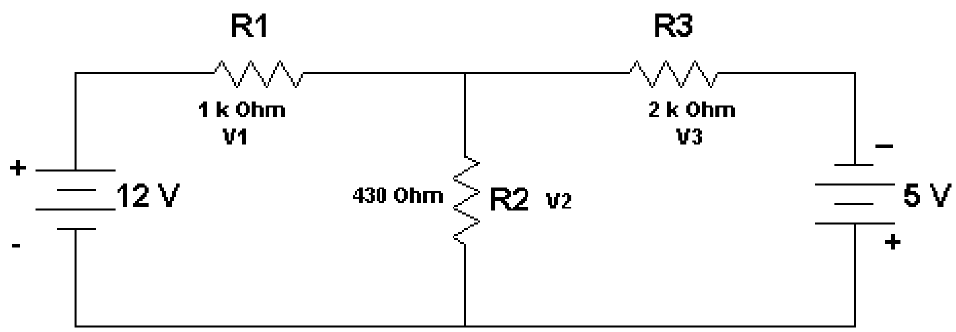


Fig-1

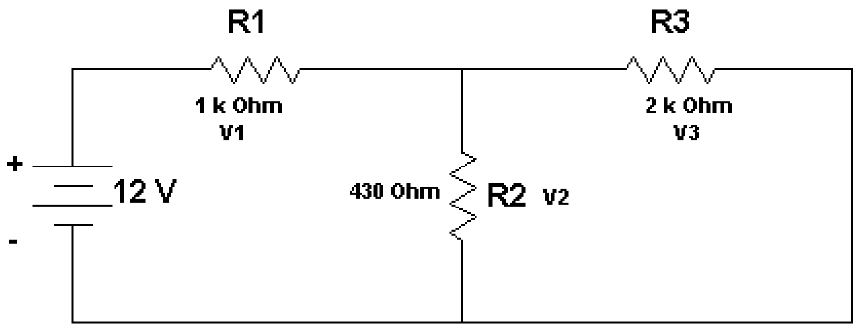


Fig – 2

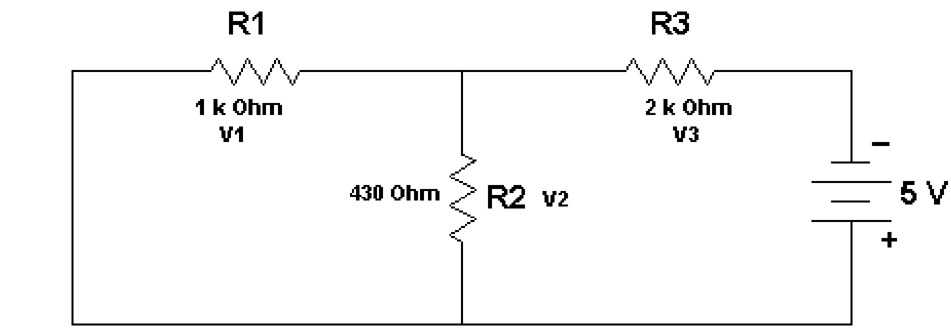


Fig – 3

PROCEDURE:

1. Construct the Network of Fig-1, where R1 = 1 k Ω, R2 = 430 Ω, R3 = 2 k Ω. Verify the resistances using DMM.
2. Using superposition and measured resistance values, calculate the currents indicated in observation Table (a), for the network of Fig-1. Next to each magnitude include a small arrow to indicate the current direction for each source and for the complete network.
3. Energize the network of Fig-1 and measure the voltages indicated in observation table b, calculate current in Table (b) using Ohm's Law. Indicate the polarity of the voltages and direction of currents on Fig-1.
4. Construct the network of Fig -2. Note that source E2 has been removed.
5. Energize the network of Fig -2 and measure the voltages indicated in Table (c). Calculate currents using Ohm's Law.
6. Now construct the network of Fig -3. Note that source E1 has been removed.
7. Energize the network of Fig -3 and measure the voltages indicated in Table (d). Calculate currents using Ohm's Law.
8. Using the results of steps # 3, 5 and 7, determine the power delivered to each resistor and insert in Table (e).

OBSERVATIONS:

Resistors:

	Nominal Values (Ω)	Measured Values (Ω)
1	1K	
2	430	
3	2K	

a) Calculated Values for the Network of Fig. 1

Due to E1	Due to E2	Algebraic Sum (∑)
I_1 =	I_1 =	I_1 =
I_2 =	I_2 =	I_2 =
I_3 =	I_3 =	I_3 =

b) Measured Values for the Network of Fig. 1

V_1	V_2	V_3	I_1	I_2	I_3

c) Measured Values for the Network of Fig. 2

V_1	V_2	V_3	I_1	I_2	I_3

d) Measured Values for the Network of Fig. 3

V_1	V_2	V_3	I_1	I_2	I_3

e) Power Absorbed (use measured values of I and V)

Due to E_1	Due to E_2	Sum of Columns 1 & 2	E_1 & E_2 Acting Simultaneously

EXPERIMENT NO: 02

VERIFICATION OF THEVENIN'S THEOREM

OBJECTIVE:

To Verify Thevenin Theorem by finding its Thevenin's Equivalent Circuit

REQUIRED:

1. VOM/DMM
2. Power Supply
3. Resistances (120Ω, 1k Ω, 390Ω)

THEORY:

Any linear circuit is equivalent to a single voltage source (Thevenin's Voltage) in series with single equivalent resistance (Thevenin's Equivalent Resistances)

The current flowing through a load resistance RL connected across any two terminals **A** and **B** of a network is given

FIGURE:

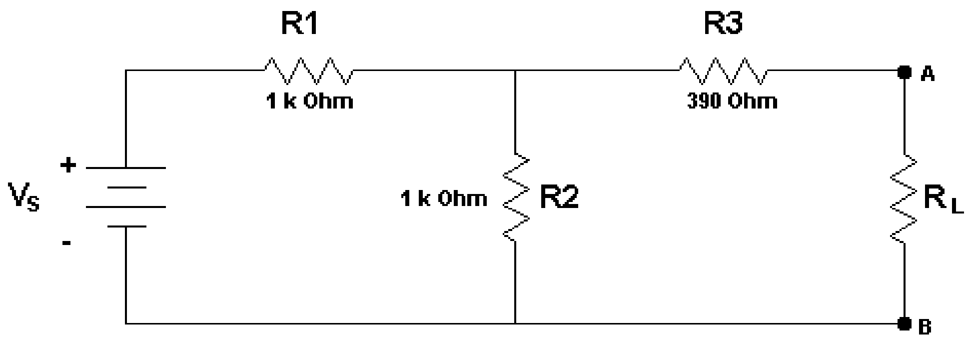


Fig – 1

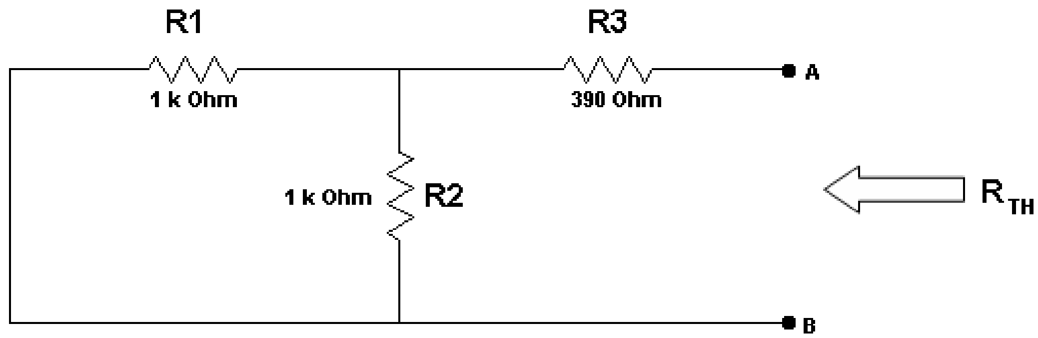


Fig – 2

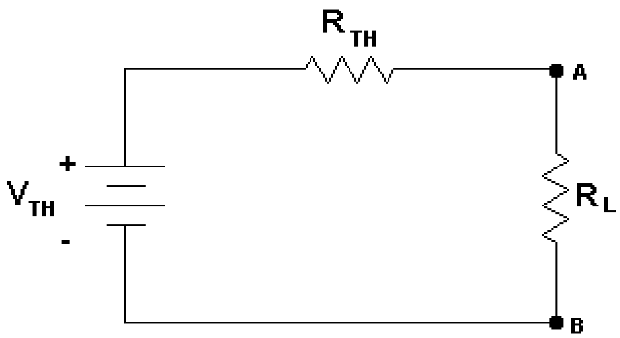


Fig – 3

PROCEDURE:

1. Reduce the circuit by calculating the Thevnin equivalent resistance across the terminals **A** & **B**
2. Determine the Thevinin equivalent voltage across terminals **"A"** and **"B"** for 5V, 10V, 15V.
3. Now, combine the Thevenin voltage with its resistance determines across 120Ω, 1K Ω, and 390 Ω resistors.

TABLE-1:

V_S	R_1	R_2	R_3	V_{TH}	R_{TH}
5V					
10V					
15V					

TABLE-2:

V_S	V_{TH}	R_{TH}	R_L	I_L
5V			**120**	
			390	
			1K	
10V			**120**	
			390	
			1K	
15V			**120**	
			390	
			1K	

EXPERIMENT NO: 03

VERIFICATION OF MAXIMUM POWER TRANSFER THEOREM

OBJECTIVE:

To Verify Maximum Power Transfer Theorem

Discussion

Maximum power transfer theorem states that any linear network, if the load resistance equals its Thevenin's equivalent resistance, the load can yield a maximum power from sources.

Now we consider the Thevenin's equivalent shown in Fig 1. By Ohm's Law, the power dissipated in the Load P_{RL} can be expressed as follows.

$$I = E_{TH} / (R_{TH} + R_L)$$

$$P_{RL} = I^2 * R_L$$

$$P_{RL} = [E_{TH} / (E_{TH} + R_L)^2 * R_L$$

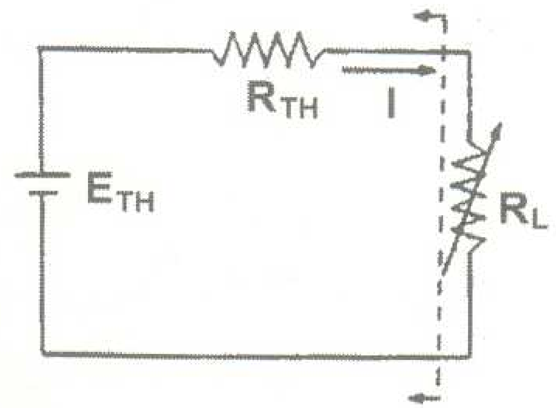


Figure-1

Suppose E_{TH} = 4V and R_{TH} = 5Ω, then P_{RL} can be expressed by the equation $P_{RL} = 16\ _{RL} / (5+R_L)^2$. Now we calculate and record each of the P_{RL} values for each R_L value from 1 Ω to 9 Ω increasing the step to 1 Ω. The results are listed in Table 1 and plotted in Fig 2. From both Table 1 and fig- 2, you can find that the maximum value of P_{RL} occurs at $R_L = R_{TH}$.

Table – 1

(Ohms)	(Watts)
1	0.445
2	0.655
3	0.750
4	0.790
5	0.800 ←
6	0.792
7	0.780
8	0.760
9	0.735

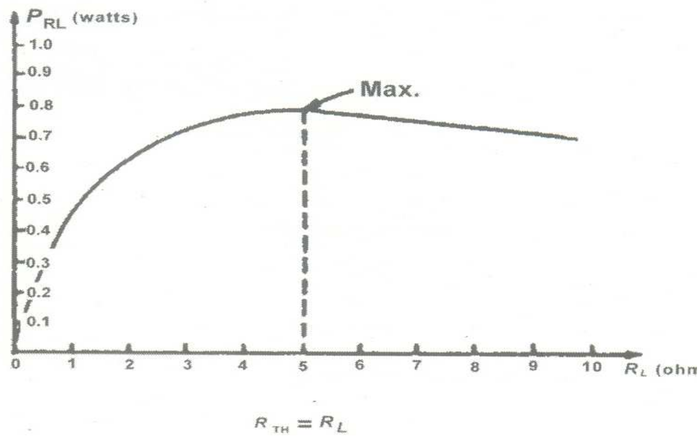


Figure -2

Procedure

1. Set the Module KL-13001 on the main KL-21001, and locate the block a.
2. According to Figs. 1 , complete the experiment circuit with short-circuit clips.
3. Apply +15V to +V.

   Turn off the power switch.
4. Adjust V_{R1} to 250 Ω. (Let R_1=R_{TH}, V_{R1}=R_l).

   Turn on the power.

   Measure and record the current flowing through VR1 as indicated by the milliammter.

   I = ________________________________ mA.

   Calculate and record the power dissipated by V_{R1} using the equation

   $P_{RL} = I^2 * R_L$. P_{RL} =________________________________ W.

   Turn off the power.
5. Adjust V_{R1} to 500 Ω and repeat step 4.

   I = ________________________________ mA

   P_{RL} = ________________________________ W
6. Adjust V_{R1} to 1 K Ω and repeat step 4.

   I = ________________________________ mA

   P_{RL} = ________________________________ W
7. Adjust V_{R1} to 1.25 K Ω and repeat step 4.

   I = ________________________________ mA

   P_{RL} = ________________________________ W
8. Adjust V_{R1} to 1.5 K Ω and repeat step 4.

   I = ________________________________ mA

   P_{RL} = ________________________________ W
9. Complete Fig. 4 by using you measured I and calculated PRL values.

EXPERIMENT NO: 04

To observe variation in impedance and current of an RC series network in ac circuit

Discussion

When an ac voltage is applied across a pure resistance, the resultant current is in phase with the applied voltage. Resistance therefore has no phase angle associated with it and is written as R<0. When an ac voltage is applied across a pure capacitor, the resultant current leads the voltage by 90. Capacitance therefore has a phase angle associated with it. The opposition that a capacitor offers to the flow of alternating current is called capacitive reactance and is written as Xc< -90, or –jXc. The magnitude of Xc is Xc=1/2π fC= 1/wC.

An RC series circuit with an ac supply voltage is shown Fig . The impedance of this circuit can be expressed as

$$Z_T = Z_1 + Z_2 = R\ 0 + X_C\ {-90}$$

The current in the across R is

$$E_R = I\ R$$

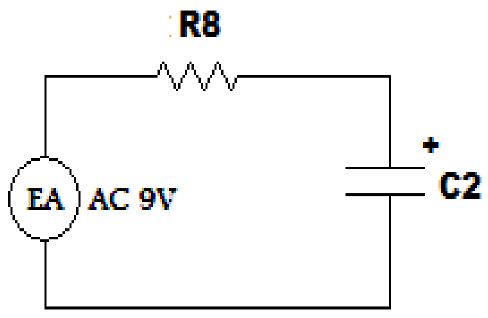
The voltage across C is

$$E_C = I\ X_C$$

By Kirchhoff's voltage law, then

$$\Sigma V = E - V_R - V_C = 0$$

Or $$E = \overrightarrow{V_R} + \overrightarrow{V_C}$$



Figure

Procedure

1. Set the module KL-13001 on the main unit KL-21001, and locate the block e.

2. According to Figs. 1 complete the experiment circuit with short-circuit clips. Apply the AC power 9V to E_A. Measure and record E_A = ________________________________ V

3. Calculated and record the values below.

   Reactance of C_2 X_C = ________________________________ Ω

   Total impedance Z_T = ________________________________ Ω

   Current in circuit I = ________________________________ mA

   Voltage across R_8 R = ________________________________ V

   Voltage across C_2 E_C = ________________________________ V

   Power dissipated P = ________________________________ mW

4. Measure and record the values of ER and EC by using the ac voltmeter.

   Voltage across R_8 R = ________________________________ V

   Voltage across C_2 E_C = ________________________________ V

   Are you sure the measured values equal to the calculated values of step 3?

   Yes NO

4. Using the equation $E = \overrightarrow{V_R} + \overrightarrow{V_C}$, calculate the applied voltage of the circuit.

   E_A = ________________________________ V

   Does the calculated value equal the measured value of step 2?

   Yes NO

   If no, explain it.

   ____

5. Using the measured values of ER and EC, calculate and record the current I.

   I = ________________________________ mA

   Does the calculated value equal the measured value of step 3?

   YES **NO**

6. Using the values of R, X_C and Z_T, plot a vector diagram in space below.

EXPERIMENT NO: 05

To observe variation in impedance and current of an RL series network in ac circuit

Discussion

When an ac voltage is applied across a pure inductance, the current lags the voltage by **90°** .Inductance therefore has phase angle associated with it .The opposition that an inductance offers to the flow of alternating current is called inductive reactance and may be expressed as $X_L < 90°$, or jX_L

The magnitude of X_L is X_L = 2πfL =2ωL

An RL series circuit with an ac supply voltage is shown in Fig-1.The impedance of this circuit can be expressed as

$$Z_T = Z_1 + Z_2$$
$$= R < 0° + X_L < +90°$$

The current in the circuit is

L =E/Z_T (the current lags the voltage)

The voltage across R is

V_R =I R

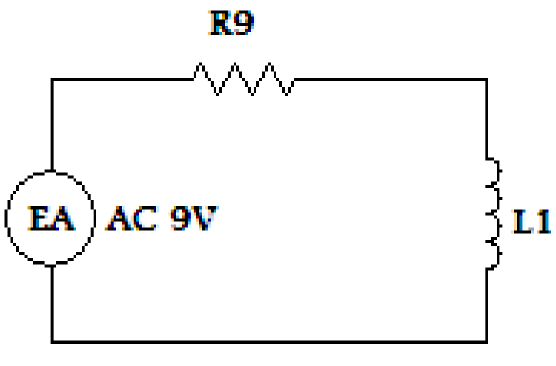
The voltage across l is

V_L =IX_L

By Kirchhoff s voltage law, then

∑V= E - V_R - V_L =0

$$E = \overrightarrow{V_R} + \overrightarrow{V_L}$$



Figure

Procedure

1. Set the module KL -13001 on the main unit KL-21001, and locate the block f, link 0.5H inductance at L1 position.
2. According to Figure complete the experiment circuit with short –circuit clips. Apply the AC power 9V to EA.

   Measure and record EA. EA =_________________________V
3. Calculate and record the values below.

   Reactance of L1 X_L = ______________________________ Ω

   Total impedance Z_T = ______________________________ Ω

   Current in circuit I = ______________________________ mA

   Voltage across R9 V_R = ______________________________ V

   Voltage across L1 V_L = ______________________________ V

   Phase angle θ = ______________________________

   Power dissipated P= ______________________________ mW
4. Measure and record the values of V_R = and V_L =by Using the AC voltmeter.

   Voltage across R9 V_R = ______________________________ V

   Voltage across L1 V_L = ______________________________ V
5. Do the measured values equal the calculated values of step 3?

   Yes **No**
6. Using the equation $E = \overrightarrow{V_R} + \overrightarrow{V_L}$, calculate the applied voltage of the circuit

   EA = ______________________________ V

   Does the calculated value equal the measured value of step 2?

   Yes **No**

   If No explain it.

   ____

   ____

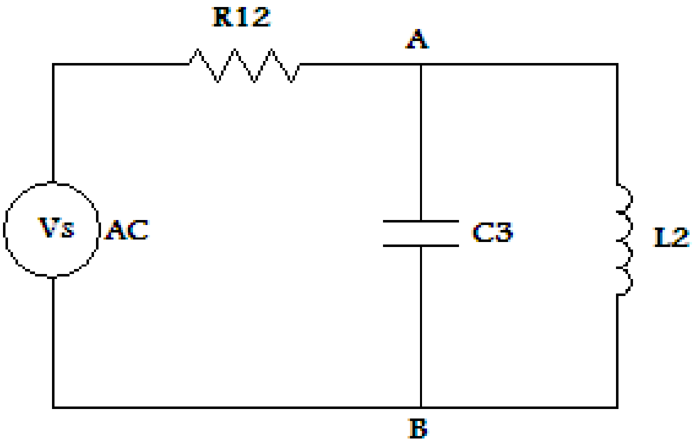
EXPERIMENT NO: 06

To Observed and determine the Resonant Frequency of a resonant circuit

Discussion:

Figure shows an RLC series-parallel circuit with an ac power supply as mentioned before. The capacitive reactance X_C and inductive reactance X_L very with frequency. Therefore, the net impedance of the parallel circuit consisting of l2 and C3 will vary with input frequency. At some frequency which we will define as the resonant frequency f_r .the parallel circuit operates in resonance and X_L equals X_C the resonant frequency can be expressed as

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



Figure

Procedure

1. *Set the module KL -13001 on the main unit KL -21001, and locate the block h.*
2. According to Figure, complete the experiment circuit with short –circuit clips.
   The L2 is the 0.1H inductor provided.

3. Set the function selector of function generator to sine wave position .connect the oscilloscope to the output of function generator.
   Adjust the amplitude and frequency control knobs to obtain an output of 1 KHz, 5Vp-p and connect it to the circuit input (I/P).

4. Using the oscilloscope, measure and record the voltage acrossL2, C3 and R12.

V_L = ______________________V p-p

V_C = ______________________V p-p

V_R = ______________________V p-p

5. Using the equation $f_r = 1/2\pi\sqrt{LC}$, calculate and record the resonant frequency of the circuit.

   f_r =_______________________Hz

6. Vary the output frequency of function generator to obtain a maximum value of VAB.

   Using the oscilloscope, measure and record the input frequency

   f = ______________________Hz

7. Is there agreement between the frequency value f and the resonant frequency f_r of step 5?

   Yes **No**

EXPERIMENT 07

DC RC CIRCUIT AND TRANSIENT PHENOMENA

DISCUSSION

The capacitor is a element which stores electric energy by charging the charge on it. Bear in mind that the charge on a capacitor cannot change instantly. Fig. 1 shows a basic RC circuit consisting a dc voltage, switch, capacitor, and resistor. Assume that the voltage across C is zero before the switch closes. Even at the instant when the switch closes (connecting to VR1 and letting VR1 = R), the capacitor voltage will still be at zero, and so the full voltage is impressed across the resistor. In other words, the peak value of charging current which starts to flow is at first determined by the resistor. That is, I_o =V/R.

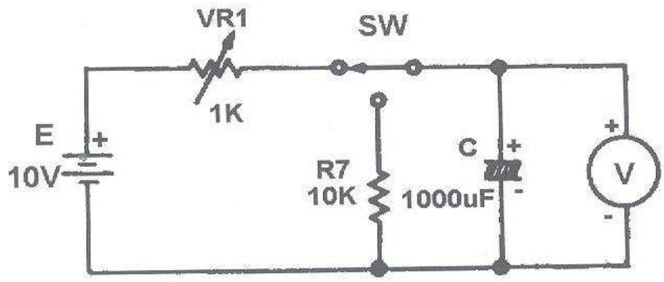
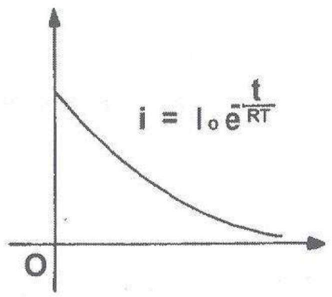


Figure -1

As C begins to charged, a voltage is built up across it which bucks the battery voltage, leaving less voltage for the resistor. As the charging continues, the current keeps decreasing. The charging current can be expressed by the formula **$i= (V/R)\acute{\varepsilon}^{-t/RC,}$** where έ = 2.718. Fig.2 shows how the charging current varies with time.

Fig.3 shows how the resistor voltage V_R and the capacitor voltage $\mathbf{V_C}$ vary with time when it is charging. The capacitor voltage V_C is expressed by $\mathbf{V_C = V(1-\acute{\varepsilon}^{-t/RC,})}$ and the resistor voltage is $\mathbf{V_R = V\acute{\varepsilon}^{-t/RC}}$ by Kirchhoff's voltage law, $\mathbf{V= V_R+V_C}$ at all times.



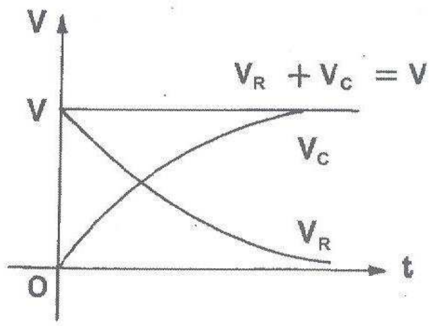


Figure -2 **Figure-3**

For the moments we assume that the VC is equal to the battery voltage. The switch is switched to connect the C and R7 in shunt. The capacitor then discharges through R7 (letting R7=R), so the discharging current, the resistor voltage, and the capacitor voltage can be expressed by the following:

$$\mathbf{L = -(V/R)\ \acute{\varepsilon}^{-t/RC} \qquad V_C = V\ \acute{\varepsilon}^{-t/RC} \qquad V_R = V\text{-}\ \acute{\varepsilon}^{-t/RC}}$$

Fig 4 shows how the discharging current varies with time. Fig.5 shows how the V_R and V_C vary with time when it is discharging.

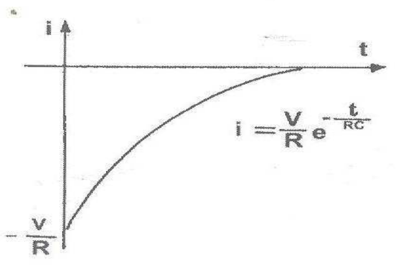


Figure – 4

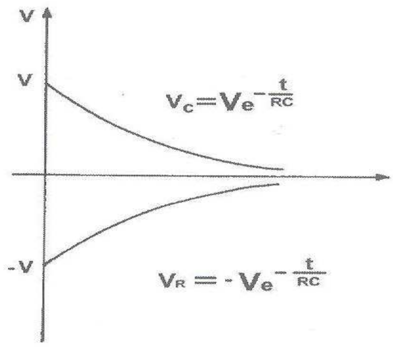


Figure- 5

When the capacitor charges, the final value of Vc is determined solely by battery voltage, and how long it takes to get there depends on the resistor and capacitor sizes. The value of RC product is referred to as the time constant (T or TC) of the RC circuit. That is, T= RC, where T is second, R in ohm, and C in farad. If t= 1T, the capacitor will build up to 63% of this final voltage. The time constant chart is shown in Fig.6 curve as the capacitor charge voltage and curve B is the capacitor discharge voltage. In practice, at t = 5T, we can consider that the Vc charges to V or Vc discharges to 0

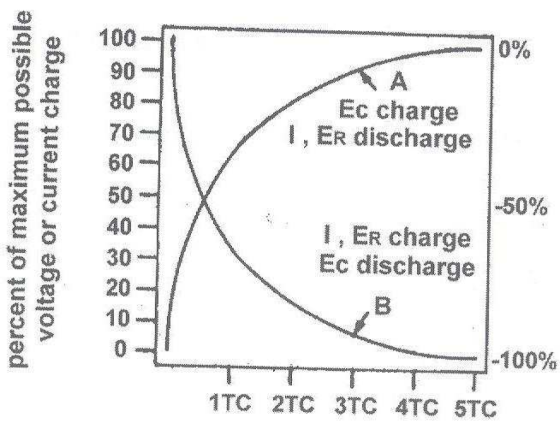


Figure - 6

PROCEDURE

1. Set the module KL-21001, and locate the block d.
2. According to figs.1 And 7 complete circuit with short- circuit clips.

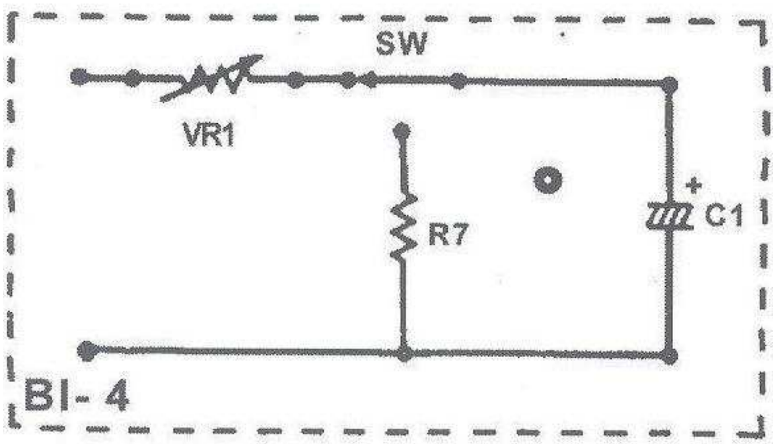


Figure - 7

3. Adjust VR1 to 1 KΩ. Turn the switch to VR1 position.
   Connect the voltmeter across the capacitor C1.
   Adjust the positive to +10V and apply it to circuit.
   At this instant the capacitor C1 begins to charge and the capacitor voltage Vc1 increases and finally reaches to 10V as indicated by the voltmeter.

4. Turn the switch to R7 position.
   The capacitor begins to discharge and the Vc decreases to 0V.

5. Using the equation T= RxC and the values of VR1 and C1 calculate the time constant
   T = _______________Sec.

6. Calculate the values of charging capacitor voltage Vc1 at t = 0T, 1T, 2T, 3T, 4T, and 5T and plot them on the graph of fig.8.
   Draw a smooth curve through these plotted points.

This will be a charging curve.

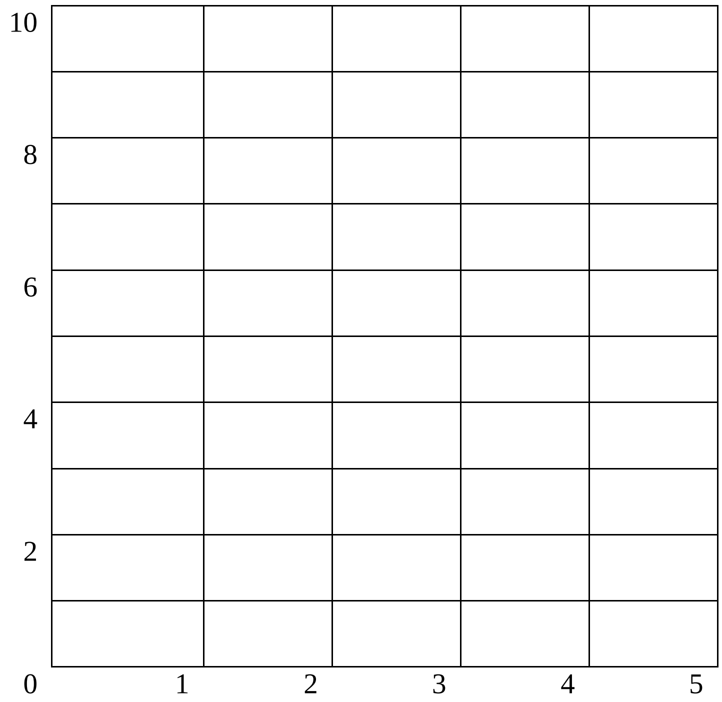


Figure-8

7. Use the stopwatch to count the time constant or oscilloscope.

   Turn the switch VR1 position, measure and record the time when the charging capacitor voltage Vc1 reaches 6.32V as indicated by the voltmeter.

   T=______________Sec.

   Note: Make sure Vc1= 0 before changing the capacitor each time.

8. Measure the values of Vc1 at time t= 1T, 2T, 3T, 4T, 5T, and record the result in table 1.

TABLE-1

Time (t)	**0T**	**1T**	**2T**	**3T**	**4T**	**5T**
V_C1						

9. Plot the recorded values of t and Vc1 on the graph of Fig.8, and then draw a smooth curve through these plotted points.
10. Comparing the curves of steps 9 and 6, is there good agreement between the two

    Yes No

11. Adjust VR1 to 200Ω.

    Calculated and record the time constant T.

    T= _________Sec.

    Charge the capacitor and observe the charge in Vc1 indicated by the voltmeter.

    Is the charging time shorter than that of step 3 for Vc1 = 10V?

    Yes No

12. Turn the switch to the VR1 position.

    Apply the power + 10V to charge the capacitor to Vc1 = 10V.

13. Turn the switch to R7 position. The capacitor will discharge through R7.

    Calculated and record the time constant for discharging.

    T =_________________Sec.

14. Repeat step 6 for discharging curve.
15. Measure and record the time that Vc1 decreases from 10V to 3.68V.

    T =_________________Sec.

    Comparing this result with step 13, is there agreement between the two?

    Yes No

16. Repeat step 8 for discharging and record the result in table 2.

TABLE-1

Time (t)	0T	1T	2T	3T	4T	5T
V_C1						

17. Repeat step 9 for discharging curve.
18. Comparing the curves or steps 17 and 14, is there good agreement between the two? Yes No

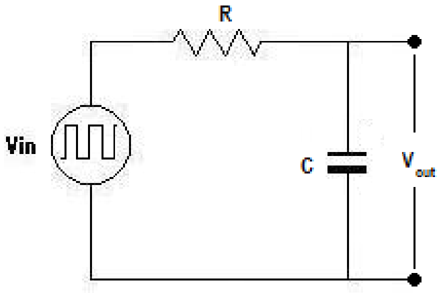
EXPERIMENT 08

PULSE RESPONSE OF A SERIES RC NETWORK

EQUIPMENT

1. Signal generator
2. Oscilloscope
3. Capacitor: 0.1µF / 0.001µF
4. Resistor: 10KΩ / 20 KΩ

CIRCUIT DIAGRAM



THEORY

The step response of a network is its behaviors when the excitation is the step function. We use a square wave source, which in fact repeats the pulse every ‘T’ Seconds and allows a continuous display of repetitive responses on a normal oscilloscope.

Charging a capacitor

We investigate the behavior of a capacitor when it is charged via a high resistor. At the instant when step voltage is applied to the network, the voltage across the capacitor is zero because the capacitor is initially uncharged. The entire applied voltage v will be dropped across the resistance R and the charging current is maximum.

But then gradually, voltage across the capacitor starts increasing as the capacitor start to charge and the charging current starts decreasing. The decrease of the charging current and the increase of voltage across the capacitor follow exponential law.

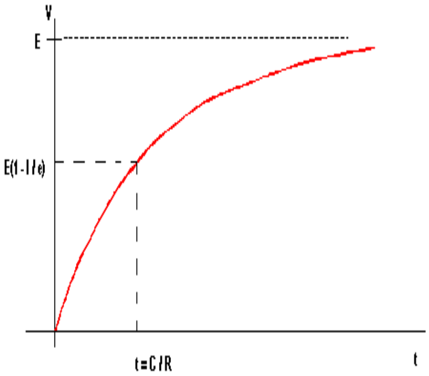
$$I(t) = V/R\ e^{-t/RC}$$

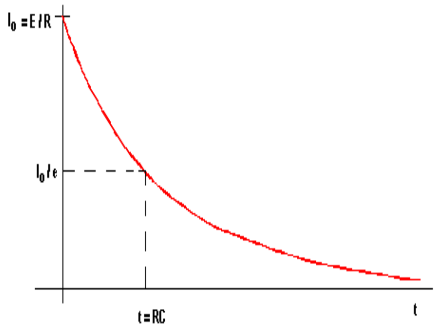
However, the voltage across the capacitor is given by,

$$V_C\ (t) = V\ (1- e^{-t/RC})$$

Where t= time elapsed since pulse is applied

τ = RC= Time constant of the circuit



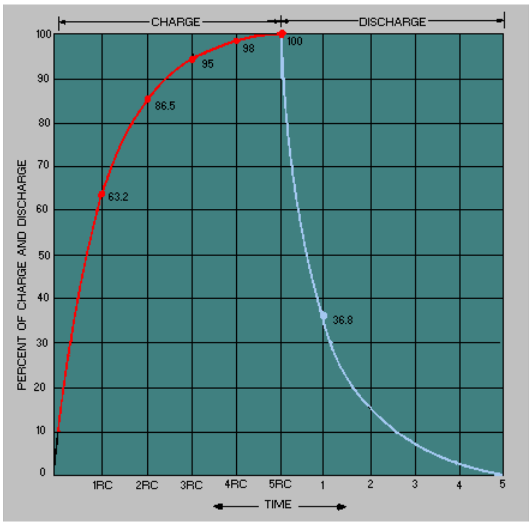


Discharging a charged Capacitor

During the next half cycle of pulse, when the pulse amplitude is zero and capacitor is charged to potential difference of V volts, now the capacitor discharges through resistor R. So, the voltage across capacitor decreases exponentially and the discharge current rises instantly to a maximum value i.e Im=V/R and then decays exponentally. Mathematically, it can be shown that voltage across the capacitor and discharging current are given value by,

$$V_C\ (t) = V\ e^{-t/CR}$$

$$I(t) = -I_m\ e^{-t/RC}$$



PROCEDURE:

1. Set the out of the function generator to a square wave with frequency 500Hz and peak to peak amplitude 5V.
2. Wire the circuit on bread board.
3. Display simultaneously voltage V_{in} (t) across the function generator (on CH1) and V_C (t) across the capacitor C (on CH2).
4. Sketch the two measure wave forms V_{in}(t) and V_c (t), calculate and sketch the waveforms, V_R(t) and I (t). Label the time, voltage and current scales note that the voltage across the R is V_R (t) also represents the current I (t).
5. Measure the time constant τ, using the waveform V_C (t). Expand the time scale and measure the time it takes for the waveform to complete 63% of its total change, i.e 5V. Enter the measured value of τ in table.
6. Computer values of theoretically expected and experimentally obtained time constants τ.

Max frequency input pulse that can be applied:

If the pulse width is at least five time constant in length, the capacitor will have sufficient time to charge and discharge when the pulse returns to 0 volts. Any increase in frequency beyond this will result in insufficient time for the charge/discharge cycle to complete. This frequency is the max frequency of input pulse that can be applied.

So min pulse width should be equal to **5RC** and form this max frequency can be calculated.

OBSERVATION AND CALCULATIONS

Table-1

No.	R	C	τ	5 τ	F
1	20KΩ	0.001μF			
2	10KΩ	0.001μF			

Charging of Capacitor

Table 2

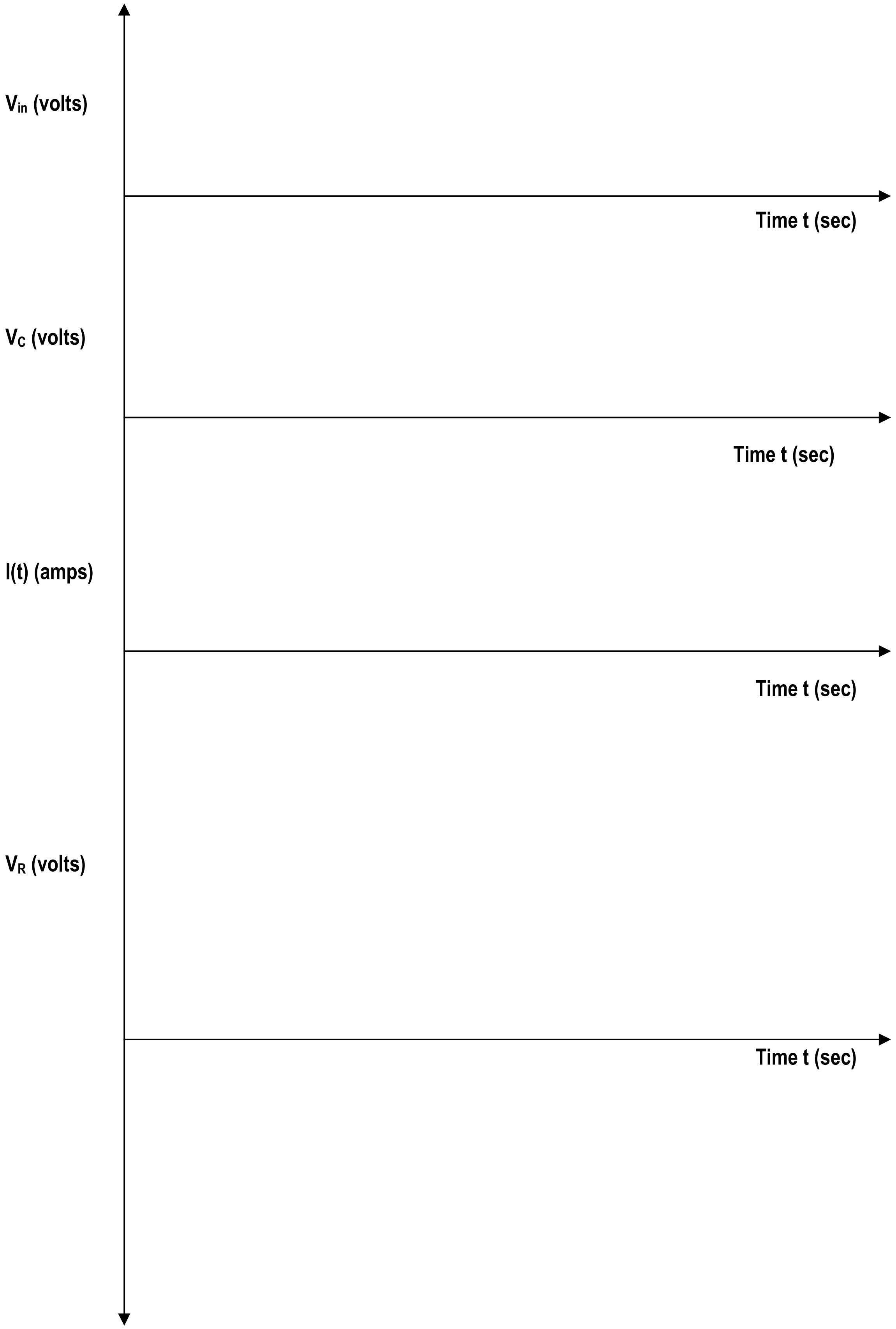
Number of Time Constant	Calculated Voltage Vc(volts)	Measured Voltage Vc(volts)
1τ		
2τ		
3τ		
4τ		
5τ		

Discharging of Capacitor

Table 3

Number of Time Constant	Calculated Voltage Vc(volts)	Measured Voltage Vc(volts)
1τ		
2τ		
3τ		
4τ		
5τ		

WAVEFORMS OF VOLTAGES& CURRENTS



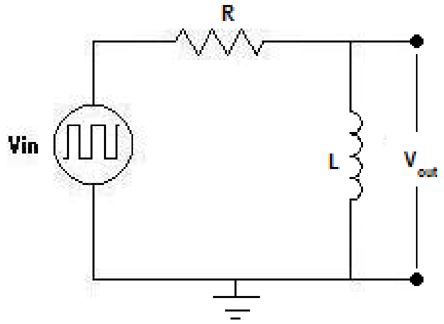
EXPERIMENT 09

PULSE RESPONSE OF A SERIES RL NETWORK

EQUIPMENT

1. Signal generator
2. Oscilloscope
3. Inductor:100mH
4. Resistor: 10KΩ /20KΩ

CIRCUIT DIAGRAM



THEORY

This lab is similar to the RC circuit lab except that an Inductor replaces the capacitor. In this experiment we apply a square waveform to the RL circuit to analyze the transient response of the circuit. The pulse –width relative to the circuit's time constant determines how it is affected by the RL circuit.

Rise of current

At the instant when step voltage is applied to an RL network, the current increases gradually and takes some time to reach the final value. The reason the current does not build up instantly to its final value is that as the current increases, the self-induced e.m.f in L opposes the change in current (Lenz's Law). Mathematically, it can be shown,

$$I(t) = V/R\,(1-e^{-t/\tau})$$

Where t = time elapsed since pulse is applid
τ = L/R= time constant of the circuit

(ii) Decay of the current

During the next half cycle of the pulse, when the pulse amplitude is zero, the current decreases to zero exponentially. Mathematically, it can be shown,

$$I(t) = V/R\ e^{-t/\tau}$$

PROCERURE

1. Set the output of the function generator to a square-wave with frequency 2 KHz and peak-to-peak amplitude 5V.
2. Wire the circuit on breadboard.
3. Display simultaneously voltage V_{in} (t) across the function generator (on CH 1) and V_L (t) across the inductor L (on CH 2).
4. Sketch the two measured waveform V_{in} (t) and V_L (t), calculate and sketch the waveform, V_R (t) and I(t), Label the time, voltage and current scales. Note that the voltage across resistor R, V_R (t), also represents the current I(t).
5. Measure the time constant, τ using the wave form V_R (t). Expand the time scale and measure the time it takes for the waveform to complete 63% of its total change, i.e. 5V. Enter the measured value of τ in Table.
6. Compare values of the theoretically expected and experimentally obtained time constants τ.

OBSERVATION AND CALCULATIONS

Table-1

No.	R	L	τ	5 τ	F_{MAX}
1	20KΩ	100 mH			
2	10KΩ	100 mH			

Rise of Current

Table 2

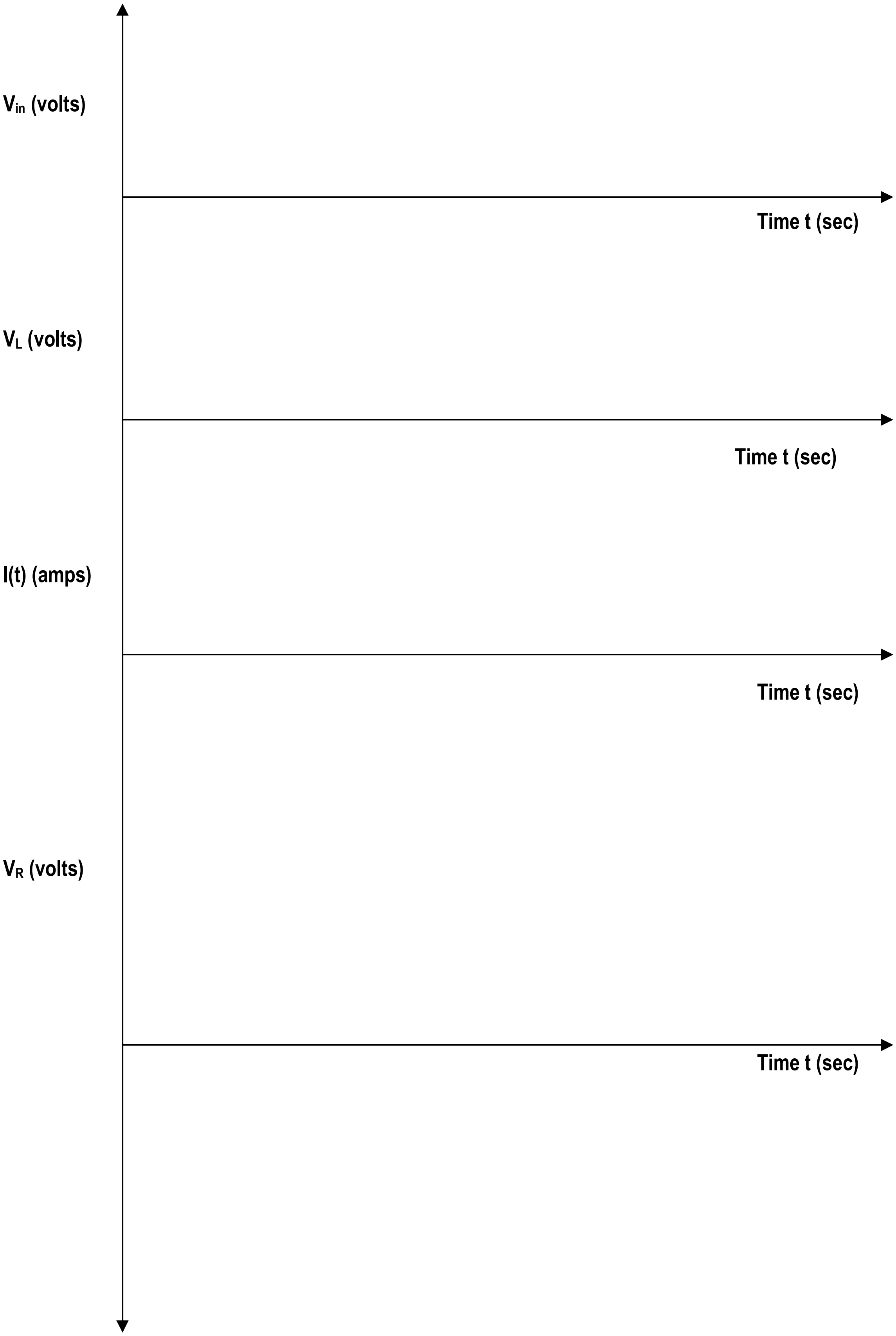
Number of Time Constant	Calculated Current (Amps)	Measured Current (Amps)
1τ		
2τ		
3τ		
4τ		
5τ		

Decay of Current

Table 3

Number of Time Constant	Calculated Current (Amps)	Measured Current (Amps)
1τ		
2τ		
3τ		
4τ		
5τ		

WAVEFORMS OF VOLTAGES& CURRENTS



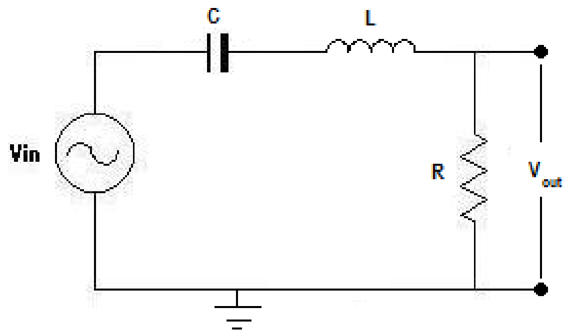
EXPERIMENT 10

TO SHOW THE FREQUENCY RESPONSE OF A SERIES RLC NETWORK AND SHOW THAT THE RESONANT FREQUENCY OF A SERIES RLC CIRCUIT IS GIVEN BY 1/2T√ LC.

EQUIPMENT

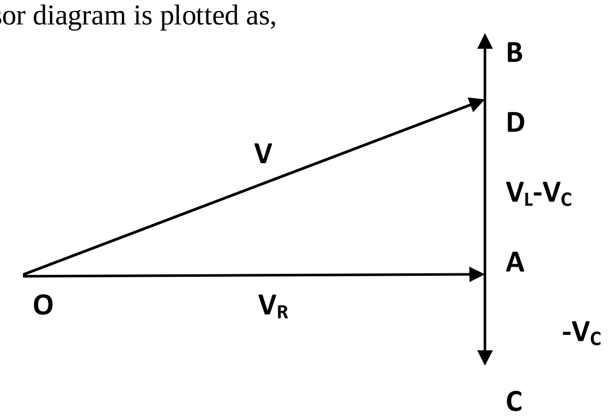
1. Signal Generator
2. Inductor: 100-200 mH
3. Capacitors: 0.001µF and 0.01µF
4. Resistor: 100Ω±5 percent
5. Oscilloscope
6. Multimeter

CIRCUIT DIAGRAM



THEORY

As shown in the circuit diagram, resistor, inductor and capacitor are connected in series with an a.c. supply of r.m.s. voltage V. The Phasor diagram is plotted as,



Let V_R = IR = voltage drop across R

V_L= IX_L = voltage drop across L

V_C = IX_C = voltage drop across C

In voltage triangle of fig 1, OA represents V_R, AB and AC represents the inductive and capacitive drop respectively. It will be seen that V_L and Vc are 180 degree out of phase with each other i.c. they are in direct opposition to each other.

Subtracting AC from AB, we get the net reactive drop AD = $I(X_L – X_C)$

The appliad voltage V is represented by OD and is the vector sum of OA and AD.

$$OD = \sqrt{(OA^2 + AD^2)}$$

$$V = \sqrt{[(IR)^2 + (IX_L - IX_C)^2]} = I\sqrt{[(R)^2 + (X_L - X_C)^2]}$$

$$I = V/\sqrt{[(R)^2 + (X_L - X_C)^2]} = V/Z$$

The term is known $[(R)^2 + (X_L - X_C)^2]$ as the impedance of the network. Obviously,

$$(\text{Impedance})^2 = (\text{Resistance})^2 + (\text{Net Reactance})^2$$

Resonance in RLC Networks

Resonance means to be in step with. When the appliad voltage and the current in an a.c. network are in step with i.e. phase angle between voltage and current is zero or pf = 1, the circuit is said to be in resonance.

An a.c. circuit containing reactive element (L and C) is said to be in resonance when the net reactance is zero.

When a series R-L-C is in resonance, it possesses minimum impedance Z = R. Hence, circuit current is maximum, it being limited by value of R alone. The current I_o = V/R and is in phase with V. since circuit current is maximum, it produces large voltage drops across L and C. but these drops being equal and opposite, cancel out each other. Taken together, L and C from part of a circuit across which no voltage develops however, large the current flowing. If it were for the presence of R, such a resonant circuit would act like a short circuit to currents of the frequency to which it is often referred to as voltage resonance.

The frequency at which the net reactance of the series circuit is zero is called the resonant frequency. Its value can be found as found as under:

$X_L - X_C = 0$

$X_L = X_C$ or $\omega_o L = 1/\omega_o C$

$\omega_o^2 = 1/LC$ or $(2\pi f_o)^2 = 1/LC$ or $f_o = 1/2\pi\sqrt{LC}$

If L is in Henry and C is in Farad, then f_o is in Hertz

PROCEDURE

1. For the given inductor and capacitor calculate the resonant frequency and connect the circuit as shown in circuit diagram
2. Apply sinusoidal signal from the generator of the 5V pk to the network and set the frequency to a value of 500 Hz
3. Observe V_R, V_L and V_C on the oscilloscope and record it.
4. Increase the frequency of the signal and for each frequency measure and record V, V_R, V_L and V_C and maintain applied voltage constant at $5V_P$
5. Now measure V_R, V_L and V_C theoretically and compare the results.

OBSERVATIONS &CALCULATIONS

$$V_{rms} = V_P/\sqrt{2}$$

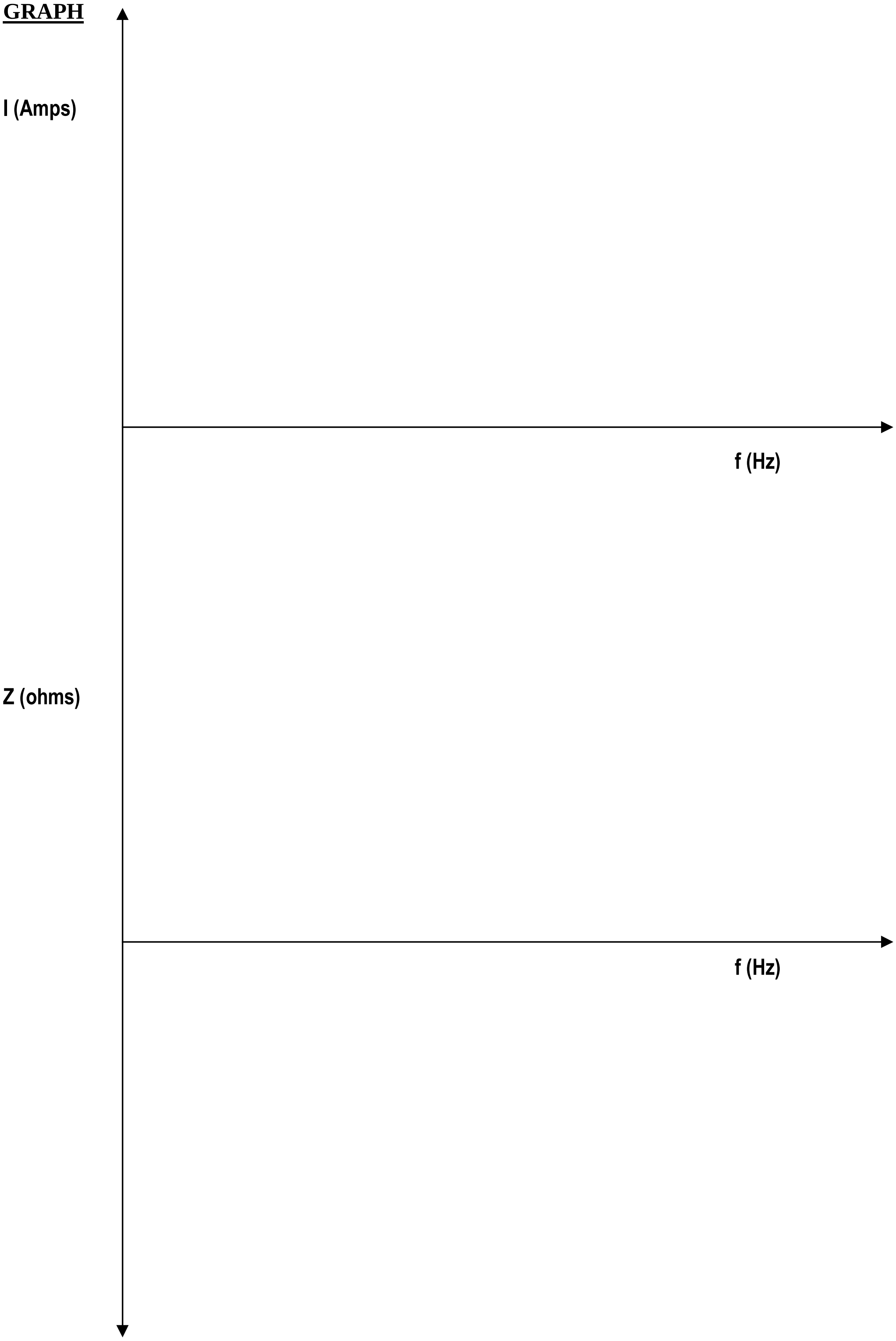
Calculated value

No.	Frequency f (Hz)	X_L (ohms)	X_C (ohms)	Z (ohms)	$I=V_R/R$ (Amps)	$V_L=IX_L$ (Volts)	$V_C=IX_C$ (Volts)
1							
2							
3							
4							
5							

Measured Values

No.	Frequency f (Hz)	X_L (ohms)	X_C (ohms)	Z (ohms)	$I=V_R/R$ (Amps)	$V_L=IX_L$ (Volts)	$V_C=IX_C$ (Volts)
1							
2							
3							
4							
5							

GRAPH



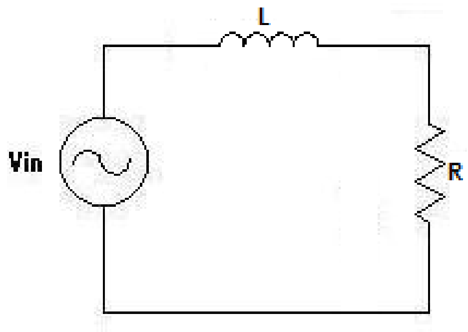
EXPERIMENT 11(a)

SINUSOIDAL RESPONSE OF RL CIRCUIT

APPARATUS

1. Signal generator
2. Oscilloscope
3. Multimeter
4. Inductor 100 mH
5. Resistor 2K

CIRCUIT DIAGRAM



THEORY

Circuit containing inductance and resistance appear in variety of electronic circuits, from power supplies to filters. In this experiment we are going to investigate the sinusoidal response of a series RL circuit. A difficulty arises in conjunction with such circuit in that real conductor are not like ideal conductor we deal in our theory. Since they are formed of coiled wire, they possess resistance as will as inductance. Furthermore their resistance is dependent on frequency as will. As a consequence, the inserted R does not represent the total resistance of the circuit. In addition, when we measure the voltage across a coil, we are getting both inductive and resistive component of voltage, not simply VL. In this experiment, we will try to overcome this problem by making R large compared with the ac resistance of coil, that is we will presume the coil is ideal.

Relation for steady state ac analysis are as follows

$Z_L = j2\pi fL$

$Z_{TOTAL} = R + Z_L$

$I = V_{in} / Z_{TOTAL}$

$V_R = IR$

$V_L = IZ_L$

PROCEDURE

1. Calculate and note down quantities Z_L, Z_{TOTAL}, I, V_R and V_L for a source voltage of 5V peak and frequency 1 KHz. Remember to use $V_{rms} = V_P/\sqrt{2}$ in calculations.
2. Connect the circuit as shown in diagram and adjust the function generator voltage and frequency to the values chosen above.
3. Use Multimeter to measure voltages V_L and V_R and note down in Table.
4. Compare measured and calculated values.
5. Explain any discrepancies between measured and calculated values of V_R and V_L.
6. Draw a phasor diagram of the calculated voltages in diagram. Include I as a reference phasor and show the position of V_R and V_L.

OBSERVATONS AND CALULATIONS

Table 1

CALCULATION PARAMETERS				
Z_L	Z_{TOTAL}	I	V_R	V_L

Table 2

MEASURED		I= V_R/R	$Z_L = V_L/I$	Z=Vi/I
V_R	V_L			

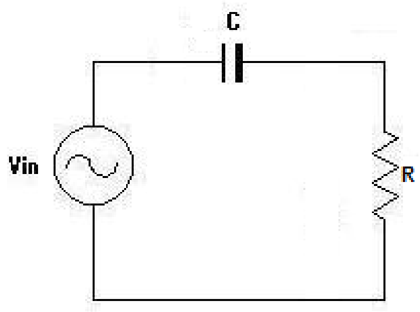
EXPERIMENT 11(b)

SINUSOIDAL RESPONSE OF RC CIRCUIT

APPARATUS

1. Signal generator
2. Oscilloscope
3. Capacitor 0.1µF
4. Resistor 2K

CIRCUIT DIAGRAM



PROCEDURE

(Similar to the above part, except a capacitor replaces inductor)

1. Calculate and note down quantities $\mathbf{Z_C}$, $\mathbf{Z_{TOTAL}}$, $\mathbf{V_R}$ and $\mathbf{V_C}$ for a source voltage of 5V peak and frequency 1 KHz. Remember to use $\mathbf{V_{rms} = Vp/\sqrt{2}}$ in calculations
2. Connect the circuit as shown in diagram and adjust the function generator voltage and frequency to the values chosen above.
3. Use Multimeter to measure voltages $\mathbf{V_C}$ and $\mathbf{V_R}$ and note down in Table.
4. Compare measured and calculated values.
5. Explain any discrepancies between measured and calculated values of $\mathbf{V_R}$ and $\mathbf{V_C}$.
6. Draw a phasor diagram of the calculated voltages in diagram. Include I as a reference phasor and show the positions of **Vi,** $\mathbf{V_R}$ and $\mathbf{V_C}$.

OBSERVATIONS AND CALCULATIONS

Table 1

Calculation Parameters				
Z_C	Z_{TOTAL}	I	V_R	V_C

Table 2

Measured		$I = V_R/R$	$Z_C = V_C/I$	$Z = Vi/I$
V_R	V_C			

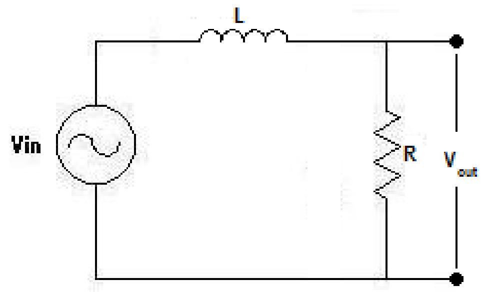
EXPERIMENT 12

FREQUENCY CHARACTERISTICS OF A SIMPLE LOW PASS RL FILTER CIRCUIT AND TO UNDERSTAND THE BEHAVIOR OF THE CIRCUIT WITH RELATION TO THE POLE ZERO LOCATION.

APPARATUS

1. Signal generator
2. Oscilloscope
3. Multi-meter
4. Inductor 100 mH
5. Resistor 2K

CIRCUIT DIAGRAM

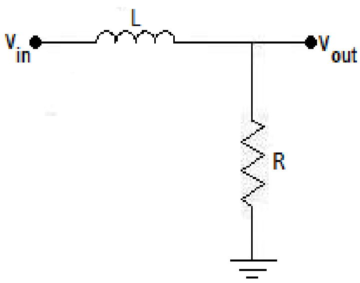


THEORY

By using various combinations of resistances capacitor and inductor we can make circuit that have the property of passing or rejecting either low or high frequencies or bands or frequencies. These frequency selective networks, which alter the amplitude and phase characteristics of the input ac signal, are called fillers. Or in other words,

"A filter is an AC circuit that separates some frequencies from other in within maxid-frequency signals."

A basic RL low-pass filter is shown in figure. Notice that the output voltage is taken across the resistor.



When the input is dc (0 Hz) the output voltage ideally equals the input voltage because X_L is a short circuit. As the input frequency is increased, X_L increases and as a result V_{out} gradually decreases unit the critical frequency is reached. At this point, X_L = R and the frequency is

$$2\pi f_C L = R$$

$$f_c = R/2\pi L$$

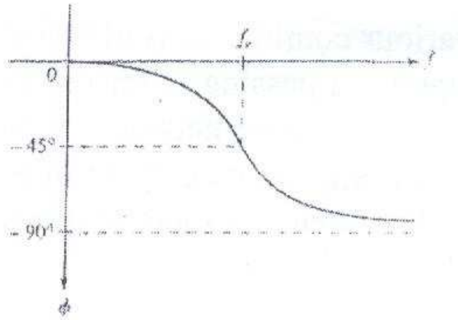
$$f_c = 1/2\pi(L/R)$$

just as in the RC low-pass filter, V_{out} = 0.707 Vin and, thus the output voltage is down 3dB at the critical frequency.

The RL low-pass filter acts as a lag network. The phase shift from input to output is expressed as

$$\theta = -\tan^{-1}(X_L/R)$$

At the critical frequency, XL = R and, therefore, $\theta = -45^o$. as the input frequency is reduced as decreases and approaches 0^o as the frequency approaches zero as shown in figure



PROCEDURE

1. Apply a 1 V_{pp} 100Hz signal as input to the network and measure the corresponding output voltage level. Determine the decibel gain of the filter.

   G (dB) = log [Vo/Vin]

2. Determine the phase difference between V_o and V_{in} in degrees.
3. Repeat step 1 and 2 for the following frequencies: 200 Hz, 500Hz, 1 KHz, 1.5 KHz, 2 KHz, 3 KHz, 5 KHz, 10 KHz, 20 KHz, 50 KHz.

OBSERVATIONS AND CALCULATIONS

$$fc = \frac{1}{2\pi(L/R}$$

No	Input frequency f(Hz)	Input voltage V_{in} RMS(volts)	output voltage V_o RMS(volts)	V_o/V_{in} (volts)	db =(20 log V_o/V_{in}	θ (degrees)

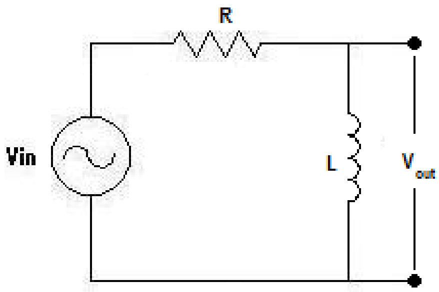
EXPERIMENTS 13

FREQUENCY CHARACTERISTICS OF A SIMPLE HIGH PASS RL FILTER CIRCUIT AND TO UNDERSTAND THE BEHAVIOR OF THE CIRCUIT WITH RELATION TO THE POLE ZERO LOCATION.

APPARATUS

1. Signal generator
2. Oscilloscope
3. Multi-meter
4. Inductor 100 mH
5. Resistor 1.5K

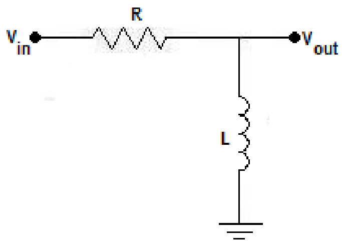
CIRCUIT DIAGRAM



THEORY

A high pass filter allows signals with higher frequencies to pass from input to output while rejecting lower frequency considered to be lower end of pass band is called the critical frequency. It is the frequency at which the output is 70.7%of the maximum.

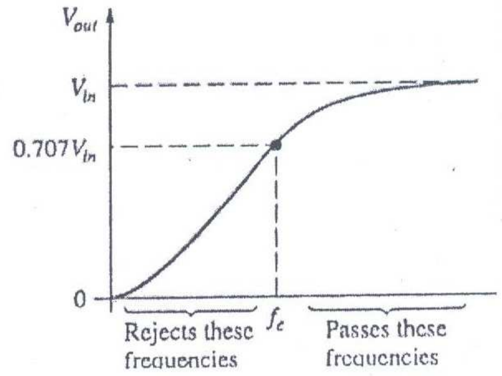
A basic RL high-pass filter is shown in figure. Notice that the output is taken across the inductor.



When the input frequency is at its critical value, XL =R, and the output voltages is 0.707Vin. As the frequency increases above f_c, X_L increases and, as a result, the output voltages increase until it equal V_{in}. The expression for the critical frequency of the high-pass filter is the same as for the low-pass filter.

$$f_c = \frac{1}{2\pi(\frac{L}{R})}$$

Frequency characteristics of high pass filter is shown below



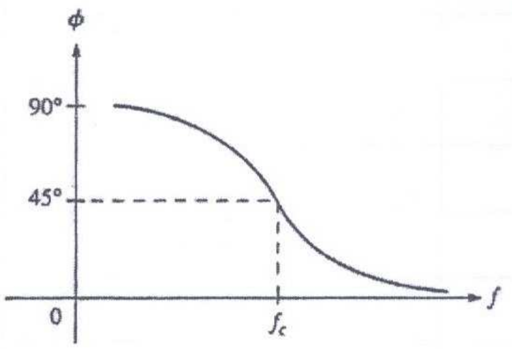
Both the RC and the RL high-pass filter act as lead network. Recall from previous experiments that the phase shift from input to output for the RC lead network is:

$$\theta = \tan^{-1}[\frac{Xc}{R}]$$

And for the RL lead network is:

$$\theta = 90^o - \tan^{-1}[\frac{XL}{R}]$$

At the critical frequency, XL = R and, therefore, $\theta = 45^o$. As the frequency is increased, θ decreases toward 0^o as shown in figure.



PROCEDURE

1. Apply a 10 V_{pp} 100 Hz signal as input to the network and measure the corresponding output voltage level. Determine the decibel gain of the filter.

   G (db) = 20 log [V_o/ V_{in}]

2. Determine the phase difference between V_o and V_{in} in degrees.
3. Repeat step 1 and 2 for the following frequencies: 200 Hz, 500Hz, 1KHz, 1.5 KHz, 2KHz, 3kHz, 5 KHz, 10 KHz, 20KHz, 50 KHz.

OBSERVATIONS AND CALCULATIONS

$$f_c = \frac{1}{2\pi\left(\frac{L}{R}\right)} \quad V_{in}$$

No	Input frequency f(Hz)	Input voltage Vin RMS(volts)	Output voltage $V_{o\ RMS(volts)}$	$V_{o/}\ V_{in}$ (volts)	dB =(20 log $V_{o/}\ V_{in)}$	θ (degrees)

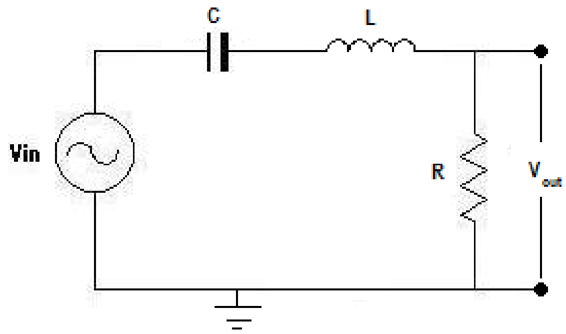
EXPERIMENT 14

TO PLOT THE MAGNITUDE AND PHASE RESPONSE OF A SERIES RESONANAT BAND FILTER

APPARATUS

1. Signal Generator
2. Oscilloscope
3. Multimeter
4. Capacitor: 0.01µ F
5. Inductor 100-200 mH
6. Resistors (1/4W): 1KΩ±5 percent

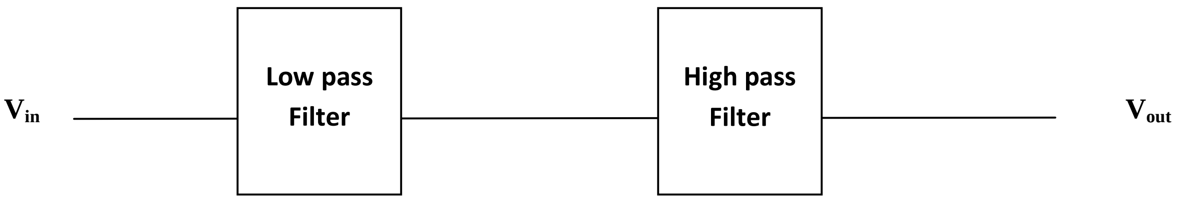
CIRCUIT DIAGRAM



THEORY

BAND PASS FILTER

It allows a certain band of frequencies to pass and attenuates or rejects all frequencies below and above the pass band. A combination of low-pass and high-pass filter can be used to form band pass filters.



Low-pass and high-pass filters used to form a band-pass filter

OPERATION OF SERIES RESONANT BAND PASS FILTERS

A series resonant filter has minimum input impedance. At critical frequency the inductor and the capacitor in series behave a simple resistor. Hence making of maximum output a cross the load resister. At the frequency other then resonant frequency, reactance offered by the inductor or capacitor is very large, hence output voltage will be very small at high as well as at low frequencies.

BANDWIDTH

The bandwidth of a band pass filter is the range of frequencies for which the current, and therefore the output voltage, is equal or greater than 70.7 percent of its value at the resonant frequency.

$$\text{Mathematically bandwidth} = \frac{\text{Resonant Frequency } f_r}{\text{Quality Factor } q}$$

QUALITY FACTOR

Quality factor is the ratio of reactive power developed in inductor or capacitor to average power the dissipated in resistor.

$$\text{Quality factor} = \frac{\text{Reactive power developed in inductor or capacitor}}{\text{Average power dissipated in resistor}}$$

Quality factor indicates the selectivity of the filter and can be expressed as,

$$\text{Quality factor} = \omega L/R$$
$$= 2\pi f_r L/R$$

PROCEDURE

1. For the components used in the circuits, calculate and record the resonant frequencies for the circuit in the fig. Calculate, also, the circuit-Q and bandwidth of the circuit.
2. Construct the circuit shown in fig
3. At a frequency of 500 Hz adjust V_{in} to some convenient value, such as 5V rms.
4. Use Multi-meter to measure V_o and record it in table.
5. Vary the frequency, measure and record V_o while maintaining constant.
6. Complete the decibel gain row of the table.
7. Plot the decibel voltage in ratio versus log frequency

OBSERVATION&CALCULATION

Resonant Frequency $f_r = 1/2\pi\sqrt{LC}$

Quality Factor Q = ώL/R

Bandwidth = f_r/Q

No.	Input frequency f(Hz)	Input voltage Vin (volts)	Output voltage Vo (volts)	Vo/Vin (volts)	db= 20log (Vo/ Vin)

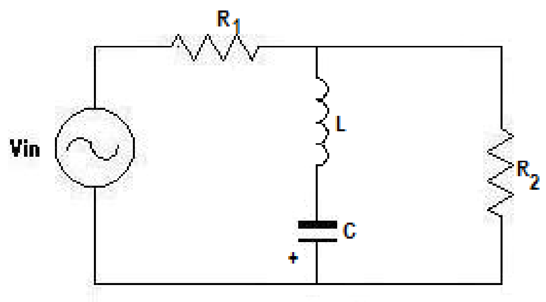
EXPERIMENT NO 15

TO PLOT THE MAGNITUDE AND PHASE RESPONSE OF A SERIES RESONANT BAND-STOP FILTER.

APPARTUS

1. Signal Generator
2. Oscilloscope
3. Multi-meter
4. Capacitor 10µF
5. Inductor 100 to 200 M Hz
6. Resistor (1/4W): 500Ω 1K Ω ±4%

CIRCUIT DIAGRAM

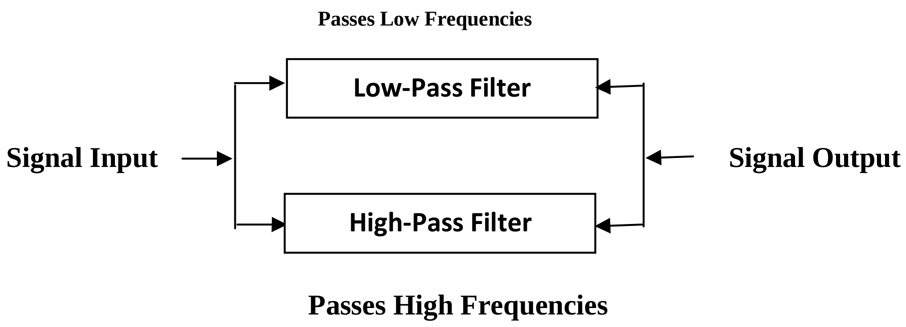


THEORY

BAND STOP FILTER

It is a filter that rejects a certain band or range of frequencies while passing all frequencies below and above the rejected band. Band stop filters block signals occurring between two given frequencies, FL and FH.

It can be made out of a low-pass and a high pass filter by connecting the two filter sections in parallel with each other instead of in series.



OPERATION OF BAND STOP FILTER

When the series LC combination reaches resonance, its very low impedance shorts out the signal, dropping it across resistor R1 and preventing its passage on to the load. Thus, within the band at which the resonant frequencies occur there is a relatively less output and that set of frequencies are attenuated.

At frequencies other the resonant frequencies, the reactance offered by inductor and capacitor is very large, thus outside the band at which resonant frequency occurs, there is large output and that set of frequencies or passed to the output.

CORNER FREQUENCY

Because a real filter rolls off gradually, you usually specify the corner frequency as the frequency at which the response is 1/√2(0.707) of that in the pass band. Because electronics engineer traditionally describe relative signal strengths in decibels, the frequency is also referred to as 3-db point.

PROCEDURE

1. For the components used in the circuits, calculate and record the resonant frequencies for the circuit in the fig. Calculate, also, the circuit-Q and bandwidth of the circuit.
2. Construct the circuit shown in fig
3. At a frequency of 500 Hz adjust V_{in} to some convenient value, such as 5V rms.
4. Use multi-meter to measure V_o and record it in table.
5. Vary the frequency, measure and record V_o while maintaining constant.
6. Complete the decibel gain row of the table.
7. Plot the decibel voltage in ratio versus log frequency

OBSERVATION & CALCULATION

Resonant Frequency $f_r = 1/2\pi\sqrt{LC}$

Quality Factor $Q = \acute{\omega}L/R$

Bandwidth = f_r/Q

No.	Input frequency f(Hz)	Input voltage Vin (volts)	Output voltage Vo (volts)	Vo/Vin (volts)	db= 20log (Vo/ Vin)

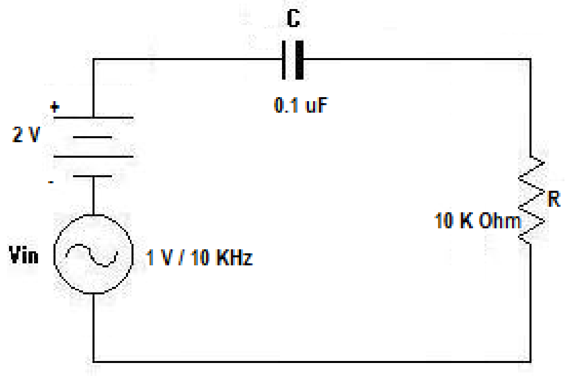
EXPERIMENT NO 16

TO VERIFY THE PRINCIPLE OF SUPER POSITION USING AC AND DC SOURCES

APPARATUS

1. Signal Generator
2. DC power Supply
3. Oscilloscope
4. Capacitor 0.1µF
5. Resistor 20 K

CIRCUIT DIAGRAM



THEORY

We often encounter circuits in which voltage and currents are made of both AC and DC components, i.e. they are energized from DC and AC sources simultaneously. Signals and such circuitry are often referred to as "AC riding on top of DC" and we can examine this behavior with the help of an Oscilloscope.

To analyze such circuits, the technique of super position may be employed. This involves analyzing the circuits separately for each source in it by "killing" the remaining sources. Recall the voltage source or treated as short circuits and current sources as open circuits.

In many applications, the capacitor in a circuit has such a low reactance at the operating frequency that it can be considered it short circuit. To a DC sources, it is treated as an open circuit, of course. These simple ideas allow us to analyze circuits with combined DC/AC signal sources very easily.

In this experiment we are going to look at a circuit that contains such a combination of sources. In addition it will contain only resistors and capacitors. Frequency will be selected in such a way that capacitive reactance is a small enough to be ignored.

PROCEDURE

1. Use principle of superposition to calculate the DC and AC components of voltage across R and C. Take f= 10KHz. Treat C as an open for DC and as a short for AC to facilitate your calculations
2. Set the output of function generator 1V rms sine wave and frequency 10 KHz. Also set the output of DC supply equal to 2V.Connect the circuit as shown in diagram. (You can also use DC offset knob on function generator instead of using DC supply. For that purpose connect oscilloscope across function generator with output 1V rms sine wave. Now change the DC offset and observe the effect on oscilloscope. Adjust the offset knob until you see a sine wave riding on a DC level of 2V with peak to peak value of 2.8V approximately).
3. Connect the oscilloscope probes across terminal A and B, set it for DC coupling and observe the wave form. You should see a sine wave riding on DC level of 2V. Sketch the wave form in your note book.
4. Change to AC coupling and note the effect.
5. Using multi-meter, measure both the DC and AC Voltage across R and C.
6. Record these values in table 1.you can also confirm your reading using oscilloscope.
7. Now connect the oscilloscope probes across R and observe the waveform. Change the coupling from DC to AC and AC to DC and observe the effect. Also sketch the waveform.
8. Now adjust the frequency of the generator to 1 KHz, and if necessary, re-adjust the terminal voltage components (DC and AC) to their original values just as instep 2.
9. Again measure AC and DC voltage across R and C using multi-meter and record in table 2. Why are things so different when the frequency is changed to 1 KHz

OBSERVATION AND CALCULATIONS

Table-1

f = 10KHz	Vc		V_R	
	dc	ac	dc	ac
Calculated				
Measured				

Table-2

V_C		V_R	
dc	ac	dc	ac