GANDHI SCHOOL OF ENGINEERING

Chidananda Hills, Bhabandha, Berhampur, Ganjam

EC LABORATORY EXPERIMENTS

EXPERIMENT NO. 01

Aim of the Experiment

To verify Thevenin's theorem.

Apparatus Required

Sl. No.	Name of the Components	Range	Quantity
01	Resistors	R1 = 1.76 kΩ, R2 = 1.78 kΩ, R3 = 2.36 kΩ, RL = 10 kΩ	4 Nos.
02	Variable DC Supply	0–20 V	1 No.
03	Variable Resistor	0–10 kΩ	1 No.
04	Multimeter	—	1 No.
05	Connecting Probes	—	1 No.

Theory

Thevenin's theorem states that any bilateral, two-terminal, linear DC circuit can be replaced by an equivalent circuit consisting of a voltage source (VTH) and a resistor (RTH) in series.

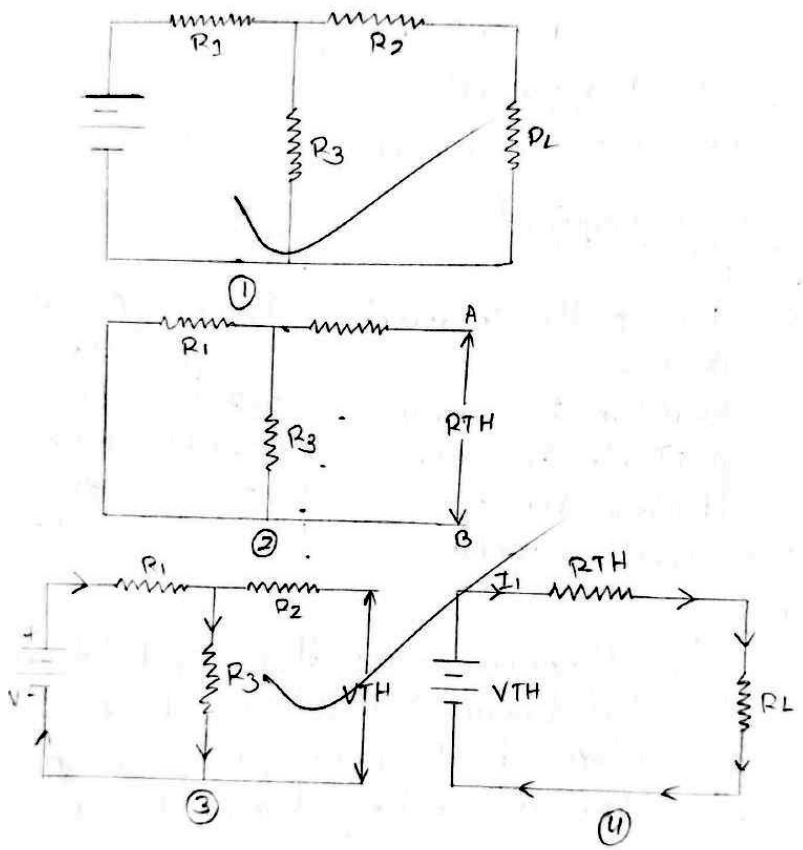


Fig.: Circuit diagrams for verification of Thevenin's theorem – (1) given circuit, (2) measurement of RTH, (3) measurement of VTH, (4) Thevenin's equivalent circuit

Procedure

1. Remove the voltage source of the given circuit and short-circuit its terminals.
2. Remove the load resistance RL.
3. Connect R1, R2 and R3 as per circuit diagram No. 2.
4. Measure RTH across AB with the multimeter.
5. Connect the voltage source (V), R1, R2 and R3 as per circuit diagram No. 3 and switch on the power supply.
6. Measure VTH across AB.
7. Adjust RTH using the variable resistor.
8. Adjust VTH using the variable DC supply.
9. Connect VTH, RTH and RL in series as per circuit diagram No. 4.
10. Switch on the power supply. Note down the load current IL with the help of the multimeter.

Theoretical Calculation

(A) To find RTH

$$RTH = (R1 \parallel R3) + R2 = (R1 \times R3) / (R1 + R3) + R2$$

$$= (1.76 \times 2.36) / (1.76 + 2.36) + 1.78 = 4.15 / 4.12 + 1.78$$

$$= 2.78\ k\Omega$$

(B) To find VTH

$$I = V / (R1 + R3) = 15 / (1.76 + 2.36) = 15 / 4.12 = 3.64\ mA$$

VTH is the voltage across R3:

$$VTH = I \times R3 = 3.64 \times 2.36 = 8.59\ V$$

(C) To find IL

$$IL = VTH / (RTH + RL) = 8.59 / (2.78 + 10) = 8.59 / 12.78 = 0.67\ mA$$

Tabulation

RTH (Theoretical)	RTH (Practical)	VTH (Theoretical)	VTH (Practical)	IL (Theoretical)	IL (Practical)
2.78 kΩ	2.79 kΩ	8.59 V	8.53 V	0.67 mA	0.60 mA

Conclusion

From the above experiment, I learnt how to verify Thevenin's theorem using the Thevenin's theorem kit.

EXPERIMENT NO. 02

Aim of the Experiment

To verify Norton's theorem using an ammeter and a voltmeter.

Apparatus Required

Sl. No.	Name of the Components	Range	Quantity
01	Resistors	R1 = 1.83 kΩ, R2 = 2.46 kΩ, R3 = 1.83 kΩ, R4 = 1.83 kΩ	4 Nos.
02	Variable Resistor	0–10 kΩ	1 No.
03	Variable DC Supply	0–15 V	1 No.
04	Variable Current Source	0–20 mA	1 No.
05	Norton's Theorem Kit	—	1 No.
06	Digital Multimeter	—	1 No.
07	Connecting Probes	—	As required

Theory

Norton's theorem states that any bilateral, two-terminal, linear DC circuit can be replaced by an equivalent circuit consisting of a current source (IN) in parallel with a resistance (RN).

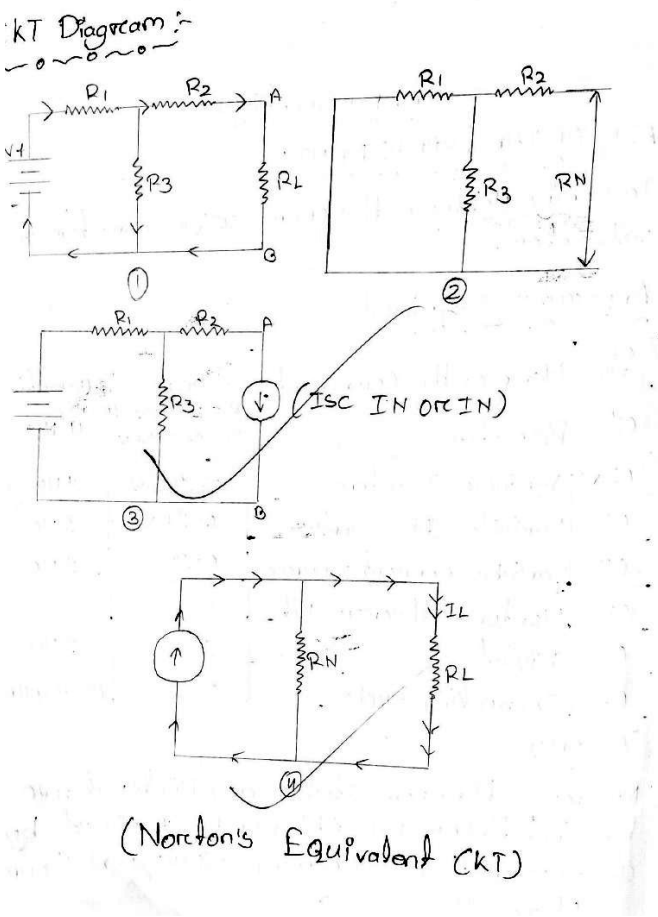


Fig.: Circuit diagrams for verification of Norton's theorem – (1) given circuit, (2) measurement of RN, (3) measurement of IN, (4) Norton's equivalent circuit

Theoretical Calculation

(A) To find RN (from Fig. No. 2)

$$RN = (R1 \parallel R3) + R2 = (R1 \times R3) / (R1 + R3) + R2$$

$$= (1.83 \times 1.83) / (1.83 + 1.83) + 2.46 = 3.34 / 3.66 + 2.46$$

$$= 0.91 + 2.46 = 3.37\ k\Omega$$

(B) To find IN

$$R = (R2 \parallel R3) + R1 = (R2 \times R3) / (R2 + R3) + R1$$

$$= (2.46 \times 1.83) / (2.46 + 1.83) + 1.83 = 4.50 / 4.29 + 1.83$$

$$= 1.04 + 1.83 = 2.87\ k\Omega$$

$$I = V / R = 15 / 2.87 = 5.22\ mA$$

$$IN = (I \times R3) / (R2 + R3) = (5.22 \times 1.83) / (2.46 + 1.83) = 9.5 / 4.29 = 2.21\ mA$$

(C) To find IL (from Fig. No. 4)

$$IL = (IN \times RN) / (RN + RL) = (2.21 \times 3.37) / (3.37 + 1.83) = 7.44 / 5.2 = 1.43\ mA$$

Procedure

(A) To find RN

1. Remove the voltage source and short-circuit the terminals.
2. Remove the load resistance RL.
3. Connect R1, R2 and R3 as per the circuit diagram.
4. Measure Norton's resistance (RN) across AB using the digital multimeter.

(B) To find IN

1. Connect the voltage source (V) and resistances R1, R2 and R3 as per the circuit diagram.
2. Switch on the DC power supply.
3. Measure IN through AB using the digital multimeter.

(C) To find IL from circuit No. 4

1. Adjust IN using the variable current source.
2. Connect IN, RN and RL as per circuit diagram No. 4.
3. Switch on the DC power supply.
4. Measure the load current through RL using the digital multimeter.

Observation Table

RN (Theoretical) kΩ	RN (Practical) kΩ	IN (Theoretical) mA	IN (Practical) mA	IL (Theoretical) mA	IL (Practical) mA
3.37	3.38	2.21	2.19	1.43	1.16

Conclusion

From the above experiment, I learnt how to verify Norton's theorem using the Norton's theorem trainer kit.

EXPERIMENT NO. 03

Aim of the Experiment

To verify the Maximum Power Transfer Theorem.

Apparatus Required

Sl. No.	Name of the Components	Range	Quantity
01	Resistors	Ra = 1.77 kΩ, Rb = 2.35 kΩ, Rc = 2.73 kΩ	3 Nos.
02	Variable Resistor	0–10 kΩ	01
03	Variable DC Supply	0–15 V	01
04	Digital Multimeter	—	1 No.
05	Maximum Power Transfer Trainer Kit	—	2 Nos.
06	Connecting Probes	—	As required

Theory

The Maximum Power Transfer Theorem states that a DC source delivers maximum power to a variable load resistor (RL) when the load resistance equals the Thevenin's resistance (RTH) of the source network.

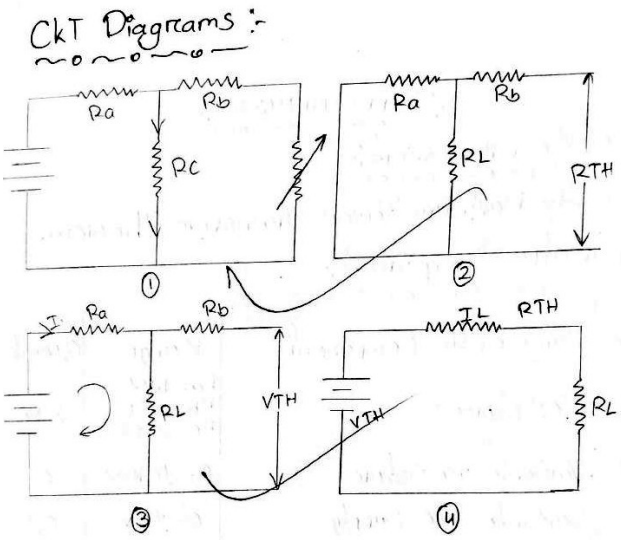


Fig.: Circuit diagrams for verification of Maximum Power Transfer Theorem – (1) given circuit, (2) measurement of RTH, (3) measurement of VTH, (4) equivalent circuit with load

Theoretical Calculation

(A) To find RTH (from Fig. No. 2)

$$RTH = (Ra \parallel Rc) + Rb = (Ra \times Rc) / (Ra + Rc) + Rb$$

$$= (1.77 \times 2.73) / (1.77 + 2.73) + 2.35 = 4.83 / 4.5 + 2.35$$

$$= 1.07 + 2.35 = 3.42\ k\Omega$$

(B) To find VTH (from Fig. No. 3)

$$I = V / (Ra + Rc) = 15 / 4.5 = 3.33\ mA$$

$$VTH = I \times Rc = 3.33 \times 2.73 = 9.09\ V$$

(C) To find IL (from Fig. No. 4)

$$IL = VTH / (RTH + RL), \text{ where } RTH = RL$$

$$IL = VTH / 2RL = 9.09 / 6.84 = 1.32\ mA$$

(D) Maximum Power

$$Pm = IL^2 \times RL = (1.32)^2 \times 3.42 = 1.74 \times 3.42 = 5.95\ mW$$

Procedure

To find RTH

1. Connect Ra, Rb and Rc as per circuit diagram No. 2.
2. Measure Ra, Rb and Rc with the help of the digital multimeter.
3. Measure RTH across AB using the digital multimeter.

To find VTH

1. Connect the voltage source V, Ra, Rb and Rc as per circuit diagram No. 3.
2. Switch on the power supply.
3. Note down VTH across AB using the digital multimeter.

To find IL

1. Adjust VTH using the variable DC supply.
2. Adjust RTH and RL using the variable resistors.
3. Connect VTH, RTH and RL as per circuit diagram No. 4.
4. Measure IL through RL with the help of the digital multimeter.
5. Calculate the maximum power using the formula $Pm = IL^2 RL$.

Observation Table

RTH (Th.) kΩ	RTH (Pr.) kΩ	VTH (Th.) V	VTH (Pr.) V	IL (Th.) mA	IL (Pr.) mA	Pm (Th.) mW	Pm (Pr.) mW
3.42	3.44	9.09	9.05	1.32	1.29	5.95	5.72

Conclusion

From the above experiment, I learnt how to verify the Maximum Power Transfer Theorem using the trainer kit.

EXPERIMENT NO. 04

Aim of the Experiment

Determination of current through a given branch of an electrical network using node analysis.

Apparatus Required

Sl. No.	Name of the Components	Range	Quantity
01	Variable DC Supply	0–15 V	1 No.
02	Resistors	Ra = 1.77 kΩ, Rb = 2.35 kΩ, Rc = 2.73 kΩ	3 Nos.
03	Digital Multimeter	—	1 No.
04	Electrical Network Trainer Kit	—	1 No.
05	Connecting Probes	—	As required

Theory

Node analysis is based on Kirchhoff's Current Law (KCL), which states that the algebraic sum of currents meeting at a node is zero ($\Sigma i = 0$).

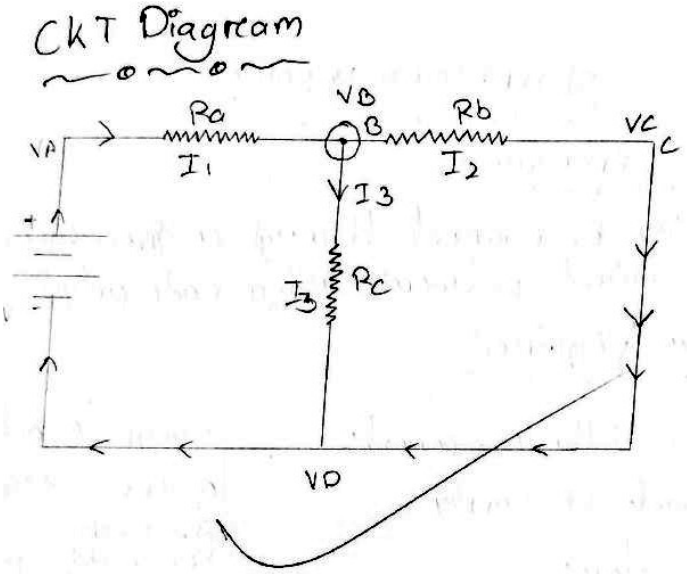


Fig.: Circuit diagram for node analysis

Theoretical Calculation

According to KCL at node B:

$$I1 - I2 - I3 = 0$$

$$(VA - VB) / Ra - (VB - VC) / Rb - (VB - VD) / Rc = 0$$

With VA = 10 V and VC = VD = 0:

$$(10 - VB) / Ra - VB / Rb - VB / Rc = 0$$

$$10 / Ra = VB / Ra + VB / Rb + VB / Rc$$

$$VB = (10 / Ra) / (1/Ra + 1/Rb + 1/Rc) = (10 / 1.77) / (1/1.77 + 1/2.35 + 1/2.73)$$

$$VB = 5.64 / (0.56 + 0.42 + 0.36) = 5.64 / 1.34 = 4.20\ V$$

$$I1 = (VA - VB) / Ra = (10 - 4.20) / 1.77 = 5.8 / 1.77 = 3.27\ mA$$

$$I2 = VB / Rb = 4.20 / 2.35 = 1.78\ mA$$

$$I3 = VB / Rc = 4.20 / 2.73 = 1.53\ mA$$

Procedure

1. Assemble the circuit on the electrical network trainer kit as shown in the circuit diagram.
2. Connect the regulated DC power supply to the network.
3. Switch on the DC power supply.
4. Adjust the supply voltage to 10 V.

5. Measure the branch currents I1, I2 and I3 using the digital multimeter.
6. Apply node analysis to determine the node voltage and calculate the branch currents theoretically.
7. Compare the theoretical values with the experimentally measured currents.
8. Switch off the supply after completing the experiment.

Observation Table

Supply Voltage (V)	Ra (kΩ)	Rb (kΩ)	Rc (kΩ)	I1 Th. (mA)	I1 Pr. (mA)	I2 Th. (mA)	I2 Pr. (mA)	I3 Th. (mA)	I3 Pr. (mA)
10	1.77	2.35	2.73	3.27	3.25	1.78	1.75	1.53	1.51

Conclusion

The current through the specified branch of the electrical network was successfully determined using the digital multimeter and verified by applying nodal analysis.

EXPERIMENT NO. 05

Aim of the Experiment

To use a voltmeter and an ammeter to determine the current through a given branch of an electric network by applying mesh analysis, and to verify the result experimentally.

Apparatus Required

Sl. No.	Name of the Components	Range	Quantity
01	Resistors	Ra = 1.76 kΩ, Rb = 2.35 kΩ, Rc = 2.72 kΩ	3
02	Regulated DC Power Supply	0–15 V	1 No.
03	Digital Multimeter	—	1 No.
04	Network Trainer Kit	—	1 No.
05	Connecting Probes	—	As required

Theory

Mesh analysis is based on Kirchhoff's Voltage Law (KVL), which states that the algebraic sum of the voltage drops around any closed loop is zero. A mesh is a loop that contains no other loop within it. A circulating mesh current is assigned to each mesh, usually in the clockwise direction, and a KVL equation is written for each mesh. For a network with n meshes, this gives n simultaneous equations in the n mesh currents.

The branch current is then obtained from the mesh currents. For a branch common to two meshes, it is the difference of the two mesh currents; for a branch in only one mesh, it equals that mesh current. Mesh analysis is most convenient when the network has more nodes than meshes and the sources are voltage sources.

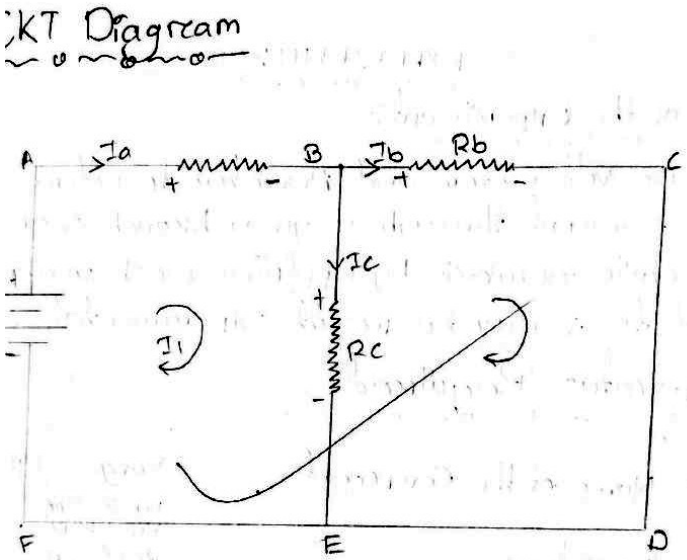


Fig.: Circuit diagram for mesh analysis

Theoretical Calculation

Applying KVL to loop ABEF:

$$V - Ia\,Ra - Ic\,Rc = 0 \quad \ldots\ldots(1)$$

Applying KVL to loop BCDE:

$$-Ib\,Rb + Ic\,Rc = 0 \quad \ldots\ldots(2)$$

By KCL:

$$Ia = Ib + Ic \quad \ldots\ldots(3)$$

Adding (1) and (2):

$$V - Ia\,Ra - Ib\,Rb = 0$$

$$10 - (Ib + Ic)\,Ra - Ib\,Rb = 0$$

$$Ib\,(Ra + Rb) + Ic\,Ra = 10 \quad \ldots\ldots(4)$$

Multiplying (2) by Ra and (4) by Rc and subtracting:

$$Ib = 10\,Rc / (Ra\,Rb + Rb\,Rc + Rc\,Ra)$$

$$Ib = 27.2 / (4.13 + 6.39 + 4.78) = 27.2 / 15.3 = 1.77\ mA$$

From equation (2):

$$Ic = (Ib \times Rb) / Rc = (1.77 \times 2.35) / 2.72 = 4.15 / 2.72 = 1.52\ mA$$

$$Ia = Ib + Ic = 1.77 + 1.52 = 3.29\ mA$$

Observation Table

Supply Voltage (V)	Ra (kΩ)	Rb (kΩ)	Rc (kΩ)	Ia Th. (mA)	Ia Pr. (mA)	Ib Th. (mA)	Ib Pr. (mA)	Ic Th. (mA)	Ic Pr. (mA)
10	1.76	2.35	2.72	3.29	3.28	1.77	1.78	1.52	1.53

Procedure

1. Draw the given network, mark the meshes and assign clockwise mesh currents.
2. Write the KVL equation for each mesh and solve the simultaneous equations for the mesh currents.
3. Compute the theoretical current through the specified branch from the mesh currents.
4. Connect Ra, Rb and Rc as per the circuit diagram.
5. Switch on the DC power supply and adjust it to 10 V.
6. Record the branch currents and voltages across the branches using the digital multimeter.
7. Tabulate the theoretical and measured currents and compute the percentage error.

Conclusion

From the above experiment, I learnt how to verify mesh analysis using an ammeter and a voltmeter.

EXPERIMENT NO. 06

Aim of the Experiment

To use a voltmeter and an ammeter to determine the current through a given branch and the voltage across a given element of a circuit by applying the superposition theorem.

Apparatus Required

Sl. No.	Name of the Components	Range	Quantity
01	Resistors	R1, R2, R3 (1–3 kΩ)	3 Nos.
02	Variable DC Supply	0–15 V (dual)	2 Nos.
03	DC Ammeter / Digital Multimeter	0–20 mA	3 Nos.
04	DC Voltmeter / Digital Multimeter	0–20 V	1 No.
05	Superposition Theorem Trainer Kit	—	1 No.
06	Connecting Probes	—	As required

Theory

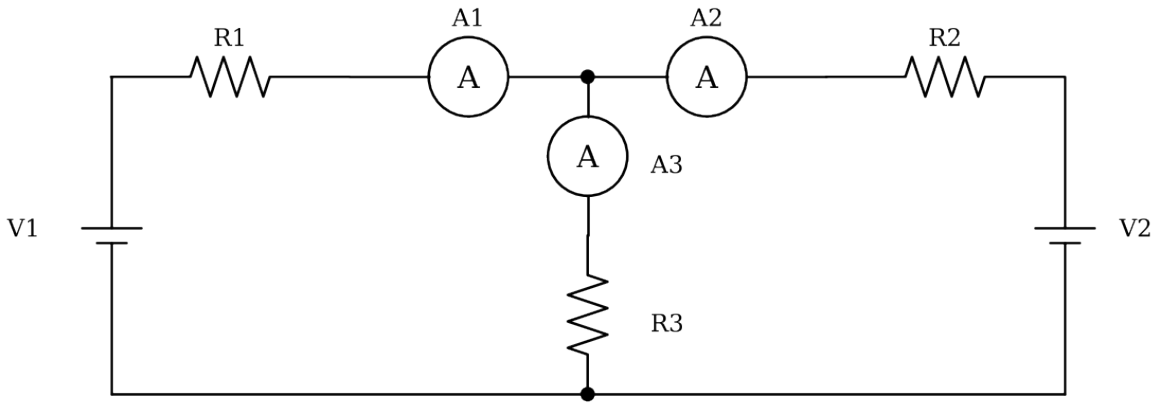
The superposition theorem states that in a linear, bilateral network containing more than one independent source, the current through (or voltage across) any element is equal to the algebraic sum of the currents (or voltages) produced by each source acting alone, with all other sources replaced by their internal resistances.

- An ideal voltage source is replaced by a short circuit.
- An ideal current source is replaced by an open circuit.

If I′ is the current through R3 when only V1 acts, and I″ is the current through R3 when only V2 acts, then:

$$I3 = I' + I''$$

$$V3 = I3 \times R3$$



V1 and V2: variable DC supplies (each can be replaced by a short circuit)

Fig.: Circuit diagram for verification of superposition theorem

Theoretical Calculation

(A) When V1 acts alone (V2 shorted):

$$\text{Total resistance } R = R1 + (R2 \times R3) / (R2 + R3)$$

$$I = V1 / R,\ I' = I \times R2 / (R2 + R3)$$

(B) When V2 acts alone (V1 shorted):

$$\text{Total resistance } R = R2 + (R1 \times R3) / (R1 + R3)$$

$$I = V2 / R,\ I'' = I \times R1 / (R1 + R3)$$

(C) When both sources act:

$$I3 = I' + I'',\ V3 = I3 \times R3$$

Procedure

1. Measure the values of R1, R2 and R3 with the digital multimeter.
2. Connect the circuit as per the circuit diagram.
3. Set V1 and V2 to the given values (e.g. V1 = 10 V, V2 = 5 V).
4. Switch on both supplies and note the current I3 through R3 and the voltage V3 across R3.
5. Remove V2, short its terminals, and note the current I′ through R3 with only V1 acting.
6. Reconnect V2, remove V1, short its terminals, and note the current I″ through R3 with only V2 acting.
7. Check that I3 = I′ + I″.
8. Compare the measured values with the theoretical values.

Observation Table

R1 = _____ kΩ, R2 = _____ kΩ, R3 = _____ kΩ

Condition	V1 (V)	V2 (V)	Current through R3 Th. (mA)	Current through R3 Pr. (mA)	Voltage across R3 Th. (V)	Voltage across R3 Pr. (V)
V1 alone		0				
V2 alone	0					
V1 and V2 together						

Conclusion

From the above experiment, I learnt how to verify the superposition theorem. The current through R3 with both sources acting was found to be equal to the sum of the currents due to each source acting alone.

EXPERIMENT NO. 07

Aim of the Experiment

To use a voltmeter, ammeter and wattmeter to determine the active, reactive and apparent power consumed in a given R-L-C series circuit, and to draw the phasor diagram.

Apparatus Required

Sl. No.	Name of the Components	Range	Quantity
01	Resistor (rheostat / lamp load)	100 Ω, 5 A	1 No.
02	Inductor (choke)	0.1–0.5 H	1 No.
03	Capacitor	10–50 µF, 440 V	1 No.
04	1-φ Variac	0–270 V	1 No.
05	AC Voltmeter (MI type)	0–300 V	1 No.
06	AC Ammeter (MI type)	0–5 A	1 No.
07	Wattmeter	5 A, 300 V	1 No.
08	Connecting Wires	1.5 mm²	As required

Theory

In an R-L-C series circuit, the same current I flows through all the elements. The voltage across R (VR) is in phase with I, the voltage across L (VL) leads I by 90°, and the voltage across C (VC) lags I by 90°.

$$V = \sqrt{[VR^2 + (VL - VC)^2]}$$

$$\text{Impedance } Z = V / I = \sqrt{[R^2 + (XL - XC)^2]}$$

$$XL = 2\pi fL, \quad XC = 1 / (2\pi fC)$$

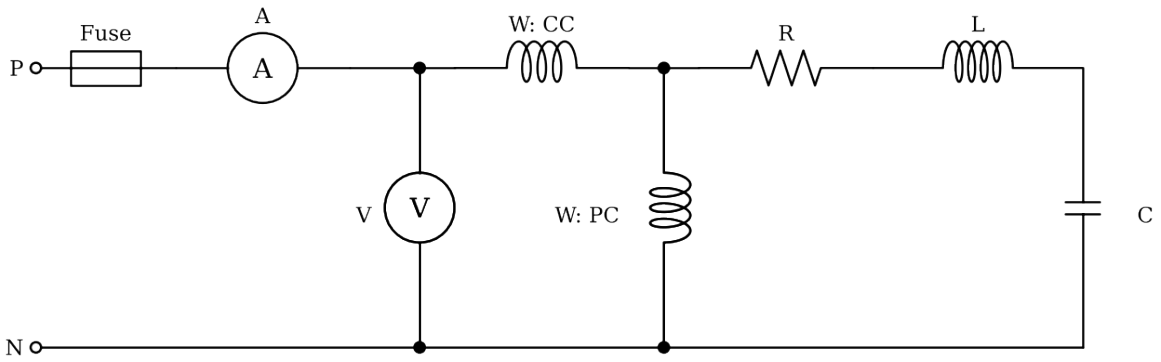
$$\text{Power factor } \cos\varphi = R / Z = P / (V \times I)$$

$$\text{Active power } P = V I \cos\varphi \ \ (W)$$

$$\text{Reactive power } Q = V I \sin\varphi \ \ (VAr)$$

$$\text{Apparent power } S = V I \ \ (VA), \quad S = \sqrt{(P^2 + Q^2)}$$

If XL > XC, the circuit is inductive and the current lags the voltage; if XC > XL, the circuit is capacitive and the current leads the voltage.



1-φ, 230 V, 50 Hz AC supply through variac (VR, VL, VC measured across R, L, C)

Fig.: Circuit diagram for R-L-C series circuit

Phasor Diagram

Take the current I as the reference phasor. Draw VR along I, VL leading I by 90° and VC lagging I by 90°. The resultant of VR and (VL − VC) is the supply voltage V, making an angle φ with I.

Procedure

1. Connect the circuit as per the circuit diagram.
2. Keep the variac at the zero position and switch on the supply.
3. Increase the voltage gradually to a suitable value.
4. Note the readings of the voltmeter, ammeter and wattmeter.
5. Measure VR, VL and VC across R, L and C with the voltmeter.
6. Repeat for different supply voltages.
7. Reduce the variac to zero and switch off the supply.
8. Calculate P, Q, S and cos φ, and draw the phasor diagram.

Observation Table

Sl. No.	V (V)	I (A)	W (W)	VR (V)	VL (V)	VC (V)	cos φ = W/VI	Q = VI sin φ (VAr)	S = VI (VA)
1									
2									
3									

Conclusion

From the above experiment, I learnt how to determine the active, reactive and apparent power consumed in an R-L-C series circuit and to draw its phasor diagram.

EXPERIMENT NO. 08

Aim of the Experiment

To create resonance in a given series R-L-C circuit using a variable frequency supply.

Apparatus Required

Sl. No.	Name of the Components	Range	Quantity
01	Function Generator (variable frequency supply)	0–1 MHz	1 No.
02	Resistor	100 Ω – 1 kΩ	1 No.
03	Inductor	10–100 mH	1 No.
04	Capacitor	0.1–1 µF	1 No.
05	AC Milliammeter / Digital Multimeter	0–100 mA	1 No.
06	AC Voltmeter / CRO	—	1 No.
07	Connecting Probes	—	As required

Theory

In a series R-L-C circuit, the inductive reactance XL = 2πfL increases with frequency and the capacitive reactance XC = 1/(2πfC) decreases with frequency. At one particular frequency, XL becomes equal to XC. This condition is called series resonance, and the frequency is called the resonant frequency (fr).

$$XL = XC \implies fr = 1 / (2\pi \sqrt{(LC)})$$

At resonance:

- The impedance is minimum and purely resistive: Z = R.
- The current is maximum: Ir = V / R.
- The power factor is unity (cos φ = 1).
- The voltages across L and C are equal and opposite, and can be much larger than the supply voltage.

$$Quality\ factor\ Q = (1/R) \sqrt{(L / C)} = fr / (f2 - f1)$$

where f1 and f2 are the half-power frequencies at which the current is 0.707 Ir.

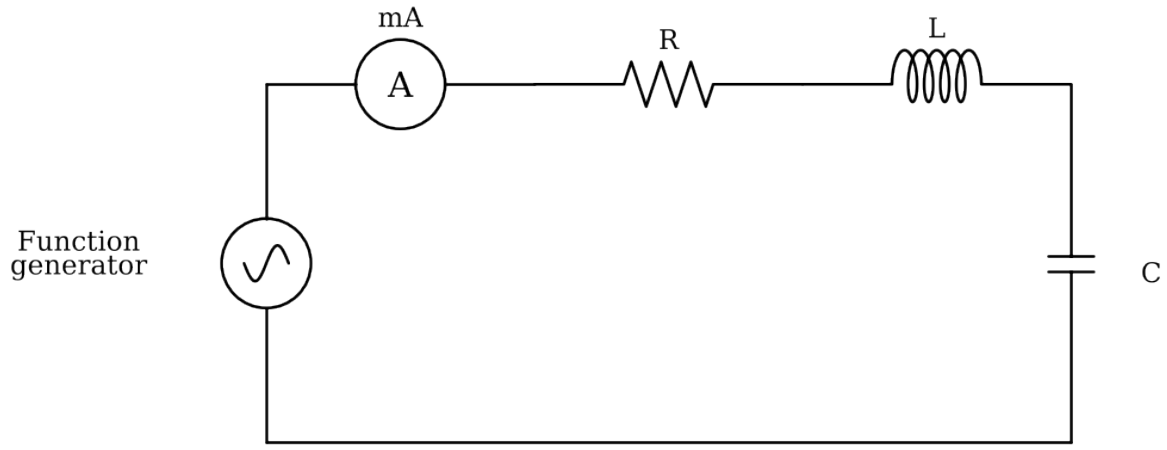


Fig.: Circuit diagram for series resonance

Procedure

1. Note the values of R, L and C and calculate the theoretical resonant frequency.
2. Connect the circuit as per the circuit diagram.
3. Set the output voltage of the function generator to a constant value (e.g. 5 V).
4. Vary the frequency in steps from a low value to a high value, keeping the voltage constant.
5. Note the current at each frequency.
6. Find the frequency at which the current is maximum; this is the resonant frequency.
7. Plot the graph of current versus frequency (resonance curve).
8. From the graph, find f1 and f2 at 0.707 Ir, and calculate the bandwidth and Q-factor.

Observation Table

R = _____ Ω, L = _____ mH, C = _____ μF, Supply voltage = _____ V

Sl. No.	Frequency f (Hz)	Current I (mA)
1		
2		
3		
4		
5		
6		
7		
8		

Calculation

$$\textit{Theoretical } fr = 1 / (2\pi \sqrt{(LC)})$$

Bandwidth = f2 − f1, Q = fr / (f2 − f1)

fr Theoretical (Hz)	fr Practical (Hz)	Ir (mA)	Bandwidth (Hz)	Q-factor

Conclusion

From the above experiment, I learnt how to create resonance in a series R-L-C circuit using a variable frequency supply. At resonance the current was maximum and the circuit behaved as a pure resistance.