SİVAS UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF ENGINEERING AND NATURAL SCIENCES

CIRCUIT THEORY - I LABORATORY

Experiments Manual Report

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SİVAS

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Experiment 1: Resistor and Ohm Law

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1. Objective of the Experiment

The objective of this laboratory experiment is to familiarize students with essential electrical measurement equipment commonly used in engineering laboratories. Specifically, the experiment focuses on the practical operation and application of instruments such as the digital multimeter and DC power supply. By engaging with these devices, students will develop a foundational understanding of their functions, capabilities, and limitations. The experiment aims to enhance students' proficiency in basic electrical measurements, circuit troubleshooting, and power supply configuration, which are critical skills in both academic and professional electrical engineering environments.

2. Theoretical Background

Understanding the behavior of electric circuits requires a foundational grasp of fundamental laws and the tools used for measurement. This experiment emphasizes Ohm's Law and the proper use of two critical instruments: the DC power supply and the digital multimeter.

In an electrical circuit, voltage (V) refers to the electrical potential difference between two points and indicates the amount of energy available to move electric charges through the circuit. Current (I) is the rate at which electric charges flow through a conductor, and it is measured in amperes (A). The ease or difficulty with which current flows is determined by resistance (R), which is the property of a material that opposes the flow of electric current and is measured in ohms (Ω). These three fundamental quantities are related by Ohm's Law, forming the basis of basic circuit analysis.

Ohm's Law is the cornerstone of circuit theory, stating that the current flowing through a conductor between two points is directly proportional to the voltage across the two points and inversely proportional to the resistance of the conductor:

$$V = I.R$$

This relationship is essential for analyzing and designing both simple and complex electrical circuits.

3. Materials Used

A DC power supply, or direct current power supply, is a device that provides a constant and steady voltage output in the form of direct current. Direct current is an electrical current that flows in one direction, as opposed to alternating current (AC), which periodically reverses direction. The DC power supply is used to generate either a constant voltage (CV) or a constant current (CC). That is, it may be used as either a DC voltage source or a DC current source. You will be using it primarily as a voltage source. Recall that DC is an acronym for direct current. The voltage produced by the power supply is controlled by the knob labeled voltage. The current is limited by adjusting the knob labeled current. As long as the circuit does not attempt to draw more current than the value set by the current knob, the voltage will remain constant. This is often a difficult concept for students to grasp. Current limiting allows the power supply to be set such that it will not generate more current than it is safe.

This can be useful as a safety feature, preventing electrocution due to accidental contact with terminals. In addition, current limiting can prevent damage to equipment and parts that may be unable to handle excessive currents. DC power supplies are used in a variety of electronic and electrical applications where a stable and controlled voltage is required to power electronic circuits, devices, or components. Fig. 1.1 is an example DC power supply. It also consists of positive, negative, and ground terminals.

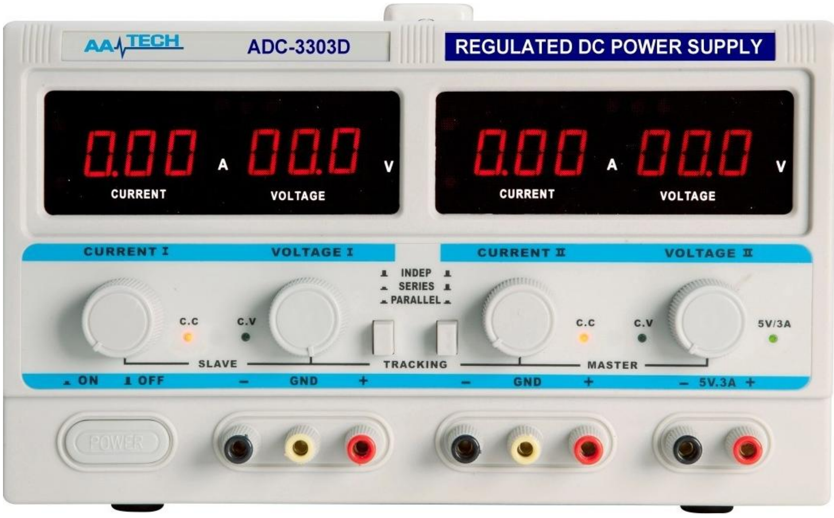


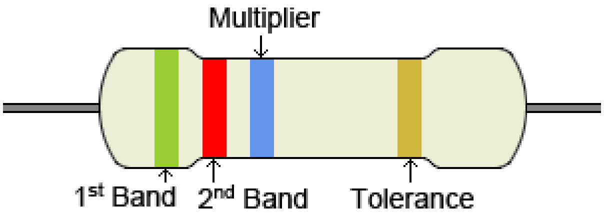
Fig. 1.1: DC power supply (two separate DC sources).

A digital multimeter a versatile tool used to measure electrical parameters in electronic circuits and devices. It typically combines several functions in one handheld device, including voltage measurement, current measurement, and resistance measurement. As can be seen in Fig.1.2, the face of a multimeter typically includes four components:
Display: Where measurement readouts can be viewed.
Buttons: For selecting various functions; the options vary by model.
Dial (or rotary switch): For selecting primary measurement values (volts, amps, ohms).
Input jacks: Where test leads are inserted.

Fig. 1.2: Multimeter

To effectively use a digital multimeter, the first step is to select the appropriate type of measurement using the device's dial or rotary switch. This allows the user to choose between voltage, current, or resistance measurements depending on the task at hand. The second step is to set the range—especially important if the multimeter does not feature auto-ranging. For instance, if voltage is being measured, one must select an appropriate range such as volts (V) or millivolts (mV) to match the expected value. The third step involves connecting the test leads properly: the red lead (positive) should be inserted into the VΩ jack, and the black lead (negative) into the COM (common) jack. In the fourth step, voltage can be measured by touching the probe tips to the specific points in the circuit, with careful attention to polarity (red to positive, black to negative) and ensuring the multimeter is set to DC voltage when required. The fifth step covers current measurements, which require moving the red lead to the current (A) jack and inserting the multimeter in series with the circuit—this involves breaking the circuit and placing the meter within the loop. Finally, the sixth step is resistance measurement: the dial is set to the resistance (Ω) position, and the test leads are applied across the component. If measuring a resistor, it must be isolated from any powered circuit to avoid inaccurate readings. By following these systematic steps, users can safely and accurately utilize a multimeter for various electrical measurements.

As indicated in Fig. 1.3. to determine the resistance value of a resistor, the color bands printed on its body must be read from left to right. These bands follow a standardized color code system. The first band represents the first significant digit of the resistance value, while the second band indicates the second significant digit. The third band serves as the multiplier, denoting the power of ten by which the combined digits are multiplied. An optional fourth band, often gold or silver, represents the tolerance of the resistor, indicating the percentage range within which the actual resistance may vary from its nominal value. Understanding and interpreting these color bands is essential for identifying resistor specifications accurately during circuit design and analysis.



Color	1st, 2nd Band Significant Figures	Multiplier	Tolerance
Black	0	× 1	
Brown	1	× 10	±1% (F)
Red	2	× 100	±2% (G)
Orange	3	× 1K	±0.05% (W)
Yellow	4	× 10K	±0.02% (P)
Green	5	× 100K	±0.5% (D)
Blue	6	× 1M	±0.25% (C)
Violet	7	× 10M	±0.1% (B)
Grey	8	× 100M	±0.01% (L)
White	9	× 1G	
Gold		× 0.1	±5% (J)
Silver		× 0.01	±10% (K)

Fig. 1.3: Color code chart for four-band resistors.

As shown in Fig. 1.4. a mnemonic in Turkish can help students easily remember the resistor color code sequence. Each color is associated with an initial letter and placed into a memorable sentence: "Sokakta Sayamam Gibi".

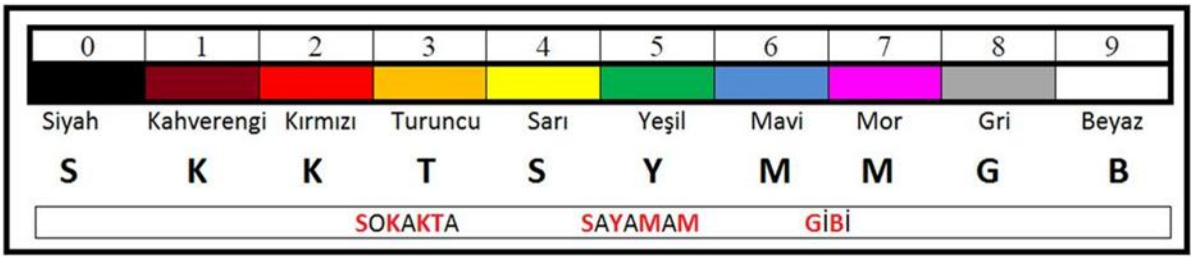


Fig. 1.4: Turkish mnemonic aid for remembering resistor color codes.

4. Procedure

Part 1: Voltage Measurement.

1. Turn on the DC Power supply.
2. Make sure that the current knob is a little bit above the minimum value
3. Adjust the voltage knob at 6.5 V.

4. Measure the voltage value using the digital multimeter, and write down the measured value.
5. Find the percentage of error for the measured values using the equation in Fig. 1.5.
6. State the reasons of the error.

$$Percentage\ error\ =\ \left|\frac{Measured\ Value\ -\ True\ Value}{True\ Value}\right| \times 100\%$$

Fig. 1.5: Formula of percentage of error

Part 2: Resistance Measurement.
1. Read the color bands on the provided resistor and determine its resistance value using the color code chart.
2. Measure the resistance of the same resistor using a digital multimeter.
3. Assume the resistor is connected to a 3V DC power supply. Using Ohm's Law, calculate the current that would flow through the resistor.
4. Using a breadboard, connect the resistor to a DC power supply and set the voltage to 5V.
5. Measure the current flowing through the resistor using the digital multimeter.

5. Evaluation of Results

Tabulate the data obtained during the tests.

Table.1.1. Voltage Measurement

True Value	Measured Value	Percentage Error

Table.1.2. Resistance Measurement

Resistance value based on color codes	Measured Value of Resistor	Estimated current value	Measured current value

6. Safety Precautions

- Ensure all circuit connections are correct before powering the circuit to avoid short circuits or damage to components.
- Always turn off the DC power supply before modifying the circuit or changing component values on the breadboard.
- Use appropriate resistor values as specified, and avoid exceeding their power ratings to prevent overheating.

- Do not touch conductive parts while the circuit is powered; even low voltages can cause burns or shocks in case of faulty connections.
- Place measurement probes securely when using a multimeter to avoid accidental slips that may cause short circuits.
- Keep the work area dry and organized, and handle all instruments with dry hands to minimize the risk of electrical accidents.
- Check power supply voltage settings before connecting to the circuit to ensure they match the experiment requirements.

7. References

- Alexander, C. K., Sadiku, M. N., & Sadiku, M. (2007). Fundamentals of electric circuits (pp. 34-39). Boston, MA, USA: McGraw-Hill Higher Education.

Experiment 2: Kirchhoff's Laws

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1. Objective of the Experiment

The objective of this laboratory experiment is to introduce students to the fundamental principles of Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL), which are essential for analyzing electrical circuits. By constructing and examining the provided resistor networks, students will apply nodal and loop analysis techniques to calculate currents and voltage drops across various elements. The experiment aims to reinforce the theoretical understanding of current and voltage conservation in electrical circuits and to develop practical skills in measurement using digital multimeter. Through direct comparison of calculated and measured values, students will gain insight into real-world deviations and improve their ability to interpret and verify circuit behavior using Kirchhoff's laws.

2. Theoretical Background

In circuit analysis, understanding the flow of current and distribution of voltage is essential for accurate evaluation of electrical networks. Two fundamental principles that govern these behaviors are Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL), both of which are derived from the conservation laws of physics.

Kirchhoff's Current Law (KCL) states that the total quantity of current that enters to the node is equal to the current that leaves the node. Therefore, the total current towards the node is equal to zero in other words. Fig. 2.1 shows an example of Kirchhoff's Current Law.

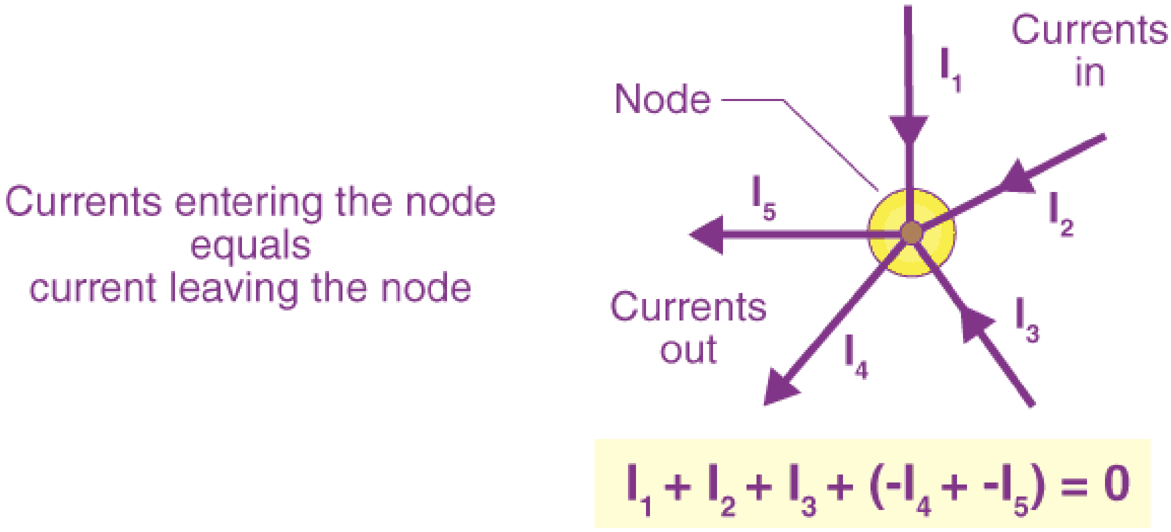

Fig. 2.1: Kirchhoff's Current Law Example

Kirchhoff's Voltage Law states that the sum of voltages around a loop is equal to zero. Fig. 2.2 shows an example of Kirchhoff's Voltage Law example.

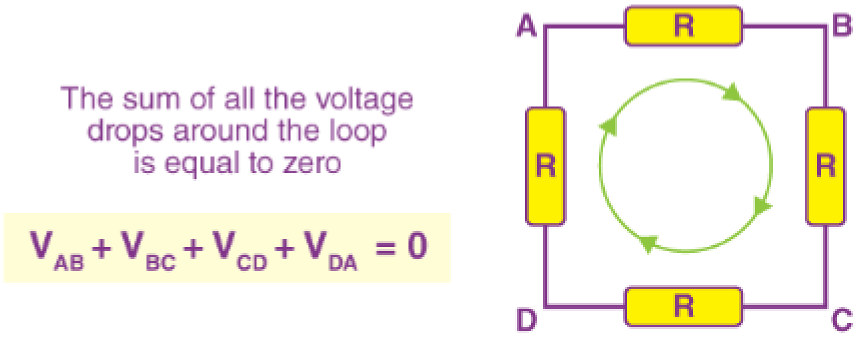

Fig. 2.2: Kirchhoff's Voltage Law Example

By applying KCL and KVL together, any linear electrical circuit can be systematically analyzed. These laws form the foundation of network theory and are essential for verifying the correctness of circuit designs and understanding their behavior under different conditions. In this experiment, students will explore these laws by building simple resistor networks, taking precise measurements, and comparing experimental data with theoretical predictions.

3. Materials Used

- Breadboard
- DC power supply
- Four 1kΩ resistors, one 2.2kΩ resistor, one 330kΩ resistor, and one 100kΩ resistor
- Multimeter

4. Preliminary(PreLab)

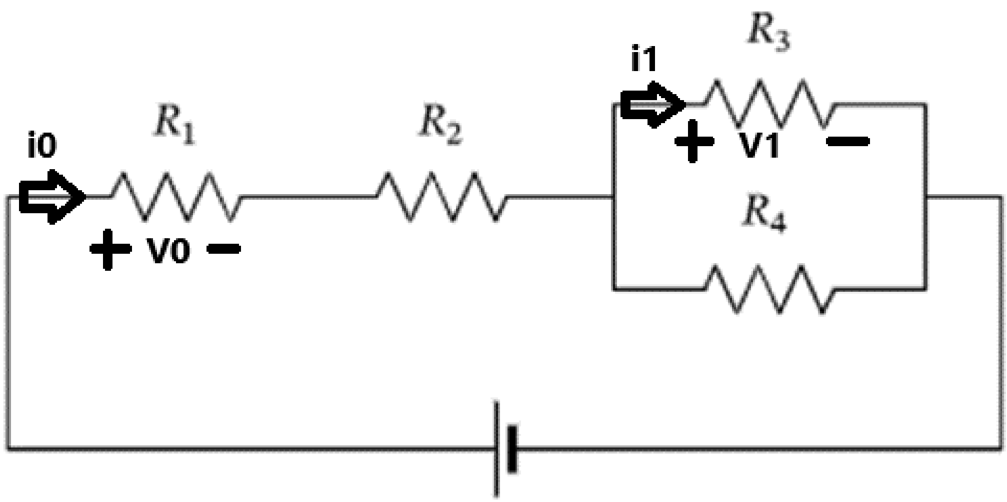

Fig. 2.3: Circuit for prelab section

For the circuit shown in Fig. 2.3;

First situation

- DC voltage supply to 12 V.

- R_1 = 1k Ω, R_2 = 1k Ω, R_3 = 1k Ω, R_4 = 1k Ω
  Calculate i_0, i_1, V_0, V_1.

Second situation

- DC voltage supply to 20 V.
- R_1 = 1k Ω, R_2 = 2.2k Ω, R_3 = 330k Ω, R_4=100k Ω
  Calculate i_0, i_1, V_0, V_1

5. Procedure

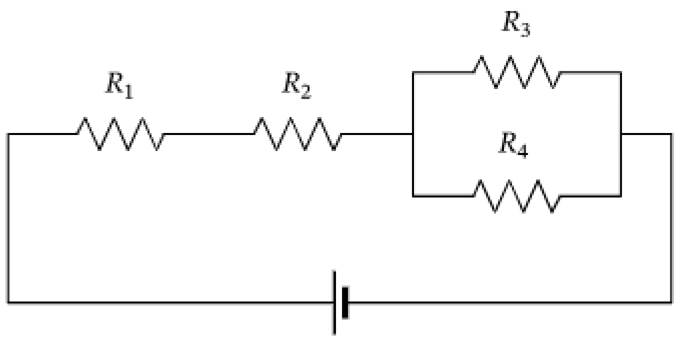

Fig. 2.4: Circuit for experiment

1. Build the circuit given in Fig. 2.4 with given resistance values and dc voltage supply to 12 V.
   R_1 = 1k Ω, R_2 = 1k Ω, R_3 = 1k Ω, R_4 = 1k Ω.
2. Connect the voltmeter to measure the voltage drop on each resistor.
3. Note your readings of measurements.
4. Disconnect the voltmeter and connect the amperemeter to measure current passes through each resistor.
5. Note your readings of measurements.
6. Change resistors for given resistance values:
   R_1 = 1k Ω, R_2 = 2.2k Ω, R_3 = 330k Ω R_4=100k Ω
7. Repeat the steps for measurement and recordings.
8. Compare your calculations with the measurements and comment on the results in the post lab report

6. Evaluation of Results

Tabulate the data obtained during the tests.

Table 2.1. Measured voltage and current values on the resistors in the circuit

	R1(1k Ω)	R2(1k Ω)	R3(1k Ω)	R4(1k Ω)
I(mA)				
V(Volt)				

Table 2.2. Measured voltage and current values on the resistors in the circuit

	R1(1k Ω)	R2(2.2k Ω)	R3(330k Ω)	R4(100k Ω)
I(mA)				
V(Volt)				

7. Safety Precautions

- Ensure all circuit connections are correct before powering the circuit to avoid short circuits or damage to components.
- Always turn off the DC power supply before modifying the circuit or changing component values on the breadboard.
- Use appropriate resistor values as specified, and avoid exceeding their power ratings to prevent overheating.
- Do not touch conductive parts while the circuit is powered; even low voltages can cause burns or shocks in case of faulty connections.
- Place measurement probes securely when using a multimeter to avoid accidental slips that may cause short circuits.
- Keep the work area dry and organized, and handle all instruments with dry hands to minimize the risk of electrical accidents.
- Check power supply voltage settings before connecting to the circuit to ensure they match the experiment requirements.

8. References

- Alexander, C. K., Sadiku, M. N., & Sadiku, M. (2007). Fundamentals of electric circuits (pp. 34-39). Boston, MA, USA: McGraw-Hill Higher Education.

Experiment 3: Node Analysis

1. Objective of the Experiment

The primary objective of this experiment is to introduce students to the concept of node (nodal) analysis, which is a fundamental method for analyzing complex electrical circuits. By focusing on the behavior of electrical potentials at circuit nodes, students will learn how to apply Kirchhoff's Current Law (KCL) systematically to determine unknown voltages and currents in multi-branch circuits. The experiment is designed to enhance students' analytical skills in identifying nodes, setting up nodal equations, and solving them to interpret circuit behavior both theoretically and experimentally.

2. Materials Used

- Breadboard
- DC power supply
- One 2.2kΩ resistor, one 3.3kΩ resistor and one 4.7kΩ resistor
- Multimeter

3. Preliminary(PreLab)

For the circuit shown in Fig. 3.1; (with Node Analysis)

1- Calculate the voltages of nodes A and B.

2- Find the branch currents I_1, I_2, I_3, I_4, I_5 in the circuit.

3- Show the circuit on Proteus

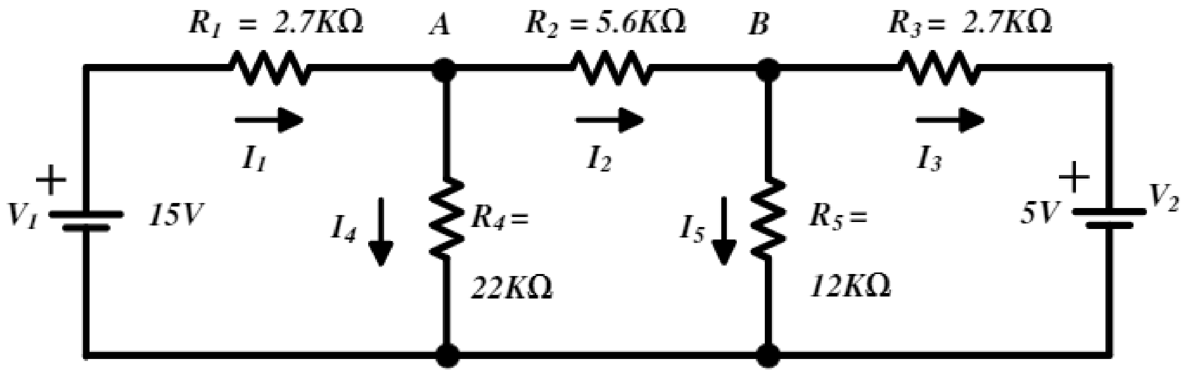

Fig. 3.1: Circuit for prelab section

4. Procedure

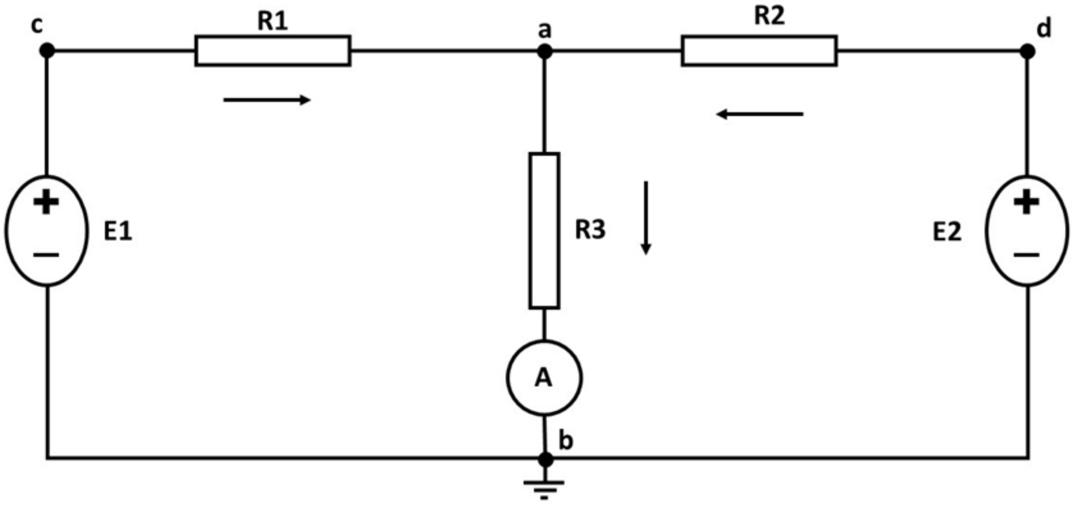

Fig. 3.2: Circuit for experiment

1. Solve the circuit in Fig. 3.2 theoretically. Obtain I_{R1}, I_{R2}, I_{R3}, and V_{ab} values.
2. Build the circuit given in Fig. 3.1 with given resistance values and dc voltage supply. E1 = 12V, E2 = 20V, R1 = 2.2k Ω, R2 = 3.3k Ω and R3 = 4.7k Ω.
3. Connect the voltmeter to measure the voltage drop on each resistor.
4. Note your readings of measurements.
5. Disconnect the voltmeter and connect the amperemeter to measure current passes through each resistor.
6. Note your readings of measurements.

5. Evaluation of Results

Tabulate the data obtained during the tests.

Table 3.1. Measured current values on the resistors in the circuit.

	R1(2.2k Ω)	R2(3.3k Ω)	R3(4.7k Ω)
I(mA)			

Table 3.2. Measured voltage values in the circuit.

	V_{ab}	V_{ac}	V_{ad}
V(Volt)			

Table 3.3. Comparison table of theoretical and measured data.

	R1	R2	R3	V_{ab}
Theoretically calculated data				
Measured data				

6. Safety Precautions

- Ensure all circuit connections are correct before powering the circuit to avoid short circuits or damage to components.
- Always turn off the DC power supply before modifying the circuit or changing component values on the breadboard.
- Use appropriate resistor values as specified, and avoid exceeding their power ratings to prevent overheating.
- Do not touch conductive parts while the circuit is powered; even low voltages can cause burns or shocks in case of faulty connections.
- Place measurement probes securely when using a multimeter to avoid accidental slips that may cause short circuits.
- Keep the work area dry and organized, and handle all instruments with dry hands to minimize the risk of electrical accidents.
- Check power supply voltage settings before connecting to the circuit to ensure they match the experiment requirements.

7. References

- Alexander, C. K., Sadiku, M. N., & Sadiku, M. (2007). Fundamentals of electric circuits (pp. 34-39). Boston, MA, USA: McGraw-Hill Higher Education.

Experiment 4: Mesh Analysis

1. Objective of the Experiment

The objective of this experiment is to introduce students to mesh analysis, a systematic method for analyzing planar electrical circuits using Kirchhoff's Voltage Law (KVL). By identifying independent loops (meshes) within a circuit and applying KVL to each, students will learn how to derive a set of simultaneous equations that can be solved to determine unknown currents. The experiment reinforces theoretical knowledge through practical measurement of voltages and currents across various circuit elements, allowing students to compare analytical predictions with real-world data. This process enhances their understanding of current distribution in multi-loop circuits and improves their circuit analysis skills using fundamental laws of electricity.

2. Materials Used

- Breadboard
- DC power supply
- Two 1kΩ resistors, one 2.2kΩ resistor, one 3.3kΩ resistor, and one 4.7kΩ resistor
- Multimeter

3. Preliminary(PreLab)

For the circuit shown in Fig. 4.1; (with Mesh Analysis)
1- Calculate the voltages of resistors.
2- Find the branch currents I_1 and I_2 in the circuit.

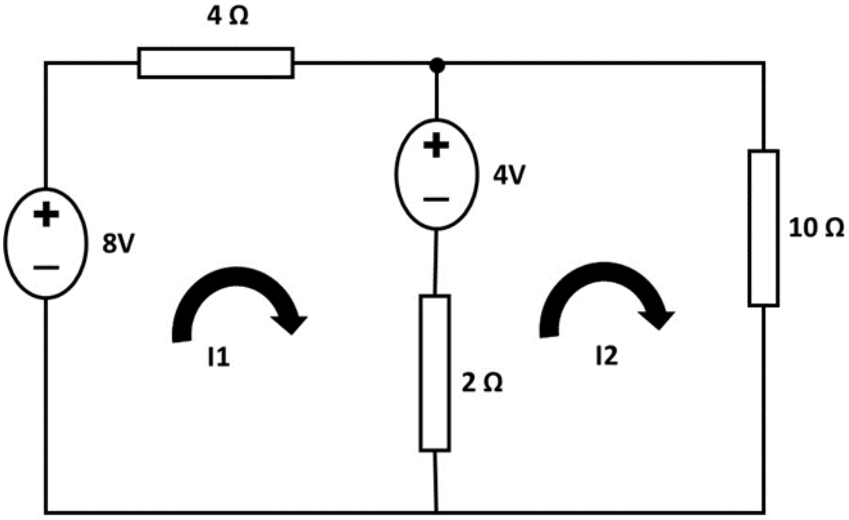

Fig. 4.1: Circuit for prelab section

4. **Procedure**

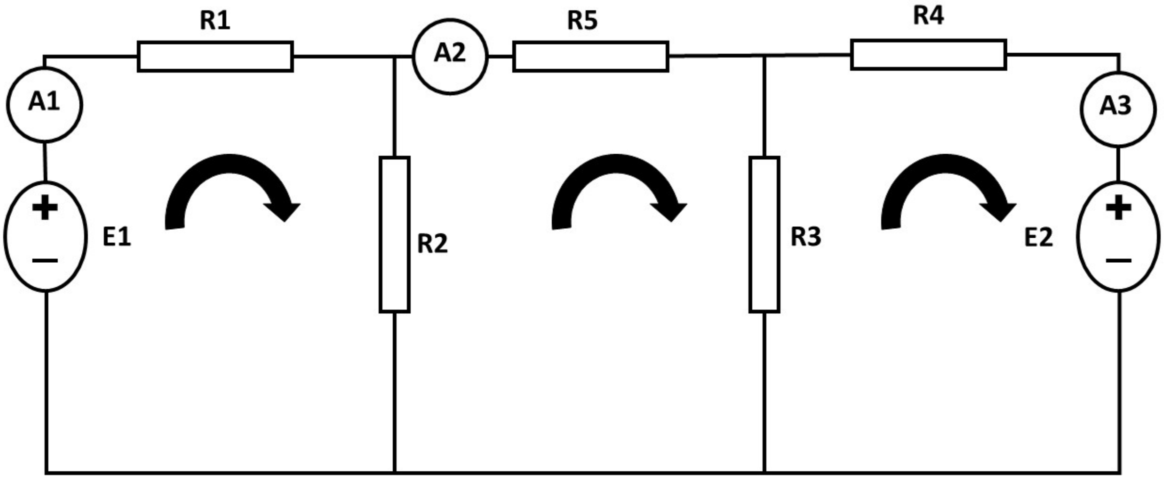

Fig. 4.1: Circuit for experiment

1. Build the circuit given in Fig. 4.1 with given resistance values and DC voltage supply E1 = 12V E2 = 20V R1 = 1k Ω, R2 = 3.3k Ω, R3 = 2.2k Ω, R4 = 4.7k Ω and R5 = 1k Ω.
2. Connect the voltmeter to measure the voltage drop on each resistor.
3. Note your readings of measurements.
4. Disconnect the voltmeter and connect the amperemeter to measure current passes through each resistor.
5. Note your readings of measurements.
6. Compare your calculations with the measurements and comment on the results in the post lab report

5. **Evaluation of Results**

Tabulate the data obtained during the tests.

Table 4.1. Measured current values on the circuit.

	A1	A2	A3
I(mA)			

Table 4.2. Measured voltage and current values in the circuit.

	R1(1k Ω)	R2(3.3k Ω)	R3(2.2k Ω)	R4(4.7k Ω)	R5(1k Ω)
V(Volt)					
I(mA)					

Table 4.3. Comparison table of theoretical and measured data.

	I_{R1}	I_{R4}	I_{R5}	V_{R3}
Theoretically calculated data				
Measured data				

6. Safety Precautions

- Ensure all circuit connections are correct before powering the circuit to avoid short circuits or damage to components.
- Always turn off the DC power supply before modifying the circuit or changing component values on the breadboard.
- Use appropriate resistor values as specified, and avoid exceeding their power ratings to prevent overheating.
- Do not touch conductive parts while the circuit is powered; even low voltages can cause burns or shocks in case of faulty connections.
- Place measurement probes securely when using a multimeter to avoid accidental slips that may cause short circuits.
- Keep the work area dry and organized, and handle all instruments with dry hands to minimize the risk of electrical accidents.
- Check power supply voltage settings before connecting to the circuit to ensure they match the experiment requirements.

7. References

- Alexander, C. K., Sadiku, M. N., & Sadiku, M. (2007). Fundamentals of electric circuits (pp. 34-39). Boston, MA, USA: McGraw-Hill Higher Education.

Experiment 5: Thevenin and Norton Equivalent Circuits

1. Objective of the Experiment

The objective of this experiment is to provide students with a comprehensive understanding of Thevenin's and Norton's Theorems, which are fundamental tools in circuit simplification and analysis. Students will first explore the theoretical foundation of these theorems, learning how any linear electrical network can be reduced to an equivalent voltage or current source with a single equivalent resistance. Then, through practical implementation, they will verify the validity of these theorems by constructing circuits, taking measurements, and comparing the results with theoretical predictions. This experiment aims to strengthen students' ability to analyze complex circuits using equivalent models.

2. Theoretical Background

2.1- Thevenin's Theorem

A linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source Vth in series with a resistor Rth, where Vth is the open-circuit voltage at the terminals and Rth is the input or equivalent resistance at the terminals when the independent sources are turned off.

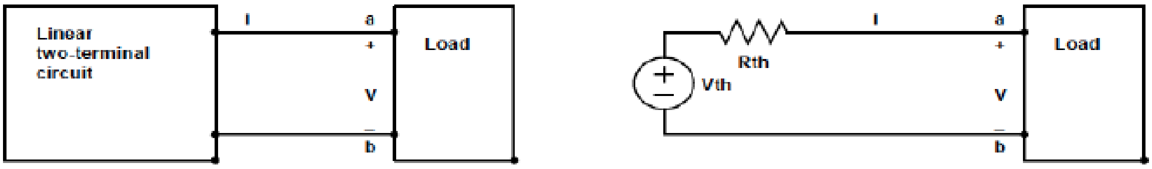

Fig. 5.1: Replacing a linear two-terminal circuit by its Thevenin equivalent: (a) original circuit, (b) the Thevenin equivalent circuit

2.2- Norton's Theorem

A linear two-terminal circuit can be replaced by an equivalent circuit consisting of a current source IN in parallel with a resistor RN, where IN is the short-circuit current through the terminals and RN is the input or equivalent resistance at the terminal when the independent sources are turned off.

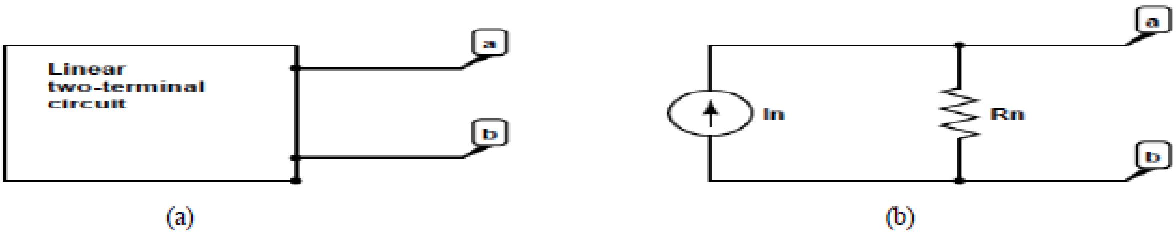

Fig.5.2: (a) Original circuit, (b) Norton equivalent

3. Materials Used

- Breadboard
- DC power supply
- Three 1kΩ resistors, one 2.2kΩ resistor and one 330Ω resistor
- Multimeter

4. Preliminary(PreLab)

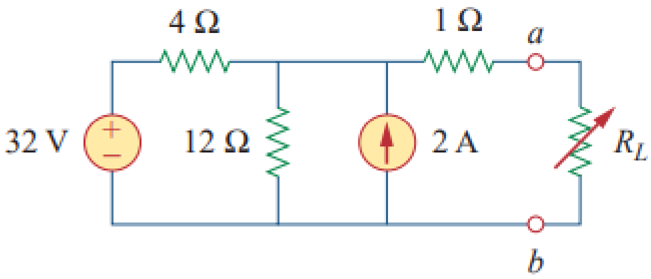

Fig. 5.3: Circuit for prelab section

Find the Thevenin equivalent circuit of the circuit as shown in Fig. 5.3.

Solve the circuit at Fig. 5.4 theoretically. Add the findings to the theoretical column in Table 5.1.

5. Procedure

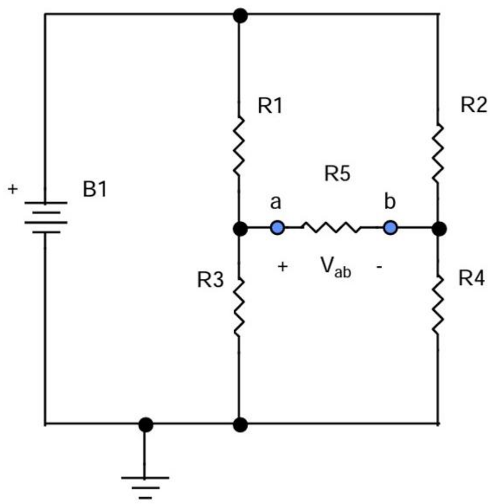

Fig. 5.4: Test Circuit for Part 1 of the Experiment

1. Build the circuit given in Fig. 5.4 with given resistance values and dc voltage supply to: B1 = 12V, R1 = 1k Ω, R2 = 1k Ω, R3 = 2.2k Ω, R4 = 330 Ω and R5 = 1k Ω
2. Connect the voltmeter to measure the voltage drop on R5.
3. Note your readings of measurements.
4. Remove the 1 kΩ resistor from the circuit in Fig 5.4. and measure Thevenin's open circuit voltage, V_{OC}, for the remaining circuit. Fig 5.5. shows the circuit used to make the open circuit voltage measurements.

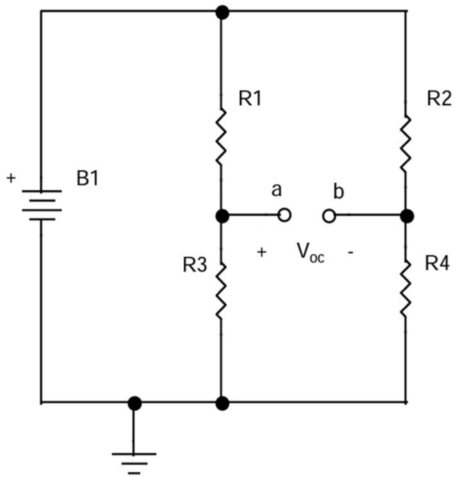

Fig. 5.5: Circuit Connections for Measuring Thevenin's Open Circuit Voltage

5. Connect an ammeter between points a and b as shown in Fig 5.6. and measure the short circuit current, I_{SC}. Record the value in Table 5.1 for future use. Note the positive direction of the current flow.

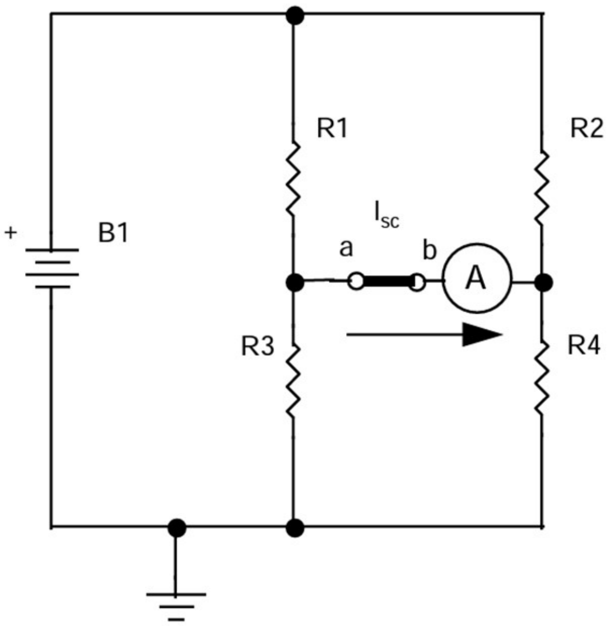

Fig. 5.5: Short Circuit Current Measurement.

6. From the measurements made in parts 2 and 3, calculate the Thevenin's equivalent resistance for the circuit. This is numerically equal to Norton's equivalent resistance. Use the formula below to find these values.

$$R_{TH} = R_N = \frac{V_{oc}}{I_{sc}},$$

where: R_{TH} = the Thevenin's equivalent resistance
R_N = the Norton's equivalent resistance.

Fig. 5.6: Mathematical relationship showing the equivalence of Thevenin's and Norton's resistances

7. Calculate the theoretical values of R_{TH}, R_N, V_{OC}, and I_{SC} for the circuit above. Record the computed values in Table 5.1.
8. Using Thevenin's equivalent circuit, compute the value of V_{ab} with the 1kΩ resistor attached to points a-b.
9. Using Norton's equivalent circuit, compute the value of V_{ab} with the 1kΩ resistor attached to points a-b.

6. Evaluation of Results

Tabulate the data obtained during the tests.

Table 5.1. Measured voltage and current values on the resistors in the circuit

Quantity	Value	
	Measured	Theoretical
V_{ab}(V)		
V_{OC}(V)		
I_{SC}(mA)		
R_{TH}		
R_N		
V_{ab}(Thevenin)		
V_{ab}(Norton)		

$$\%error = \frac{(\text{theoretical value - measured value})}{\text{theoretical value}} \times 100\%$$

Fig. 5.7: Percentage error between theoretical and measured values in circuit experiments.

7. Safety Precautions

- Ensure all circuit connections are correct before powering the circuit to avoid short circuits or damage to components.
- Always turn off the DC power supply before modifying the circuit or changing component values on the breadboard.
- Use appropriate resistor values as specified, and avoid exceeding their power ratings to prevent overheating.
- Do not touch conductive parts while the circuit is powered; even low voltages can cause burns or shocks in case of faulty connections.
- Place measurement probes securely when using a multimeter to avoid accidental slips that may cause short circuits.
- Keep the work area dry and organized, and handle all instruments with dry hands to minimize the risk of electrical accidents.
- Check power supply voltage settings before connecting to the circuit to ensure they match the experiment requirements.

8. References

- Alexander, C. K., Sadiku, M. N., & Sadiku, M. (2007). Fundamentals of electric circuits (pp. 34-39). Boston, MA, USA: McGraw-Hill Higher Education.

Experiment 6: Superposition Theorem

1. Objective of the Experiment

The objective of this experiment is to introduce students to the Superposition Theorem, a fundamental principle in linear circuit analysis. The experiment aims to demonstrate that in a linear network with multiple independent sources, the voltage or current at any component can be determined by considering the contribution of each source separately, while all other independent sources are replaced by their internal impedances. Students will gain practical experience by analyzing circuits with multiple sources, calculating partial contributions, and verifying the overall response by summing individual effects. This reinforces the understanding of linear system behavior and the superposition principle, which is essential in analyzing complex electrical circuits systematically.

2. Theoretical Background

The Superposition Theorem is a fundamental method used in the analysis of linear DC circuits that contain more than one independent source. According to the theorem, the voltage across or the current through any element in a linear circuit is equal to the algebraic sum of the responses produced by each independent source acting alone. When applying the theorem, each independent source is considered separately while the others are deactivated—meaning that voltage sources are replaced with short circuits and current sources with open circuits.

This approach relies on the linearity property of the circuit, which ensures that the principle of additivity and proportionality holds true. Only passive linear components such as resistors can be included when using superposition; the presence of non-linear elements like diodes would invalidate the method.

The analysis involves solving the circuit multiple times, each time with only one source active. After computing the partial voltages or currents from each source, the final result is obtained by summing them algebraically. For instance, if a resistor has a current I_1 due to one source and I_2 due to another, the total current through the resistor when both sources are active is $I_{total} = I_1 + I_2$.

In this experiment, students will construct a DC resistive network with two or more independent sources, calculate and measure the response due to each source individually, and then verify that the combined effect matches the response when all sources are active. This procedure reinforces the concept of linear superposition and enhances systematic problem-solving skills in circuit analysis.

3. Materials Used

- Breadboard
- DC power supply
- One 1kΩ resistor one 10kΩ resistor and one 4.7kΩ resistor

- Multimeter

4. Preliminary(PreLab)

In the circuit in Fig 6.1. find the V_0 output voltage in terms of V_i, R_1 and R_2, assuming that the op-amp is ideal and operates in the linear region.
Solve the circuit at Fig. 6.1 theoretically with given values below:
R_1= 6,8kΩ, R_2= 4,7 KΩ, R_3 = 10kΩ, v_1= 5V, v_2= 10V
Add the findings to the Table 6.1.

Table 6.1. Theoretically calculated data of Fig 6.1

	I_{V1}	I_{V2}	I_{total}
I(mA)			

5. Procedure

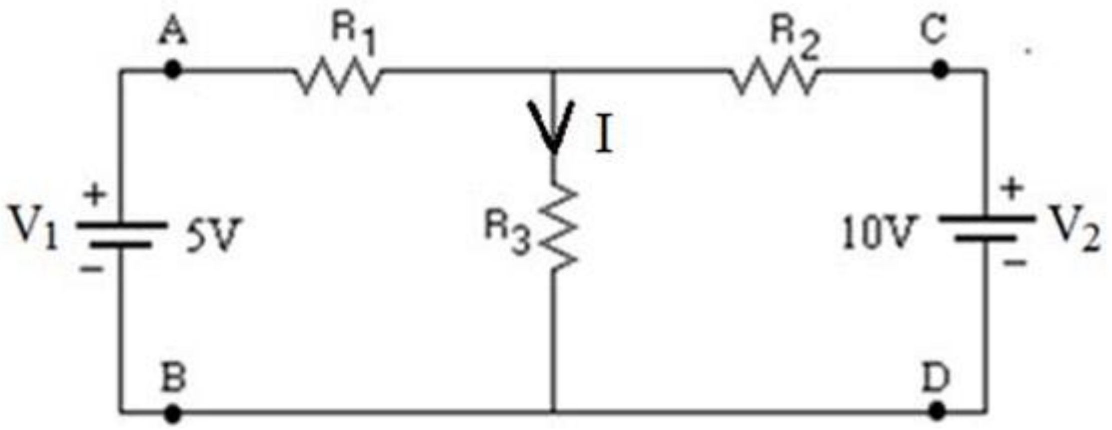

Fig. 6.1: Circuit for experiment

1. Build the circuit given in Fig. 6.1 with given resistance values and dc voltage supply to :
   R_1= 1kΩ, R_2= 4,7 KΩ, R_3 = 10kΩ, V_1= 5V, V_2= 10V,
2. Connect the amperemeter to measure current.
3. Note your readings of measurements.
4. Remove the V_1 from the circuit in Fig 6.1.
5. Connect the amperemeter to measure current.
6. Note your readings of measurements.
7. Remove the V_2 from the circuit in Fig 6.1.
8. Connect the amperemeter to measure current.
9. Note your readings of measurements.

6. Evaluation of Results

Tabulate the data obtained during the tests.

Table 6.2. Measured voltage and current values on the resistors in the circuit

	I_{total}	I_{V1}	I_{V2}
I(mA)			

7. Safety Precautions

- Ensure all circuit connections are correct before powering the circuit to avoid short circuits or damage to components.
- Always turn off the DC power supply before modifying the circuit or changing component values on the breadboard.
- Use appropriate resistor values as specified, and avoid exceeding their power ratings to prevent overheating.
- Do not touch conductive parts while the circuit is powered; even low voltages can cause burns or shocks in case of faulty connections.
- Place measurement probes securely when using a multimeter to avoid accidental slips that may cause short circuits.
- Keep the work area dry and organized, and handle all instruments with dry hands to minimize the risk of electrical accidents.
- Check power supply voltage settings before connecting to the circuit to ensure they match the experiment requirements.

8. References

- Alexander, C. K., Sadiku, M. N., & Sadiku, M. (2007). Fundamentals of electric circuits (pp. 34-39). Boston, MA, USA: McGraw-Hill Higher Education.

Experiment 7: OPAMP

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1. Objective of the Experiment

The objective of this experiment is to analyze the behavior of an operational amplifier in a differential input configuration, where two separate input voltages are applied simultaneously. By using an ideal op-amp model operating in the linear region, students will investigate how the output voltage V_0 depends on the input voltages V_1 and V_2 , as well as on the resistor values that determine the gain. The experiment aims to reinforce theoretical understanding of differential amplification and common-mode rejection, while also allowing students to experimentally validate their calculations by constructing the circuit and measuring the resulting output. Through this, students gain practical insight into how op-amp circuits process multiple input signals and how resistor selection influences amplification behavior.

2. Theoretical Background

An Operational amplifiers (op-amps) are versatile components widely used in analog signal processing. In a differential amplifier configuration, the op-amp amplifies the voltage difference between two input terminals, typically labeled V_1 and V_2. This configuration is essential in applications where the signal of interest is the difference between two voltages, such as in sensor signal conditioning, audio amplification, and analog computation.

Assuming the op-amp operates in the linear region and behaves ideally (infinite input impedance, zero output impedance, and infinite open-loop gain), the voltage difference between the inverting and non-inverting terminals is approximately zero (virtual short), and no current flows into the input terminals.

The general output voltage V_0 of a differential amplifier can be expressed as:

$$V_0 = A_d(V_2 - V_1)$$

where A_d is the differential gain, determined by the resistor values in the feedback and input paths. In symmetric configurations, the gain can be designed as:

$$V_0 = \left(\frac{R_2}{R_1}\right)(V_2 - V_1)$$

where R_1 and R_2 define the input and feedback resistor pairs for each input path.

In this experiment, students construct such a differential amplifier using the LM741 op-amp, as shown in Fig. 7.1, apply different voltage values to V_1 and V_2, and observe how the output responds. The behavior of the output will confirm the linear superposition principle and demonstrate how resistor ratios directly affect gain. This reinforces both theoretical circuit analysis and practical measurement skills.

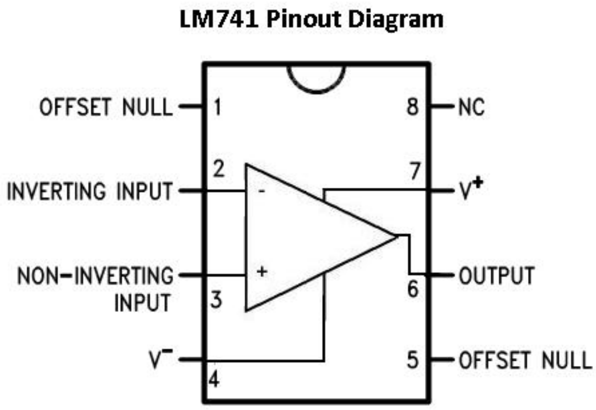


Fig. 7.1: Pinout Diagram of LM741

3. Materials Used

- Breadboard
- DC power supply
- Two 1kΩ resistors one 10kΩ resistor, one 330Ω resistor and one LM741
- Multimeter
- Osiloscope

4. Preliminary(PreLab)

In the circuit in Fig.7.2., assuming that the op-amp is ideal and operates in the linear region, find the output voltage V_0 in terms of V_i (with V_1 and V_2).

5. Procedure

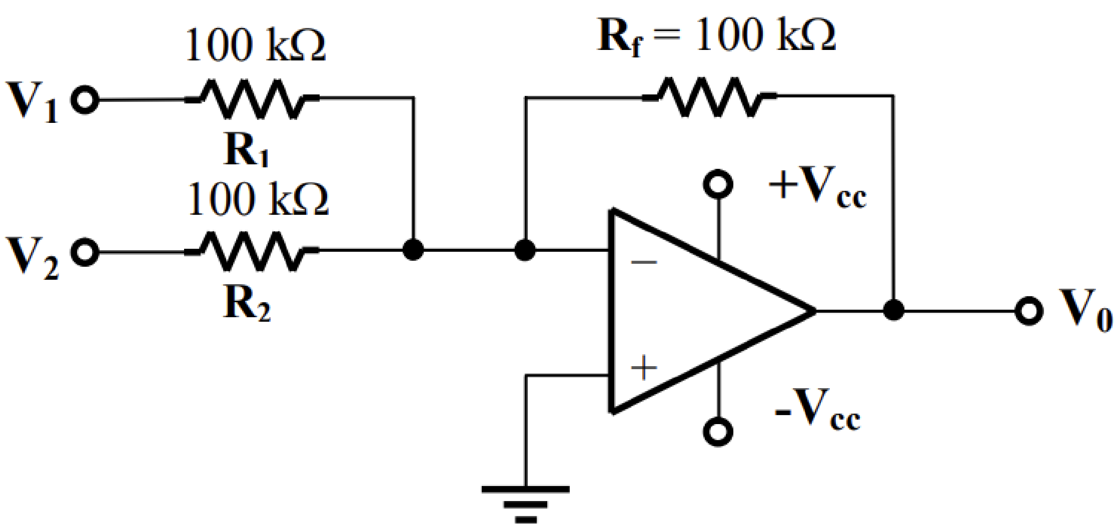


Fig. 7.2: Circuit for experiment

10. Build the circuit given in Fig. 7.2 with given resistance values and dc voltage supply to :
    V_1 = 0V, V_2 = 1V, +V_{CC} = 12V, -V_{CC} = -12V, R_1 = 100k Ω, R_2 = 100k Ω, R_f = 100k Ω,
11. Connect the voltmeter to measure the voltages.
12. Note your readings of measurements.
13. Change voltages for given voltage values:
    V_1 = 1V, V_2 = 0V
14. Connect the voltmeter to measure the voltages.
15. Note your readings of measurements.
16. Change voltages for given voltage values:
    V_1 = 1V, V_2 = 1V
17. Connect the voltmeter to measure the voltages.
18. Note your readings of measurements.
19. Change voltages for given voltage values:
    V_1 = -1V, V_2 = 1V
20. Connect the voltmeter to measure the voltages.
21. Note your readings of measurements.
22. Change voltages for given voltage values:
    V_1 = -2V, V_2 = 4V
23. Connect the voltmeter to measure the voltages.
24. Note your readings of measurements.

6. Evaluation of Results

Tabulate the data obtained during the tests.

Table 7.1. Measured voltage and current values on the resistors in the circuit

	V_1 = 0V V_2 = 1V	V_1 = 1V V_2 = 0V	V_1 = 1V V_2 = 1V	V_1 = -1V V_2 = 1V	V_1 = -2V V_2 = 4V
V_0(Volt)					

Answer following comments:

1) Comment on whether there is a parallelism between the signal gain you observed as a result of the experiments and the one you found. Here, state how the R1 and R2 resistors affect the gain separately.

2) Compare the V0 values you found in the preliminary preparation section with the values you obtained in the experiment. If there is a difference, what could be the reasons?

3) Considering the results you obtained from the experiment, comment on the purposes for which the circuit can be used.

7. Safety Precautions

- Ensure all circuit connections are correct before powering the circuit to avoid short circuits or damage to components.
- Always turn off the DC power supply before modifying the circuit or changing component values on the breadboard.
- Use appropriate resistor values as specified, and avoid exceeding their power ratings to prevent overheating.
- Do not touch conductive parts while the circuit is powered; even low voltages can cause burns or shocks in case of faulty connections.
- Place measurement probes securely when using a multimeter to avoid accidental slips that may cause short circuits.
- Keep the work area dry and organized, and handle all instruments with dry hands to minimize the risk of electrical accidents.
- Check power supply voltage settings before connecting to the circuit to ensure they match the experiment requirements.

8. References

- Alexander, C. K., Sadiku, M. N., & Sadiku, M. (2007). Fundamentals of electric circuits (pp. 34-39). Boston, MA, USA: McGraw-Hill Higher Education.

Experiment 8: CAPACITANCE

1. Objective of the Experiment

The objective of this experiment is to examine the fundamental characteristics of capacitors and to observe the effect of capacitance in electrical circuits. Through both theoretical analysis and simulation-based implementation, students will explore how capacitors store and release energy, and how their behavior varies depending on the type of applied voltage. The experiment focuses on analyzing voltage and current relationships in RC circuits, understanding the time-dependent nature of capacitor charging and discharging, and visualizing the transient response $V_C(t)$ under different resistance values. This provides a foundational understanding of capacitive components in circuit dynamics and their role in filtering, timing, and energy storage applications.

2. Theoretical Background

A capacitor is a passive electrical component that stores energy in the form of an electric field between two conductive plates separated by a dielectric (insulating) material. When a voltage is applied across the plates, positive and negative charges accumulate on opposite sides, creating an electric field that opposes changes in voltage.

In DC circuits, once a capacitor is fully charged, it behaves like an open circuit—preventing further current flow. However, in AC circuits, the capacitor continuously charges and discharges as the voltage changes direction, allowing alternating current to pass depending on the signal frequency. The opposition a capacitor offers to AC is called capacitive reactance, given by the formula:

$$X_C = \frac{1}{2\pi f C}$$

where X_C is the reactance in ohms, f is the frequency in hertz, and C is the capacitance in farads. In RC (resistor-capacitor) circuits, the charging and discharging of a capacitor follow exponential functions described by the time constant τ=RC. The voltage across the capacitor as a function of time during charging is given by:

$$V_C(t) = V_{max}(1 - e^{-t/RC})$$

and during discharging:

$$V_C(t) = V_0 e^{-t/RC}$$

These relationships are essential for understanding the transient response of circuits, signal filtering, and timing operations. In this experiment, students will investigate how different resistor values affect the charging rate of a capacitor by plotting $V_C(t)$, thus gaining insight into the dynamic behavior of capacitive components in time-varying circuits.

3. Materials Used

- Breadboard
- DC power supply
- One 1kΩ resistor, one 10kΩ resistor, one 330Ω resistor and 2.2mF capacitor
- Multimeter
- Osiloscope

4. Preliminary(PreLab)

1. Calculate per resistance value for each τ value in given Fig. 8.1.
2. Implement the circuit in proteus.
3. Find the V(t) and I(t) for each situation.
4. Tabulate the calculated data.

Table 8.1. Calculated resistance values

Values	R
τ = 7.26 sec C = 2.2mF	
τ = 10.34 sec C = 2.2mF	
τ = 22 sec C = 2.2mF	

5. Procedure

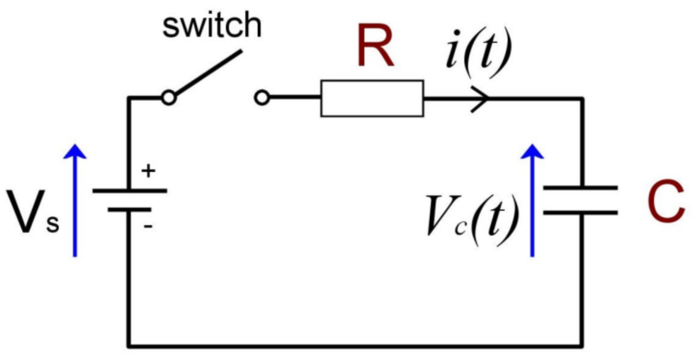


Fig. 8.1: Circuit for experiment

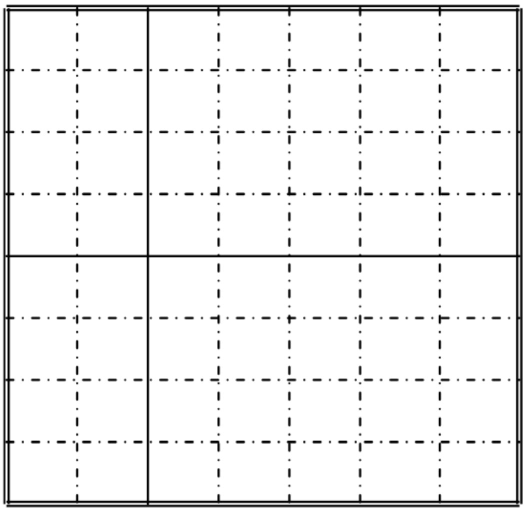
1. Build the circuit given in Fig. 8.1. with given resistance values and dc voltage supply to : V_S = 12V, R = 1k Ω, C=2.2mF
2. Note your readings of measurements.
3. Change resistors for given resistance values:
   R1 = 10k Ω,
4. Note your readings of measurements.
5. Change resistors for given resistance values:

R1 = 330 Ω,

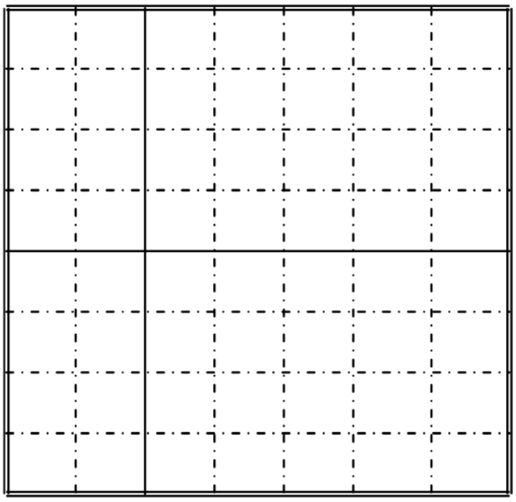
6. Note your readings of measurements.

6. Evaluation of Results

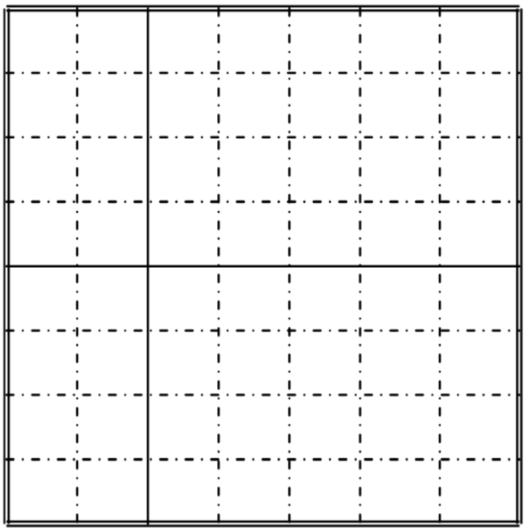
Draw the data obtained during the tests.



Case 1



Case 2



Case 3

7. Safety Precautions

- Ensure all circuit connections are correct before powering the circuit to avoid short circuits or damage to components.
- Always turn off the DC power supply before modifying the circuit or changing component values on the breadboard.

- Use appropriate resistor values as specified, and avoid exceeding their power ratings to prevent overheating.
- Do not touch conductive parts while the circuit is powered; even low voltages can cause burns or shocks in case of faulty connections.
- Place measurement probes securely when using a multimeter to avoid accidental slips that may cause short circuits.
- Keep the work area dry and organized, and handle all instruments with dry hands to minimize the risk of electrical accidents.
- Check power supply voltage settings before connecting to the circuit to ensure they match the experiment requirements.

8. References

- Alexander, C. K., Sadiku, M. N., & Sadiku, M. (2007). Fundamentals of electric circuits (pp. 34-39). Boston, MA, USA: McGraw-Hill Higher Education.

Experiment 9: RLC Circuits

1. Objective of the Experiment

The objective of this experiment is to analyze the time-domain behavior of series and parallel RLC circuits powered by a DC voltage source. The aim is to help students understand how resistors (R), inductors (L), and capacitors (C) interact in different configurations when subjected to a constant voltage. Students will observe the transient response of the circuits during switching events, such as the charging and discharging of capacitors and the buildup of current in inductors. Through both theoretical analysis and practical measurements, the experiment demonstrates how energy is stored and exchanged between inductive and capacitive elements, and how resistance affects the rate of change in current and voltage. This provides a foundation for understanding dynamic circuit behavior in DC-powered systems.

2. Theoretical Background

An RLC circuit is an electric circuit composed of three passive components: a resistor (R), an inductor (L), and a capacitor (C). When powered by a DC voltage source, these components interact in characteristic ways, particularly during the transient period immediately after the source is applied or removed. In a series RLC circuit, the resistor, inductor, and capacitor are connected end-to-end in a single path for current flow. Upon closing the circuit, the capacitor begins to charge and the inductor initially resists changes in current due to its stored magnetic energy. The transient behavior of the circuit is governed by a second-order differential equation derived from Kirchhoff's Voltage Law (KVL). The solution to this equation describes the voltage and current as a function of time, depending on the damping factor determined by the R, L, and C values. The circuit may exhibit overdamped, critically damped, or underdamped behavior before reaching a steady-state DC condition, in which the inductor behaves as a short circuit and the capacitor as an open circuit. In contrast, a parallel RLC circuit has the resistor, inductor, and capacitor connected in parallel branches between two common nodes. When a DC voltage is applied, the capacitor begins to charge and the inductor resists the sudden rise in current in its branch. The transient response here is also described by a second-order differential equation, but the current distribution among the branches differs significantly from that of the series configuration. In the steady-state, current flows only through the resistive and inductive paths, while the capacitor maintains a constant voltage. For both configurations, the transient response is the key aspect under DC excitation. The inductor stores energy in the form of a magnetic field ($E_L = \frac{1}{2}LI^2$) and resists sudden changes in current, while the capacitor stores energy in an electric field ($E_C = \frac{1}{2}CI^2$) and resists sudden changes in voltage. The resistor dissipates energy and contributes to the damping of oscillatory responses. In this experiment, students will build series and parallel RLC circuits using a DC power supply, observe and analyze the time-dependent behavior of current and voltage, and relate their findings to theoretical predictions. This enhances understanding of energy exchange, damping effects, and transient dynamics in reactive circuits.

3. Materials Used

- Breadboard
- DC power supply
- One 100Ω resistor, one 1mH inductor, one 100mH inductor, one 10nF capacitor and one 1μF capacitor
- Multimeter
- Osiloscope
- Function generator

4. Preliminary(PreLab)

The theoretical solution for the circuits presented in Fig. 9.1 and Fig. 9.2 must be determined, and the results must be depicted in Fig. 9.3. Subsequently, the circuits in Fig. 9.1 and Fig. 9.2 should be simulated, and the results must be presented in Fig. 9.4.

5. Procedure

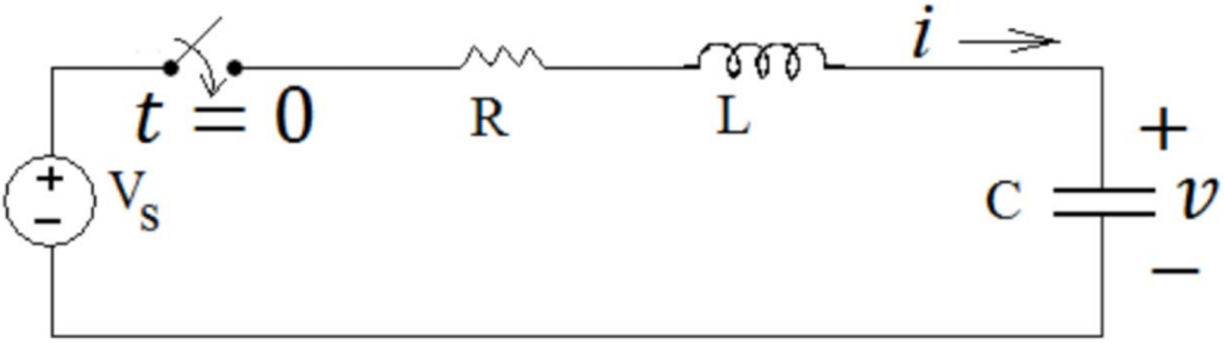


Fig. 9.1: First circuit for experiment

1. Set up the circuit shown in Fig. 9.1 using R = 100 Ω, L = 100 mH, and C = 1 μF.
2. The circuit will be powered by a 30 V DC voltage source.
3. In this experiment, measurements will be made using an oscilloscope.
   a. 1. The oscilloscope probe (CH1) will remain fixed across the resistor.
   b. 2. The oscilloscope probe (CH2) will be used to measure across the capacitor and the inductor.
4. Initially, keep the switch open and apply the required voltage to the circuit.
5. Close the switch and observe the voltage change across the resistor (CH1) and the capacitor (CH2). Plot the change over time.
6. Open the switch and short-circuit the terminals of the power supply.
7. Close the switch again and this time observe the voltage change across the resistor (CH1) and the inductor (CH2). Plot the change over time.
8. Remove the 100 mH inductor from the circuit and replace it with a 1 mH inductor, then repeat the steps of the experiment.
9. Remove the 1 μF capacitor from the circuit and replace it with a 10 nF capacitor, then repeat the steps of the experiment. (At this stage, the 100 mH inductor should be used.)
10. Remove the 30 V DC supply and apply a PULSE signal of 200 Hz frequency and 10 V amplitude using a function generator (repeat the experiment for all component variations).

11. Observe and interpret the time-dependent behavior of V_R, V_C and V_L voltages on the oscilloscope screen.

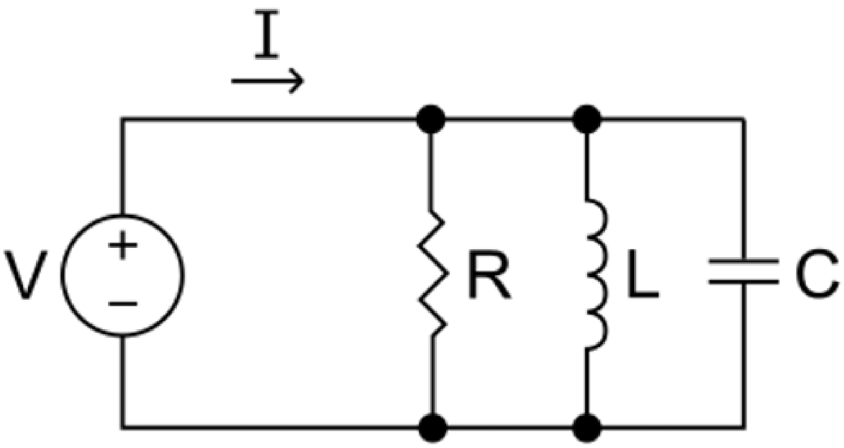


Fig. 9.2: Second circuit for experiment

1. Set up the circuit shown in Fig. 9.2 using R = 100 Ω, L = 100 mH, and C = 1 μF.
2. Power the circuit with a 30 V DC voltage source.
3. In this experiment, measurements will be made using an oscilloscope. Connect the first probe (CH1) of the oscilloscope in parallel with the capacitor. Since the voltage across all components in a parallel circuit is the same, only the output across the capacitor will be observed in this experiment.
4. Close the switch and observe the voltage change across the capacitor (CH1). Plot the voltage-time graph.
5. Remove the 30 V DC supply and apply a PULSE signal with 200 Hz frequency and 10 V amplitude using a function generator.
6. Observe the time-domain variation of the output voltage on the oscilloscope screen and include a photograph of the waveform in your lab report.

6. Evaluation of Results

Plot the given graphs based on the results you obtained.

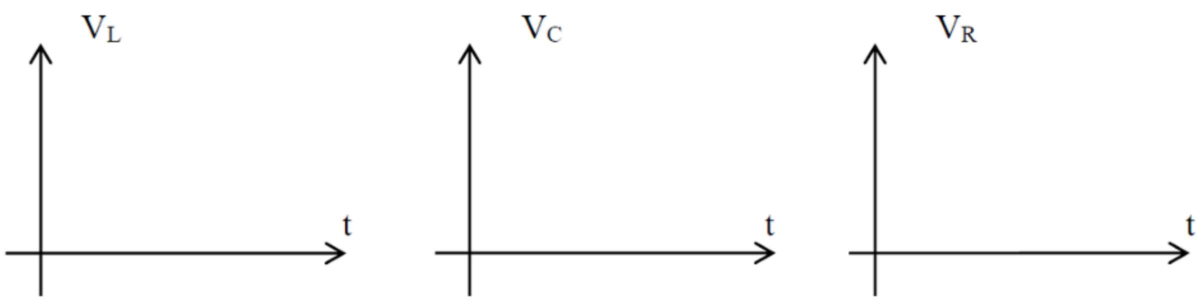


Fig. 9.3: Theoretical voltage vs. time plots

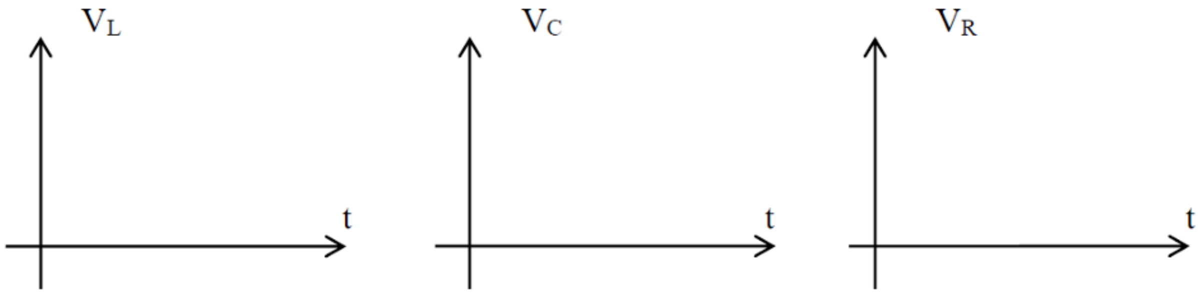


Fig. 9.4: Simulated voltage vs. time plots

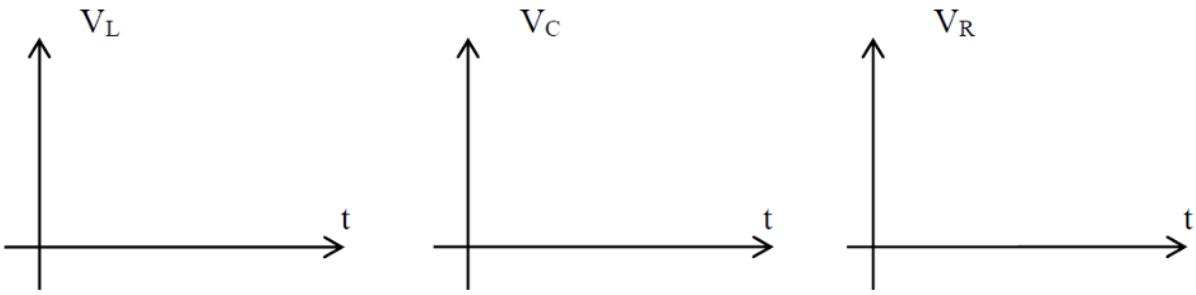


Fig. 9.5: Measured voltage vs. time plots

7. Safety Precautions

- Ensure all circuit connections are correct before powering the circuit to avoid short circuits or damage to components.
- Always turn off the DC power supply before modifying the circuit or changing component values on the breadboard.
- Use appropriate resistor values as specified, and avoid exceeding their power ratings to prevent overheating.
- Do not touch conductive parts while the circuit is powered; even low voltages can cause burns or shocks in case of faulty connections.
- Place measurement probes securely when using a multimeter to avoid accidental slips that may cause short circuits.
- Keep the work area dry and organized, and handle all instruments with dry hands to minimize the risk of electrical accidents.
- Check power supply voltage settings before connecting to the circuit to ensure they match the experiment requirements.

8. References

- Alexander, C. K., Sadiku, M. N., & Sadiku, M. (2007). Fundamentals of electric circuits (pp. 34-39). Boston, MA, USA: McGraw-Hill Higher Education.