Lab Report for EE202 Circuit Analysis

Laboratory 2

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1 Introduction

This lab aims to determine the current through a specific resistor and the voltage across its nodes using Thevenin's and Norton's theorems and superposition, based on circuit measurements under short-circuit and open-circuit conditions.

1.1 Preliminary Work

1.1.1 Pre Task 1

To determine the Thevenin and Norton of the circuit shown in **Figure 1.**, below steps are followed:
To find R_{eq}:

1. **Short the voltage source** by replacing it with a wire.

2. **Remove** R_3 to analyze the circuit without it.

3. **Find** R_{eq} by simplifying the resistor network.

Following these steps, the circuit in **Figure 2** is obtained. In this configuration, R_1 and R_5 are in parallel, as well as R_2 and R_4. The equivalent resistance, R_{eq}, is calculated as:

$$R_{eq} = R_{(1,5)} + R_{(2,4)}$$

where:

$$R_{(1,5)} = \frac{R_1 R_5}{R_1 + R_5} = \frac{4.7\text{k}\Omega \times 1\text{k}\Omega}{4.7\text{k}\Omega + 1\text{k}\Omega}$$

$$R_{(2,4)} = \frac{R_2 R_4}{R_2 + R_4} = \frac{3.3\text{k}\Omega \times 6.8\text{k}\Omega}{3.3\text{k}\Omega + 6.8\text{k}\Omega}$$

Thus, the total equivalent resistance simplifies to:

$$R_{eq} = \frac{4.7 \times 1}{4.7 + 1}\text{k}\Omega + \frac{3.3 \times 6.8}{3.3 + 6.8}\text{k}\Omega$$

$$R_{eq} \approx \frac{4.7}{5.7}\text{k}\Omega + \frac{22.44}{10.1}\text{k}\Omega$$

$$R_{eq} \approx 0.824\text{k}\Omega + 2.22\text{k}\Omega$$

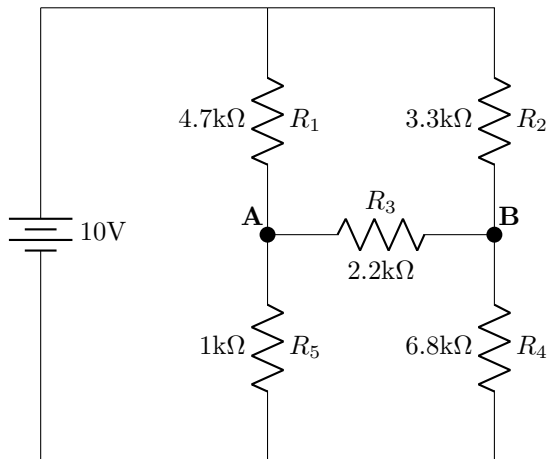$$R_{eq} \approx 3.04\text{k}\Omega$$
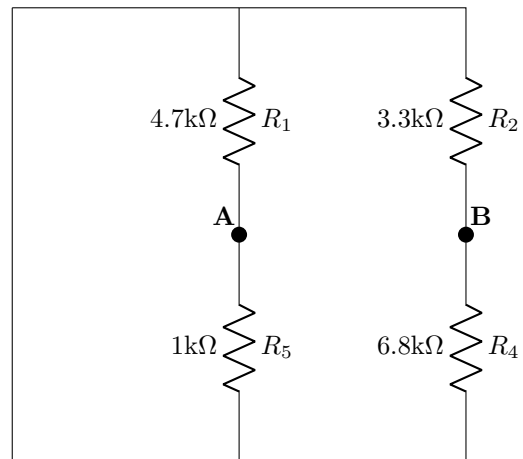

Figure 1: Original Circuit Diagram

Figure 2: Circuit for Finding R_{eq}

To determine the voltage across nodes A and B ($V_A - V_B$), **the voltage divider rule** is applied:

$$V_A = V_{\text{source}} \times \frac{R_5}{R_1 + R_5}$$

$$V_B = V_{\text{source}} \times \frac{R_4}{R_2 + R_4}$$

Substituting the given values:

$$V_A = 10V \times \frac{1\text{k}\Omega}{4.7\text{k}\Omega + 1\text{k}\Omega}$$

$$V_B = 10V \times \frac{6.8\text{k}\Omega}{3.3\text{k}\Omega + 6.8\text{k}\Omega}$$

Solving for each:

$$V_A = 10V \times \frac{1}{5.7} = 10V \times 0.175 = 1.75V$$

$$V_B = 10V \times \frac{6.8}{10.1} = 10V \times 0.673 = 6.73V$$

Finally, the voltage difference across nodes A and B is:

$$V_{AB} = V_A - V_B = 1.75V - 6.73V = -4.98V$$

Since the result is negative, it means that node B is at a higher potential than node A.

$$|V_{th}| = 4.98V$$

The Norton current is given by:

$$I_N = \frac{V_{th}}{R_{th}} = \frac{4.98V}{3.04k\Omega}$$

$$I_N = \frac{4.98}{3040}A \approx 1.64mA$$

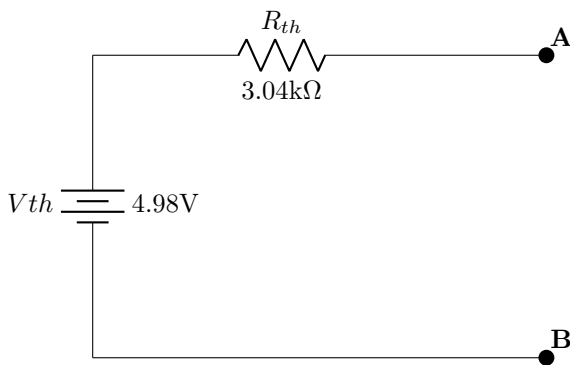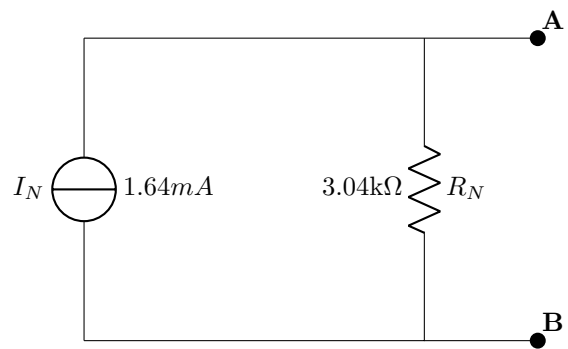Figure 3: Thevenin Equivalent Circuit

Figure 4: Norton Equivalent Circuit

1.1.2 Pre Task 2

To determine the current through resistor R_4 in **Figure 5**, the Superposition Theorem is applied by considering each independent source separately. The steps are as follows:

- **Step 1: Considering 10V only**

  When the 5V source is turned off by replacing it with a short circuit, the circuit simplifies as shown in **Figure 6**.

  Using Nodal Analysis, the equation for node A is:

  $$\frac{V - 10}{2.2\,\text{k}\Omega} + \frac{V - 10}{4.7\,\text{k}\Omega} + \frac{V}{10\,\text{k}\Omega} = 0$$

  Multiply through by the LCM of 2.2, 4.7, and 10 (approximately 103.4):

  $$47(V - 10) + 22(V - 10) + 10.34V = 0$$

  Expanding and simplifying:

  $$(47 + 22 + 10.34)V = 690 \quad \Rightarrow \quad 79.34V = 690 \quad \Rightarrow \quad V = \frac{690}{79.34} \approx 8.7\,\text{V}.$$

  $$I_{R_4} = \frac{V - 10}{4.7\,\text{k}\Omega} = \frac{8.7 - 10}{4.7} = -0.27\text{mA}$$

- **Step 2: Considering 5V only**

  When the 10V source is turned off by replacing it with a short circuit, the circuit simplifies as shown in **Figure 7**.

  Using Nodal Analysis, the equation for node B is:

  $$\frac{V - 5}{2.2\,\text{k}\Omega} + \frac{V}{4.7\,\text{k}\Omega} + \frac{V}{10\,\text{k}\Omega} = 0$$

  Multiplying through by the LCM of the denominators (which is approximately $47\,\text{k}\Omega$):

  $$47(V - 5) + 22(V) + 10.34(V) = 0$$

  Expanding and simplifying:

  $$47V - 235 + 22V + 10.34V = 0$$

  $$(47 + 22 + 10.34)V = 235$$

  $$79.34V = 235$$

  $$V = \frac{235}{79.34} \approx 2.96\,\text{V}$$

  Now, the current through the $4.7\,\text{k}\Omega$ resistor is given by:

  $$I_{4.7} = \frac{V}{4.7\,\text{k}\Omega} = \frac{2.96}{4.7}\,\text{mA} \approx 0.63\,\text{mA}$$

  Summing the values obtained from the different equations:

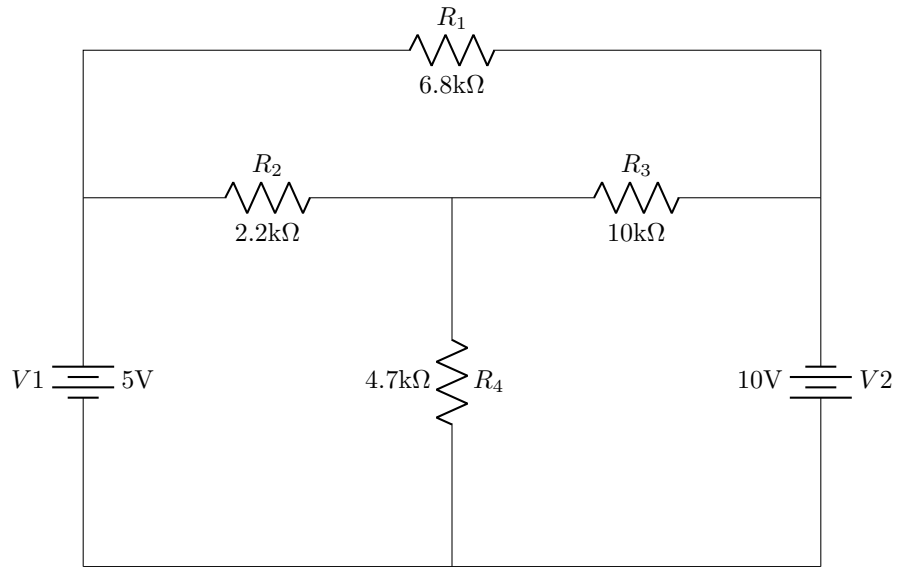 $$0.63\,\text{mA} + (-0.27\,\text{mA}) = 0.36\,\text{mA}$$
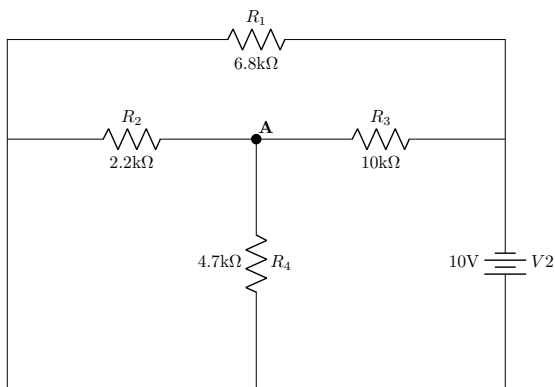
Figure 5: Original Circuit

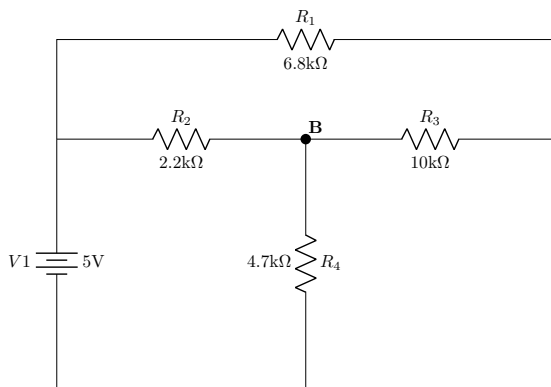Figure 6: Circuit with Only 10V Source

Figure 7: Circuit with Only 5V Source

1.2 Lab Tasks

This lab aims to determine the current through a specific resistor and the voltage across its nodes using Thevenin's and Norton's theorems. These methods simplify circuit analysis by representing complex networks with equivalent circuits. Additionally, the Superposition Theorem is used to analyze circuits with multiple independent sources by evaluating each source separately and summing the effects.

1.2.1 Task 1

The circuit depicted in Figure 1 was assembled on a breadboard using the required resistors and appropriate connections.

1. The measured voltage between nodes A and B was found to be 2.097V.

2. The open-circuit voltage between nodes A and B (Vth) was measured as 4.978V.

3. To measure the short-circuit current, R_3 was replaced with a 1-ohm resistor, and the voltage drop V_d was recorded. Using Ohm's Law, the short-circuit current (I_{sc}) is calculated as:

$$I_{sc} = \frac{V_d}{1\Omega}, V_d = 1.62\text{mV}$$

$$I_{sc} = 1.62\text{mA}$$

4. To calculate Thevenin's equivalent resistance, the following formula is used:

$$4.978V = R_\text{Thevenin} \times 1.62\text{mA}$$

$$R_\text{Thevenin} = \frac{4.978V}{1.62\text{mA}} = 3.072\,\text{k}\Omega$$

5. The theoretical Thevenin and Norton equivalent values were determined in the **Pre-Lab Task 1**, and their values are summarized in the table below:

   - Thevenin Voltage $V_{th} = 4.98V$
   - Thevenin Resistance $R_{th} = 3.04\,\text{k}\Omega$
   - Norton Current $I_N = 1.64\,\text{mA}$

6. To calculate the V_{AB} when 2.2kΩ resistor connected Voltage divider rule is applied as follows:

$$V_{AB} = \frac{R_\text{load}}{R_\text{th} + R_\text{load}} \times V_\text{th} = \frac{2.2\,\text{k}\Omega}{3.04\,\text{k}\Omega + 2.2\,\text{k}\Omega} \times 4.98V = 2.09V$$

7. Using Ohm's Law in combination with the Current Divider Rule, V_{AB} is determined as follows:

$$V_{AB} = \frac{R_\text{th}}{R_\text{th} + R_\text{load}} \times I_N \times R_\text{load}$$

$$= \frac{3.04\,\text{k}\Omega}{3.04\,\text{k}\Omega + 2.2\,\text{k}\Omega} \times 1.64\,\text{mA} \times 2.2\,\text{k}\Omega$$

$$V_{AB} = 2.08V$$

8. Using three 1 kΩ resistors, an approximate Thevenin resistance of 3.04 kΩ was obtained. After completing the circuit with the appropriate resistors and voltage source, voltage drop over 2.2 kΩ resistor is measured as:

$$V_{AB} = 2.168V$$

Parameter	Calculated Value	Measured Value	Error (%)
V_{AB} across R_3 (V)	2.1	2.097	0.14%
Open Circuit Voltage (V)	4.98	4.978	0.04%
Short Circuit Current (mA)	1.64	1.62	1.22%
R_{th} ($k\Omega$)	3.04	3.072	1.05%
Voltage Over 2.2kΩ on Thevenin(V)	2.09	2.168	3.73%

Table 1: Comparison of Calculated and Measured Values with Error Percentages

The error percentage is calculated using the following formula:

$$\text{Error Percentage} = \left(\frac{|\text{Measured Value} - \text{Calculated Value}|}{\text{Calculated Value}} \right) \times 100\%$$

The percentage error values in Table 2 indicate that the measured values are in close agreement with the theoretical calculations.

1.2.2 Task 2

To determine the current passing through resistor R_4, the **Superposition Theorem** was applied. The circuits shown in **Figures 6 and 7** were constructed using a breadboard and the necessary resistors. The respective voltage sources were applied as specified.

After assembling the circuits, the current passing through R_4 was measured using the appropriate probes of a digital multimeter. The theoretical and measured values are summarized in the following table:

Condition	Calculated Value (mA)	Measured Value (mA)
10V on, 5V off	-0.27	-0.28
5V on, 10V off	0.63	0.63
Total	**0.36**	**0.35**

Table 2: Comparison of Calculated and Measured Values for Current through R_4

2 Conclusion

2.0.1 Task 1

The circuit was converted into its Thevenin and Norton equivalents, determining V_{th}, R_{th}, I_N, and V_{AB} while analyzing voltage drops. The results for the 2.2 kΩ resistor (R_3) confirm that the Thevenin Equivalent Circuit simplifies analysis, making it easier to determine terminal voltage and current through Norton transformation. Error percentages in Table 1 indicate consistency with theoretical values, with minor deviations likely due to component tolerances, placement inaccuracies, or signal distortions. Additionally, the three 1 kΩ resistors in the Thevenin circuit did not sum precisely to 3 kΩ, introducing a systematic error affecting measurements.

2.0.2 Task 2

In Task 2, the superposition method was applied by constructing a common ground circuit and measuring currents while shorting each voltage source individually. Theoretical and experimental results were nearly identical, confirming the method's effectiveness in analyzing circuits with multiple sources. Error percentages in Table 2 were close to zero, indicating consistency with theoretical values. Minor deviations may stem from approximations, component tolerances, placement inaccuracies.