Lab Exercise No. 7
Thévenin's Theorem

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Abstract— **This experiment applies Thévenin's Theorem to simplify complex circuits, verifying its accuracy by comparing load voltages in both original and Thévenin equivalent circuits for 8.2 kΩ and 2.2 kΩ resistors. Results show minimal deviation between theoretical and experimental values, demonstrating the efficiency and reliability of Thévenin's Theorem for circuit analysis. The simplified approach significantly reduces computation time when analyzing circuits with multiple loads, making it a valuable tool in electrical engineering.**

Keywords- Thevenin's Theorem,Short circuit, Open Circuit

I. Introduction

Thevenin's Theorem is a fundamental concept in electrical engineering and circuit analysis. It simplifies the analysis of complex electrical networks by reducing them into a simpler equivalent circuit. This theorem is especially useful when determining the current or voltage across a particular element in a circuit. The theorem states that *any linear electrical network with multiple voltage sources, current sources, and resistors can be replaced by an equivalent circuit consisting of a single voltage source*($\mathbf{V_{th}}$) *in series with a resistor* ($\mathbf{R_{th}}$).

The equivalent circuit created is then called the **Thevenized Circuit** or alternatively, the **Thevenin Equivalent Circuit**. Some components of this include the:

- **Thevenin Voltage($\mathbf{V_{th}}$)**: This is the open-circuit voltage across the terminals where the load is connected.
- **Thevenin Resistance($\mathbf{R_{th}}$)**: Which is the equivalent resistance of the network when viewed from the load terminals with all independent voltage sources replaced by short circuits and independent current sources replaced by open circuits.

Once the Thévenin voltage and Thévenin resistance are determined, they form a simplified equivalent circuit: a voltage source (Vth) in series with a resistor (Rth), connected to the load. The behavior of this equivalent circuit is identical to that of the original network when viewed from the load terminals.

Consider a circuit with multiple resistors and voltage sources. Using Thévenin's theorem, the circuit can be reduced to a single voltage source in series with a single resistor, allowing for easy calculation of the voltage across or current through different loads.

II. Procedure

A. *Solving for Theoretical values*

Start by building the circuit:

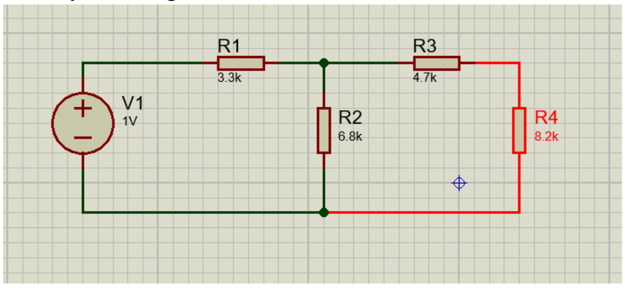

Figure 2.1: The Circuit

After this, start by solving for the theoretical values. The first value we would get would be the Thevenin Resistance($\mathbf{R_{th}}$) and we start by **shorting the circuit** as well as turning the part which we are looking for into an **open circuit.** After doing this, the circuit should look like this:

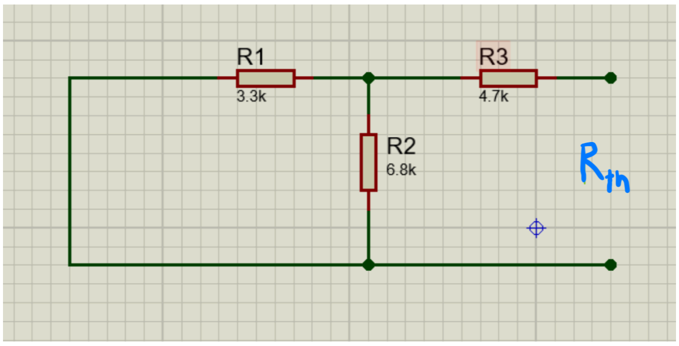

Figure 2.2: Shorted and Opened Circuit

To solve for $\mathbf{R_{th}}$ **,** we can see that **R1** and **R2** are parallel to each other, so we write that as **(R1//R2)** and we add **R3** so we get:

$$R_{AB} = R_{TH} = \left(R_1 // R_2\right) + R_3$$

After this, we can start solving for $\mathbf{V_{th}}$ by first determining the current(**I**). Using **Ohm's Law** we can see that

$$I = \frac{V}{R}$$

$$= \frac{10V}{3.3k + 6.8k}$$

Then using the value of the current, we can determine $\mathbf{V_{th}}$ by multiplying the current to 6.8kΩ. Now, $\mathbf{V_{th}}$ or $\mathbf{E_{th}}$ can be used to determine the **Voltage loads($\mathbf{V_{load}}$)**. We now make the **Thevenized circuit**. Which should look like this:

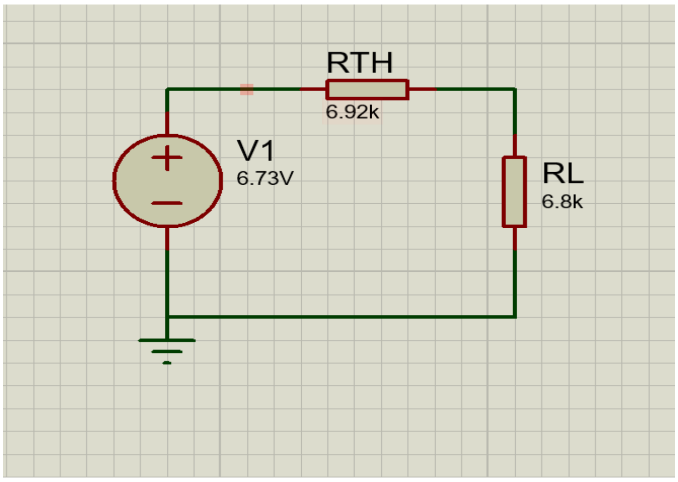

Figure 2.3 Thevenized Circuit

After building the circuit, we calculate for the V_{load} by first finding the Current flowing through **RL** by using the formula:

$$I_L = \frac{V_{TH}}{R_{TH} + R_L}$$

With the value of **RL** being first 8.2kΩ and then switching to 2.2kΩ

B. Measuring for Experimental values

To measure for V_{load} we simply apply the voltmeter as follows:

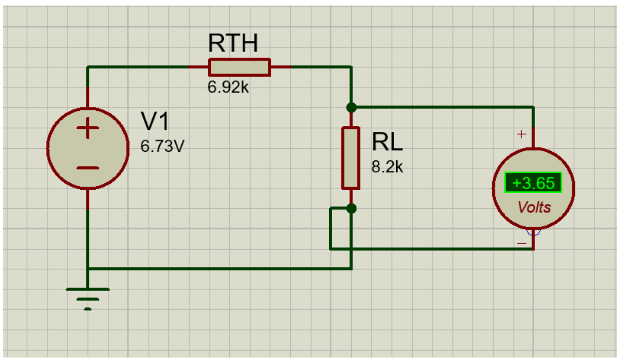

Figure 2.4 Thevenized circuit

Switching the values of RL from 8.2kΩ and 2.2kΩ.

III. Results and Analysis

A. Original Circuit

This table shows the theoretical values from the original circuit (Figure 2.1) for both the V_{Load} alongside its experimental values, and their corresponding percent deviation.

R_4 (Load)	V_{Load} Theory	V_{Load} Experimental	V_{Load} Deviation
8.2 k	3.65 V	3.614 V	0.99 %
2.2 k	1.62 V	1.62 V	0 %

Table 3.1

B. Thévenized Circuit

This table shows the theoretical values from the thévenized circuit (Figure 2.3) of E_{TH} and R_{TH} alongside its experimental values.

	Theory	Experimental
E_{TH}	6.73 V	6.83 V
R_{TH}	6.92k **Ω**	6.93k **Ω**
R_{TH} Method 2	X	6.94k **Ω**

Table 3.2

This table shows the theoretical values from the thévenized circuit (Figure 2.4) for both the V_{Load} alongside its experimental values, and their corresponding percent deviation.

R_4 (Load)	V_{Load} Theory	V_{Load} Experimental	V_{Load} Deviation

8.2 k	3.65 V	3.612 V	1.04 %
2.2 k	1.62 V	1.620 V	0 %

Table 3.3

Calculations:

This section explains the process used to determine the theoretical values for the Thevenin resistance (R_{TH}), Thevenin voltage (E_{TH}), and the load voltage across the 8.2kΩ and 2.2kΩ resistors.

Thévenin resistance (R_{TH}) calculation:

$$R_{AB} = R_{TH} = \left(R_1 // R_2\right) + R_3$$

$$= (3.3k // 6.8k) + 4.7k$$

$$= \left(\frac{1}{3.3k} + \frac{1}{6.8k}\right)^{-1} + 4.7k$$

$$R_{TH} = 6921.78\ \Omega \approx \mathbf{6.92k\ \Omega}$$

Thévenin voltage (E_{TH}) calculation:

$$I = \frac{V}{R}$$

$$= \frac{10V}{3.3k + 6.8k}$$

I = 0.000990099 A

$$V_{TH} = IR$$

$$= (0.000990099)\ (6.8k)$$

$$V_{TH} = \mathbf{6.73\ V}$$

V_{Load} calculations:

$$I_L = \frac{V_{TH}}{R_{TH} + R_L}$$

$$I_{L1} = \frac{6.73\ V}{6.92k + 8.2k}$$

$$I_{L1} = 4.45x10^{-4}\ A$$

$$V_{L1} = I_{L1} \cdot R_L$$

$$V_{L1} = (4.45x10^{-4}\ A)\ (8.2k\ \mathbf{\Omega})$$

$$V_{L1} = \mathbf{3.649\ V \approx 3.65\ V}$$

$$I_{L2} = \frac{6.73\ V}{6.92k + 2.2k}$$

$$I_{L2} = 7.38x10^{-4}\ A$$

$$V_{L2} = I_{L2} \cdot R_{L2}$$

$$V_L = (7.38x10^{-4}\ A)\ (2.2k\ \mathbf{\Omega})$$

$$V_L = \mathbf{1.623\ V \approx 1.62\ V}$$

Questions:

Do the load voltages for the original and Thévenized circuits match for both loads? Is it logical that this could be extended to any arbitrary load resistance value?

- Yes, the load voltages for the original and Thévenized circuits match for both loads. According to the report, for an 8.2 kΩ load, the theoretical voltage was 3.65 V, and the experimental voltage was 3.614 V for the original circuit, with a deviation of 0.99%. For the Thévenin equivalent, the theoretical voltage was 3.65 V, and the experimental voltage was 3.612 V, with a deviation of 1.04%. For a 2.2 kΩ load, both the original and Thévenin equivalent circuits showed perfect matching between theoretical and experimental voltages (1.62 V) with 0% deviation. This matching suggests that the process could be extended to arbitrary load resistances, as Thévenin's theorem is applicable for any linear electrical network and simplifies the analysis of complex circuits.

Which is faster, analyzing each load with the original circuit or with the Thévenin equivalent?

- Analyzing each load with the Thévenin equivalent circuit is generally faster. Once the Thévenin equivalent is derived (i.e., Thévenin resistance and Thévenin voltage), the analysis of different load resistances becomes straightforward because you only need to solve for the current and voltage in a simple series circuit. On the other hand, analyzing the original circuit each time would involve repeatedly solving more complex networks, making it more time-consuming.

How would the Thévenin equivalent computations change if the original circuit contained more than one voltage source?

- If the original circuit contained more than one voltage source, the computation of the Thévenin equivalent would require using *superposition* to find the Thévenin voltage.

Superposition involves calculating the contribution of each independent voltage source while turning off the other sources (replacing voltage sources with short circuits and current sources with open circuits). The Thévenin resistance would still be computed by deactivating all independent sources and determining the equivalent resistance seen from the terminal .

IV. Discussions and Conclusions

The original circuit and the Thévenin equivalent circuit produced consistent findings, with very slight differences between the theoretical and experimental values. The estimated load voltage for an 8.2 kΩ resistor in the original circuit was 3.65 V, whereas the measured value was 3.614 V, resulting in a 0.99% difference. Likewise, in the Thévenin equivalent circuit, the experimental value was 3.612 V, with a 1.04% variation, while the theoretical value for the same load was 3.65 V. This small discrepancy can be ascribed to tiny measurement errors, like loose connections or tolerances in the components.

Both the original and Thévenized circuits produced identical theoretical and actual findings, with no divergence (1.62 V), for a 2.2 kΩ load. This consistency attests to Thévenin's Theorem's use in streamlining circuit analysis without compromising precision. Thévenin's theorem makes it possible to more effectively calculate load voltages by breaking down a complicated network into a simpler equivalent circuit, especially when taking into account numerous loads.

It is also evident that analyzing each load using the Thévenin equivalent is faster and more efficient than solving the original circuit every time. Once the Thévenin voltage and resistance are determined, the calculation of voltage and current for any load becomes straightforward, significantly reducing computational effort.

We used Thévenin's Theorem to simplify a complex circuit and found that the load voltages for 8.2 kΩ and 2.2 kΩ resistors were nearly identical. The minimal variations between theoretical and experimental data show that the theorem holds true under practical conditions, with any discrepancies most likely attributable to experimental mistakes or component tolerance.

The findings demonstrate that Thévenin's Theorem is an effective circuit analysis method that allows for the efficient calculation of load behavior without requiring the full circuit to be analyzed many times. This method is very useful when studying circuits with various loads, as it greatly simplifies the process.

Furthermore, this experiment shows that Thévenin’s Theorem can be reliably extended to any arbitrary load resistance. This general applicability makes it a valuable method in both academic and practical electrical engineering applications, particularly in cases involving complex networks and varying load conditions.

References

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