Experiment - 05: Verification of Superposition Theorem

Objective:

In this experiment we have learnt

- Verifying Superposition Theorem
- Building Circuit with multiple power source

List of Equipment:

- Bread Board
- DC power source
- DMM
- 1 x 3.3kΩ resistor
- 1 x 4.7kΩ resistor
- 1 x 1KΩ resistor

Theory:

Superposition Theorem: The current or voltage passing through any element of a network is equal to the algebraic sum of the currents or voltages produced independently by each source.

Circuit Diagram:

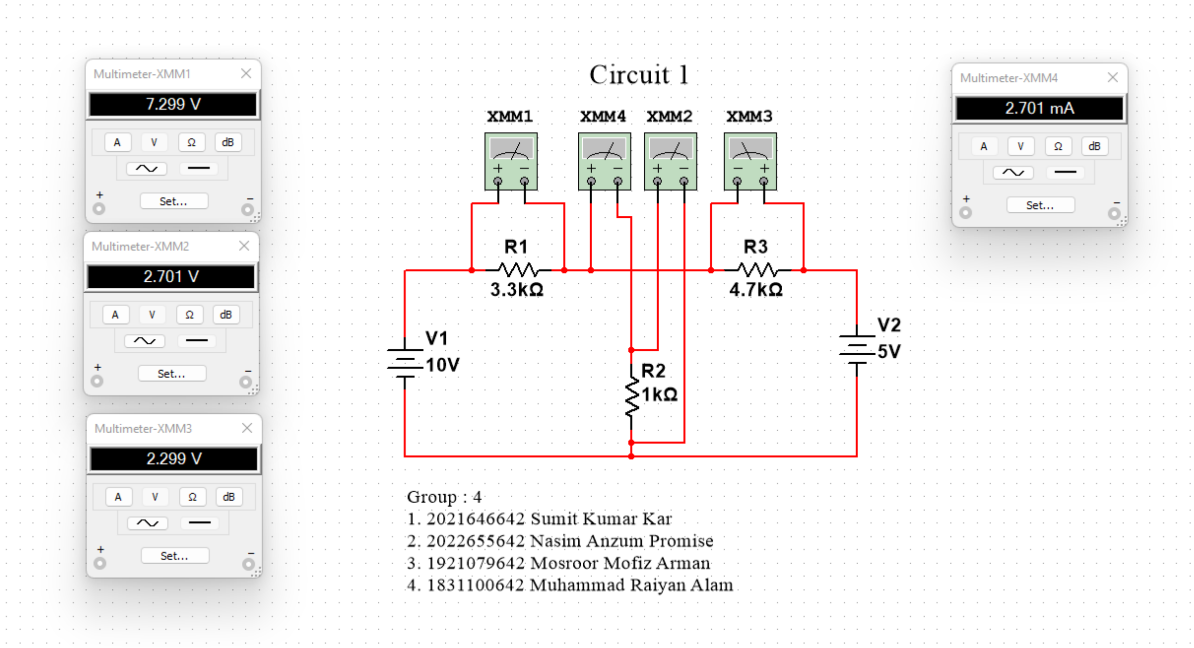

Figure 1: Circuit 1

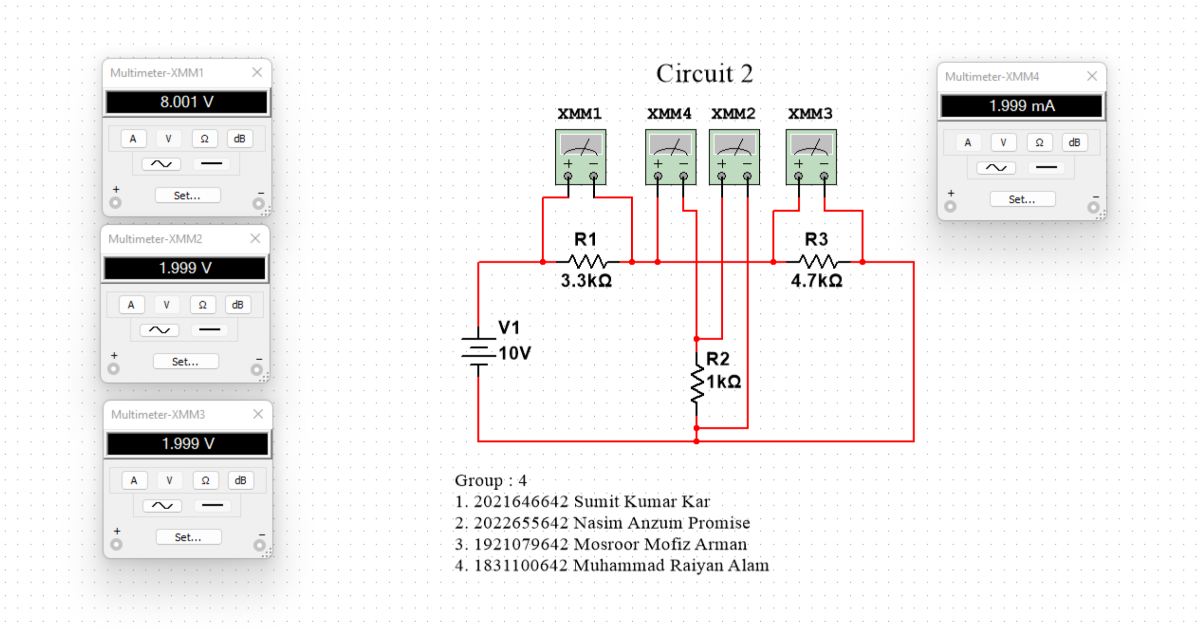

Figure 2: Circuit 2

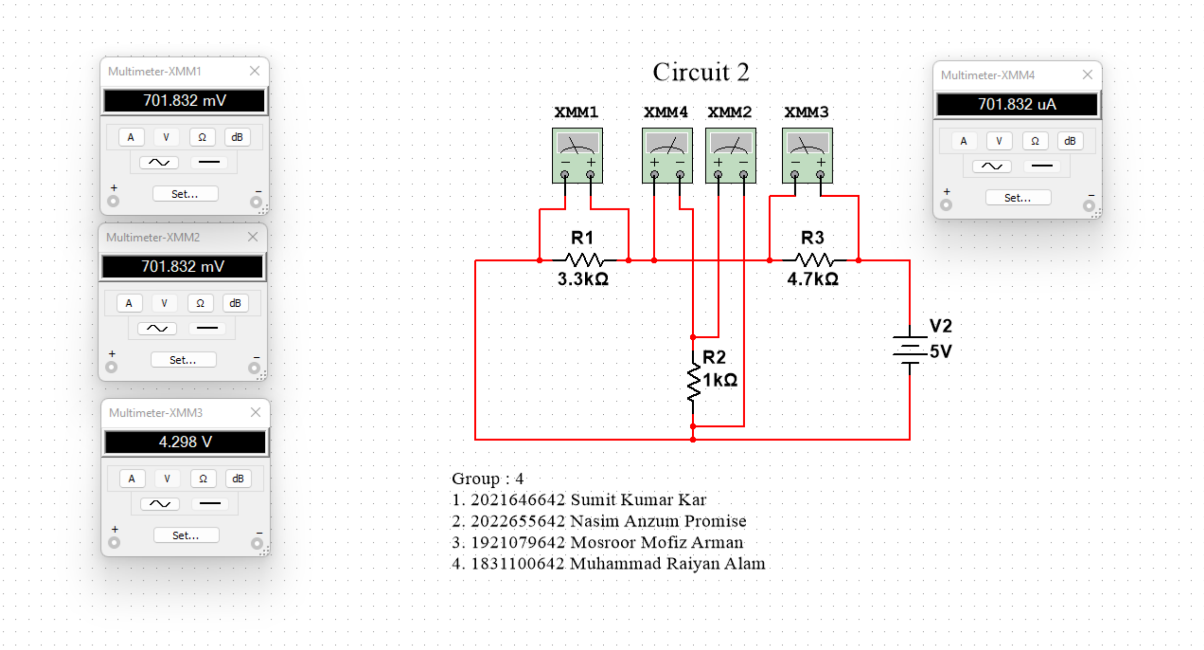

Figure 3: Circuit 3

Question and Answers:

1. What is Superposition Theorem?

Answer: The current through, or voltage across, any element of a network is equal to the algebraic sum of the currents or voltages produced independently by each source.

2. Theoretically calculate all values of Table 1 to Table 4. Show all the steps in details.

Answer: Here for Circuit 2

$$R_T' = R_1 + \frac{R_2 R_3}{R_2 + R_3} = 3.3K\Omega + \frac{1K\Omega \times 4.7K\Omega}{1K\Omega + 4.7K\Omega} = 4.12K\Omega$$

Now,

$$I' = \frac{V}{R_T'} = \frac{10V}{4.12K\Omega} = 2.43mA$$

Again for I_2' and I_3'

$$I_2' = \frac{I' R_3}{R_2 + R_3} = \frac{2.43mA \times 4.7K\Omega}{1K\Omega + 4.7K\Omega} = 2mA$$

$$I_3' = \frac{I' R_2}{R_2 + R_3} = \frac{2.43mA \times 1K\Omega}{1K\Omega + 4.7K\Omega} = 0.43mA$$

Here,

$$\begin{aligned}V'_{R1} = I' \times R_1 &= 2.43mA \times 3.3K\Omega \\ &= 8.02V \\ V'_{R2} = I'_2 \times R_2 &= 2mA \times 1K\Omega \\ &= 2V \\ V'_{R3} = I'_3 \times R_3 &= 0.43mA \times 4.7K\Omega \\ &= 2V\end{aligned}$$

Here for Circuit 3

$$R''_T = R_3 + \frac{R_1R_2}{R_1+R_2} = 4.7K\Omega + \frac{3.3K\Omega \times 1K\Omega}{3.3K\Omega + 1K\Omega} = 5.47K\Omega$$

Now,

$$I'' = \frac{V}{R''_T} = \frac{5V}{5.47K\Omega} = 0.91mA$$

Again for I''_2 and I''_1

$$I''_2 = \frac{I''R_1}{R_1+R_2} = \frac{0.91mA \times 3.3K\Omega}{3.3K\Omega + 1K\Omega} = 0.70mA$$

$$I''_1 = \frac{I''R_2}{R_1+R_2} = \frac{0.91mA \times 1K\Omega}{3.3K\Omega + 1K\Omega} = 0.21mA$$

Here,

$$\begin{aligned}V''_{R1} = I''_1 \times R_1 &= 0.21mA \times 3.3K\Omega \\ &= 0.7V \\ V''_{R2} = I''_2 \times R_2 &= 0.70mA \times 1K\Omega \\ &= 0.7V \\ V''_{R3} = I'' \times R_3 &= 0.91mA \times 4.7K\Omega \\ &= 4.27V\end{aligned}$$

Finally for Circuit 1, Using Superposition Theorem

$$\begin{aligned}I_2 &= I'_2 + I''_2 \\ &= 2mA + 0.7mA \\ &= 2.7mA \\ V_{R1} &= V'_{R1} + V''_{R1} \\ &= |8.02V - 0.7V| \\ &= 7.32V \\ V_{R2} &= V'_{R2} + V''_{R2} \\ &= |2V + 0.7V| \\ &= 2.7V \\ V_{R3} &= V'_{R3} + V''_{R3} \\ &= |2V - 4.27V| \\ &= 2.27V\end{aligned}$$

3. Using measured data, show that your circuit followed superposition theorem.

Answer: From the measured data we get,
$I_2, V_{R1}, V_{R2}, V_{R3}, I_2' + I_2'', V_{R1}' + V_{R1}'', V_{R2}' + V_{R2}'', V_{R3}' + V_{R3}''$
Here,

$$\begin{aligned}
&I_2 = 2.76mA, && I_2' + I_2'' = 2.79mA\\
&I_2 \approx I_2' + I_2''\\
&V_{R1} = 7.34V, && V_{R1}' + V_{R1}'' = 7.29V\\
&V_{R1} \approx V_{R1}' + V_{R1}''\\
&V_{R2} = 2.71V, && V_{R2}' + V_{R2}'' = 2.63V\\
&V_{R2} \approx V_{R2}' + V_{R2}''\\
&V_{R3} = 2.23V, && V_{R3}' + V_{R3}'' = 2.13V\\
&V_{R3} \approx V_{R3}' + V_{R3}''
\end{aligned}$$

From the above equation we can say that our circuit follows the superposition theorem

4. Find the % Error between your theoretical and experimental values

Answer: Now we calculate the error percentage

$$\frac{|ExperimentalValue - TheoreticalValue|}{TheoreticalValue} \times 100\%$$

$$I_2 = \frac{|2.76mA - 2.7mA|}{2.7mA} \times 100\% = 2.22\%$$

$$V_{R1} = \frac{|7.34V - 7.32V|}{7.32V} \times 100\% = 0.27\%$$

$$V_{R2} = \frac{|2.71V - 2.7V|}{2.7V} \times 100\% = 0.37\%$$

$$V_{R3} = \frac{|2.23V - 2.27V|}{2.27V} \times 100\% = 1.76\%$$

$$I_2' = \frac{|2.10mA - 2mA|}{2mA} \times 100\% = 5.00\%$$

$$V_{R1}' = \frac{|7.91V - 8.02V|}{8.02V} \times 100\% = 1.37\%$$

$$V_{R2}' = \frac{|2.02V - 2.00V|}{2.00V} \times 100\% = 1.00\%$$

$$V_{R3}' = \frac{|2.02V - 2.00V|}{2.00V} \times 100\% = 1.00\%$$

$$I_2'' = \frac{|0.69mA - 0.7mA|}{0.7mA} \times 100\% = 1.42\%$$

$$V_{R1}'' = \frac{|0.62 - 0.7V|}{0.7V} \times 100\% = 11.42\%$$

$$V_{R2}'' = \frac{|0.62V - 0.7V|}{0.7V} \times 100\% = 11.42\%$$

$$V_{R3}'' = \frac{|4.15V - 4.27V|}{4.27V} \times 100\% = 2.81\%$$

Result analysis and Discussion

In this lab we have learnt about Superposition theorem. And how we can use superposition theorem to calculate current and voltage passing through each element in a circuit with multiple power sources. In the lab we were provided 1KΩ, 3.3KΩ and 4.7KΩ resistors with a Digital Multi meter(DMM) and Breadboard. We figured out the resistance of the resistors using color coding and we verified the actual resistance using DMM.

Then we built Circuit 1 first and measured voltage across R1, R2 and R3. To measure the voltage we connected the probes of DMM in parallel to the resistors. Then we measured the current passing through R2, to measure the current we connected the probes of DMM in serial to R2. Then we wrote down V_{R1}, V_{R2}, V_{R3} and I_{R2}.

Then we built the Circuit 2. For this we just removed the 5V power source and shorted the path where it was connected. Then we measured V'_{R1}, V'_{R2}, V'_{R3} and I'_{R2} and wrote down the values we found.

After that we built the Circuit 3. For this we re-connected 5V power source and removed the 10V power source and shorted the path where it was connected. Then we measured V''_{R1}, V''_{R2}, V''_{R3} and I''_{R2} and wrote down the values we found.

Then after calculating $I'_2 + I''_2$, $V'_{R1} + V''_{R1}$, $V'_{R2} + V''_{R2}$, $V'_{R3} + V''_{R3}$. We can see that these values are almost equal to I_{R2}, V_{R1}, V_{R2}, V_{R3}. This proves that our experiment follows the superposition theorem. The values we measured are all written in Table-1, Table-2, Table-3, Table-4

We also faced few problems during the experiment. One of our power supply had issues maintaining a steady voltage output. So, we had to measure every value more than once.

Table of Contributions

During the experiment in class:

- 2021646642 Sumit Kumar Kar and 2022655642 Nasim Anzum Promise :
  Building the Circuit
- 1831100642 Muhammad Raiyan Alam:
  Wrote data in Lab Manual and helped group members with the steps
- 1921079642 Mosroor Mofiz Arman:
  Checked whether all the circuits were built correctly or not and whether all the data were written carefully and accurately or not.

During Lab Report:

- 2022655642 Nasim Anzum Promise:
  Wrote objective, theory part and Discussion.
- 2021646642 Sumit Kumar Kar:
  Drew Multisim and Solved Questions and Answers
- 1831100642 Muhammad Raiyan Alam:
  Helped with Question and Answer
- 1921079642 Mosroor Mofiz Arman:
  Report Writing according to the Guideline given in the canvas.