North South University

Department of Electrical & Computer Engineering

LAB REPORT- 05

Course Code: **EEE141L**

Course Title: **Electrical Circuits Lab**

Section: **07**

Lab Number: **05**

Experiment Name:

Verification of Superposition Theorem

Experiment Date: **4th April, 2024**

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Submitted by Group Number: **02**

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1. Experiment name : Verification of Superposition Theorem

2. Objective :

- To verify Superposition Theorem
- To get to know with Superposition Theorem practically

3. Theory :

Superposition Theorem:

The superposition theorem states that in a circuit with two or more independent sources (voltage or current), we must first calculate each independent source's contribution to the variable in order to get its value.

The superposition theorem is mostly used because working with a single independent source makes the circuit much more manageable and simpler. This makes it easier to determine the values of the variables for each independent source, which can then be added together to obtain the final result.

We always need to remember two things while applying superposition theorem:

- We always take into account one independent source for the circuit and disable the remaining sources. In order to replace a voltage source with 0V, we use a short circuit; in order to replace a current source with 0A, we use an open circuit.

- Dependent sources are left intact as they are controlled by circuit variables.

Application of Superposition Theorem:

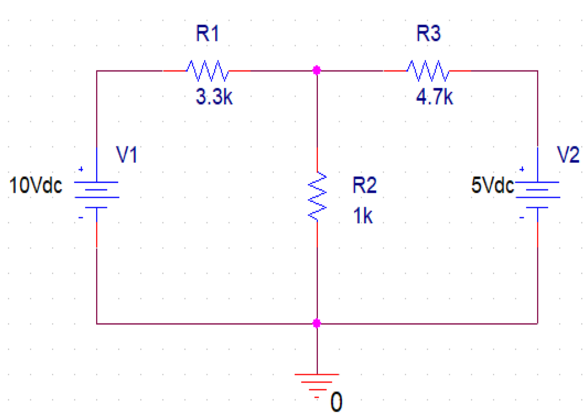


Figure-01

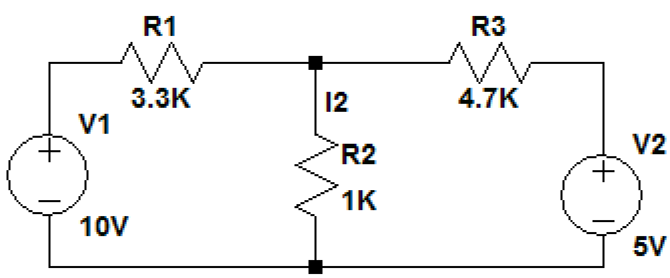
Therefore, in order to use the superposition theorem to determine the current flowing through the R_2 resistor in a circuit with multiple independent sources, such as the one shown in Figure-01, we must first short the circuit's V_2 voltage source in order to calculate the current flowing through R_2. Next, we must short the V_1 voltage source from the original circuit in order to continue shorting the V_2 voltage source and determine the current flowing through R_2.

After getting the values of the current going through R_2 resistor for each voltage source we need to add them up and that'll be the original amount of current going through the circuit with both V_1 and V_2 voltage source alive.

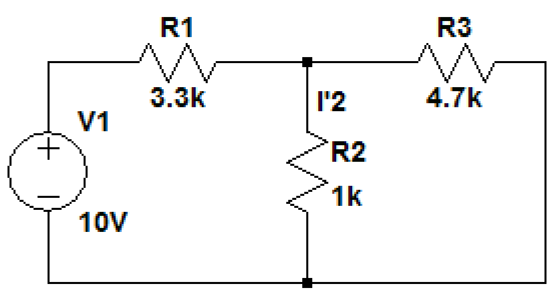
4. Apparatus List :

- Trainer Board
- Digital Multimeter
- Connecting Wire
- 1 x 3.3kΩ resistor
- 1 x 4.7kΩ resistor
- 1 x 1KΩ resistor
- Multisim Software

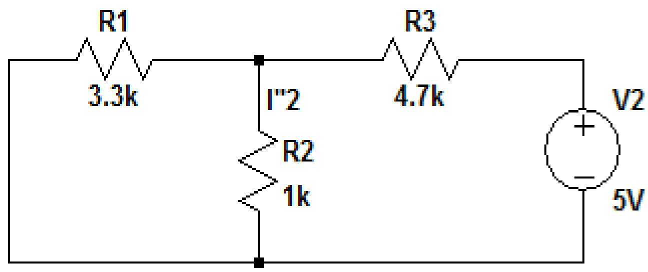
5. Circuit Diagram :



Circuit - 01



Circuit - 02



Circuit - 03

6. Experimental Procedure :

1. Set up Circuit 1.
2. Mark the polarities of each resistor.
3. With both the voltage source connected to the circuit, measure I_2, V_{R1}, V_{R2}, V_{R3} and record the values in appropriate tables.
4. Setup Circuit 2. Measure and record I'_2, V'_{R1}, V'_{R2}, V'_{R3}.
5. Setup Circuit 3. Measure and record I''_2, V''_{R1}, V''_{R2}, V''_{R3}.

7. Results :

Experimental Values :

Table 1:

I_2	I'_2	I''_2	$I'_2 + I''_2$
2.73 mA	2.03 mA	0.70 mA	2.73 mA

Here,

$I'_2+I''_2$

$= (2.03 + 0.70)$ mA

$= 2.73$ mA

$= I_2$

Table 2:

V_{R_1}	V'_{R_1}	V''_{R_1}	$V'_{R_1} + V''_{R_1}$
7.29 Volt	7.99 Volt	-0.70 Volt	7.29 Volt

Here,

$V'_{R1} + V''_{R1}$

= (7.99 + (-0.70)) Volt

= 7.29 Volt

= V_{R1}

Table 3:

V_{R2}	V'_{R2}	V''_{R2}	$V'_{R2} + V''_{R2}$
2.74 Volt	2.04 Volt	0.70 Volt	2.74 Volt

Here,

$V'_{R2} + V''_{R2}$

= (2.04 + 0.70) Volt

= 2.74 Volt

= V_{R2}

Table 4:

V_{R3}	V'_{R3}	V''_{R3}	$V'_{R3} + V''_{R3}$
2.26 Volt	-2.03 Volt	4.29 Volt	2.26 Volt

Here,

$V'_{R3} + V''_{R3}$

= ((-2.03) + 4.29) Volt

= 2.26 Volt

= V_{R3}

Theoretical Values :

Table 5:

I_2	I'_2	I''_2	$I'_2 + I''_2$
2.701 mA	1.999 mA	0.701 mA	2.7 mA

Here,

$I'_2 + I''_2$
= (1.999 + 0.701) mA
= 2.7 mA
= I_2

Table 6:

V_{R_1}	V'_{R_1}	V''_{R_1}	$V'_{R_1} + V''_{R_1}$
7.299 Volt	8.001 Volt	- 0.702 Volt	7.299 Volt

Here,

$V'_{R1} + V''_{R1}$
= (8.001 + (-0.702)) Volt
= 7.299 Volt
= V_{R1}

Table 7:

V_{R2}	V'_{R2}	V''_{R2}	$V'_{R2} + V''_{R2}$
2.701 Volt	1.999 Volt	0.701 Volt	2.7 Volt

Here,

$V'_{R2} + V''_{R2}$
= (1.999 + 0.701) Volt
= 2.7 Volt
= V_{R2}

Table 8:

V_{R3}	V'_{R3}	V''_{R3}	$V'_{R3}+V''_{R3}$
2.299 Volt	- 1.998 Volt	4.296 Volt	2.299 Volt

Here,

$V'_{R3}+V''_{R3}$

= ((-1.998) + 4.296) Volt

= 2.299 Volt

= V_{R3}

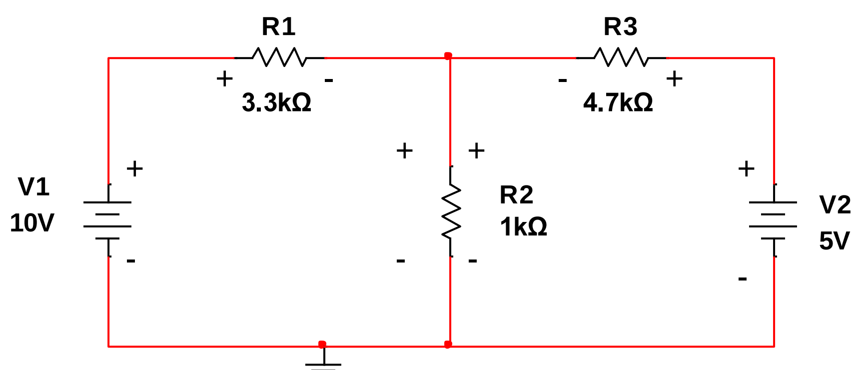
8. Question & Answer :

1. What is Superposition Theorem?

Answer : The superposition theorem states that in a linear circuit with multiple independent sources, the total response (voltage or current) at any given point is the sum of the responses brought about by each source operating independently while the other sources are off. The circuit's total response by first analyzing the impacts of each source independently and then combining them. This theorem breaks complicated circuits down into smaller, easier-to-manage components, making the analysis of those circuits simpler.

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

Answer : Applying Mesh analysis on Circuit – 01,



Circuit-01 (With Polarity)

Applying KVL at loop 1,

$10 – 3.3\, i_1 - 1\, (i_1 - i_2) = 0$

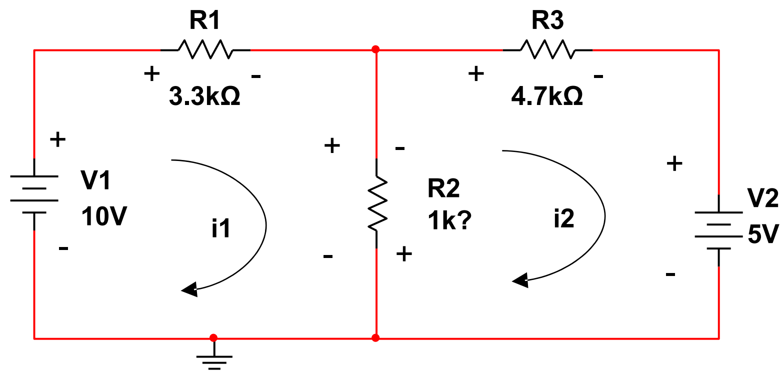
$=> - 4.3\, i_1 + i_2 = - 10$ ---------- (1)

Applying KVL at loop 2,

$- 4.7 i_2 - 5 – (i_2 - i_1) = 0$

$=> - 4.7 i_2 – i_2 + i_1 = 5$

$=> i_1 – 5.7 i_2 = 5$ --------- (2)



Circuit-01

Solving equation (1) and equation (2) using calculator,

$i_1 = 2.212$ mA

and $i_2 = – 0.489$ mA

$I_{\therefore 2} = i_1 - i_2 = 2.212 – (– 0.489) = 2.701$ mA

$V_{R1} = I_{local} \times R_1$

$= i_1 \times R_1$

$= 2.212 \times 3.3$

$= 7.299$ Volt

$V_{R2} = I_{local} \times R_2$

$= (i_1 - i_2) \times R_2$

$= 2.701 \times 1$

$= 2.701$ Volt

$V_{R3} = I_{local} \times R_3$

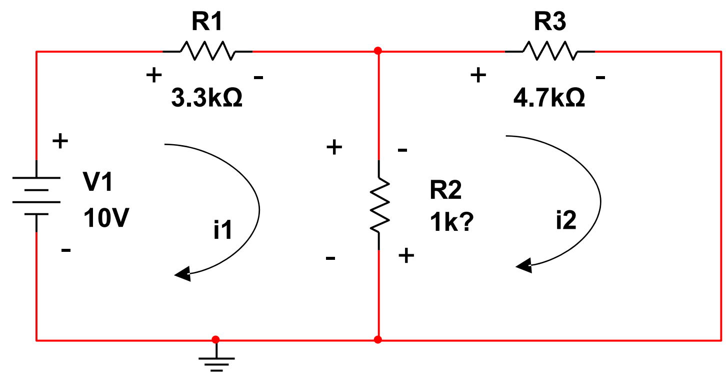
$= (- i_2) \times R_3$

$= - (-0.489) \times 4.7$

$= 2.299$ Volt

Now, Applying Superposition theorem to calculate all the other values of the tables,

For 10 Volt source,



Circuit-02

Applying KVL at loop 1,

$10 - 3.3\ i_1 - 1(i_1 - i_2) = 0$
$\Rightarrow -\ 3.3\ i_1 - i_1 + i_2 = -10$
$\Rightarrow -\ 4.3\ i_1 + i_2 = -10$ ---------- (3)

Applying KVL at loop 2,

$-\ 4.7\ i_2 - (i_2 - i_1) = 0$
$\Rightarrow i_1 - 5.7\ i_2 = 0$ ---------- (4)

Solving equation (3) and equation (4) using calculator,

$i_1 = 2.424$ mA
and $i_2 = 0.425$ mA

$'I \therefore_2 = i_1 - i_2 = (2.424 - 0.425) = 1.999$ mA

$V'_{R1} = I_{local} \times R_1$
$= i_1 \times R_1$
$= 2.424 \times 3.3$
$= 8.001$ Volt

$V'_{R2} = I_{local} \times R_2$
$= (i_1 - i_2) \times R_2$
$= 1.999 \times 1$
$= 1.999$ Volt

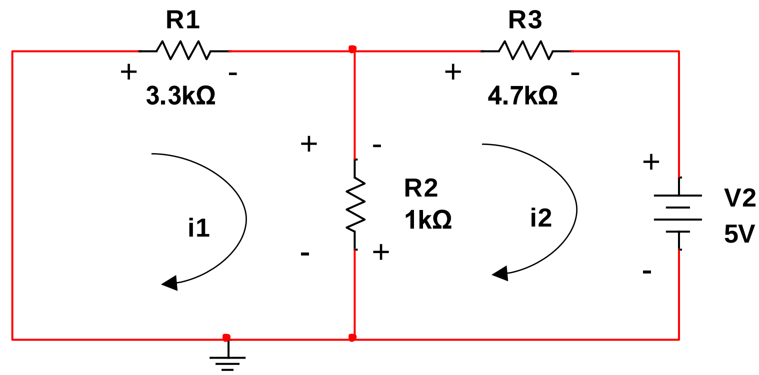
$V'_{R3} = I_{local} \times R_3$
$= (-\ i_2) \times R_3$
$= -\ 0.425 \times 4.7$
$= -\ 1.998$ Volt

For 5 Volt source,

Applying KVL at loop 1,

$-3.3\ i_1 - 1(i_1 - i_2) = 0$
$\Rightarrow -4.3\ i_1 + i_2 = 0$ ---------- (5)

Applying KVL at loop 2,
$-(i_2 - i_1) - 4.7\ i_2 - 5 = 0$
$\Rightarrow i_1 - 5.7\ i_2 = 5$ ---------- (6)



Circuit-03

Solving equation (3) and equation (4) using calculator,

$i_1 = -0.213$ mA
and $i_2 = -0.914$ mA

$\therefore I''_2 = i_1 - i_2 = (-0.213) - (-0.914) = 0.701$ mA

$V''_{R1} = I_{local} \times R_1$
$= i_1 \times R_1$
$= -0.213 \times 3.3$
$= -0.702$ Volt

$V''_{R2} = I_{local} \times R_2$
$= (i_1 - i_2) \times R_2$
$= 0.701 \times 1$
$= 0.701$ Volt

$V''_{R3} = I_{local} \times R_3$
$= (-i_2) \times R_3$
$= -(-0.914) \times 4.7$
$= 4.296$ Volt

$\therefore$ According to superposition theorem,

$I_2 = I'_2 + I''_2 = 1.999 + 0.701 = 2.7$ mA
$V_{R1} = V'_{R1} + V''_{R1} = 8.001 + (-0.702) = 7.299$ Volt
$V_{R2} = V'_{R2} + V''_{R2} = 1.999 + 0.701 = 2.7$ Volt
$V_{R3} = V'_{R3} + V''_{R3} = (-1.998) + 4.296 = 2.299$ Volt

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

Answer : From the Tables we can get the measured data,

I_2 = 2.73 mA
$I'_2 + I''_2$ = (2.03 + 0.70) mA = 2.73 mA

V_{R1} = 7.29 Volt
$V'_{R1} + V''_{R1}$ = (7.99 + (-0.70)) Volt = 7.29 Volt

V_{R2} = 2.74 Volt
$V'_{R2} + V''_{R2}$ = (2.04 + 0.70) Volt = 2.74 Volt

V_{R3} = 2.26 Volt
$V'_{R3} + V''_{R3}$ = ((-2.03) + 4.29) Volt = 2.26 Volt

Here, if we take a look at the values of each variable for all the independent sources and the summation of the contribution of each source, they're both the same.

For example, the value of I_2 for all the sources is 2.73 mA but the summation of contribution of each source ($I'_2 + I''_2$) is also 2.73 mA. And it's the same way for V_{R1}, V_{R2} and V_{R3} as well. So according to these measured data we can say that our circuit follows superposition theorem.

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

Answer :

We know,

The formula to calculate % error $= \left| \frac{\text{Experimental value} - \text{Theoretical value}}{\text{Theoretical value}} \right| \times 100\%$

$\therefore$ % Error for $I_2 = \left| \frac{2.73-2.701}{2.701} \right| \times 100\% = 1.07\%$

$\therefore$ % Error for $I'_2 = \left| \frac{2.03-1.999}{1.999} \right| \times 100\% = 1.55\%$

$\therefore$ % Error for $I''_2 = \left| \frac{0.701-0.70}{0.701} \right| \times 100\% = 0.14\%$

$\therefore$ % Error for $(I'_2 + I''_2) = \left| \frac{2.73-2.7}{2.7} \right| \times 100\% = 1.11\%$

$\therefore$ % Error for V_{R1} = $\left|\frac{7.299-7.29}{7.299}\right| \times 100\% = 0.12\%$

$\therefore$ % Error for V'_{R1} = $\left|\frac{8.001-7.99}{8.001}\right| \times 100\% = 0.14\%$

$\therefore$ % Error for V''_{R1} = $\left|\frac{-0.702-(-0.70)}{-0.702}\right| \times 100\% = 0.28\%$

$\therefore$ % Error for $(V'_{R1} + V''_{R1})$ = $\left|\frac{7.299-7.26}{7.299}\right| \times 100\% = 0.53\%$

$\therefore$ % Error for V_{R2} = $\left|\frac{2.74-2.701}{2.701}\right| \times 100\% = 1.44\%$

$\therefore$ % Error for V'_{R2} = $\left|\frac{2.04-1.999}{1.999}\right| \times 100\% = 2.05\%$

$\therefore$ % Error for V''_{R2} = $\left|\frac{0.701-0.70}{0.701}\right| \times 100\% = 0.14\%$

$\therefore$ % Error for $(V'_{R2} + V''_{R2})$ = $\left|\frac{2.74-2.7}{2.7}\right| \times 100\% = 1.48\%$

$\therefore$ % Error for V_{R3} = $\left|\frac{2.299-2.26}{2.299}\right| \times 100\% = 1.70\%$

$\therefore$ % Error for V'_{R3} = $\left|\frac{-1.998-(-2.03)}{-1.998}\right| \times 100\% = 1.60\%$

$\therefore$ % Error for V''_{R3} = $\left|\frac{4.296-4.29}{4.296}\right| \times 100\% = 0.14\%$

$\therefore$ % Error for $(V'_{R3} + V''_{R3})$ = $\left|\frac{-2.299-(-2.300)}{-2.300}\right| \times 100\% = 0.04\%$

9. Discussion :

We now know what the superposition theorem is and how to use it thanks to this experiment. It is difficult to determine a variable's value when a circuit includes several independent sources. Normally, we could do this by utilizing mesh or nodal analysis, and similar to those analyses, we could also use the superposition theorem for the same goal. To use the superposition theorem, however, we must take one source at a time, determine the value of the variable required for each source separately, and then add up all of the values to get the final result.

As we move on to the outcome of our experiment, we can see that our application of the superposition theorem was successful because the proportion of error is very low—almost zero for all data. Such, for I_2 we got theoretical value of 2.701 mA and experimental value of 2.73 mA; and %error is 1.07%.

And no, we had no issues with this experiment because everything was very apparent and easy to follow in class.