North South University

Department of Electrical & Computer Engineering

LAB REPORT

Course Code: EEE141L

Course Title: Electrical Circuits I Lab

Course Instructor: Dr. Mohammad Abdul Matin (Mtn)

Experiment Number: 5

Experiment Name:

Verification of Superposition Theorem

Experiment Date: 1/4/2021

Date of Submission: 7/4/2021

Section: 3

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Objectives:

• To verify Superposition Theorem.

List of Equipment:

• OrCAD Software
• PSpice Simulation Software
• 1 × 3.3kΩ resistors
• 1 × 4.7kΩ resistor
• 1 × 1kΩ resistor
• Connecting wire

Theory:

Superposition Theorem:

If a circuit has two or more independent sources (voltage or current), then to determine the value of a specific variable, according to the superposition theorem we determine the contribution of each independent source to the variable and then add them up.

The main reason we use superposition theorem is because when we work with one independent source the circuit becomes much simpler and manageable and that way, we can get the values of a variable for each independent source much more easily and then just add them all to get the result.

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

❖ We always consider one independent source for the circuit and turn rest of the sources off. For voltage sources we use a short circuit so that the voltage gets replaced with 0V and for current sources we use open circuit which replaces the current source with 0A value.

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

Application of Superposition Theorem:

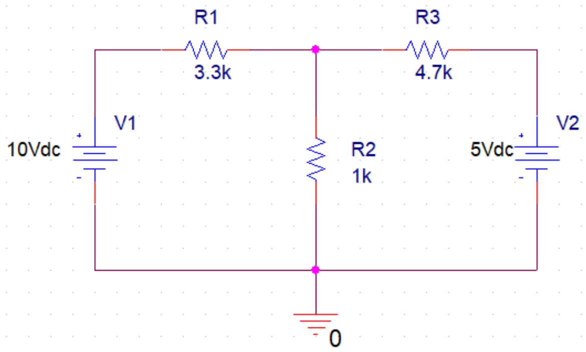
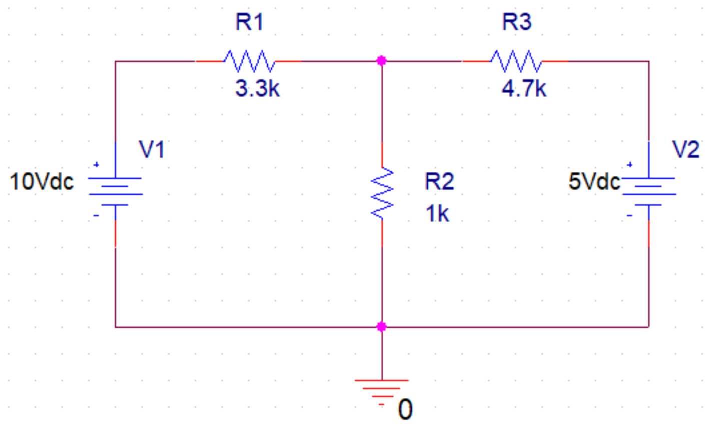


Figure – 1

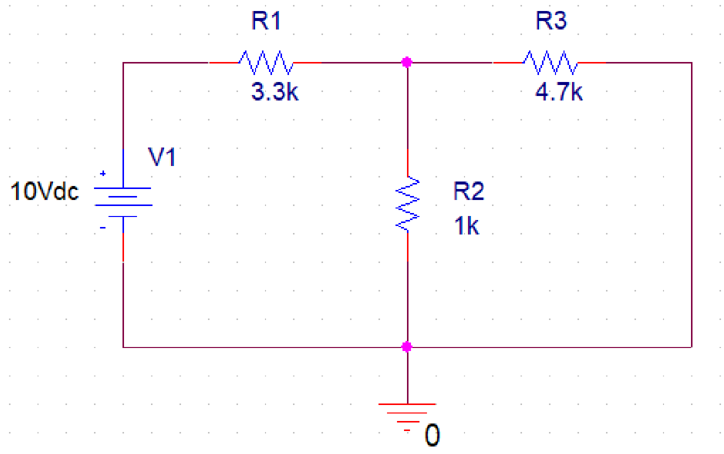
So, if we have a circuit with more than one independent source like the one in figure – 1 and we want to find the value of the current going through the R_2 resistor using superposition theorem then first we have to short the V_2 voltage source in the circuit and calculate the current going through R_2 and then again from the original circuit we have to short the V_1 voltage source and this time we have to keep V_2 voltage source alive and find the current going 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.

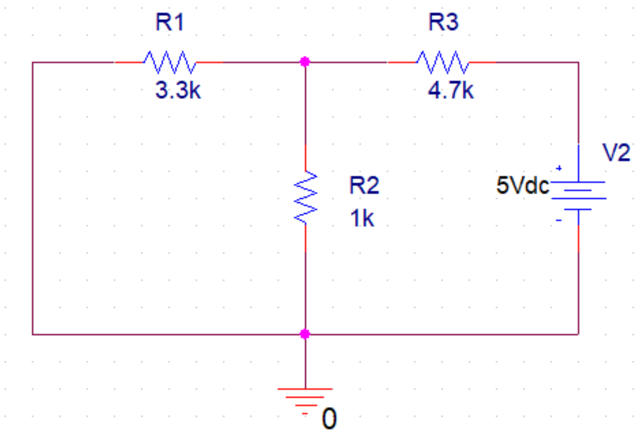
Circuit Diagram:



Circuit – 1



Circuit – 2



Circuit – 3

Data, Readings and Results:

Table 1:

I_2	I'_2	I''_2	$I'_2 + I''_2$
2.701mA	1.999mA	0.702mA	2.701mA

Table 2:

V_{R1}	V'_{R1}	V''_{R1}	$V'_{R1} + V''_{R1}$
7.299V	8.001V	-0.702V	7.299V

Table 3:

V_{R2}	V'_{R2}	V''_{R2}	$V'_{R1} + V''_{R2}$
2.701V	1.999V	0.702V	2.701V

Table 4:

V_{R3}	V'_{R3}	V''_{R3}	$V'_{R3} + V''_{R3}$
-2.299V	1.999V	-4.298V	-2.299V

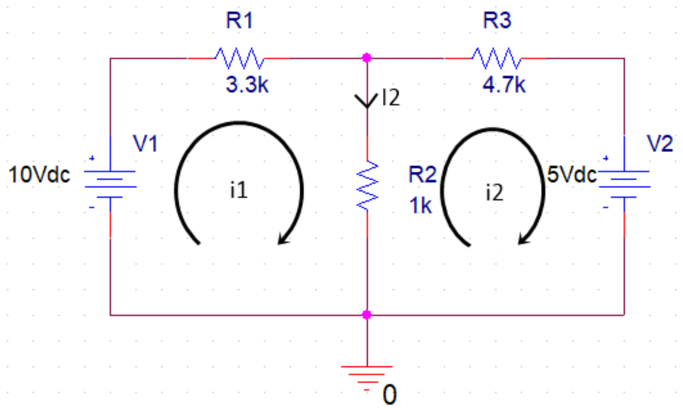
Questions and Answers:

Answer of Question 1:

If a circuit has two or more independent sources, then to determine the value of a specific variable, we determine the contribution of each independent source to the variable and then sum them up, this is called the superposition theorem.

Answer of Question 2:

Applying Mesh analysis on circuit – 1,



Applying KVL at loop 1,
$-10 + 3.3\, i_1 + i_1 - i_2 = 0$
$\Rightarrow 4.3\, i_1 - i_2 = 10$ ………… (1)

Applying KVL at loop 2,
$i_2 - i_1 + 4.7\, i_2 + 5 = 0$
$\Rightarrow -i_1 + 5.7\, i_2 = -5$
$\Rightarrow 5.7\, i_2 = i_1 - 5$
$\Rightarrow i_2 = \frac{i1-5}{5.7}$ ………… (2)

From (1),

$4.3\, i_1 - \frac{i1-5}{5.7} = 10$
$\Rightarrow 24.51\, i_1 - i_1 + 5 = 57$
$\Rightarrow 23.51\, i_1 = 52$
$\therefore i_1 = 2.212$ mA

From (2),

$i_2 = \frac{2.212 - 5}{5.7} = - 0.489$ mA

$\therefore I_2 = i_1 - i_2 = 2.212 - (- 0.489) = 2.701$ mA

$V_{R1} = i_1 \times R_1 = 2.212 \times 3.3 = 7.300$ V
$V_{R2} = I_2 \times R_2 = 2.701 \times 1 = 2.701$ V
$V_{R3} = i_2 \times R_3 = - 0.489 \times 4.7 = - 2.298$ V

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

Given,

$V_1 = 10V$
$V_2 = 5V$
$R_1 = 3.3k\Omega$
$R_2 = 1k\Omega$
$R_3 = 4.7k\Omega$

For 10V source,

$$
\begin{aligned}
R_T &= R_1 + (R_2 || R_3) \\
&= R_1 + \frac{R2 \times R3}{R2 + R3} \\
&= 3.3 + \frac{1 \times 4.7}{1 + 4.7} \\
&= 4.125 \text{ k}\Omega
\end{aligned}
$$

$\therefore I_T = \frac{10}{4.125} = 2.424$ mA

$\therefore I'_2 = \frac{R3}{R2 + R3} \times I_T = \frac{4.7}{1 + 4.7} \times 2.424 = 1.999$ mA

$$
\begin{aligned}
\therefore V'_{R1} &= \frac{V1}{RT} \times R_1 \\
&= \frac{10}{4.125} \times 3.3 \\
&= 8.000 \text{ V}
\end{aligned}
$$

$$
\begin{aligned}
\therefore V'_{R2} = V'_{R3} &= \frac{V1}{RT} \times (R_2 || R_3) \\
&= \frac{10}{4.125} \times \frac{1 \times 4.7}{1 + 4.7} \\
&= 1.999 \text{ V}
\end{aligned}
$$

For 5V source,

$R_T = (R_1||R_2) + R_3$
$= \frac{R1 \times R2}{R1 + R2} + R_3$
$= \frac{3.3\times1}{3.3+1} + 4.7$
$= 5.467\ k\Omega$

$\therefore I_T = \frac{5}{5.47} = 0.915\ mA$

$\therefore I''_2 = \frac{R1}{R1+R2} \times I_T = \frac{3.3}{3.3+1} \times 0.915 = 0.702\ mA$

In Circuit – 3, the current flows through R_1 resistor from negative polarity to positive polarity,

$\therefore V''_{R1} = -\left(\frac{V2}{RT} \times (R_1||R_2)\right)$
$= -\left(\frac{5}{5.467} \times \frac{3.3\times1}{3.3+1}\right)$
$= -0.702\ V$

$\therefore V''_{R2} = \frac{V2}{RT} \times (R_1||R_2)$
$= \frac{5}{5.467} \times \frac{3.3\times1}{3.3+1}$
$= 0.702\ V$

Again, in R_3 resistor the current flows from negative polarity to positive polarity,

$\therefore V''_{R3} = -\left(\frac{V2}{RT} \times R_3\right)$
$= -\left(\frac{5}{5.467} \times 4.7\right)$
$= -4.299\ V$

$\therefore$ According to superposition theorem,

$I_2 = I'_2 + I''_2 = 1.999 + 0.702 = 2.701\ mA$
$V_{R1} = V'_{R1} + V''_{R1} = 8.000 - 0.702 = 7.298\ V$
$V_{R2} = V'_{R2} + V''_{R2} = 1.999 + 0.702 = 2.701\ V$
$V_{R3} = V'_{R3} + V''_{R3} = 1.999 - 4.299 = -2.300V$

Answer of Question 3:

From the Tables we can get the measured data,

I_2 = 2.701 mA
$I'_2 + I''_2$ = 2.701 mA

V_{R1} = 7.299 V
$V'_{R1} + V''_{R1}$ = 7.299 V

V_{R2} = 2.701 V
$V'_{R2} + V''_{R2}$ = 2.701 V

V_{R3} = –2.299V
$V'_{R3} + V''_{R3}$ = –2.299V

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 2.701mA but the summation of contribution of each source ($I'_2 + I''_2$) is also 2.701mA. 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.

Answer of Question 4:

We know,

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

$\therefore$ % Error for $I_2 = \left| \frac{2.701-2.701}{2.701} \right| \times 100\% = 0\%$

$\therefore$ % Error for $I'_2 = \left| \frac{1.999-1.999}{1.999} \right| \times 100\% = 0\%$

$\therefore$ % Error for $I''_2 = \left| \frac{0.702-0.702}{0.702} \right| \times 100\% = 0\%$

$\therefore$ % Error for $(I'_2 + I''_2) = \left| \frac{2.701-2.701}{2.701} \right| \times 100\% = 0\%$

$\therefore$ % Error for V_{R1} = $\left|\frac{7.299-7.300}{7.300}\right| \times 100\%$ = 0.01%

$\therefore$ % Error for V'_{R1} = $\left|\frac{8.001-8.000}{8.000}\right| \times 100\%$ = 0.01%

$\therefore$ % Error for V''_{R1} = $\left|\frac{-0.702-(-0.702)}{-0.702}\right| \times 100\%$ = 0%

$\therefore$ % Error for $(V'_{R1} + V''_{R1})$ = $\left|\frac{7.299-7.298}{7.298}\right| \times 100\%$ = 0.01%

$\therefore$ % Error for V_{R2} = $\left|\frac{2.701-2.701}{2.701}\right| \times 100\%$ = 0%

$\therefore$ % Error for V'_{R2} = $\left|\frac{1.999-1.999}{1.999}\right| \times 100\%$ = 0%

$\therefore$ % Error for V''_{R2} = $\left|\frac{0.702-0.702}{0.702}\right| \times 100\%$ = 0%

$\therefore$ % Error for $(V'_{R2} + V''_{R2})$ = $\left|\frac{2.701-2.701}{2.701}\right| \times 100\%$ = 0%

$\therefore$ % Error for V_{R3} = $\left|\frac{-2.299-(-2.298)}{-2.298}\right| \times 100\%$ = 0.04%

$\therefore$ % Error for V'_{R3} = $\left|\frac{1.999-1.999}{1.999}\right| \times 100\%$ = 0%

$\therefore$ % Error for V''_{R3} = $\left|\frac{-4.298-(-4.299)}{-4.299}\right| \times 100\%$ = 0.02%

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

Discussion:

From this experiment we've learned what superposition theorem is and how to apply that. When a circuit has multiple independent sources it's not easy to find the value of a variable however normally we could find those values using mesh or nodal analysis and like those analysis we can also use the superposition theorem for the same purpose. However, to apply superposition theorem we need to consider one source at a time and calculate the value of the variable that we need for each individual source and then finally sum the values for each source and that's our result. Now coming to the result of our experiment, the percentage of error is very low, zero for some and close to zero for some variables, which indicates that our superposition theorem application was a success. And no during this experiment we didn't face any problem as everything was crystal clear and understandable during the class.