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Experiment No. 3

Verification of Superposition Principle

Objective

The aim of this experiment is to experimentally verify the Superposition theorem, which is an analytical technique for determining currents/voltages in a circuit with more than one emf source.

Theory

The Superposition Principle is a fundamental concept in electrical circuits that states that in any linear, active, bilateral network having more than one source, the response across any element is the sum of the responses obtained from each source considered separately, and all other sources are replaced by their internal resistance. The superposition theorem is used to solve networks where two or more sources are present and connected. The current or voltage through any component in a circuit is the sum of the effects of each individual source acting alone. In other words, the principle states that **the total response of a circuit with multiple sources is the sum of the responses of the circuit to each individual source acting alone.** This principle is widely used in circuit analysis to simplify complex circuits and solve them with ease.

In a **linear circuit** containing multiple independent sources and linear elements (e.g., resistors, inductors, and capacitors), the voltage across (or the current through) any element when all the sources are acting simultaneously may be obtained by adding algebraically all the individual voltages (or currents) caused by each independent source acting alone, with all other sources deactivated.

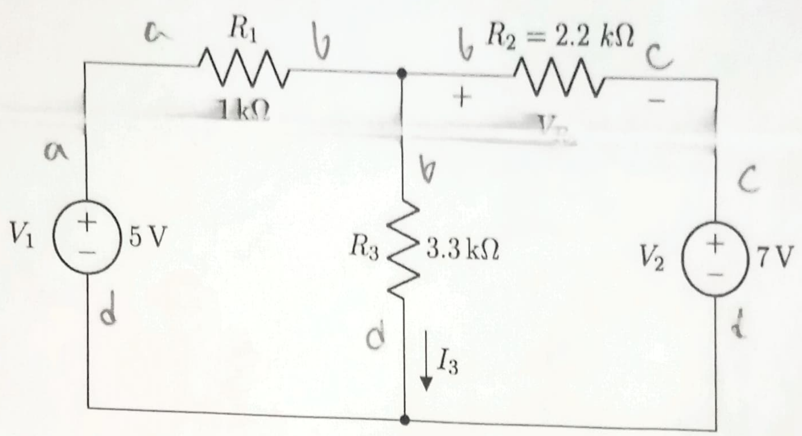
An independent **voltage source** is deactivated (made zero) by **shorting** it, and an independent **current source** is deactivated (made zero) by **open circuiting** it. However, if a dependent source is present, it must remain active during the superposition process.

Apparatus

- Multimeter
- Resistors ($1\ k\Omega$, $2.2\ k\Omega$, $3.3\ k\Omega$).
- DC power supply
- Breadboard
- Jumper wires

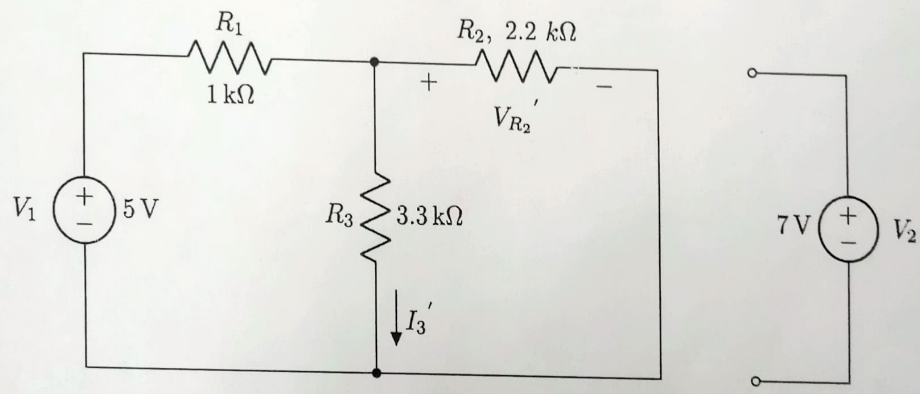
Procedures

- Measure the resistances of the provided resistors and fill up the data table (Table 1).
- Construct the following circuit on a breadboard. Try to use minimum number of jumper wires:



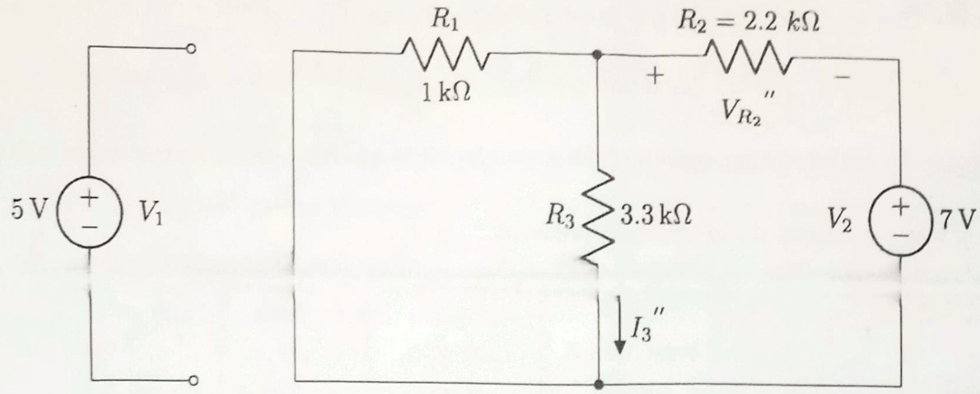
Circuit 1

- Measure the voltage across the resistors R_2, R_3 and current through the resistor R_3. Use a Multimeter for measuring the voltage and use Ohm's law to calculate the current (I_3) through R_3. Fill up the data tables.
- Render V_1 inactive (keeping V_2 active) and construct the following circuit.



Circuit 2

- Measure the voltage across the resistors R_2, R_3 and current through the resistor R_3. Use a Multimeter for measuring the voltage and use Ohm's law to calculate the current (I_3') through R_3. Fill up the data tables.
- Render V_2 inactive (keeping V_1 active) and construct the following circuit.



Circuit 3

- Measure the voltage across the resistors R_2, R_3 and current through the resistor R_3. Use a Multimeter for measuring the voltage and use Ohm's law to calculate the current (I_3'') through R_3. Fill up the data tables.
- Verify if $I_3 = I_3' + I_3''$ which would validate the superposition theorem for the current through R_3.
- Verify if $V_{R_2} = V_{R_2}' + V_{R_2}''$ which would validate the superposition theorem for the voltage across R_2.

Data Tables

Signature of Lab Faculty: Jishnu Mahmud **Date:** 3/2/24

** <u>*For all the data tables, take data up to three decimal places, round to two, then enter into the table.*</u>

Table 1: Resistance Data

For all your future calculations, please use the observed values only **(even for theoretical calculations)**.

Notation	Expected Resistance	Observed Resistance (kΩ)
R_1	1 kΩ	1.011 kΩ
R_2	2.2 kΩ	2.162 kΩ
R_3	3.3 kΩ	3.273 kΩ

Table 2: Current through R_3 and voltage across R_2

In the following table, I_3 is the current through R_3 and V_{R_2} is the voltage drop across the resistor R_2. Similar syntax applies to the remaining resistors. Also, calculate the percentage of error between expected and observed values of $I_3' + I_3''$.

Observation	I_3 with both V_1 and V_2 active (mA)	I_3' with only V_1 is active (mA)	I_3'' with only V_2 is active (mA)	$I_3' + I_3''$ (mA)
Experimental	1'44	0·873	0·664	1·437
Theoretical	1'423	0'86	0'563	1'423
Observation	V_{R_2} with both V_1 and V_2 active (V)	V_{R_2}' with only V_1 is active (V)	V_{R_2}'' with only V_2 is active (V)	$V_{R_2}' + V_{R_2}''$ (V)
Experimental	-2'322	2·86	-5·18	-2·32
Theoretical	2·343	-2·815	5'157	2'342

- **Percentage of error** $= \left|\dfrac{\textit{Observed Value} - \textit{Expected Value}}{\textit{Expected Value}}\right| \times 100\%$

N.B: Here, the Expected values are I_3, V_{R_2} and the Observed values are $I_3' + I_3''$ and $V_{R_2}' + V_{R_2}''$ respectively.

Hence, Percentage of error in $I_3' + I_3''$ calculation = 0·21 %

Hence, Percentage of error in $V_{R_2}' + V_{R_2}''$ calculation = 0·08 %

Questions

1. Calculate the **power associated** with R_2 using the experimentally measured values of currents or voltages when:

   - Only V_1 source is active.
   - Only V_2 source is active.
   - Both V_1 and V_2 sources are active.

   Fill out the Table given below and verify, whether the superposition theorem is verified or not in this case. If not, comment on the reasons. **You don't need to take any new readings for this task.** Use previous data from Table 2 to calculate the power. Remember, power consumed by a resistor, $P = VI = I^2R = \frac{V^2}{R}$

Observation	P_{R_2} when both V_1 and V_2 active $P_{R_2} = \frac{V_{R_2}^2}{R_2}$ (W)	P'_{R_2} when only V_1 is active $P'_{R_2} = \frac{V'^2_{R_2}}{R_2}$ (W)	P''_{R_2} when only V_2 is active $P''_{R_2} = \frac{V''^2_{R_2}}{R_2}$ (W)	$P'_{R_2} + P''_{R_2}$ (W)
Experimental	2·494	3·78	12·41	16·19
Theoretical	2·54	3·66	14·08	17·74

Is the Superposition Principle applicable in the case of Power?

☐ Yes ☑ No

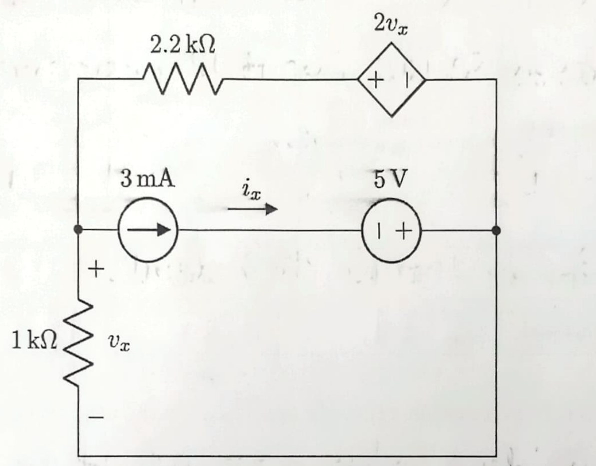
How would you relate your findings from this to the concept of linearity? Why does/doesn't it work when it comes to Power?

Superposition Principle can be applied in the linear circuits to find the voltage or current due to their linearity property. From the Ohm's law, $V \propto I$, when R is const. However, when it comes to power, the relations are $P \propto V^2$ and $P \propto I^2$, where R is const. and doesn't follow the concept of linearity, which is why it doesn't work when it comes to Power.

2. Why was a short circuit wire required to be connected between the corresponding terminals while turning off a voltage source? Why wasn't simply turning off the power switch enough to deactivate the source?

To turn an active voltage source to zero(0), we tend to short circuit the terminals because it ensures the disattachment of any leftover charges or potential differences from the circuit. So that, we can prevent any temporary current or voltage. which could demonstrate unreliable reading.

3. For the circuit shown below,



(a) Show using the Superposition Principle that the 5 V voltage source has no effect on the current i_x.

According to the Superposition theorem, the current or voltage through the components are the summation of the effects of each different sources acting alone. The voltage source with 5V only create a fixed voltage across it's terminals & will not affect current i_x. The constant current source 3mA will control the current flowing through the circuit.

(b) Why the 5 V voltage source does not contribute to the current i_x?

A voltage source, such as 5V (from the circuit), does the work of controlling voltage across the components in the circuit, which does not include contributing directly to the current flowing through the circuit.

(c) Can you draw any conclusions about the resistances of an ideal voltage and current source from this? If so, what are they?

An ideal voltage source has zero internal resistance and an ideal current source has infinite internal resistance.

Report

1. Fill up the theoretical parts of all the data tables.
2. Answer to the questions.
3. Discussion *[your overall experience, accuracy of the measured data, difficulties experienced and your thoughts on those]*. Add pages if necessary.

Comment:

For "Experiment No. 03 - Verification of Superposition Principle", We built a circuit on breadboard using 3 resistor and a DC circuit power supply with multiple wires properly. We used 2 jumper wires to measure the voltage V_{R_2} across R_2 ($2.162\,k\Omega$) and R_3 ($3.273\,k\Omega$) and current i_3 through R_3. We used multimeter for measuring voltage and by using Ohm's law of $V=IR$, we measured i_3 across R_3. We used the same process 3 times where ~~fi~~ at first 2 voltage sources ($V_1=5V$ & $V_2=7V$) were active. On the next attempts we used only one source ~~for~~ (V_1 & V_2) for each time each. According to our measure, We found $I_3 = 1.44\,mA$ & $V_{R_2} = -2.322\,V$ which is equal to $(I_3' + I_3'')$ and $(V_{R_2}' + V_{R_2}'')$, thus ~~valt~~ validates the superposition theorem. At the end, we obtained ~~and~~ the actual value and compared with the calculated value which resulted only 0.21% error for $I_3' + I_3''$ and 0.08% error for $V_{R_2}' + V_{R_2}''$.

And. the experiment concludes.