Lab Report: Electrical Circuits (CSE 209)

Expt. No: 02

Title: Series-Parallel DC Circuit and Verification of Kirchhoff's Laws.

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Date of Performance: 05/11/24

Date of Submission: 12/11/24

Title: Series-Parallel DC Circuit and Verification of Kirchhoff's Laws.

Objectives:

1. To learn analysis of de series-parallel circuit.
2. To verify Kirchhoff's Voltage Law (KVL).
3. To verify Kirchhoff's Current Law (KCL).

Theory: Kirchhoff's Voltage Law (KVL) states that the sum of the voltage rises around a closed path equals the sum of the voltage drops. The KVL can be written in the following mathematical form:

$$\boldsymbol{\Sigma V_{rises} = \Sigma V_{drops}}$$

The sum of the voltage rises and the sum of the voltage drops are to be calculated in a given direction (normally in the clockwise direction). For example, in the simple series circuit of Figure 1, there are two voltage sources (E1 and E2) and two resistors (R1 and R2). The voltage drops across the two resistors are V_1 and V2, respectively. If we write the KVL equation for the clockwise direction, then the KVL equation will be

$$\boldsymbol{E_1 - E_2 = V_1 + V_2}$$

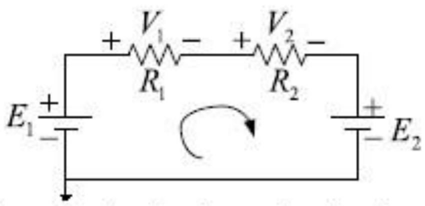

Figure 1. A simple series dc circuit.

Kirchhoff's Current Law (KCL) states **that the sum of the currents entering a node of a circuit is equal to the sum of the currents leaving the node.** The KCL can be written in the following mathematical form:

$$\boldsymbol{\Sigma I_1 = \Sigma I_0}$$

For example, in the simple parallel circuit of Figure 2, there is a voltage source (E) and two resistors (R) and R2). The source current drawn from the voltage source is I,. The currents through resistors R_1 and R_2 are I, and 2, respectively. If we consider the node a of the circuit, then I, is entering the node and I, and 12 are leaving the node. Then, the KCL equation for the node a is

$$\boldsymbol{I_s = I_1 + I_2.}$$

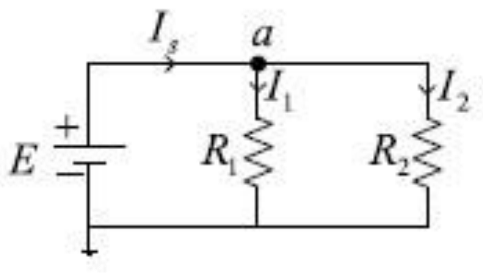

Figure 2. A simple parallel DC circuit.

A series-parallel circuit is one that is formed by a combination of series and parallel resistors. For solving series-parallel circuit, parallel combinations of resistors and series combination of resistors are clearly identified. Then series-parallel reduction method is used to determine the values of the circuit variables. For example, in the simple series-parallel circuit of Figure 3, the resistors R_2 and R_3 are in parallel and this parallel combination is in series with the resistor R_1. As the resistors R_2 and R_3 are in parallel, $V_2 = V_3$. Let $R_p = R_2 \parallel R_3$,. Then, the equivalent resistance of the series-parallel combination is $R_{eq} = R_1 + R_p$. Now, the circuit variables can be calculated using the formulas

$$I_1 = E / R_{eq}$$

$$V_1 = I_1 R_1$$

$$V_2 = V_3 = I_1 Rp$$

$$I_2 = V_2 / R_2$$

$$I_3 = V_3 / R_3$$

The KVL equations for the circuit of Figure 3 can be written as

$$E=V_1+V_{12}$$

$$E=V_1 +V_3$$

The KCL equation for the circuit of Figure 3 can be written as

$$I_1 = 1_2 +1_3$$

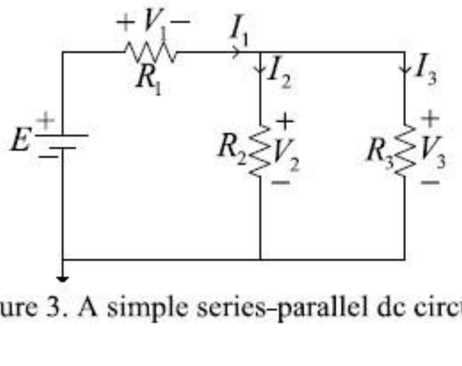

Figure 3. A simple series-parallel dc circuit.

Circuit Diagram:

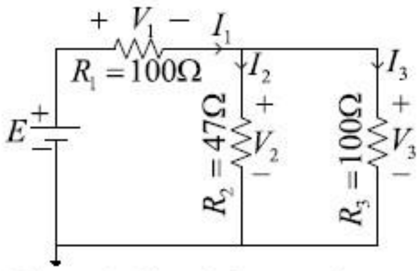

Figure 4. Circuit for experiment.

Equipment and Components Needed:

1. DC power supply
2. DC voltmeter
3. DC ammeter
4. Multimeter
5. Resistor 100Ω (two) and 47Ω (one)
6. Breadboard
7. Connecting wires

Answer to the pre-lab Questions:

Q1. Theoretically calculate the values of V_1, V_2, V_3, I_1, I_2, and I_3 of the circuit of Figure 1 with E = 3V.

Solution:

From the circuit, Since R_2 and R_3 are in parallel:

Calculating the equivalent resistance:

$R_2 \parallel R_3 = (R_2 * R_3) / (R_2 + R_3) = 31.9\ \Omega = R'$
resistance, $R_{eq} = R' + R_1 = 131.9\ \Omega$

We know, $I_1 = E / Req$

$= (3/131.9)$ A

$= 22.74$ mA

$V_1 = I_1 * R_1$

$= (22.74 * 100 * 10^{-3})$ V

$= 2.27$ V

In parallel circuits, voltages are equal, so V2 = V3.

$V_2 = V_3 = I_1 * R'$

$= (22.74 * 10^{-3} * 31.9)$ V

$= 0.73$ V

Now, $I_2 = V_2 / R_2$

$= 15.53$ mA

$I_3 = V_3 / R_3$

$=7.21$ mA

Q2. From the calculated values, show that (i) V2=V3 , (ii) KVL holds, that is, E=V1+V2 , and (iii) KCL holds, that is,I1=I2+I3 .

Solution:

From Calculated values of, $V_1 = 2.27$ V, $I_1 = 22.74$ mA

$V_2 = 0.73$ V, $I_2 = 15.53$ mA

$V_3 = 0.73$ V. $I_3 = 7.21$ mA

(i) From the calculated values we get, $V_2 = V_3 = 0.73$V

(ii) E = 3V

Applying Kirchhoff's Voltage Law (KVL):

$E = V_1 + V_2 = 2.27 + 0.73 = 3$ V

This confirms that KVL holds in the circuit.

(iii) Applying Kirchhoff's Current Law (KCL):

$I_1 = I_2 + I_3$

Therefore, $I_1 = I_2 + I_3 = (15.53 + 7.21)$ mA $= 22.74$ mA

Hence, it is confirmed that KCL holds in the circuit.

Pre-Lab Report Questions:

1. Theoretically calculate the values of V_1, V_2, V_3, I_1, I_2, and I_3 of the circuit of Figure 4 with E = 3V.
2. From the calculated values, show that (i) $V_2 = V_3$, (ii) KVL holds, that is, $E = V_1 + V_2$, and (iii) KCL holds, that is, $I_1 = I_2 + I_3$.

Equipments and Components Needed:

1. DC power supply
2. DC voltmeter
3. DC ammeter
4. Multimeter
5. Resistor 100Ω (two) and 47Ω (one)
6. Breadboard
7. Connecting wires

Lab Procedure:

1. Measure the resistance values of the resistors supplied and record them in Table 1.
2. Construct the circuit of Figure 4. Set the value of E at 3 V. Measure the values of E, V_1, V_2, V_3, I_1, I_2, and I_3 and record them in Table 1.
3. From experimental data, (i) show that $V_2 = V_3$, (ii) verify KVL, that is, $E = V_1 + V_2$, and (iii) verify KCL, that is, $I_1 = I_2 + I_3$.

Table 1. Experimental Datasheet

Measured Value of E (V)	Measured Value of V_1 (V)	Measured Value of V_2 (V)	Measured Value of V_3 (V)	Measured Value of I_1 (mA)	Measured Value of I_2 (mA)	Measured Value of I_3 (mA)	Measured Value of Resistances (Ω)
03	2.32	0.73	0.73	24.7	18.9	5.8	R_1= 98.4Ω R_2= 46Ω R_3= 98.1Ω

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4. Have the datasheet signed by your instructor.

Post-Lab Report Questions:

1. Calculate the values of V_1, V_2, V_3, I_1, I_2, and I_3 of the circuit of Figure 4 using measured values of E, R_1, R_2, and R_3. Compare the calculated values with the measured values and give reason if any discrepancy is found.
2. From the calculated values of V_1, V_2, V_3, I_1, I_2, and I_3, show that (i) $V_2 = V_3$, (ii) $E = V_1 + V_2$ (KVL), and (iii) $I_1 = I_2 + I_3$ (KCL).

Table 1: Experimental Datasheet

Measured value of E(V)	Measured value of V_1(V)	Measured value of V_2(V)	Measured value of V_3(V)	Measured value of I_1(mA)	Measured value of I_2(mA)	Measured value of I_3(mA)	Measured value of Resistances (Ω)
3	2.32	0.73	0.73	24.7	18.9	5.8	R1= 98.4 Ω R2= 46 Ω R3= 98.1 Ω

Answer of Post Lab Questions

1. **Calculate the values of V_1, V_2, V_3, I_1, I_2, and I_3 of the circuit diagram using measured values of E, R_1, R_2, and R_3. Compare the calculated values with the measured values and give a reason if any discrepancy is found.**

Solution:

The resistances R_2 and R_3 are in parallel:
Calculating the equivalent resistance:
$R_2 \parallel R_3 = (R_2 * R_3) / (R_2 + R_3) = 31.32\ \Omega = R'$
resistance, $R_{eq} = R' + R_1 = 129.72\ \Omega$

We know, $I_1 = E / Req$
$= (3/129.72)$ A
$= 23.13$ mA

$V_1 = I_1 * R_1$
$= (23.13 * 98.4 * 10^{-3})$ V
$= 2.28$ V

In parallel circuits, voltages are equal, so V2 = V3.
$V_2 = V_3 = I_1 * R'$
$= (23.13 * 10^{-3} * 31.32)$ V
$= 0.72$ V

Now, $I_2 = V_2 / R_2$
$= 15.75$ mA

$I_3 = V_3 / R_3$
$=7.38$ mA

From the calculated and measured values, we can observe that there are some little differences between these values. This is due to discrepancy of the resistors which were provided for the lab and these happened mainly because of mechanical and human error.

2.From the calculated values of V_1, V_2, V_3, I_1, I_2, and I_3, show that (i) $V_2 = V_3$, (ii) $E = V_1 + V_2$ (KVL), and (iii)$I_1 = I_2 + I_3$ (KCL).

Solution:

(i) From the calculated value we find,

$V_2 = 0.72V$ and $V_3 = 0.72V$

$\therefore$ **$V_2 = V_3$**

From the measured value, we have,
$V_2 = 0.73V$ and $V_3 = 0.73V$

The difference between the calculated value and measured value is negligible.

(ii) Here, E = 3v

Calculated values, $V_1 = 2.28V$, $V_2 = 0.72V$ and $V_3 = 0.72V$

$V_1 + V_2 = (2.28+.72)$ V

$= 3V$

$= E$

So, it can be said that,

$E = V_1 + V_2$ (KVL)

(showed)

(iii) From the calculated values we get,

$I_1 = 23.13mA$, $I_2 = 15.75mA$ and $I_3 = 7.38mA$
Here, $I_2+I_3 = (15.75+7.38)$ mA $= 23.13 = I_1$

Therefore,

$I_1 = I_2+I_3$ (KCL)

(showed)

Discussions:

1. The diagram should be established as the given diagram and the polarity of the connections should be ensured to avoid short circuit.

2. It is needed to ensure that resistance, multimeter, power supply and other components works properly to get accurate result.

3. The values of the resistances should be measured and be careful about the series-parallel sequence of the circuit, while establishing the resistances.

4. In order to avoid the errors of this experiment, it should be ensured the values of voltage, current and resistance are measured accurately.

5. Because of instrumental error or human error there may occur some changes in the result of this experiment.