East West University

Lab Report

Semester: Summer-2025

Course Title: Electrical Circuits

Course Code: CSE209

Sec: 01

Expt No: 02

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

Group No: 05

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2024-3-60-503

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Date of Submission: 02-08-2025

Experiment NO: 02

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

Objectives:

1. To learn analysis of dc 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 is equal to the sum of the voltage drops. The KVL can be written in the following mathematical form:

Σ V rises = Σ 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 ($E_1$and E_2) and two resistors ($R_1$and R_2) The voltage drops across the two resistors are V_1 and V_2, respectively. If we write KVL equation for the clockwise direction, then the KVL equation will be

$$E_1 - E_2 = V_1 + V_2 .$$

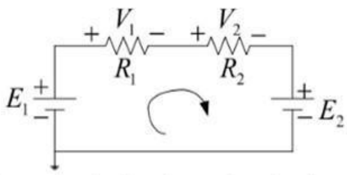

Figure 1. A simple series dc circuit.

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

$$\sum I_i = \sum I_o .$$

For example, in the simple parallel circuit of Figure 2, there is a voltage source (E) and two resistors (R_1 and R_2). The source current drawn from the voltage source is I_s. The currents through resistors R_1 and R_2 are I_1 and I_2, respectively. If we consider the node a of the circuit, then $I_s$is enters the node and I_1 and I_2 are leaving the node. Then, the KCL equation forthe node a is

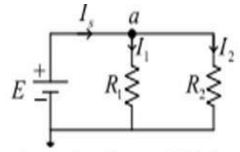

Figure 2. A simple parallel dc circuit.

$$I_S = I_1 + I_2$$

A series-parallel circuit is one that is formed by a combination of series and parallel resistors. For solving series-parallel circuits, parallel combinations of resistors and series combination of resistors are clearly identified. Then the 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_1 and R_2 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, $V2 = V3$. 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

$$I_1 = \frac{E}{R_{eq}}$$

$$V_1 = I_1 R_1$$

$$V_2 = V_3 = I_1 R_p$$

$$I_2 = \frac{V_2}{R_2}$$

$$I_3 = \frac{V_3}{R_3}$$

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

$$E = V_1 + V_2$$
$$E = V_1 + V_3$$

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

$$I_1 = I_2 + I_3$$

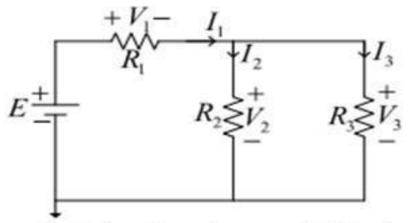

Figure 3. A simple series-parallel dc circuit.

Circuit Diagram:

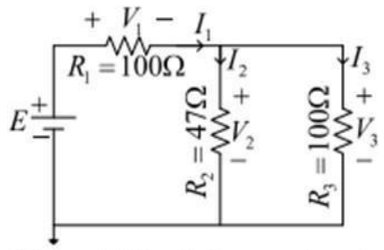

Figure 4. Circuit for experiment.

Pre-Lab Report Questions:

1. Theoretically calculate the values of E, V_1, V_2, V_3, I_1, I_2 and I_3 of the circuit of Figure4 with E =3V.

Ans:

Given that,

R_1 =100Ω

R_2 = 47Ω

$R_3 = 100\Omega$

$E = 3\text{V}$

Here, R_2 & R_3 is in parallel connection.

So, $R_p = \left(\frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} \Omega$

$= \left(\frac{1}{47} + \frac{1}{100}\right)^{-1} \Omega$

$= 31.98\Omega$

Now, R_p and R_1 is in series connection.

So, $R_{eq} = R_p + R_1$

$=(31.98+100)\Omega$

$= 131.98\ \Omega$

We know that,

$I_1 = \frac{E}{R_{eq}}$

$= \frac{3}{131.98}\ \text{A}$

$= 0.022\text{A}$

So, $I_1 = 0.022\text{A}$

Here,

$V_1 = I_1 R_1 = 0.022 \times 100 = 2.27\text{V}$

$$V_2 = I_2 R_P = 0.022 \times 31.98 = 0.73\text{V}$$

$$V_3 = I_3 R_P = 0.022 \times 31.98 = 0.73\text{V}$$

$$I_2 = \frac{V_2}{R_2} = \frac{0.73}{47} = 0.015\text{A}$$

$$I_3 = \frac{V_3}{R_3} = \frac{0.73}{100} = 0.0073\text{A}$$

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, $I_1 = I_2 + I_3$.

<u>Ans:</u>

i.

$$V_2 = V_3 = 0.72\text{V}$$

ii.

From the calculated value we get that,

$$V_1 + V_2$$

$$= (2.23 + 0.72)\ \text{V}$$

$$= 3\text{V}$$

iii

$$I_2 + I_3 = (0.015+0.007)\text{A}$$

$$=0.022\text{A}$$

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)	Measure d Value of I_2 (mA)	Measured Value of I_3 (mA)	Measured Value of Resistances (Ω)
3	2.3	0.9	0.7	22	7	13	R_1=97.8
							R_2=98.9
							R_3=48.2
5	3.7	1.3	1.1	33	11	20	R_1=97.8
							R_2=98.9
							R_3=48.2

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 and R_2. Compare the calculated values with the measured values and give reason if any discrepancy is found.

Ans:

Given, E = 3V

Here, R_2 & R_3 are in parallel.

So,

$$\frac{1}{R_p} = \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{98.9} + \frac{1}{49.2}\ \Omega$$

$$R_p = 32.85\ \Omega$$

And R_1 & R_p are in series,

$$R_{eq} = R_1 + R_p = 97.8\ \Omega + 32.85\ \Omega = 130.62\ \Omega$$

Now,

$$I_1 = \frac{E}{R_{eq}}$$

$$= \frac{3}{130.62} \text{ A}$$

$$= 0.023\text{A}$$
$$= 23\text{mA}$$

$$V_1 = I_1R_1 = 0.023 \times 97.8 = 2.25\text{ V}$$

$$V_2 = V_3 = I_1R_p = 0.023 \times 32.85 = 0.76\text{V}$$

$$I_2 = \frac{V_2}{R_2}$$

$$= \frac{0.76}{98.9} \text{ A}$$

$$= 0.008\text{A} = 8\text{mA}$$

$$I_3 = \frac{V_3}{R_3}$$

$$= \frac{0.76}{48.2} \text{ A}$$

$$= 0.016\text{A} = 16\text{mA}$$

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	2.3	0.9	0.7	22	7	13	R_1=97.8 R_2=98.9 R_3=48.2
Calculated Value of E (V)	Calculated Value of V_1 (V)	Calculated Value of V_2 (V)	Calculated Value of V_3 (V)	Calculated Value of I_1 (mA)	Calculated Value of I_2 (mA)	Calculated Value of I_3 (mA)	Calculated Value of Resistances (Ω)
3	2.25	0.76	0.76	23	8	16	R_1= 100 R_2= 47 R_3= 100

Table 2. The discrepancy between theoretical and measured values of V_1, V_2, V_3, I_1, I_2, I_3, R_1,

The calculated and measured values for voltages V_1, V_2, and V_3 show relatively small differences, which could be attributed to measurement inaccuracies. However, the calculated and measured values for currents I_1 , I_2, and I_3 exhibit significant discrepancies, suggesting potential measurement errors or incorrect units. It's essential to double-check the measurement equipment, units, and calibration to ensure accurate readings for current values.

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).

Ans:

From the calculated values,

V_1 = 2.25V
V_2 = 0.76V
V_3 = 0.76V
I_1 = 0.023A
I_2 = 0.008A
I_3 = 0.016A
E = 3V

i

Here, we can see that $V_2 = V_3$; (As R_2 & R_3 are in parallel and in parallel circuit voltages are Same).

ii

Again,

$V_1 + V_2 = 2.25V + 0.76V = 3.1V$

So, we can say that, $E = V_1 + V_2$

iii

Here,

$I_2 + I_3 = 0.008A + 0.016\,A$

$= 0.024A$

$= I_1$

So, we can say that, $I_1 = I_2 + I_3$

Discussion:

In this experiment, we analyzed a series-parallel DC circuit to verify KVL and KCL through both theoretical calculation and experimental measurement. The goal was to observed the behavior of voltage and current in a circuit combining both series and parallel resistor arrangements.

* Theoretical Analysis:

- Total current (I_1) $\approx 0.022A$
- Voltage across R_1 (V_1) $\approx 2.27V$
- Voltage across parallel branch ($V_2 = V_3$) $\approx 0.73V$
- Branch currents ($I_2 \approx 0.015A$, $I_3 \approx 0.0073A$)

These value satisfied both KVL ($E = V_1 + V_2$) and KCL ($I_1 = I_2 + I_3$) theoretically.

* Experimental Observation:

- $V_1 = 2.3V$, $V_2 = 0.9V$, $V_3 = 0.7V$
- $I_1 = 22mA$, $I_2 = 7mA$, $I_3 = 13mA$

Here, $V_2 \neq V_3$, indicating a slight discrepancy. Similarly, $I_1 \neq I_2 + I_3$ by a small margin.

* These inconsistencies could arise due to:

1. Measurement errors or meter calibration issues.
2. Resistor tolerances differing from their nominal values.
3. Loose connections or contact resistance.
4. Environmental factors, such as temperature affecting resistance.

* Comparison & Verification:

In the post-lab analysis using the measured resistor values, $R_1 = 97.8\Omega$, $R_2 = 98.9\Omega$, $R_3 = 48.2\Omega$. recalculated values closely matched measured voltages but showed greater deviation in current measurements. Despite this, KVL and KCL were resonably verified based on the adjused theoretical values:

- KVL: $V_1 + V_2 \approx E$
- KCL: $I_1 \approx I_2 + I_3$