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ECEN 50L

Monday 2:15 - 5:00 PM

Lab 2 - Week 3

Lab 2: Circuits with Series and Parallel Resistors

Objective

In this assignment, we will become familiar with power supply and multimeter equipment and the measurements of voltage, current, and resistance in electric circuits. We will also practice determining the equivalent resistance of series and parallel combinations and applying Kirchhoff's Laws to solve electric circuits.

Part 1: Resistance in Series and Parallel Connections

(1) First, we read the resistor color codes to confirm their nominal values. Then, we recorded their actual values with the multimeter:

TABLE I
RESISTOR VALUES

R (kΩ)	R_1	R_2	R_3	R_4	R_5	R_6
Nominal Values	2	1	7.5	3	1	10
Measured Values	1.98	0.99	7.56	2.98	0.98	9.82

(2) Then, we built the circuit in Figure 1 on the breadboard.

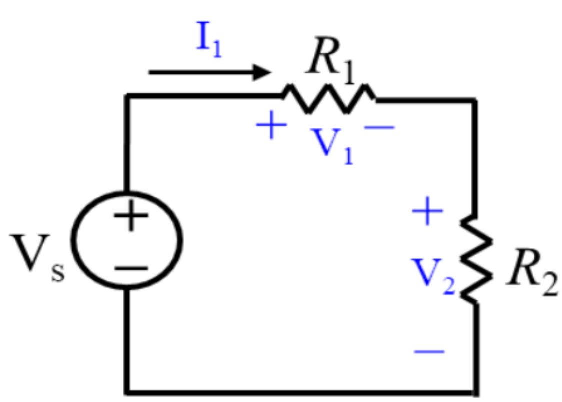

Fig. 1. Resistors in series. [1]

We (3) calculated and (4) measured the theoretical and actual current and voltages respectively:

TABLE II
FIGURE 1 CIRCUIT CURRENT AND VOLTAGES

	I_1 (mA)	V_1 (V)	V_2 (V)
Theoretical (using nominal *R*)	3.33	6.67	3.33
Theoretical (using measured *R*)	3.37	6.67	3.33
Measured	3.37	6.69	3.30
(5) Percent Error	0	0.29	0.9

(6) V_1:V_2 = 2 and R_1:R_2 = 2, confirming the voltage division rule, which states:

$$\frac{V_0}{V} = \frac{R_0}{R} \quad (1)$$

(7) Then, we added a resistor in parallel, as shown in Figure 2:

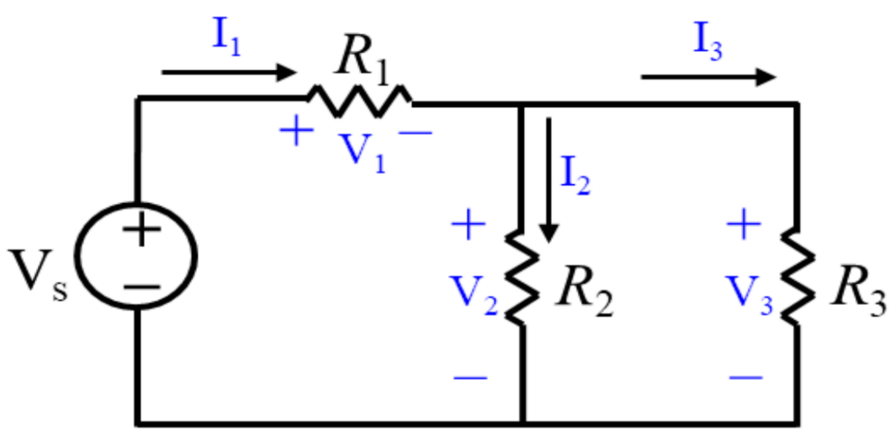

Fig. 2. Resistors in series and parallel. [2]

(8) Then we calculated and measured the theoretical and real currents and voltages respectively:

TABLE III
FIGURE 2 CIRCUIT CURRENTS AND VOLTAGES

	I_1 (mA)	I_2 (mA)	I_3 (mA)	V_1 (V)	V_2 (V)	V_3 (V)
Theoretical (using nominal *R*)	3.5	3.1	0.4	6.94	3.06	3.06
Theoretical (using measured *R*)	3.5	3.1	0.41	6.93	3.07	3.07
Measured	3.51	3.11	0.41	6.96	3.04	3.04
Percent Error	0.28	0.32	0	0.43	0.98	0.98

(9) V_2 must be less than that of Figure 1 because the current is split between both resistors. It follows that the equivalent resistance must be lower than the resistance of each resistor in parallel.

$R_{eq} = R_2R_3 / (R_2 + R_3) = 7.5 / 8.5 = 0.882$ kΩ.
I_1 is higher in Figure 2 because the equivalent resistance of R_2 and R_3 in parallel is less than that of R_2. The difference in V_2 between Figure 1 and Figure 2 is due to voltage division: the equivalent resistance after R_1 is lesser in Figure 2, so the voltage across each resistor will be lesser.

(10) $I_2 / I_3 = 7.75$ and $R_2 / R_3 = 1/7.75$. Due to current division, the ratios are reciprocals of each other:
$I_2R_2 = I_3R_3$ (KVL)
$I_2/I_3 = R_3/R_2$

(11) We then modified the circuit to add a fourth resistor R_4 in parallel with R_2 and R_3, and (12) calculated and measured their theoretical and real currents and voltages respectively:

TABLE IV
FOUR RESISTOR CIRCUIT CURRENTS AND VOLTAGES

	I_1 (mA)	I_2 (mA)	I_3 (mA)	I_4 (mA)	V_1 (V)	V_2 (V)	V_3 (V)	V_4 (V)
Theoretical (nominal *R*)	3.72	2.54	0.34	0.85	7.46	2.54	2.54	2.54
Theoretical (measured *R*)	3.76	2.57	0.34	0.85	7.45	2.55	2.55	2.55
Measured	3.78	2.59	0.34	0.86	7.47	2.53	2.53	2.53
Percent Error	0.53	0.77	0	1.16	0.27	0.79	0.79	0.79

(13) R_{eq} of R_2, R_3, and R_4 = $\frac{R_2R_3R_4}{R_2R_3+R_2R_4+R_3R_4}$ = 0.67 kΩ.

(14) The current division rule states that the lower resistance a resistor is, the more current goes through it. We can see that I_2 is the highest current of the three, and R_2 has the lowest resistance (1 kΩ).

<u>Part 2: Kirchhoff's Laws</u>

(1) We first built the circuit in Figure 3 on the breadboard:

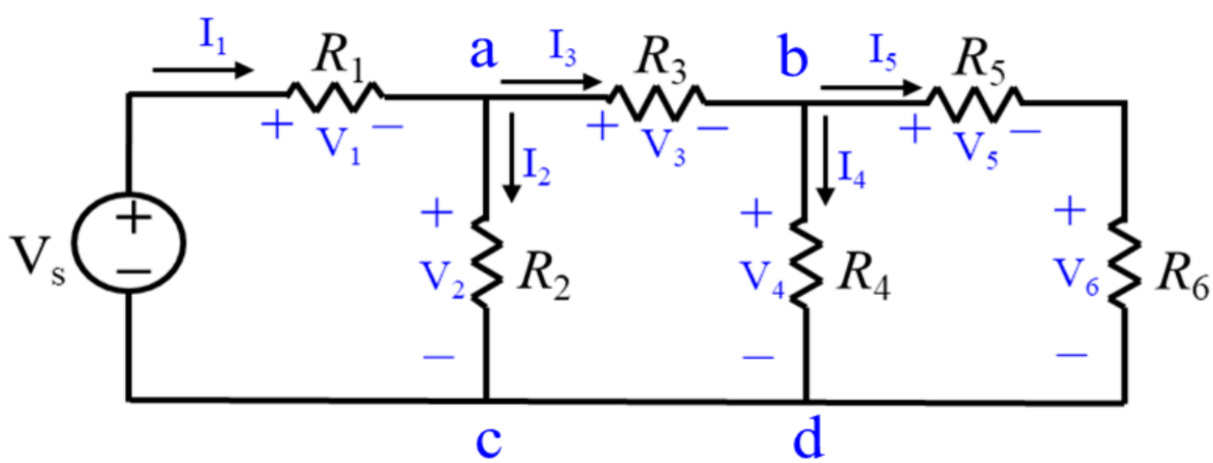

Fig. 3: Kirchhoff's Laws

(2) Then, we calculated and measured the theoretical and actual currents and voltages respectively:

TABLE V
FIGURE 3 CIRCUIT CURRENTS AND VOLTAGES

	I_1 (mA)	I_2 (mA)	I_3 (mA)	I_4 (mA)	I_5 (mA)	V_s (V)	V_1 (V)	V_2 (V)	V_3 (V)	V_4 (V)	V_5 (V)	V_6 (V)
Theoretical (using nominal *R*)	3.44	3.12	0.32	0.25	0.068	10	6.88	3.12	2.38	0.75	0.068	0.68
Theoretical (using measured *R*)	3.47	3.16	0.316	0.25	0.068	10	6.87	3.12	2.39	0.74	0.067	0.67
Measured	3.47	3.17	0.32	0.25	0.075	9.998	6.90	3.1	2.37	0.73	0.067	0.66

Then, we used (3) Kirchhoff's Current Law on each node and (4) Kirchhoff's Voltage Law on each loop to confirm the accuracy of our calculations and measurements:

TABLE VI
KIRCHHOFF'S LAWS

	Σ I a	Σ I b	Σ I cd	Σ V left	Σ V mid	Σ V right
Theoretical (using measured R)	$I_1 - I_2 - I_3 =$ -0.006 mA	$I_3 - I_4 - I_5 =$ -0.002 mA	$I_2 + I_4 + I_5 - I_1 = 0.008$ mA	$V_s - V_1 - V_2$ = 0.008 V	$V_2 - V_3 - V_4$ = -0.01 V	$V_4 - V_5 - V_6$ = 0.003 V
Measured	-0.005	-0.002	0.0076	0.009	-0.098	0.005

Since the net current in and out of each node and the net voltage in each loop was close to 0, our analysis was correct.

Next, we (5) measured the equivalent resistance of the whole circuit using the multimeter to get a resistance of 2.88 kΩ. We also calculated the theoretical equivalent resistance given the actual measured resistance values, resulting in a resistance of 2.88 kΩ. Then, we used (6) Ohm's law to get the equivalent resistance by dividing the source voltage by the source current to get 2.88 kΩ.

TABLE VII
EQUIVALENT RESISTANCE

R_{eq}	Calculation with MATLAB	Direct Measurement	Based on Ohm's law
Value (kΩ)	2.88	2.88	2.88

(7) If some unknown resistor replaced R_6, all we would need to do to measure the resistance is the current through and voltage across that resistor.