Electric Circuits I

Laboratory 2 – Circuits with Series and Parallel Resistors

Objective:

- To become familiar with power supply and multimeter equipment.
- To become familiar with the measurements in electric circuits.
- To determine the equivalent resistance of series and parallel combinations.
- To use Kirchhoff Laws.

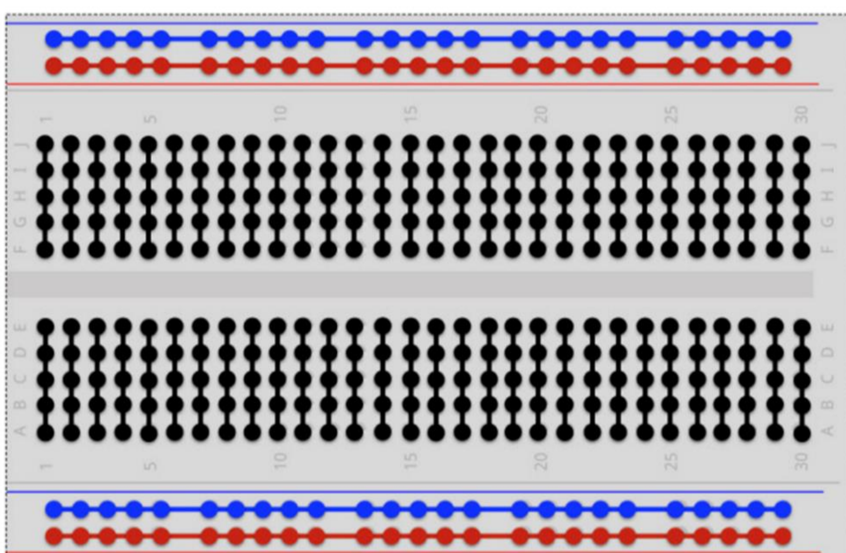
I. Equipment:

- DC Power Supply (Keysight EDU36311A)
- Digital Multimeter (Keysight EDU34450A)

DC Power Supply (Keysight EDU36311A)

Digital Multimeter (Keysight EDU34450A)

- Breadboard for connecting resistors.



Note: holes in rows and columns are internally connected according to the lines.

- 6 resistors with values in the range 1kΩ to 20kΩ.

II. Background & Theory

A. Equivalent Resistance in Series and Parallel Connections

The equivalent resistance of N resistors connected in series is expressed as:

$$R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{n=1}^{N} R_n$$

The equivalent resistance of N resistors connected in parallel is expressed as:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N} = \sum_{n=1}^{N} \frac{1}{R_n}$$

Note: For only two resistors in parallel, the above equation reduces to:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

Also, note that for resistors of the same value in parallel, this reduces to:

$R_{eq} = \frac{R_1}{2}$ for two resistors

$R_{eq} = \frac{R_1}{3}$ for three resistors

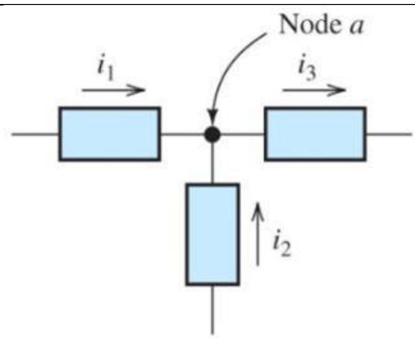
$R_{eq} = \frac{R_1}{4}$ for four resistors

Table 1 – Standard Resistors (K = *1e3, M = *1e6)

1.0	5.6	33	160	820	3.9K	20K	100K	510K	2.7M
1.1	6.2	36	180	910	4.3K	22K	110K	560K	3M
1.2	6.8	39	200	1K	4.7K	24K	120K	620K	3.3M
1.3	7.5	43	220	1.1K	5.1K	27K	130K	680K	3.6M
1.5	8.2	47	240	1.2K	5.6K	30K	150K	750K	3.9M
1.6	9.1	51	270	1.3K	6.2K	33K	160K	820K	4.3M
1.8	10	56	300	1.5K	6.6K	36K	180K	910K	4.7M
2.0	11	62	330	1.6K	7.5K	39K	200K	1M	5.1M
2.2	12	68	360	1.8K	8.2K	43K	220K	1.1M	5.6M
2.4	13	75	390	2K	9.1K	47K	240K	1.2M	6.2M
2.7	15	82	430	2.2K	10K	51K	270K	1.3M	6.8M
3.0	16	91	470	2.4K	11K	56K	300K	1.5M	7.5M
3.3	18	100	510	2.7K	12K	62K	330K	1.6M	8.2M
3.6	20	110	560	3K	13K	68K	360K	1.8M	9.1M
3.9	22	120	620	3.2K	15K	75K	390K	2M	10M
4.3	24	130	680	3.3K	16K	82K	430K	2.2M	15M
4.7	27	150	750	3.6K	18K	91K	470K	2.4M	22M
5.1	30								

B. Kirchhoff Laws:

1. **Kirchhoff Current Law (KCL)**

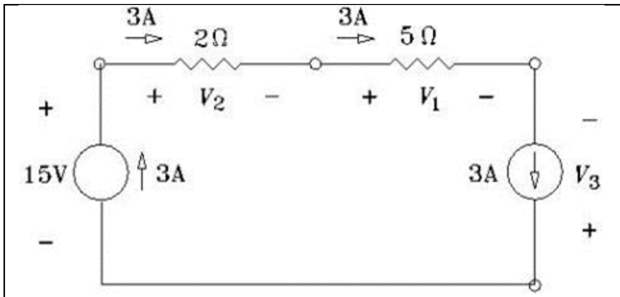


The sum of all the currents at any node in a circuit equals zero:

$$\sum i\,(node) = 0$$

$$-i_1 - i_2 + i_3 = 0$$

2. **Kirchhoff Voltage Law (KVL)**



The sum of all the voltages around any closed path in a circuit equals zero:

$$\sum v\,(closed\ path) = 0$$

$$-15V + V_2 + V_1 - V_3 = 0$$

III. Prelab Assignment:

The prelab assignments should be completed and submitted to Camino before the lab.

A. Part 1 – Test Equipment

1. Quickly read through the manuals of DC Power Supply (PowerSupply_EDU36311A-Triple-Output-Bench-Power-Supply.pdf from page 5 onward) and Digital Multimeter (Multimeter_EDU34450-90002.pdf from page 16 onwards) to understand how to operate them.
2. Learn from the manual how to use the digital multimeter to measure: resistance, voltage, and current.

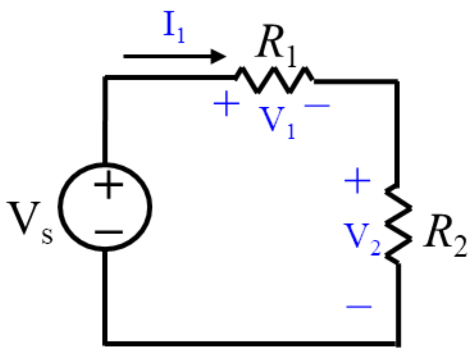


Figure 1 – Resistors in series

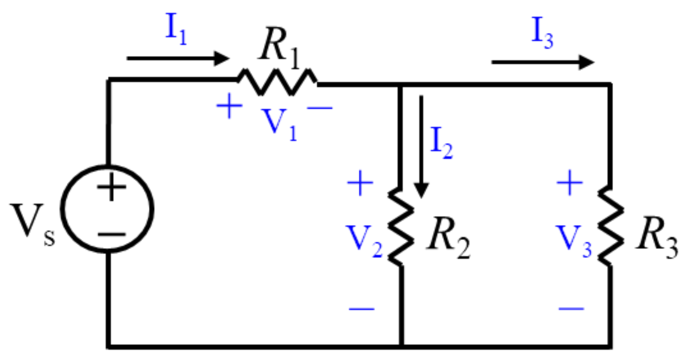


Figure 2 – Resistors in series and parallel

B. Part 2 – Resistance in Series and Parallel Connections

1. Select 6 resistors (R_1, R_2, R_3, R_4, R_5, and R_6) with values in the range 1kΩ to 20kΩ from **Table 1**.
2. Create a MATLAB script with the nominal values of resistors and $V_s = 10V$:
   a. Calculate the values for I_1, V_1, and V_2 for the circuit shown in **Figure 1**.
   b. Calculate the values for I_1, I_2, I_3, V_1, V_2, and V_3 for the circuit shown in **Figure 2**.
   c. Calculate the values of the currents and voltages across each resistor of the circuit described in **Laboratory Part 1** Step 11.

C. Part 3 – Kirchhoff Laws

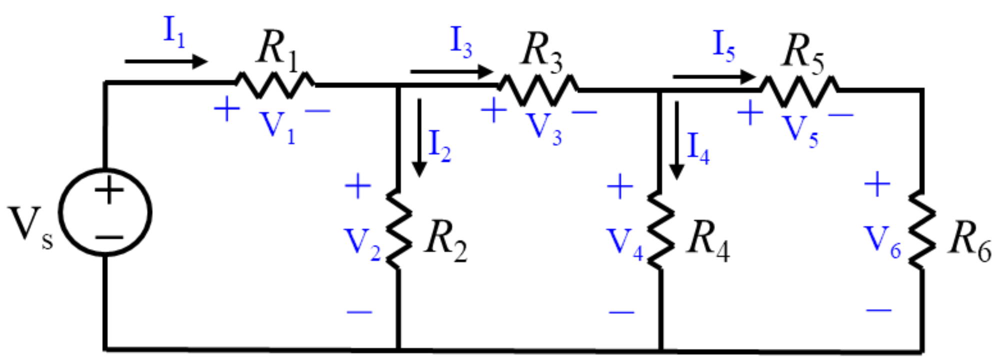


Figure 3 – Kirchhoff Laws

1. With the chosen values of R_1, R_2, R_3, R_4, R_5, and $R6$, create a MATLAB script with $V_s = 10V$:
   a. Calculate the equivalent resistance seen by the voltage source V_s in the circuit shown in **Figure 3**.

b. Calculate the theoretical values of I_1, I_2, I_3, I_4, I_5, V_1, V_2, V_3, V_4, V_5, and V_6 for the circuit shown in **Figure 3**.

c. Calculate KCL for each node and KVL for each loop.

IV. Laboratory Part 1 – Resistance in Series and Parallel Connections

Verify the results of MATLAB scripts of your prelab assignment with the TA before working on the lab procedures.

1. Use the digital multimeter to measure 6 chosen resistors in the prelab assignments. Record their measured values in **Table 2** below.

Table 2 – Resistance Values

	R_1	R_2	R_3	R_4	R_5	R_6	
Nominal Values							kΩ
Measured Values							kΩ

2. Build the circuit in **Figure 1** on the breadboard with chosen resistors and set the DC power supply to 10 V.
3. Use MATLAB to recalculate the theoretical values for I_1, V_1, and V_2 with the measured values of resistors. Record them in **Table 3**.
4. Measure I_1, V_1, and V_2 and record the measurements in **Table 3**. *Note that the measured current is calculated using Ohm's Law with measured voltage and resistance.*

Table 3 – Currents and Voltages

	I_1	V_1	V_2
Theoretical values (nominal values of R)			
Theoretical values (meas. values of R)			
Measured by DMM			
Percent Error			

5. Calculate the percent error between the theoretical values (with measured values of R) and the measured values by DMM. The percent error is calculated as:

$$\frac{|Measured - Theoretical|}{Theoretical} \times 100$$

6. Compute the ratio of V_1 to V_2 and the ratio of R_1 to R_2. How are they related?

7. Modify the circuit by adding a third resistor R_3 as shown in **Figure 2.**
8. Measure the currents and the voltages shown. Record the measured values in **Table 4**. *Use the MATLAB script in the prelab assignments to recalculate theoretical voltages and currents with the measured values of R.* Calculate percent error between the theoretical values (with *R*) and the measured values by DMM.

Table 4 – Currents and Voltages

	I_1	I_2	I_3	V_1	V_2	V_3
Theoretical (nominal R)						
Theoretical (measured R)						
Measured by DMM						
Percent Error						

9. Compute the equivalent resistance of the parallel combination of R_3 and R_2. How does this explain the values of I_1 and V_2 in this circuit compared to those measured with the first circuit?
10. What is the ratio of I_2 to I_3? What is the ratio of R_2 to R_3? How are they related?
11. Modify the circuit by adding a fourth resistor R_4, connected in parallel to R_2 and R_3.
12. Measure the currents and voltages across each resistor. Record them in **Table 5**. Calculate the percent error between the theoretical values (with measured values of *R*) and the measured values by DMM. Compute the equivalent resistance R_{eq} of R_2, R_3, and R_4. How is the current I_1 divided by the three resistors connected in parallel?

Table 5 – Currents and Voltages

	I_1	I_2	I_3	I_4	V_1	V_2	V_3	V_4
Theoretical (nom. *R*)								
Theoretical (meas. *R*)								
Measured								
Percent Error								

V. Laboratory Part 2 – Kirchhoff Laws

1. Build the circuit in **Figure 3** on the breadboard and set the DC power supply V_s to 10V.
2. Measure all the currents and voltages in the circuit and record them in **Table 6**.

Table 6 – Currents and Voltages of Voltage Divider Circuit

	I_1	I_2	I_3	I_4	I_5	V_s	V_1	V_2	V_3	V_4	V_5	V_6
Theoretical (nom.)												
Theoretical (meas.)												
DMM Measured												

3. Write Kirchhoff Current Law (KCL) for each node with the measurements, and verify that KCL is satisfied at each node. If there is any discrepancy, recheck the measurements.
4. Write Kirchhoff Voltage Law (KVL) for each loop with the measurements, and verify that KVL satisfies each loop. If there is any discrepancy, recheck the measurements.
5. Measure the equivalent resistance of the circuit, as shown in **Figure 4**. Compare it to the theoretical value calculated in the pre-lab.

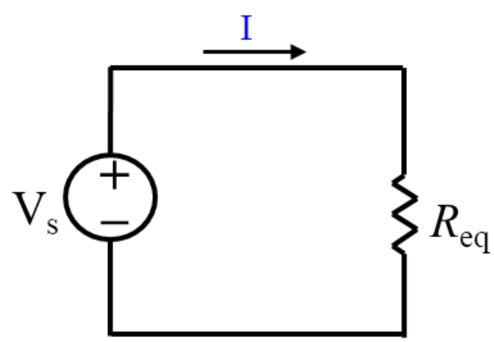


Figure 4 – Equivalent Resistance

6. Use the measured value of the voltage V_S and the current I_1 from Step 2 to calculate the equivalent resistance. Compare this value to the measurement from Step 5.
7. If an unknown resistor value replaced R_6, how could you find the value of R_6 from the measurement and the calculation method?

Make sure to check off with the TA before leaving the lab section.

VI. Laboratory Report:

Include all measurements, computations, tables, and answers to all questions from the laboratory procedure. Clearly label all steps.