

2. (Lab #6) Ohm's Law, Series and Parallel Connection

Objective:

The objectives of this experiment are:

- 1) to understand and use Ohm's Law
- 2) to learn, understand, and use resistors connected in series and parallel
- 3) to learn the basic concepts and relationships of current and voltage measurements in DC circuits containing resistors wired in series and parallel
- 4) to learn the relationships of the total resistance of resistors connected in series and parallel
- 5) to learn to use ammeters, voltmeters, ohmmeters, and multimeters to properly measure voltages, currents, and resistances.

Introduction:

Most common household electrical circuits are made of many devices connected in parallel. Each device is hooked to the power source in parallel with all the other devices, each connected to the same voltage source and availing itself of the same voltage. Each device has its own characteristic resistance, and therefore each draws from the source a different amount of current, depending on its resistive value. While the voltage being accessed is nearly the same for all devices, the amount of current drawn from the source increases as each device draws its respective current based on its resistance. As a result as more and more devices are connected in parallel, the total amount of current drawn from the source increases. It thus has the effect of causing the resistance to decrease with each additional resistance added. Additional devices added to a circuit, require additional current from the source until something is overloaded. More current is required beyond that which can be supplied by the source or carried by the conductors without burning up.

Series circuits are not as common, except for old time Christmas tree lights that are a challenge to fix when one unknown bulb has burned out and all the rest fail to work.

However, all wires that make connections and the connections themselves qualify as series resistance. Wires have resistance that depend on wire size, length, and type of material. Wires add series resistance to circuits, just as good and bad connections add also. In order to fully understand electrical circuits and their behavior, one must first understand Ohm's Law and the principles regarding resistors in series and parallel circuits.

Background Theory:

1) Ohm's Law

Ohm's Law is the relationship between the current I flowing through a resistance R and the potential drop across it V . The current is directly proportional to the potential difference across the resistance and is inversely proportional to the resistance,

$$I = \frac{V}{R} \quad (6 - 1)$$

As an alternative, Ohm's Law may be stated as: The potential difference V across a resistance is directly proportional to the current I flowing through the resistance and the resistance R , or

$$V = I \times R \quad (6 - 2)$$

Ohm's Law can be rearranged to define the resistance R so that

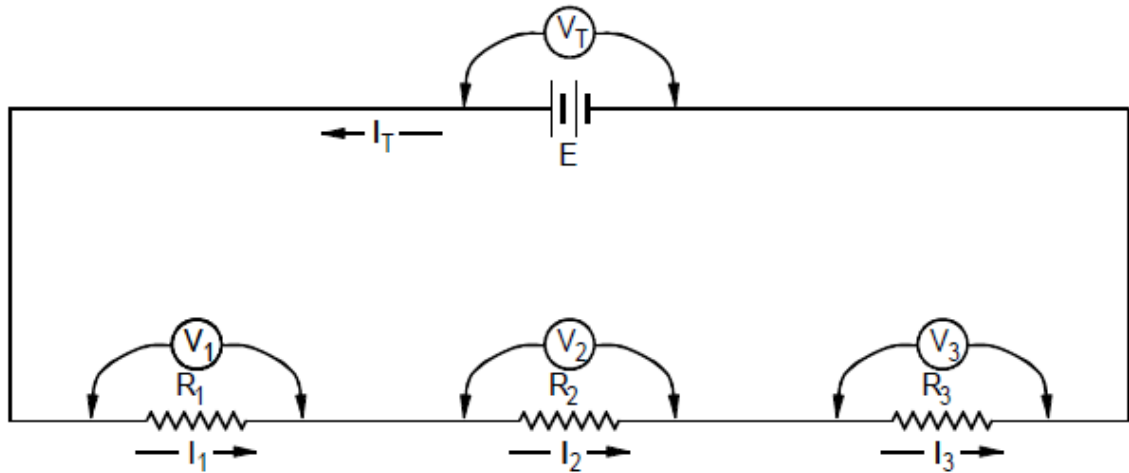
$$R = \frac{V}{I} \quad (6 - 3)$$

If the potential difference across the resistance is measured in volts (V) and the current flowing through the resistance is measured in amperes (A), then the resistance values will be in units of ohms.

2) Resistors in Series

Figure (6-1) shows 3 resistors, R_1 , R_2 , and R_3 , connected in series in a closed circuit powered by a single battery or Emf source. In this circuit the current supplied by the battery flows through each resistor, with the current in each resistor being the same. If the current supplied by the battery is I_T , the current in each resistor is I_1 , I_2 , and I_3 , and they are all one and the same, then

$$I_T = I_1 = I_2 = I_3 \quad (6 - 4)$$



[Figure 6-1] Three resistors R_1 , R_2 , and R_3 connected in series.

The voltage drop across the battery V_T will be the total sum of the individual drops across each of the 3 resistors, and

$$V_T = V_1 + V_2 + V_3 \quad (6 - 5)$$

where V_1 is the potential difference across R_1 , V_2 is the potential difference across R_2 , and V_3 is the potential difference across R_3 . From Equation (6-2),

$$V_T = I_T \times R_T \quad (6 - 6)$$

$$V_1 = I_1 \times R_1 \quad (6 - 7)$$

$$V_2 = I_2 \times R_2 \quad (6 - 8)$$

And

$$V_3 = I_3 \times R_3 \quad (6 - 9)$$

Substituting these equations into Equation (6- 5) gives

$$I_T R_T = I_1 R_1 + I_2 R_2 + I_3 R_3 \quad (6 - 10)$$

and since $I_T = I_1 = I_2 = I_3$

$$R_T = R_1 + R_2 + R_3 \quad (6 - 11)$$

Therefore, when resistors are connected in series, the total resistance is just the sum of the individual resistances. While this has been shown for 3 resistors, the total resistance of any

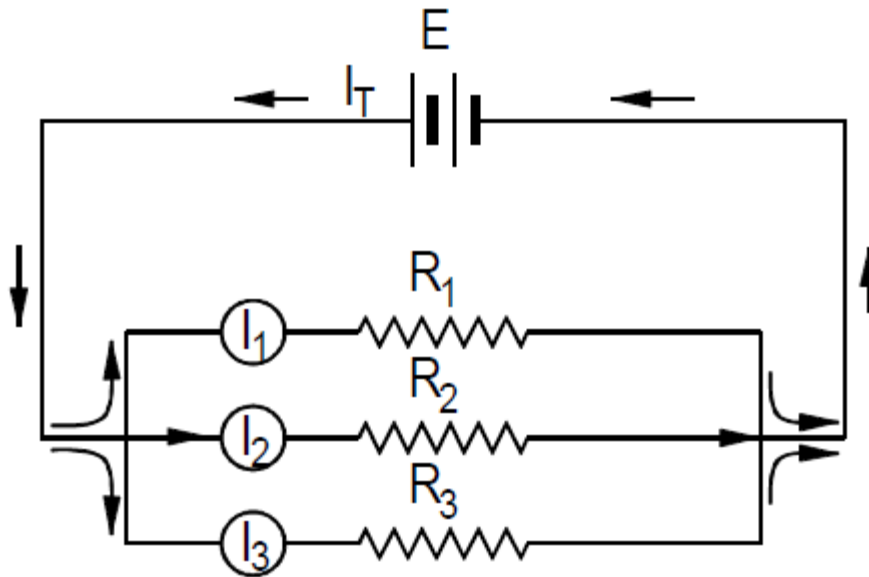
number N ($N \geq 2$) of resistors connected in series, end to end, can be found using the same general procedure. Therefore for resistors connected in series

$$R_T = \sum_{i=1}^N R_i \quad (6 - 12)$$

3) Resistors in Parallel

Resistors are connected in parallel when one end of each resistor is connected to a common point and each of their other ends is connected to another common point as shown in Figure (6-2). The current I_T that is supplied by the battery is divided into 3 separate currents, I_1 , I_2 , and I_3 , each flowing through resistors R_1 , R_2 , and R_3 respectively. After flowing through the resistors, the 3 currents rejoin into a common current, I_T , or that current flowing back to the battery. The total current flowing in the circuit is the sum of the separate currents flowing through the resistors,

$$I_T = I_1 + I_2 + I_3 \quad (6 - 13)$$



[Figure 6-2] Three resistors R_1 , R_2 , and R_3 connected in parallel showing the flow of current

From Equation (6-1) the total current is related to the total voltage and total resistance by

$$I_T = \frac{V_T}{R_T} \quad (6 - 14)$$

and the current, potential difference, and resistance of each separate resistor is given by

$$I_1 = \frac{V_1}{R_1} \quad (6 - 15)$$

$$I_2 = \frac{V_2}{R_2} \quad (6 - 16)$$

And

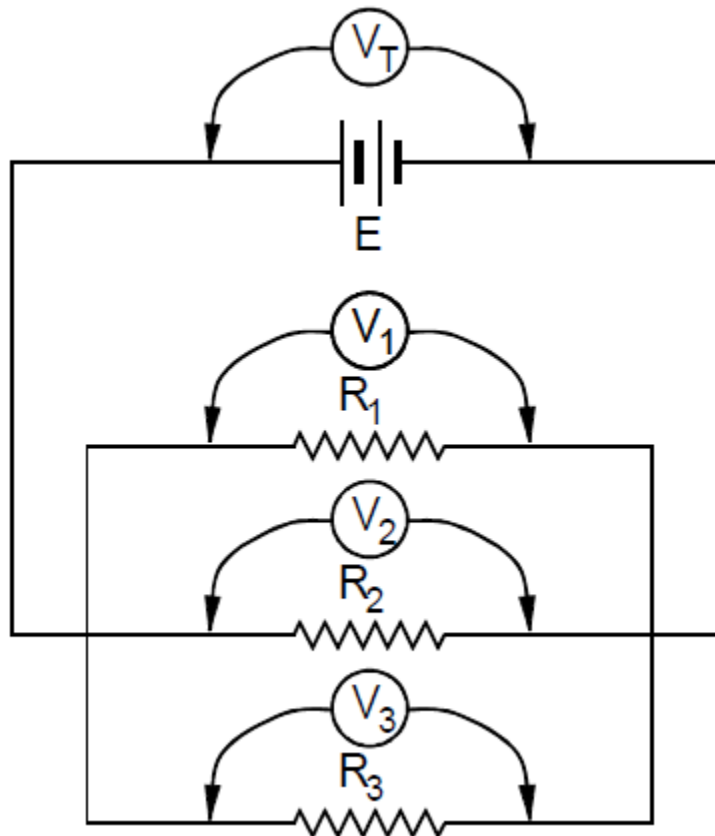
$$I_3 = \frac{V_3}{R_3} \quad (6 - 17)$$

Substituting these equations into Equation (6-13)

$$\frac{V_T}{R_T} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \quad (6 - 18)$$

The voltage drops across the battery and resistors are all equal, and as illustrated in Figure (6-3),

$$V_T = V_1 = V_2 = V_3 \quad (6 - 19)$$



[Figure 6-3] Three resistors R_1 , R_2 , and R_3 connected in parallel showing the potential differences all being equal.

Since all the potentials are equal Equation (6-18) reduces to

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad (6 - 20)$$

which is the equation for the total resistance of 3 resistors connected in parallel. As was the case for series resistors, the total resistance of any number N ($N \geq 2$) of resistors connected in parallel can be found using the same general procedure and will result in the relationship

$$\frac{1}{R_T} = \sum_{i=1}^N \frac{1}{R_i} \quad (6 - 21)$$

In circuits with combinations of resistors in series and parallel, the total resistance can be found by breaking the circuit down into its simplest unit consisting of either resistor in series or parallel and then adding its total resistance back into the next simplest unit and finding its total resistance, and so on until the entire circuit has been reconstructed.

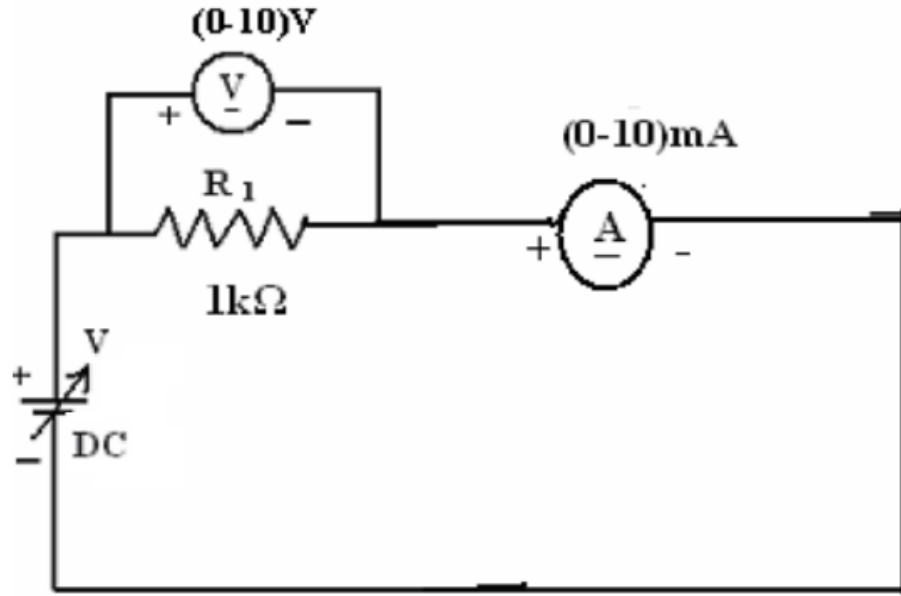
Tasks for the (Lab #6): Ohm's Law, Series and Parallel Connection

1) Applying Ohm's Law practically

Ohm's Law circuit

Equipment

- (1) Adjustable DC Power Supply
- (2) Digital Multimeter
- (3) 1 k Ω resistor
- (4) 6.8 k Ω resistor
- (5) 33 k Ω resistor



[Figure 6-4] Ohm's Law Circuit

Procedure

1. Construct the circuit shown in Figure (6-4) using the 1 kΩ resistor. Set the DMM to measure DC current and insert it in-line between the source and resistor. Set the source to zero volts. Measure and record the current in Table (6-1).
2. Set V to 2 volts, calculate the current based on Ohm's law and record it in Table (6-1). Measure the actual current, determine the deviation, and record these in Table (6-1). Note that Deviation = 100 * (measured – calculated) / calculated.
3. Repeat step 2 for the remaining source voltages in [Table 6-1].
4. Remove the 1 kΩ and replace it with the 6.8 kΩ. Repeat steps 1 through 3 and record the results in Table (6-2).
5. Remove the 6.8 kΩ and replace it with the 33 kΩ. Repeat steps 1 through 3 and record the results in Table (6-3).

6. Using the measured currents from Tables (6-1), (6-2), and (6-3), create a plot of current versus voltage. Plot all three curves on the same graph. Voltage is the horizontal axis and current is the vertical axis.

[Table 6-1] 1 k Ω Circuit Results

V volts	I calculated	I measured	Deviation
0V			
2V			
4V			
6V			
8V			
10V			
12V			

[Table 6-2] 6.8 k Ω Circuit Results

V volts	I calculated	I measured	Deviation
0V			
2V			
4V			
6V			
8V			
10V			
12V			

[Table 6-3] 33 K Ω Circuit Results

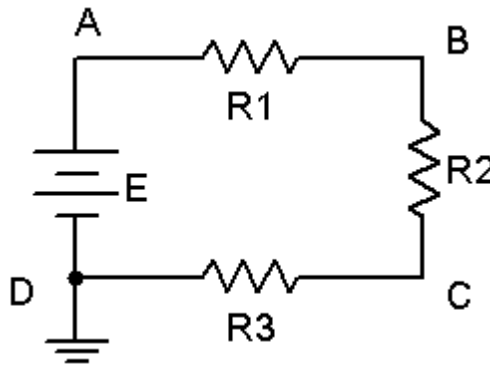
V volts	I calculated	I measured	Deviation
0V			
2V			
4V			
6V			
8V			
10V			
12V			

2) Understand Series Connection

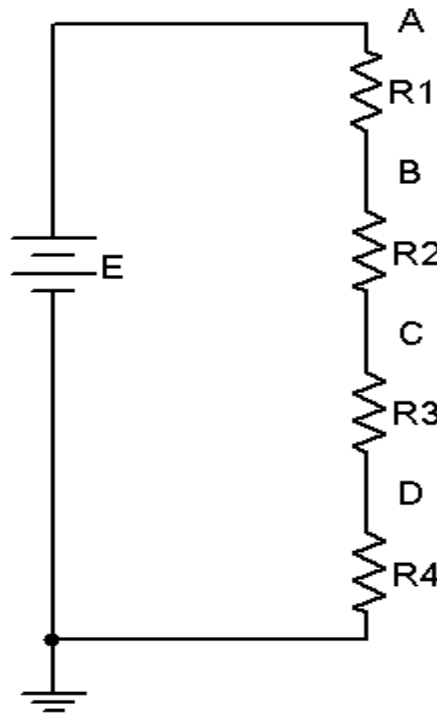
Series Connection circuit

Equipment and Components

- (1) Adjustable DC Power Supply
- (2) Digital Multimeter
- (3) Resistors :1 k Ω , 2.2 k Ω , 3.3 k Ω and 6.8 k Ω



[Figure 6-5] 3-Resistors Series Connection Circuit



[Figure 6-6] 4- Resistors Series Connection Circuit

Procedure

- Using the circuit of Figure (6-5) with $R_1 = 1\text{ k}$, $R_2 = 2.2\text{ k}$, $R_3 = 3.3\text{ k}$, and $E = 10$ volts, calculate the current and record it in Table (6-4). Construct the circuit. Set the DMM to read DC current and insert it in the circuit at point A. Record the measured current in Table (6-4). Repeat the current measurements at points B and C.
- Using the calculated current found in Step 1, apply Ohm's law to determine the expected voltage drops across R_1 , R_2 , and R_3 . Record these values in the calculated column of Table (6-5).
- Set the DMM to measure DC voltage. Place the DMM probes across R_1 and measure its voltage. Record the measured value in Table (6-5). Repeat this process for the voltages across R_2 and R_3 . Determine the percent deviation between calculated and measured for each of the three resistor voltages and record these in the final column of Table (6-5).
- Consider the circuit of Figure (6-6) with $R_1 = 1\text{ k}$, $R_2 = 2.2\text{ k}$, $R_3 = 3.3\text{ k}$, $R_4 = 6.8\text{ k}$ and $E = 20$ volts. Using the voltage divider rule, determine the voltage drops across each of the four resistors and record the values in Table (6-6) under the calculated column. Note that the larger the resistor, the greater the voltage should be. Also determine the potentials V_{AC} and V_B , again using the voltage divider rule.
- Connect the circuit of Figure (6-6) with $R_1 = 1\text{ k}$, $R_2 = 2.2\text{ k}$, $R_3 = 3.3\text{ k}$, $R_4 = 6.8\text{ k}$ and $E = 20$ volts. Set the DMM to measure DC voltage. Place the DMM probes across R_1 and measure its voltage. Record this value in Table (6-6). Also determine the deviation. Repeat this process for the remaining three resistors.
- To find V_{AC} , place the red probe on point A and the black probe on point C. Similarly, to find V_B , place the red probe on point B and the black probe on ground. Record these values in Table (6-6) with deviations.

[Table 6-4] Check Current in Series Circuit Results

I calculated	I at Point A	I at Point B	I at Point C

[Table 6-5] 3 Resistors in Series Circuit Results

V volts	V _{calculated}	V _{measured}	Deviation
R ₁			
R ₂			
R ₃			

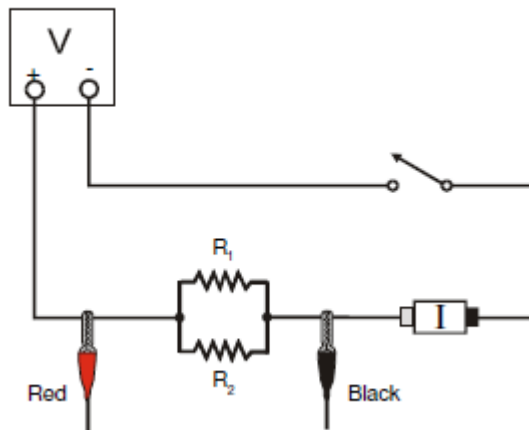
[Table 6-6] 4 Resistors in Series Circuit Results

V volts	V _{calculated}	V _{measured}	Deviation
R ₁			
R ₂			
R ₃			
R ₄			
V _{AC}			
V _B			

3) Understand Parallel Connection

Equipment and Components

- (1) Adjustable DC Power Supply
- (2) Digital Multimeter
- (3) Resistors :50 Ω, 68Ω



[Figure 6-7] 2- Resistors Parallel Connection Circuit

1. Connect the parallel circuit shown below using 50 Ω resistors for both R₁ and R₂. the Voltage Probe is used to measure the voltage applied to both resistors. The Current Probe is used to measure the total current in the circuit.
2. You can take readings from the Meter window at any time. To test your circuit, briefly press on the switch to complete the circuit. Both current and voltage readings should increase. If they do not, recheck your circuit.
3. Press the switch to complete the circuit again and read the total current (I) and total voltage (VTOT). Record the values in the data table.
4. Connect the leads of the Voltage Probe across resistor 1. Press on the switch to complete the circuit and read the voltage (V₁) across resistor 1. Record this value in the data table (6-7).
5. Connect the leads of the Voltage Probe across resistor 2. Press on the switch to complete the circuit and read the voltage (V₂) across resistor 2. Record this value in the data table (6-7).
6. Repeat Steps 1 – 5 with a 68 Ω resistor substituted for resistor 2.
7. Repeat Steps 1 – 1 with a 68 Ω resistor used for both resistor 1 and resistor 2.

[Table 6-7] 2-Resistors in Parallel Circuit Results

	$R_1 (\Omega)$	$R_2 (\Omega)$	$I (A)$	$V_1 (V)$	$V_2 (V)$	$R_{eq} (\Omega)$	$V_{Tot} (V)$
1	50	50					
2	50	68					
3	68	68					