

Chapter 9

Ohm's Law - Series and Parallel Circuits

9.1 Purpose

. Ohm's law will be explored in this lab using series and parallel circuits.

9.2 Introduction

Tiny electrons, which orbit the nucleus of atoms, are the basic carriers of all electric charges in the universe. When an atom has the same number of positively charged protons in the nucleus as negatively charged electrons orbiting it, their respective electrical charges cancel each other out and the atom is called neutral. If we change these neutral atoms by adding (or removing) an electron, the system becomes electrically charged. Adding an electron to a neutral system makes the system negatively charged, while removing an electron makes it positively charged.

If a positively charged system is attached to a negatively charged system (using a wire or other metal object), the extra electrons in the negative system will flow to the positive system. This flow of electrons creates what is called current (I) in the wire. Current is measured in Amperes, which is the same as 6.25×10^{18} electrons/second, and the direction of the current flow is traditionally in the opposite direction of the actual electron flow i.e. current flows from positive to negative.

The amount of current produced between two connected, oppositely charged systems depends on two things: Voltage (V) and Resistance (R). Voltage or "electric potential" is the energy per electron of the system and is related to the difference in charge between the positive and the negative side of the system. Voltage or potential is measured in volts, which is the same as joules/coulomb.

As the electrons move through an object, they tend to collide with atoms and other electrons. The energy from these collisions is given off in the form of heat, and the amount of heat generated depends on the resistance of the material the current is flowing through. Resistance is measured in Ohms (Ω) and tells us how much the material blocks the movement of the electrons. When designing an electrical circuit, devices which have a high resistance

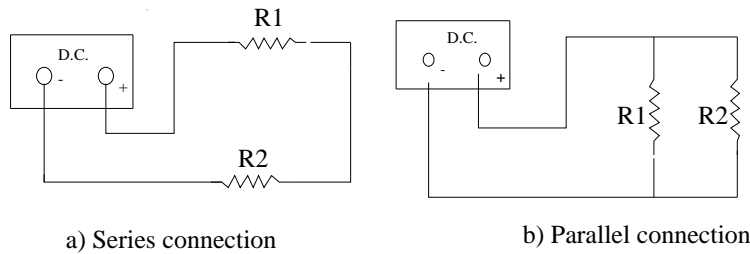


Figure 9.1: a) This is a series resistor circuit. b) This is a parallel resistor circuit.

can be placed in the path of moving electrons in order to reduce the electron flow (current). These devices are simply called resistors.

We can see that when voltage increases, the amount of current also increases, and when resistance increases, the amount of current decreases. These ideas are expressed by Ohm's Law:

$$V = IR \quad \text{or} \quad R = \frac{V}{I} \quad (9.1)$$

where I is the amount of current, V is the voltage, and R is the resistance of the material.

Resistors and other electrical devices are generally arranged two different ways to form a circuit for electrons to flow through. Series circuits have all of the devices arranged so that the electrons must travel through each device. See Figure 9.1a. Parallel circuits generally have two or more different paths for the electrons to travel through the resistors and devices. See Figure 9.1b.

Series Circuits: When resistors are placed in series with each other, the current flow through each resistor is the same:

$$I_{Total} = I_1 = I_2 = \dots \quad (9.2)$$

To get the total resistance of the circuit you can just add up the resistance of each resistor:

$$R_{Total} = R_1 + R_2 + R_3 + \dots \quad \text{Series resistors} \quad (9.3)$$

The total voltage of the circuit can also be found by adding up the voltage across each individual resistor. However the voltage across each resistor is different, and must be calculated using Ohm's Law (equation 9.1). For example $V_2 = I R_2$.

Parallel Circuits: The rules governing parallel circuits are a bit different than for series circuits. When resistors are placed in parallel with each other, the voltage across each resistor is the same:

$$V_{Total} = V_1 = V_2 = \dots \quad (9.4)$$

To get the inverse of the total resistance of the circuit you must add up the inverse of the resistance of each resistor:

$$\frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots \quad \text{Parallel resistors} \quad (9.5)$$

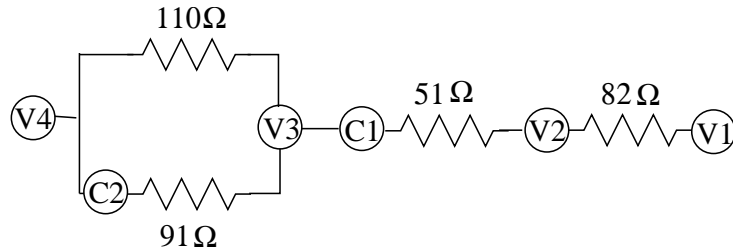


Figure 9.2: Schematic diagram of the circuit box.

The total current of the circuit can be found by simply adding up the current across each individual resistor. However, the current through each resistor is different, and must be calculated using Ohm's Law (equation 9.1):

$$I_1 = \frac{V}{R_1} \quad (9.6)$$

Circuits can contain resistors in both parallel and series arrangements. In these cases, one applies the series or parallel formula to reduced the problem step by step.

9.3 Equipment:

Circuit box, power supply, two digital multimeters (one for current and one for voltage), assorted wires and connectors.

9.4 Procedure:

All of the circuits that we will need for this experiment are already assembled in the circuit box. See Figure 9.2 for a diagram of the circuit in the box.

Note that banana style connectors (red or black) are used with the multimeter to measure voltage. The large 'phone jack' is used with the multimeter for current measurements.

CAUTION: The digital multimeter has a very low resistance when measuring current. **Never plug the power supply directly into the multimeter with the current (amps) mode selected.** This will destroy the both the multimeter and power supply.

9.4.1 Series Circuits

- Connect the power supply across the two resistors in series by connecting the positive terminal of the power supply to V1 and the negative terminal to V3 (see Figure 9.2).
- Connect the voltage multimeter across V1 and V3 and adjust the power supply so that the meter reads 5 volts.
- With the voltage multimeter, record the voltage between points V1 and V2 and between points V2 and V3. Do the voltages V1-V2 and V2-V3 sum to the value of the voltage from the power supply. Why?

- Disconnect the voltage multimeter and connect the current multimeter (phone jack) to C1. Record the current at point C1.
- Using equation 9.1, calculate the resistance of the resistor between points V2 and V3. Calculate the resistance of the resistor between V1 and V2. Find the percentage error of the calculated value for the resistors and the resistor values labeled on the circuit box.

9.4.2 Parallel Circuits

- Connect the power supply across the two resistors in parallel by connecting the positive terminal of the power supply to V3 and the negative terminal to V4 as shown in Figure 9.2.
- Connect the voltage multimeter across V3 and V4 and adjust the power supply so that the meter reads 5 volts.
- With the current multimeter, measure the current at point C2.
- Using equation 9.1, calculate the resistance of the resistor labeled 91Ω .
- Calculate the total resistance of the two parallel resistors. Also calculate the total current through the parallel circuit, and the current across the 110Ω resistor.

9.5 Questions:

1. If we have N resistors, all with equal resistance R, what is the total resistance if all of the resistors are in series?
2. If we have N resistors, all with equal resistance R, what is the total resistance if all of the resistors are in parallel?
3. From Ohm's Law (Equation 9.1), how much current is present in a closed circuit with no resistors present? (Hint: This is why we must be careful with current multimeter connections in this lab.)