This presentation will
• Define voltage, current, and resistance.
• Define and apply Ohm’s Law.
• Introduce series circuits.
  o Current in a series circuit
  o Resistance in a series circuit
  o Voltage in a series circuit
• Define and apply Kirchhoff’s Voltage Law.
• Introduce parallel circuits.
  o Current in a parallel circuit
  o Resistance in a parallel circuit
  o Voltage in a parallel circuit
• Define and apply Kirchhoff’s Current Law.

Electricity – The Basics
An understanding of the basics of electricity requires the understanding of three fundamental concepts.

• Voltage
• Current
• Resistance
A direct mathematical relationship exists between voltage, resistance, and current in all electronic circuits.

Voltage, Current, & Resistance
Current – Current is the flow of electrical charge through an electronic circuit. The direction of a current is opposite to the direction of electron flow. Current is measured in **AMPERES** (AMPS).
Voltage

Voltage – Voltage is the electrical force that causes current to flow in a circuit. It is measured in VOLTS.

Resistance

Resistance – Resistance is a measure of opposition to current flow. It is measured in Ohms.

First, An Analogy

The flow of water from one tank to another is a good analogy for an electrical circuit and the mathematical relationship between voltage, resistance, and current.

Force: The difference in the water levels ≡ Voltage
Flow: The flow of the water between the tanks ≡ Current
Opposition: The valve that limits the amount of water ≡ Resistance

Anatomy of a Flashlight

A flashlights is composed of a battery, switch, and light bulb. The battery provides the voltage, the switch controls the flow, and the light bulb represents the opposition.
Flashlight Schematic

- Closed circuit (switch closed)
- Current flow
- Lamp is on
- Lamp is resistance, uses energy to produce light (and heat)

- Open circuit (switch open)
- No current flow
- Lamp is off
- Lamp is resistance, but is not using any energy

Current Flow

- **Conventional Current** assumes that current flows out of the positive side of the battery, through the circuit, and back to the negative side of the battery. This was the convention established when electricity was first discovered, but it is incorrect!

- **Electron Flow** is what actually happens. The electrons flow out of the negative side of the battery, through the circuit, and back to the positive side of the battery.

Engineering vs. Science

- The direction that the current flows does not affect what the current is doing; thus, it doesn’t make any difference which convention is used as long as you are consistent.

- Both **Conventional Current** and **Electron Flow** are used. In general, the science disciplines use **Electron Flow**, whereas the engineering disciplines use **Conventional Current**.

- Since this is an engineering course, we will use **Conventional Current**.

Ohm’s Law

- Defines the relationship between voltage, current, and resistance in an electric circuit

- **Ohm’s Law**:
  
  \[ I = \frac{V}{R} \]

- Stated mathematically:
  
  \[ \text{Current} \text{ in a resistor varies in direct proportion to the voltage applied to it and is inversely proportional to the resistor's value.} \]

  Where:  
  
  - \( I \) is the current (amperes)
  - \( V \) is the potential difference (volts)
  - \( R \) is the resistance (ohms)
1.2  Introduction to Analog

Ohm’s Law Triangle

\[ I = \frac{V}{R} \text{ (amperes A)} \]

\[ R = \frac{V}{I} \text{ (ohms } \Omega) \]

\[ V = IR \text{ (volts V)} \]

Example: Ohm’s Law

Example:
The flashlight shown uses a 6 volt battery and has a bulb with a resistance of 150 \( \Omega \). When the flashlight is on, how much current will be drawn from the battery?

Solution:

\[ V = 6 \text{ V} \]
\[ R = 150 \text{ } \Omega \]
\[ I = \frac{V}{R} = \frac{6}{150} = 0.04 \text{ A} = 40 \text{ mA} \]

Circuit Configuration

Components in a circuit can be connected in one of two ways.

Series Circuits
- Components are connected end-to-end.
- There is only a single path for current to flow.

Parallel Circuits
- Both ends of the components are connected together.
- There are multiple paths for current to flow.
Characteristics of a series circuit

- The current flowing through every series component is equal.
- The total resistance ($R_T$) is equal to the sum of all of the resistances (i.e., $R_1 + R_2 + R_3$).
- The sum of all of the voltage drops ($V_{R1} + V_{R2} + V_{R3}$) is equal to the total applied voltage ($V_T$). This is called Kirchhoff's Voltage Law.

Example: Series Circuit

Solution:

Total Resistance:

- $R_1 = R_2 + R_3$
- $R_1 = 220 \Omega + 470 \Omega = 1.2 \text{k}\Omega$
- $R_1 = 1890 \Omega = 1.89 \text{k}\Omega$

Current Through Each Component:

I = \frac{V}{R}$ (Ohm's Law)

Current $I = \frac{12}{1.299\Omega} = 6.349 \text{mA}$

Since this is a series circuit:

I = I_{R1} + I_{R2} + I_{R3} = 6.349 \text{mA}

Example: Series Circuit

Solution:

Voltage Across Each Component:

- $V_{R1} = I_R \times R_1 = (\text{Ohm's Law})$
- $V_{R1} = 6.349 \text{mA} \times 220 \Omega = 1.397 \text{volts}$
- $V_{R2} = I_R \times R_2 = (\text{Ohm's Law})$
- $V_{R2} = 6.349 \text{mA} \times 470 \Omega = 2.984 \text{volts}$
- $V_{R3} = I_R \times R_3 = (\text{Ohm's Law})$
- $V_{R3} = 6.349 \text{mA} \times 1.2 \text{K}\Omega = 7.619 \text{volts}$
Example: Series Circuit

Solution:
Verify Kirchhoff's Voltage Law:
\[ V_T = V_1 + V_2 + V_3 \]
\[ 12 \text{ V} = 1.397 \text{ V} + 2.984 \text{ V} + 7.619 \text{ V} \]
\[ 12 \text{ V} = 12 \text{ V} \]

Parallel Circuits

Characteristics of a Parallel Circuit
• The voltage across every parallel component is equal.
• The total resistance \( R_T \) is equal to the reciprocal of the sum of the reciprocal:
  \[ \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \]
• The sum of all of the currents in each branch \( (I_{R1} + I_{R2} + I_{R3}) \) is equal to the total current \( I_T \). This is called Kirchhoff's Current Law.

Example: Parallel Circuit

Example:
For the parallel circuit shown, use the laws of circuit theory to calculate the following:
• The total resistance \( R_T \)
• The voltage across each component \( V_T, V_{R1}, V_{R2}, \text{ and } V_{R3} \)
• The current flowing through each component \( I_{R1}, I_{R2}, \text{ and } I_{R3} \)
• Use the results to verify Kirchhoff's Current Law.

Example: Parallel Circuit

Solution:
Total Resistance:
\[ R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} \]
\[ R_T = \frac{1}{\frac{1}{470 \Omega} + \frac{1}{2.2 \text{ k}\Omega} + \frac{1}{3.3 \text{ k}\Omega}} \]
\[ R_T = \frac{1}{0.001 + 0.000454 + 0.000303} \]
\[ R_T = 346.59 \Omega \]

Voltage Across Each Component:
Since this is a parallel circuit:
\[ V_T = V_{R1} = V_{R2} = V_{R3} = 15 \text{ volts} \]
Example: Parallel Circuit

Solution:
Current Through Each Component:

\[ I_1 = \frac{V_1}{R_1} = \frac{15 \text{ V}}{470 \text{ } \Omega} = 31.915 \text{ mA} \]

\[ I_2 = \frac{V_2}{R_2} = \frac{15 \text{ V}}{2.2 \text{ k}\Omega} = 6.818 \text{ mA} \]

\[ I_3 = \frac{V_3}{R_3} = \frac{15 \text{ V}}{3.3 \text{ k}\Omega} = 4.545 \text{ mA} \]

\[ I = \frac{V}{R} = \frac{15 \text{ V}}{346.59 \text{ } \Omega} = 43.278 \text{ mA} \]

Verify Kirchhoff's Current Law:

\[ I = I_1 + I_2 + I_3 \]

\[ 43.278 \text{ mA} = 31.915 \text{ mA} + 6.818 \text{ mA} + 4.545 \text{ mA} \]

Summary of Kirchhoff's Laws

Kirchhoff's Voltage Law (KVL):
The sum of all of the voltage drops in a series circuit equals the total applied voltage.

Kirchhoff's Current Law (KCL):
The total current in a parallel circuit equals the sum of the individual branch currents.