BASIC ELECTRONICS FOR FIELD MEASUREMENT
2017 American School of Gas Measurement Technology

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Introduction

Electricity has become the life blood of our society. From years past of it being a miracle just to switch on a light bulb, to something that is used 24 hours a day, seven days a week. Today, we depend on it for every aspect of our lives, yet take it completely for granted. Electricity is used for everything from powering motors, to running the most complicated computer systems, factories and defense systems, to charging our iPods and iPhones.

This paper will focus on the use of electric circuits that apply to the devices used in the oil and gas industry.

Basics

Electricity is made-up, in part by electrons and protons. Electrons have a negative charge and protons have a positive charge. Electrons repel each other, protons repel each other, but electrons and protons are attracted to each other. The heart of all this is the electron movement. This electron movement is enabled by electric circuits.

There exists what are called Alternating Current (AC) circuits, and Direct Current (DC) circuits. An in depth discussion of these topics and the differences between them are out of the scope of this document. Only DC circuits will be discussed.

There are three elements always present in an operating electric circuit are:

Current. A progressive movement of free electrons along a wire or other conductor. Current is expressed in Amperes or Amps.

Electromotive Force. This is also known as voltage. This is the force that pushes or pulls electrons (current) through the circuit. Voltage is expressed in Volts

Resistance. Any opposing effect that hinders free-electron progress (current flow) through wires when an electromotive force (voltage source) is attempting to produce a current in the circuit. Resistance is expressed in Ohms or (Ω)

The simplest of circuits consists of the following:

1. A voltage Source, such as a battery.
2. A load, such as a light bulb.

3. Connecting wires.
4. Control device (switch).

Figure 1 shows a diagram of a simple circuit.

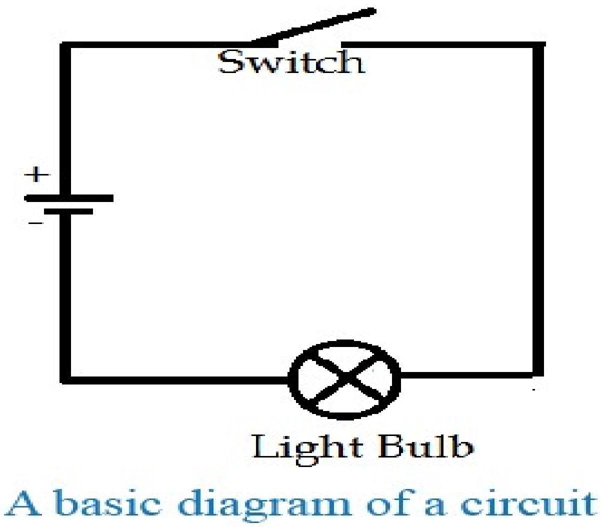

Figure 1.

Ohm's Law

One of Ohm's major contributions was the establishment of a definite relationship between voltage, current, and resistance in a closed (complete) circuit. Ohm stated this relationship as : Current is directly proportional to voltage in inversely proportional to resistance.

Ohm's law can be expressed mathematically as

$$I = E/R \quad \text{(equation 1)}$$

Where I = current (amps)

E = voltage (volts)

R = resistance (ohms, Ω)

Solving for voltage can be accomplished by multiplying both sides of the equation by R. This will create the equation

$$E = IR \quad \text{(equation 2)}$$

With this equation, if you divide by I the Ohm's law formula becomes

$$R=E/I \quad \text{(equation 3)}$$

These variations of the formula make it possible to determine current if voltage and resistance are known (equation 1), voltage if current and resistance are known (equation 2), and resistance if voltage and current are known. Figure 1 shows a method of helping to remember when to use each equation.

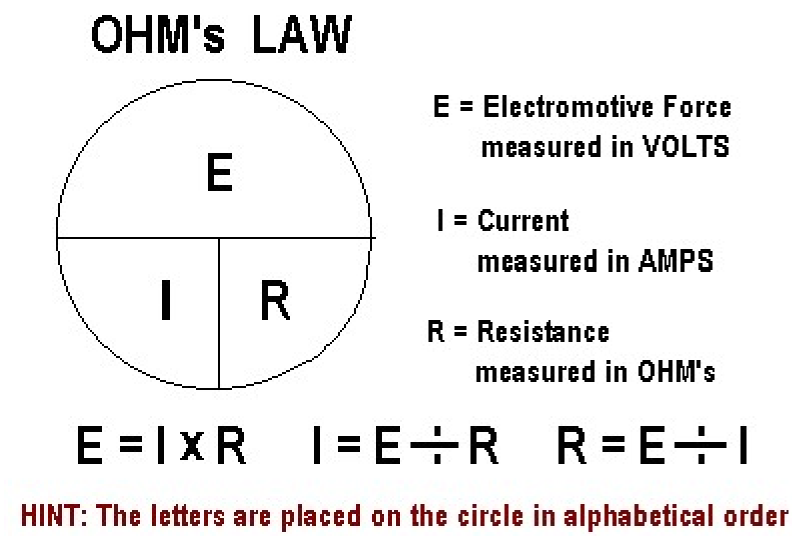

Figure 1.

Circuit Components and Basic Circuit

Conductors are basically the wire or etching path on a circuit board that make the path for the circuit. Although there are no conductors with zero resistance, for practical purposes they are considered to be zero ohms. Silver, copper and gold are considered some of the best conductors. Figure 2 shows the symbol for a conductor.

Insulators are the opposite of conductors. They have a very high resistance and are used to insulate. An example would be insulating between two conductors with a rubber coating or sleeve.

There may be a need to reduce the magnitude of current flow in a circuit to protect a device. This is accomplished by manufactured resistors. Figure 3 shows the symbol for a resistor.

A battery is a common source for creating a DC voltage. Power supplies also create voltages for DC circuits. Figure 4 shows a common symbol which is often use to symbolize a DC voltage source whether from a power supply or battery.

Figure 2 Conductor.

Figure 3 Resistor.

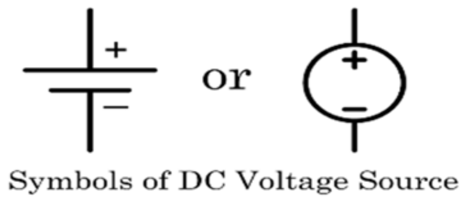

Figure 4. DC Voltage Source.

Figure 5 shows a schematic diagram of a very basic circuit.

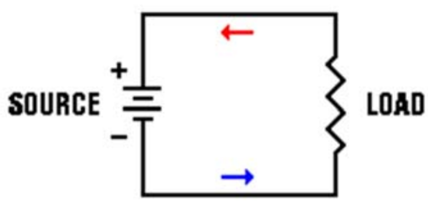

Figure 5 Schematic of a basic circuit.

Power

Voltage is the pressure which causes current through resistance. Power is a measure of the energy used per unit time. The unit of measure for power is the watt. When one amp of current passes through a one-ohm resistor, energy is dissipated at the rate of one watt. Figure 6 shows the power equations.

Power equations

$$P = IE \qquad P = \frac{E^2}{R} \qquad P = I^2R$$

Figure 6. P is power, E is voltage, I is current.

Series Circuits

The circuit below in Figure 7 is known as a series circuit. In this circuit, the current is constant and the voltage drop across each resistor will equal the supply voltage.

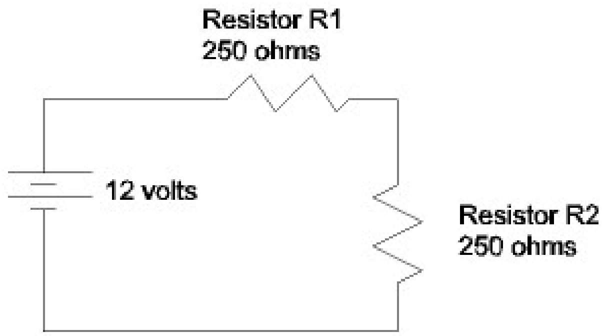

Figure 7. Series Circuit

Taking Ohm's law, let's determine the current.

I = E/R = 12v/500 ohms = .024 amps or 24 milliamps

In this case R will be the total resistance of R1 + R2. Since the current is constant is a series circuit, the resistance can be computed by using the equation

E1 = I*R1 = .024 amps * 250 ohms = 6 volts.

Since R2 is the same resistance value it is equal to 6 volts. This confirms that the voltage drop of each resistor equals the supply voltage.

Vsupply = E1 + E2 = 6 volts + 6 volts = 12 volts.

Parallel Circuits

The circuit in Figure 8 is known as a parallel circuit. In this circuit, the voltage is constant and the total current is equal the sum of currents in each branch. The total resistance is not additive, but a reciprocal of the reciprocals. Figure 9 shows the formula.

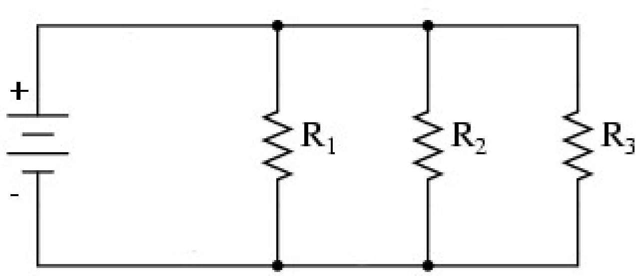

Figure 8. Parallel Circuit

$$R_{total} = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \ldots + \frac{1}{R_n}}$$

Figure 9. Parallel Resistance Formula

If the supply voltage is 12 volts then there will be 12 volts across R1, R2 and R3. The current will be calculated per branch and will vary depending on the value of the resistors. Assuming R1 is 100 ohms, R2 is 10000 (10K) ohms and R3 is 25K ohms, the current for each leg will utilize the equation

$$I = E/R.$$

To compute the current for the first branch, I1 = 12/100 = .12 amps or 120 milliamps. I2 = 12/10000 = 1.2 milliamps. I3 = 12/25000 = .48 milliamps. The total current = I1 + I2 + I3 = .12 + .0012 + .00048 = 121.68 milliamps.

Using the resistance formula in Figure 9, the total resistance is 98.62 ohms. As a rule, the total resistance in a parallel circuit will be less the smallest value resistor.

Practical Applications

Batteries

One of the most common batteries is the wet cell, consisting of a mixture of water and acid. Automobiles use this type of battery. Generally, a lead acid gel cell is what is used for electronic devices in the oil and gas industry. This type of cell uses an acid paste or gel. Individual lead acid cells make up a battery. The cells have a nominal 2.1 volt output. A 12 volt battery would have six cells, providing a nominal output of 12.6 volts.

The capacity of a battery is rated in discharge current for a specific time period, 8 amp hours for example. This means the battery should be able to deliver one amp for 8 hours. The amp hour capacity is increased by adding more cells in parallel. When battery cells are wired in series the voltage increases. When wired in parallel, the current, or capacity increases. If 6 2.1 volt cells in series provide 12.6 volts at 8 amp hours, then adding 6 more cells in parallel would double it to 16 amp hours but the output voltage would remain the same. To summarize, cells wired in series, increases voltage, cells wired in parallel increase capacity.