

Basic Electrical Theory

by: Brian H. Hurd

Work

Work is the transfer of energy from one form to another. Electricity is one form of energy that results from a transfer of energy from any of several other energy types to include: wind, water, steam, chemical, geothermal, mechanical, nuclear, fossil fuels, bio and solar.

The water cycle is a good example of energy transfer. The sun converts matter into radiant heat. Water on earth is heated by the sun, causing it to vaporize and overcome gravity. It rises into the atmosphere and condenses into clouds, rains back down to earth, collects into reservoirs, and flows through piping at high pressure through hydro electric dams that turn giant turbines that transfer the energy to dynamos (giant generators that have magnetic cores) which produce large amounts of electricity. The depressurized water is then heated by the sun and the cycle begins again.

Charges

An electric **current** is made of a moving electric charge. Moving charges have electrical energy. There are two types of electrical charges: positive & negative. These charges follow certain rules:

1. negative charges repel each other
2. positive charges repel each other
3. negative and positive charges attract each other (positive attracts negative - negative attracts positive)

In other words: like charges repel and unlike charges attract

Every atom of matter has electrical charges in it . The central part of the atom, or nucleus, has a positive charge. The tiny particles that are in orbit around the nucleus are called electrons. Electrons have a negative charge. The positive charge of the nucleus attracts the negative charge of the electrons. This attraction holds the parts of the atom together.

Conductors

Conductors have free electrons. In other words some of the electrons can move from atom to atom. Most good conductors are metals. An electrical current in a conductor such as the metal copper is made of moving electrons. All electrons have a negative charge and repel each other. When a current is induced in a conductor the electrons push each other along as they go from atom to atom using the conductor as a pathway.

Insulators

Insulators don't have free electrons and do not carry electrical current. Good insulators include: plastic, rubber, clothe, paper, fiber glass, ceramics, and glass. Flexible plastics are the most affordable and practical insulators. Insulators allow us to use electricity safely. Conductors are encased in plastic or rubber insulation for safe handling and transfer of electricity.

Current / Amps

Current is the rate of flow of electrons through a conductor and is measured in **Ampères or Amps.** (The amount of electrical current it takes to burn a 120 watt bulb is approx 1 amp.) Current flows through a conductor much the same as water flows through a pipe. Amps in a conductor would be similar to the measure of gallons per minute of water flowing through a pipe. Different size conductors have different capacities to carry electrical current. Generally, the larger the conductor the greater the capacity.

Electro Motive Force / Volts

The pressure that pushes electricity through a conductor is measured in **Volts.**

Just as water pressure pushes water through a pipe, **electro motive force** pushes electricity through a conductor. The higher the pressure the greater the flow. If it were a water pipe the pressure would be measured in pounds per square inch. (PSI)

In a wire it is measured in **Volts.** Just as a water valve can shut water off or on, a switch is used to turn electrical current on or off in a conductor.

Resistance / Ohms

Every conductor has some resistance to the flow of electrons. This resistance is caused by friction within the conductor. Resistance is measured in **Ohms.** Different conductors have different rates of resistance. Commonly used conductors such as copper and aluminum have low resistance. Tungsten steel has high resistance, so much so that the metal glows a bright yellow white and puts off heat when electricity runs through it. (Tungsten steel is used for the elements in light bulbs.)

Resistance in a conductor is determined by four factors:

1. The type of conductor (the material it is made of)
 - A good conductor like copper has low resistance.
2. The cross section or diameter of the conductor
 - The smaller the diameter of the wire the greater the resistance.
3. The length of the conductor
 - The longer the conductor or wire the greater the resistance to the flow of current.
4. The surrounding temperature
 - The temperature around the conductor will cause the wire to heat up.
This causes less free electrons to safely carry electricity.

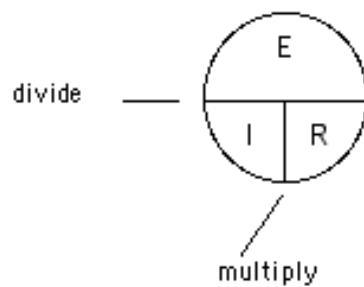
Ohms Law

A German scientist, George Ohm, discovered that there was a direct relationship between Amps, Volts, and Resistance. It is known today as **Ohms Law**:

$$\frac{E}{R} = I \quad \text{or } I \times R = E$$

I - for Amps
E - for Volts
R - for Resistance:
or $\frac{E}{I} = R$

A common way that ohms law is displayed is in a circle like the one below:



Example:

$$120 \text{ v at } 15 \text{ amps would have how much resistance? } \frac{120\text{v}}{15\text{a}} = 8 \text{ ohms}$$

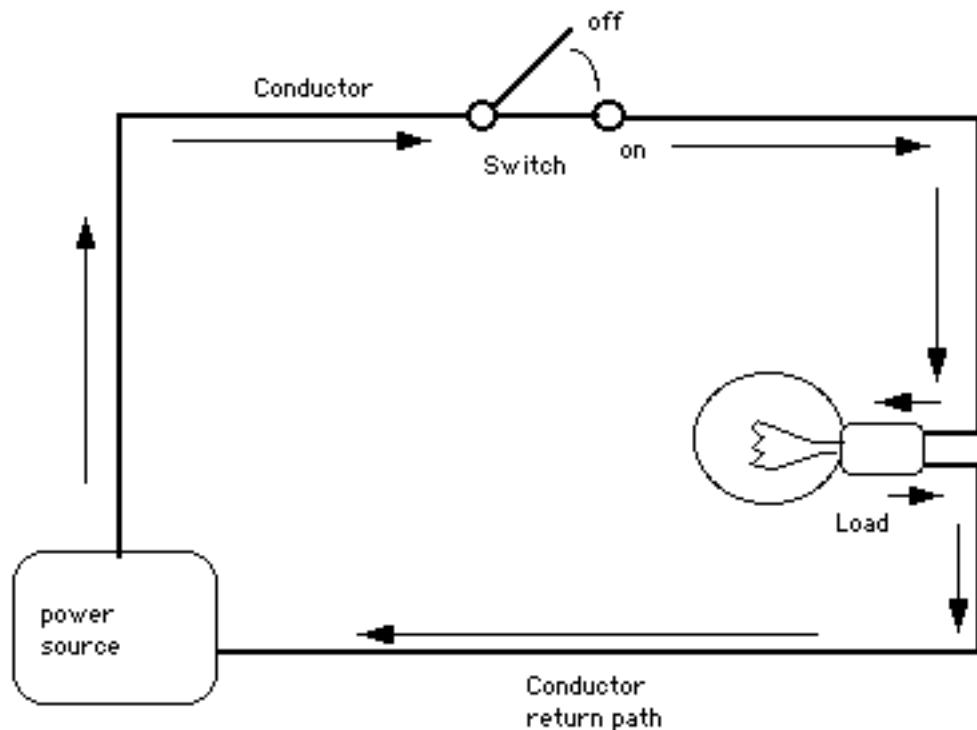
Simple Circuit

For electricity to work for us it must be in a circuit. Cars run on roads. Trains run on tracks. Water runs through pipes. The path that electric current flows on is called a **Circuit**. If the circuit is closed the current flows. If the circuit is open the current stops. (drawing below)

For an electrical circuit to work it needs these 5 things:

1. A power source.
 - This could be a battery, a solar cell, or a wall outlet
2. An isolated or insulated conductor to carry current.
 - For example, a plastic jacketed copper wire.
3. A way to turn the circuit on and off.
 - A switch
4. A load.
 - A light bulb, radio, etc.
5. A conductor to carry the current back to the power source and complete the path of electricity.

Diagram of A Simple Circuit



Power / Watts

Power is the time rate in which work is done. When work is being done using electricity power is being expended and electricity is used. The use of electricity is measured in **Watts**.

All appliances and devices take different amounts of energy to operate correctly. For example, a 60 watt light bulb uses 60 watts of electrical energy. A 100 watt bulb uses 40 more watts of energy than a 60 watt bulb. A micro wave oven can use up to 1500 watts of energy. A large electric furnace can use 5,000 to 10,000 watts of energy.

How much energy is a Watt ?

$$740 \text{ watts} = 1 \text{ horse power}$$

$$1 \text{ horse power} = 30,000 \text{ foot pounds per minute}$$

We pay for electricity by the kilowatt hour. (a kilo = 1000). Electricity use is measured by electrical meters located at every home & building that uses electricity supplied by a power company.

Watts Law

There is a direct relationship between Amps, Volts, and Watts. This is known as **Watts Law**:

$$\text{Amps} \times \text{Volts} = \text{Watts}$$

or

$$\frac{\text{Watts}}{\text{Amps}} = \text{Volts}$$

or

$$\frac{\text{Watts}}{\text{Volts}} = \text{Amps}$$

Examples:

1. A 250 watt heat lamp on standard 120 volt house current would require how many amps of current?

$$\frac{250 \text{ w}}{120 \text{ v}} = 2.08 \text{ amps}$$

2. An electric drill is rated at 5 amps. At 120 volts how many watts of power would the drill use ?

$$5 \text{ a} \times 120 \text{ v} = 600 \text{ watts}$$

Watts Law is very important for calculating loads when laying out or designing electrical circuits for a home or structure.

Types of Current A/C , D/C

There are two types of electrical current: **Direct Current and Alternating Current.**

1. Direct current ,or D/C, electricity flows in one direction in a conductor.
D/C current usually deals with low voltage.

Devices in a residence that operate on D/C could include: smoke alarm, thermostats for heat or air, door bells and chimes, landscape lighting, and remote control devices such as garage door openers.

Batteries, solar cells, and fuel cells all produce direct current.
D/C can also be produced by converting alternating current.

2. Alternating Current, or A/C, electricity alternates direction of flow 60 times per second. This is called 60 cycle current.

Alternating current is used in residential wiring and is used for higher voltage requirements. Most lighting, appliances, and electrical fixtures use A/C.

Alternating Current is usually generated at large power plants. Most power plants use water pressure or steam to turn giant turbines that transfer the energy to dynamos (giant generators that have magnetic cores) which produce alternating current.

Voltage Drop

Voltage drop occurs in all conductors because of the resistance in conductors caused by friction and heat. (as discussed above on page 2) Some of the free electrons that enable current to flow are occupied by the heat in the conductor. This heat can be caused by the friction within the conductor and/ or by the temperature outside the conductor. In other words, there is more resistance to the flow of electrons in a conductor in a hot attic than there would be in a similar conductor in a cool basement.

Voltage Drop Chart

2% voltage drop x number of feet - 120 volts (copper conductor at ambient temperature)

Wire size	#14	#12	#10	#8
Amps 5	90'	140'	225'	360'
10	45'	70'	115'	180'
15	30'	45'	70'	120'
20		35'	55'	70'
30			35'	60'
40				45'
50				55'

Ground

What is “ground” in electricity?

1. Is most often the common return path of electrical current or a direct physical connection to the ground, or earth. Every electrical service on a structure must be grounded, usually by a rod or “electrode” driven 8 feet or more into the earth.

Picture the ground, in most circumstances, as an abundant sponge capable of absorbing infinite amounts of electricity. This capacity is the draw of electricity, from high potential at the power source to very low or no potential.

2. Ground is also the reference point in an electrical circuit from which other voltages are measured. Some soil conditions have high resistance or low conductance and are not good grounds. In these situations the earth cannot be used as a good reference point. Expanded grounding systems with vastly increased surface area may also be required.

3. An equipment ground is connected to exposed metal of equipment and metal hardware connected to or part of an electrical system. Equipment grounds protect people from electrical shock. The use of the term ground (or earth) is so common in electrical and electronics applications that circuits in vehicles such as automobiles, boats, RV's, aircraft, and spacecraft, etc. are spoken of as having a "ground" connection without any real connection to the Earth. In these cases the entire metal frame or chassis of the vehicle serves as the grounding connection.