

Introduction to Voltage and Current

Atomic Structure

The importance of knowing the structure of atoms is because electronics technology is the science of controlling the movement of electrons. These electrons are contained in the valence or highest energy band of atoms. The atom is constructed from three basic elements: neutrons, protons, and electrons. The neutrons and protons make up the center mass of the atom and is referred to as the atoms nucleus. The electron possesses a negative electrical charge, the proton possesses a positive electrical charge, and the neutron does not possess an electrical charge. The outer shell of the atom's electron orbit is the band that we are most interested with, it contains the electrons that will do work for us and the ones that we will have to control. These electrons are only loosely bonded to the atom than those closer to the nucleus. The force of the attraction between the protons contained in the nucleus and the negatively charged electron decreases with increasing distance from the nucleus. The outer shell is referred to as the valence band and the electrons it contains are referred to as valence electrons. When an atom is stimulated do to energy from a power source such as, heat, or light a valence electron will possess enough energy to escape its valence band orbit and become a "free electron" or part of a directed conduction path. Its travel will include collisions will other electrons causing it to lose its gained energy. The lost energy will be converted into heat or light and this electron will rejoin another atoms valence band. When an electron leaves a balanced atom the atom will contain 1 more proton than electrons giving that atom a net positive charge. This type of atom is referred to as a "positive ion". Likewise, when an atom contains more electrons than protons then the atom has a net negative charge and is referred to as a "negative ion". The movement of these valence electrons is called "current", nothing more than electrons moving in a controlled direction.

If an atoms valence band contains 1 to 3 electrons then the material comprised of this type of atom is called a "conductor", if the band contains four electrons then the material is called a "semiconductor", and an atom with 5 to 8 electrons is called an "insulator". The valence band of any atom will not contain more than 8 electrons. In nature all atoms are balanced, meaning that they contain the same number of protons as electrons. The "Atomic Number" of an atom represents the number of protons that the atom contains (because of balance there are the same number of electrons). [See Period Table](#).

Electrical Charge

The electrical charges on electrons and protons are equal in magnitude: Q is the symbol used to represent "Charge" and C, short for "Coulomb" is the unit that represents the quantity of charge. One electron or proton has a $Q = 1.6 \times 10^{-19} \text{ C}$.

One coulomb of charge is the total charge possessed by 6.25×10^{18} electrons (pretty large number of electrons to form one coulomb of charge). The charge or Q for a given number of electrons can be determined by:

$$Q = \frac{\text{number of electrons}}{6.25 \times 10^{18} \text{ electrons / C}}$$

Charge (Q) is only introduced here to define two very important properties: Voltage and Current.

One ampere (1A) of current exists if one coulomb of charge passes a single point in one second. Again, current is nothing more than the directed movement of electrons.

Remember that just like with magnets charged bodies with like charges repel each other and unlike charges are attracted to each other.

Voltage

Voltage is the force of attraction between positive and negative charges. Sometimes voltage is referred to as potential difference. Voltage is the driving force in our circuits. Without voltage current could not exist. One volt is the potential difference between two points when one joule of energy is used to move one coulomb of charge from one point to another. Here is the equation that reflects voltage with respect to energy used to move charge:

$$V = J/Q \quad \text{where } J \text{ is the amount of work in Joules and } Q \text{ is the charge in Coulombs}$$

Current

By definition electrical current is nothing more than the rate of flow of charge. This means the directed flow or movement of electrons in the units of coulombs. The symbol used to refer to the current property is the letter "I". The unit that is used for current is "Ampere", usually abbreviated as "amp" or "A". In other words the current flowing in a circuit has a magnitude of 2 milliamps can be referenced as $I=2\text{mA}$. One ampere (1A) of current is the amount that exists when one coulomb (1C) of charge moves through a given point of a circuit in one second (1s) or simply $I=Q/t$, where Q is the amount of charge in coulombs and t is the amount of time in seconds.

Conservation of Energy

"Conservation of Energy" states that we cannot create nor destroy energy. We can only convert energy from one form into other forms. **This is a very important fact, one that will help us to understand circuit behavior and help us with our analysis of any circuit or system.**

Forms of Energy

Energy can be converted five ways:

1. Chemical Action

- a. Batteries produce electrical energy by means of a chemical action.

2. Heat

- a. Heat can be applied to free electrons from some metals and if another positively charged metal surface is close by it will attract these electrons. This is how a vacuum tube controls current and how some temperature sensors function. Heat is also a byproduct in our electrical circuits – electrical energy used by many electronic components is converted to heat energy.

3. Light

- a. Light striking some semiconductor materials will free electrons and produce electric energy – photovoltaic cells.

4. Pressure

- a. Pressure (force) applied to certain crystals can be used to produce electric energy – record player needles attached to crystals changes voltage because of the variations of the record grooves.

5. Magnetism

- a. Most common way to generate electric energy. Coil of wire rotated in a magnetic field converting mechanical energy into electrical energy.