# Basics of Electronics, Part I

Want to understand electronics, build your own projects, and maybe invent new things in the future? Well, in order to be able to do that, you will have to understand some basics first.

**What is Electricity ?**

Electricity is made up of atom matter. To understand that you have to understand the basics of atomic structure.

Matter is commonly made up of mass which occupies space. This mass can become and take into form several different states:

- solid

  liquid

  gas

  plasma

Matter has mass and weight. The atom also has motion and two kinds of energy types:

POTENTIAL ENERGY, which is a result of its position and KINETIC ENERGY, which is the energy of motion.

The structure of matter can be confusing, but I will try to do my best to describe it. Matter consists of very extremely small and tiny particles which together form an atom. There are 92 different naturally occurring atoms called elements. They are placed in a periodic table in sequence of their atomic number and weight.

There are also about 14 man made elements which do not occur in nature thereby making about 106 elements known to date. The elements value can not be changed by chemical means, only by atomic or nuclear reaction.

By value I mean the atom abject can not be changed by chemical means, but only by nuclear reaction.

How do you think they made the H and Atomic BOMBS ? They can also be combined to make countless number of things or compounds that we use every day. Kinda like mixing three colors; blue, red and green to make almost any number of countless colors or in this case, compounds.

The actual atom it's self looks much like our very own solar system. What I mean by this is, that it has a center like our sun, and planets rotating around it. The following example isn't 100% correct but it is very useful in visualizing the atom for the purpose here.

The center of the atom is called the nucleus (our sun), and it the center or the nucleus is primarily made up of particles called protons and neutrons. These two particles make up most of the atoms weight and mass. Orbiting around it are electrons (like our planets orbiting around the sun). The electrons are many times smaller in mass then their friends protons and neutrons. In a way this is true of our planets too :- ). There are other subatomic particles, but these aren't really all that important in understanding the basics and besides if you ever study quantum mechanics, they will teach you that.

All 106 elements posted in the periodic table are constructed out of these three major particles. The only exception is hydrogen atom, which has two of our friends, a single proton and a single electron orbiting around the center. Also for your information, the proton and the neutron have a mass that is greater by about 1845 approx. times that of an electron.

**A Question that I got from a reader: Q. Didn't you say the hydrogen atom only had a proton and electron ? If so, why is the weight of the proton and neutron have a combined mass of 1845 times that of the electron, if there is no neutron present ?**

I was simply implying that the weight on the proton and neutron have a combined mass of 1845 times that of a electron, that means that the electron is much more lighter then the proton and the neutron that makes up most of the atoms weight and mass.

As mentioned earlier, these elements are refered to by their atomic number and weight, and of course by their name too. Normally an atom has an equal amount of protons in the center as it has electrons around it. The number of electrons and protons is called the atomic number. The atomic weight is calculated by the total number of protons and neutrons in the center, rounded to the nearest integer.

An example of this is as follows: The element of Oxygen has 8 protons and 8 neutrons, so it is assigned an atomic number of 8 and an atomic weight of 16. In another example Copper has an atomic number of 29 and an atomic weight of 64. It has 29 electrons, 29 protons and 35 neutrons. 29+35 = 64 and the total number of electrons and protons is 29.

The electrons which orbit around the center of an atom are arranged by orbits, why! how about that, just like our planets :- ) In physics, these orbits are refered to as shells. Each orbit or shell represents a different energy level away from the center or nucleus and are only permitted at particular points in the atom and away from the center.

The total amount of electrons in the shell of an atom can not be more then a certain amount of electrons and the rules are spelled out as follows:

The first orbit closest from the sun, chuckle (from the center) can only contain 2 electrons, the second 8, third 8, fourth 18. The last outer most shell is called the valerance shell. The first four shells by definition have a name of, they are called: Helium, Neon, Argon and Krypton and they are named such because they represent the element formed when the shell is completely filled to maximum with electrons.

**If you did not like my above cloun example, done to make learning easy, here is a more english correct version:**

**The first orbit closest to the nucleus can only contain 2 electrons, the second 8 electrons, the third 8 electrons, and the fourth 18 electrons. The outermost shell is called the valence shell. The name of each successive shell, when filled with electrons, is called: helium, neon, argon, and krypton.**

Combinations of two or mote atoms of any kind are called molecules. Molecules constitute matter. Compounds that we earlier talked about are made up of molecules. If you for example take the compound salt (NaCl) which is a chemical combination of sodium (Na) and chlorine (Cl), and try to divide it an infinite number of times, you would still have salt. Because you would still have 1 atom sodium and one atom of chlorine. Once you chemically divide salt, it will no longer be salt. Interesting, isn't it ?

These major shells are further broken down into smaller shells within their orbit called subshells or orbitals. I will end here, if this interests you pick up a few books on the study of solid-state physics or chemistry and good luck :- )

I will try to make some pictures to better illustrate the above SALT example and write an example where the salt is chemically divided so that it won't be salt any more.

**So, how is electricity made ?**

Somehow I knew you were gona ask me this, hehe. Ok, the protons in the center and the electrons that orbit the center exert forces onto one another over and above the forces of gravitational attraction between them. It has been said that besides mass and weight, the electrons carry an electric charge that carry an electrical force. As far as who determined this, don't know exactly, but this is true.

There is a difference in electrical force between these masses and the gravitational force of attraction and repulsion exist. Protons and electrons attract one another to put it simply. Remember, like forces repel while unlike forces attract. This is why protons and electrons attract one another. Protons exert forces of repulsion on other protons and electrons exert forces of repulsion on other electrons.

From this, two types of electric charges were established, positive and negative. Protons in the center have been classified as having positive ( + ) charge and the electrons, you guessed it, a ( - ) negative charge. The neutron that is in the center together with the proton has a ? neutral charge :- ) and thus why it is called a neutron. Electricity is based on the law of attraction and repulsion. Just like life on planet earth is based on attraction between the opposite sexes. If that fails, we die :- ) If that isn't true in an atom, electricity dies.

Here is your first law to memorize:

| |
|---|
| **Law of ELECTROSTATICS** |
| Unlike charges attract each other, like charges repel each other. |

There are many ways that the normal balance within the atom can be altered, natural and not. The key to remember is that a charge remains until it is discharged. Then once it is discharged and it starts to move, it forms a current.

**Charge Fundamentals**

It is agreed that all electrons have precisely the same amount of negative charge in magnitude then positively charged protons. The directional quality of each charge is called polarity. Every object contains atoms and most of the time the amount of protons and electrons is the same and the net charge is neutral. But if on a dry summer day you rub your hair with a comb, then the net charge of the atoms in both your hair and the comb will change. As you rub the comb through your hair, you also rub off some of the electrons from your hair thereby making the comb more negatively charged with electrons and the hair more positively charged with protons. If you turn off the lights, you can even see small sparks of electricity jumping from the comb to the hair. This by the way is called static electricity. Why not from the hair to the comb ? Because of equilibrium, and in order so that the atoms of both objects can become neutral again, more will flow into less to create an even level. It's like opening a refrigerator on a hot summer day. If you keep it open long enough, sooner or later the temperature in the fridge will be the same as outside, taking into consideration that you turn off the generator that produces the cold.

There are many other examples, and I urge you to pick up a book and read it, otherwise don't expect to learn it.

A charged body, or atom is one that has an excess (that means more then it should) or deficiency (that means less then it normally should) of electrons orbiting around the protons and we know what they are, right ?

This difference can be written with a special number that states that difference. Most people think that when something is charged it has a positive charge, and this is not true. You should not confuse the word charge with a + or a -, because it can be either. Charged simply means that the atom is lacking some electrons thereby making more protons then electrons and this makes that atom more positively charged because there are more protons then electrons. Or if you have more electrons then protons, a such atom is said to be more negatively charged.

In real life, the scientists need a special number that states this difference. And because electrons are so small this number has to be larger then the individual electron or proton to make practical sense.

In honor of a famous scientists Charles Coulomb (1736-1806 Charles Augustin Coulomb), a large number or unit of measure of electric charge called the coulomb was adopted for everyday practical use. ONE COULOMB is equivalent to 6.24 billion billion of elementary charges and this can be either positive or negative.

Scientists have a special way of writing this and this special way is called the scientific notation. And here is how this notation of one coulomb looks like:

ONE COULOMB = 6.24 x 10 to the 18 power of electrons or protons. A lower case letter of q represents excess positive and the capital letter Q represents excess negative charge in a body. So one 1 coulomb that is positive can be simply represented by a q, and negative by a Q. ONE COULOMB IS 6,240,000,000,000,000,000 electrons or protons. Working with large numbers like this would be a real pain in the ass, so that is why special notations were invented to basically write the same thing but using much less space.

Charles Coulomb work in the investigation of forces showed that the force of attraction or repulsion between two charges or bodies follows an inverse law similar to Newton's law of gravitational forces between masses. Coulombs law is as follows:

## COULOMB'S LAW OF ELECTROSTATIC FORCES

*The force (F) of attraction or repulsion exerted between two charged bodies is directly proportional to the product of their charges (Q) and inversely proportional to the square of the distance between them.*

So, what the hell does that exactly mean ? :- ) Sometimes we have to read things one word at a time and look them up if you aren't sure to be able to understand something of complex nature.

It means, that the **(FORCE** \ strength or energy), of attraction or repulsion **(EXERTED** \ to put forth, to put something into action) between two charged bodies is directly (**PROPORTIONAL** \ corresponding in size, degree, or intensity, having the same or constant ratio) to the product of their charges (Q) and (**INVERSELY** \ opposite, reverse) proportional to the (SQUARE \ raised to the second power) of the distance between them.

The word Electron is Greek and it means amber, just so you know. What is an ion ? The outer most electron in an atom or in the valerance shell of an atom departs and the direct result of this is that the atom is no longer neutral. This is so because there are now more protons then electrons. This unbalanced atom is called an ion and it can be either positive ion or negative ion depending if an electron has been lost or gained. Imagine for a second this to make the following illustration easier. We all know how our solar system works in theory right ? The star is the sun, and then we have planets that orbit around the sun. Now imagine that all those planets are the electrons and that the sun is the proton, but instead of having just one sun there are many that occupy a space so close together that they all look like they are all one from far.

So now imagine that there are an equal amount of electrons and protons.  If one planet or the electron looses it's orbit maybe because it was hit by a HUGE comet or asteroid, it might have received enough energy to enable it to leave it's magnetic orbit.

When it leaves the orbit and our solar system, it is leaving the atom.  Over time it will go through space and join in with other atoms or solar systems where there is a lack of electrons to make them neutral or maybe join into an atom where there is already a neutral state and change it into a negative ion because now there is one more electron then the total number of protons and the atom is no longer neutral and this is where it becomes an ion (long sentence).  This isn't how our solar system works, but it will help you to visualize the process.  When there are more electrons in the atom, this atom ion is called a negative ion and when there is more protons it is called a positive ion, makes sense ?

Now the energy to make the electrons jump from atom to atom can be brought by many means: light, heat, magnetic energy, understand ? good.  An ion is simply a charged atom, an atom that is not neutral.  Different elements or materials in real life that are made up of atom give up or accept these loose atoms at varying levels.  Now I will tell you about these elements as they are very important in electronics and this is where you will actually start to get familiar with some of the terms used in electronics.

**Source of Electricity and Common acceptable units of measurement used in Electronics**

Energy can not be destroyed or created, it can only be converted from one source to another.  But I sometimes wonder if this is true :- ), where did the energy come from to create the universe ?  The big bang, it had to come from somewhere, and that somewhere where did it come from ?

So maybe it is possible that something can be created out of nothing, magic ?

Anyway back to our subject.  We always think of a SOURCE of energy as a battery, that would be a good example or the A/C electrical outlet.  However, please remember that a SOURCE is not necessarily a reservoir or storage for and of energy. A more correct way is to call a source a means of converting some other form(s) of energy into electrical energy.  An everyday battery that we use in our flashlight for example stores absolutely no electrical energy, believe it or not.  What it does do is convert chemical energy into electrical energy when activated.  An electrical generator simply converts mechanical energy into electrical energy.  Through the phenomenon of ionization that I explained above, atoms cam become either positive or negative ions.  Now here is the important thing to remember.  When two separate bodies have a difference in charge, what they do have is described as "DIFFERENCE of  POTENTIAL (PD)."  Without this difference batteries would not work, and this is what happens when there is no longer any difference, and the battery goes dead.

" HEIGHT=21 WIDTH=32> the electric current flow ? from + to - or from - to + ?

Rechargeable batteries when they go dead are simply recharged to introduce this difference once again, and with time it will go to neutral and it will die. An electrical circuit connected between these two bodies or simply the battery will permit a movement of energy from one body to the next. And this transfer will continue as long as there is a difference in potential. Think of it this way if it makes it any easier.

Find two big jars, clear would be the best. Fill the first one 1/2 the way and the second one all the way with water. Now place a clear plastic tube between these two jars and suck some water from the bigger jar into the smaller. The water will flow until both jars become neutral. Since the one that has more water will come closer to having the same amount of water as it's brother, there will be less and less of a potential difference and the water will flow through the tube slower and slower until PD no longer exist and there isn't enough water in jar A to keep the water pressure in the tube transferring to jar B.

Makes sense ? This is how batteries work. As the battery becomes weaker and weaker the reason for this is that it simply is losing it's PD and electricity can no longer flow and the direct result of that is that the battery goes dead.

The unit of measurement of this potential difference that I just explained to you is called **VOLT.** Finally you understand what it means, isn't it cool ?

Also, Voltage can be represented with V, E or EMF. V is obvious = VOLTS, E also stands for Volts, you will learn about that below and EMF which stands for (electron moving force).

The letter V is used as the symbol for voltage in transistor circuits.

Now to understand the full meaning of VOLT can be a little bit tricky, and that is why it is VERY important that you read everything, boring or not, because there is a reason why it is documented.

The scientific notation for the value of VOLT can be confusing to someone who is new, if you havn't read about COULOMB and what it is, now would be a good time to go back and do so, or you will be lost and this section is VERY important.

Since we know that VOLT is used to represent the PD (see above) this is what it means. When the PD movement occurs, WORK IS DONE, be it in an electrical circuit or a home circuit. This work is expressed as "WORK PER UNIT OF CHARGE" or "JOULES PER COULOMB". A JOULE is approx. .738 foot pounds of work and the COULOMB is (see above).

The VOLT is equal to the PD required to move 1 COULOMB of charge and accomplish one JOULE of work. This is expressed by this following equation:

$V = W/Q$

V stands for VOLT, W stands for work in joules and Q stands for Coulombs.

A fixed value of 1 VOLT has been established by the International Electrical Congress and by law in the United States.

The movement of electrical energy or electricity through a electrical circuit is called CURRENT. The current is what does the work in the circuit. VOLTAGE does not do any work, it does only cause the current to flow. Current is also what kills you if you don't use common sense.

Now is where this gets more interesting, but remember, DO NOT skip any sections of my writings, or you will get lost and that isn't good. An AMPERE of current is described as the current flow in a conductor at the rate of one Q (COULOMB) per second at any given point in the circuit.

Current my fellow friends is assigned the letter "I" and current is measured in AMPERES, MILLIAMPERES and MICROAMPERES. Current is simply electron flow and for the sake of complexity I will always refer to it as moving from minus to plus or negative to positive but I will also describe the difference later.

**POWER**

Energy is the ability to do work and Power is the rate of doing work. Work in Physics is the product of force and distance and work is measured in foot-pounds. For example: If you lift 1 pound over one foot from the ground, you accomplish one foot-pound of work. When you ad the element of time into this same lift scenario then you just lifted the weight once each second and your rate of doing work would or POWER would be "one foot-pound per one second". This is of course only an example, it might take you 60 second to lift that for all I know, then the answer would be "one foot-pound per 60 seconds". If you lift more then one pound then that changes to: "five foot-pounds per 60 seconds."

Therefore, power is work divided by time or:

$P = W/t$

P = Power, W = Work in foot-pounds, t = time

In electronics, we know by now that VOLTAGE is the force and that AMPS is the movement of electricity per second or current. To better illustrate this point think of it this way. Imagine a water pipe, this water pipe can be compared to an electrical piece of wire to make my point. Still (not moving) Electricity is water and the moving electricity is current or AMPS.

So, if we have water in the pipe, then we can call this as having VOLTAGE inside of the wire. Now, if the water is just sitting there in the pipe and it is not doing anything, or it is not flowing through the pipe, then there is no current of water, right ?

Well, the same thing can be illustrated with the wire, if all we have is the electric VOLTAGE, all that it shows us that we have electricity in the wire and how much of it and the force that it is capable of producing. Once we open the pipe, water flows and we have just that, running water that can be used to do something with. Same thing with electricity in the wire, once we let the circuit run, we have AMPS or current.

Later I will show you what WATTS and OHMS are.

One AMPERE = 1 COULOMB per second moving through the wire.

## Equation: P = I x E

Power is measured in WATTS. Watt is named after James Watt, the inventor of the steam engine. To convert mechanical power to electrical power this is the equation that we use.

1 HP = 746 watts. HP stands for HORSEPOWER, and in mechanics this is used to measure the rate of work.

This same above Equation can be written in three different ways. P = I x E, E = P/I or I = P/E.

/ is the division sign and x the multiply or times sign for math purposes.

When you know any of two values of current, voltage or power, then it is possible to find the third unknown value using any of the three equations above.

To give you an example here we go: An imaginary device operates on 220 VOLTS and draws 10 AMPERES of current. What is it's power ? This question is very simple to answer. P = I x E, we know I = 10 amps and E = 220 volts, so the answer is ? 10 times x 220 = 2,200 watts. Mind that this is only an example.

**CONDUCTORS, SEMICONDUCTORS and INSULATORS**

One of three most important materials in electronics and electricity are just that; conductors, semiconductors and insulators. We have probably heard of some of these and to some degree understand what they are. So therefore I am not going to waist a lot of space and will cover enough so that whatever you might think you know is corrected or refreshed and added to what you already know.

Voltage is the source of Energy at rest, it is very important again that you understand this. Voltage is part of what makes the circuit work, but voltage is only the PD at rest and not at work. For example a battery, the 9V one that everybody is familiar with must be connected to something in order for it to work, when it is connected and the switch is on, the cell :- ), is ready to do useful work.

**Here is another very easy example of VOLTAGE. Imagine a glass jar, fill it with water. There, you have voltage, a storage of potential energy, when you hook up a pipe to this glass jar and let the water run, you create current through the pipe and you have amps, the more water is moving per sec through the pipe, the higher the amps. When the water is no more in the jar, none left, you have no VOLTAGE left. The more water, the more voltage you can fit, or potential**

**energy.  Hope that you understand this, because I don't know how to explain it any easier then this.**

But I will try again :- )

Ok, when you go to a store and buy a BRAND NEW! 9VOLT cell or battery as everyone knows it by, what do you have ? a new 9Volt Battery capable of delivering 9VOLTS, right or what ? sure.

Ok, with time this brand new 9Volt battery will lose some of it's voltage and even though it is marked on the outside as a 9V battery, inside it is no longer delivering 9VOLTS, but maybe 6 volts or 4 volts.

This is why flash lights go dimmer and dimmer, because the voltage gets lower and lower.

You can compare that to our jar of water example above.  Get a jar, fill it with water, all the way up to the top, and take a marker and label it as a 9VOLT battery or a 9 gallon jar.

Now hook up a pipe to it, let the water run through the pipe, you now just created AMPS, the water in the jar is still VOLTAGE, but once it enters the pipe it is called AMPS.  The energy or water is coming out of a 9VOLT battery, so we call it just that.

So to give you a better understanding of AMPS vs. VOLTS, it is simple.  Volts is the energy and AMPS is the measurement that we use to see how fast and how much of that energy is moving through the pipe, I mean wire.

You can have a 1,000 VOLT storage battery that is capable of delivering 1,000 VOLTS, but you can increase or decrease the AMPS by turning the faucet ON more or OFF more.

But please also remember that AMPS are propotional to VOLTAGE.  If VOLTAGE is increased, AMPS are too.

You will learn more about this later.

Just like in the bathroom or a portable water storage tank.  You only have so much water in it, the more water you let through, the faster it will move, or more AMPS, when you reduce the water flow, less AMPS, but the VOLTAGE source stays the same for a time anyway.

As you increase the AMPS you will draw more VOLTS from the battery or use it up much faster.  That's like letting more water through the pipe, you use up more of it from the jar.  Now I think that this is the best example yet.

This is how it works with D/C Electronics (batteries).  A/C is much more complicated and you have to know much more to be able to understand it fully and be able to compare them both.  With A/C the voltage is contstant, because it is coming from a source that is not a battery but a freaking energy plant.  As you increase the AMPS, there is always enough water to keep it up, because it is not coming from a limited source, but from the electric company who is replacing the used up energy as fast as you use it up. This is only a theoretical example, keep that in mind.

This of course works differently with A/C electricity then with D/C. Will explain the difference later.

If you still have a problem with VOLTS and AMPS, then electronics are not for you. It's time to find a new hobby.

Just so you understand resistance better I will tell you ahead of time with this example of how this works and then you can read about it below later. As the water is flowing through the pipe, the pipe opposes the water, like friction. The less space is left in the pipe to make the moving water fit, the higher the pressure builds.

This can be compared to resistance. You'll see below anyways.

The current must past through wires so that the electricity can reach it's components, kinda like valves in water pipes and pressure generators and such. Now we will investigate the properties of certain materials with respect to their ability to conduct this electricity.

The true ability of how and why electricity is capable of moving or flowing through conductors can be reflected back to the top of my writings, it has to do with the atomic theory. I only covered the basics and this Internet Paper wasn't designed to replace books and libraries. So if you really want to understand this 100% or close to it, please pick up a book on the atomic theory. Your teacher should be able to recommend some good books for beginners or simply stop over at your local library like I did and start reading. :- )

**conductors:** basically, some materials conduct electric current very easily with little energy applied and resistance, these types of materials are called conductors.
**insulators:** other materials require a very large or much larger amount of energy to conduct an electric current only very slightly. These are called insulators. A typical electrical wire is made out of two type of materials. A type of metal that resides on the inside "this is the conductor" and some type of insulator on the outside of the wire, coated. Insulators serve several purposes. One very important one is that they will protect you from being able to touch the wire and save your life from an electrical shock and the other is so that different wires don't touch each other to prevent an electrical short circuit which can lead to a meltdown, fire, explosion and loose of life. Insulators are also used to cover sensitive electronics to shield them from static electricity and from damage.

Good conductors are: Gold, copper, silver, etc. Good insulators are: plastic, rubber, glass, bakelite, air, asbestos, etc. Now the in-between type of materials that are in-between the conductors and insulators are called the semi-conductors. Good **semi-conductors** are carbon, silicon and germanium, etc. Semi-conductors are very important and they are used all the time to make all kinds of electronic devices. From resistors to transistors to solid-state integrated circuits that your computer get's it's life from. These will be explained later.

There is another one, but this shouldn't really concern you right now. It is called **Superconductivity.** Superconductivity is the phenomenon where the electrons move through the material at no opposition at all, no friction, no resistance, no opposition. But it is hard to make it work under normal everyday human like environments. -452 F. So there is still a lot of research that has to be done there and you shouldn't concern your self with it.

**A little bit more information.**

As a general rule, conductors are materials whose atomic structure is such that the valerance shell contains less then half of the total allowable number of electrons and the insulators more then half.

In some materials, electrons that circle the nucleus "wake up!", are held very securely and very close to the nucleus. These types of materials require large amounts of energy to break loose the electrons for conduction to take place.

These are INSULATORS. Good CONDUCTORS require no energy at all to free the electrons from the material. A material which is a good conductor already has many free electrons to transfer energy by conduction.

**An INTRINSIC CONDUCTOR** is made out of atoms of all the same type or kind. It is 100% pure you might say. Pure Germanium or SILICON are examples of this type of CONDUCTOR. These materials are classified as semiconductors.

Semiconductors conduct electricity to some extent, less then the conductors might at 100%. How much depends on the type of material or it's mixture and size. For example we use semiconductor materials to manufacturer resistors. Those can be compared to valves in water pipes where you slow down the water and only let some through to the other side of the pipe, kinda like a dam. If you have 10 Volts of electricity and you wanted to reduce it to 5, you would place a special type of resistor into the circuit to slow it down and maybe a heatsink or two to dissipate the heat from the resistor so it can last longer.

We add impurities to semiconductors to make them conduct better if that's what we want to do and most semiconductors used in electronic parts are made from a semiconductor material mixed with impurities. Impurities are selected which have FIVE valerance electrons. These include: Phosphorus (P), arsenic (As), bismuth (Bi), and antimony (Sb). These are classified as **PENTAVALENTS.**

The process of adding these pollutants :-), I mean impurities is called "doping" and the impuratants are called "dopants". Only a small amount of dopants is used when doping, approx. figure is about 1 atom of dopant to 10 million atoms of 100% semiconductor. Once doped, the material is called EXTRINSIC and it's conduction characteristics will change.

I will dedicate about 4 more weeks to this Basic project and that is it. If you want to know more, then it's time to read and research on your own as it is impractical for me to write about something that can easily be found in a library, but I do this to introduce you to it in an easier manner then most books do.

**RESISTANCE**

The Greek symbol of " *p* " -(rho) is the symbol of SPECIFIC RESISTANCE. Different MATERIALS some of which are metals resist in different ways. There is a table that shows this SPECIFIC RESISTANCE for the most common used materials in electronics:

| MATERIAL | *p* (rho) |
|---|---|
| ALUMINUM | 17. |
| CARBON | 2500-7500 x copper |
| CANSTANTAN | 295. |
| COPPER | 10.4 |
| GOLD | 14. |
| IRON | 58. |
| NICHROME | 676. |
| SILVER | 9.8 |
| STEEL | 100. |
| TUNGSTEN | 33.8 |

Silver offers the least resistance, but it is expensive. Aluminum offers almost twice as much resistance as silver does. This is how I read these charts. 0 would have no resistance, and there is no material on this planet operating in normal conditions that can have a 0 unless we are talking about it operating under superconductivity, but that's another story.

**Now to explain resistance.** Certain materials vary in their ability to conduct electricity. Basically the material is resisting the flow of electricity. Resistance can be compared to friction. You know what friction is ? almost the same thing.

Resistance is like opposition. Some materials oppose the electric current more then others, but all oppose it to some degree.

Now here is another COOL new fact that you will learn today.  You might have seen this when placing your BOOM BOOM speakers into your fast car.  Well, it's time to understand what the hell those marks mean.

Resistance has been assigned the letter of R and resistance is measured in OHMS in memory of George Simon Ohm (1789-1854).  The Greek symbol for OHM is the omega symbol. $\Omega$

One ohm of resistance will permit a current of one ampere to flow at an applied potential of one volt.

Materials with greater resistance require greater energy to raise electrons to the conduction state.  Energy is consumed by resistance and it results back into the form of HEAT.  That's why many electrical appliances and computers use heatsinks to move the heat away from the components to reduce wear and to ensure a longer operational life.

Many times resistance is introduced on purpose and it has a specific use in our daily life.  Like ? Like electric ranges or heaters that we use at home.  The heaters that we use to heat water with.  Your coffee maker or that little electric heater you use to heat your aquarium water with.  Ahhhh! :- )

Resistance is also represented by a circuit drawing, called a schematic symbol for resistance: 

Resistance uses an infinite number of uses in electronics and it is impossible for me to mention them all.  As for your car speakers, that number shows the maximum resistance that the speaker is capable of withstanding before blowing up.

Just like a water pipe can only withstand so much water pressure before bursting, same thing.  Follow the OHM rules and your speakers will do just fine.  But we have a little longer to go before you will be able to understand this all clearer and I will do my best in describing it to you in as plain of an English language that I can.

Resistance in a conductor is influenced by four major factors and those are:

1. Material of conductor

   Size of conductor

   Length of Conductor

   Temperature of Conductor

More...

R = the resistance in ohms, I = the length in feet of the material being used, A = the cross-sectional area in circular mils and we will cover that later don't you worry about that, *p* = the resistivity which depends on the material structure and it's temperature and also size.

The formula for OHM is:   R = pI divided by or  R = pI/A

Before I can demonstrate this law to you and how to properly use it, it is time to introduce to you Gauge used to determine wire size and what circular mils is.

When you think about it and use some common sense, wire works like pipes.  You can expect that a larger wire or pipe will conduct electricity or water more freely and in greater quantities than a small wire or pipe.  Am I right or what ?

Sure I am.  So.  It is said in electronics that the resistance of a wire is inversely proportional to its size.  This means simply that if the wire is larger, the less resistance it will give off.  The smaller the wire, the greater the resistance.

My friend, he doesn't know much about electronics, just some simple basics and even those aren't very clear.  What he did was very dumb, please don't laugh, but I have to tell you this.  He has a car, daaa :- ) and his radiator fan stopped working.  So he checked the fan, it works, he checked the thermo switch, that was good and he checked the fuses, they were good, but the fan refused to turn ON when the engine got hot.  I really didn't know what the problem was, maybe a short circuit somewhere or maybe the computer was busted.  But he decided to cut the wire off that led to the thermo-switch and create a manual switch override to turn on the fan.  He went to radio shack, bought the wrong wire and the wrong switch and then connected them to the car's battery and then to the radiator fan.  The plan seemed simple, whenever he noticed the temperature gauge inside the car get up there to indicate that the engine was getting hot, he switched the switch ON.

What happened ? At first nothing, it worked.  But the wire got hot quickly very fast and so did the switch.  Now why do you suppose that happened ?

This wire he got wasn't designed to carry this much APMS and wasn't able to handle the current.  Sure it carried the current, but because it was too small the wire began to get very hot.  If he didn't turn it off quickly enough, there was a good chance that the wire would burst, like a water pipe when trying to pipe too much water at high pressure through a small pipe resulting in a possible fire, explosion and he could maybe even have died.

Really stupid!  Don't do that boys and girls.

Electricity can be your best friend or your worse enemy.  So even if you are not planning to become a rocket scientist, it is a good idea to know these basics.

## Conductors, Semiconductors, Insulators

| GAGE NO. | DIAM. MILS | CIRCULAR MIL AREA | OHMS PER 1,000 FT. OF COPPER WIRE AT 25°C | GAGE NO. | DIAM. MILS | CIRCULAR MIL AREA | OHMS PER 1,000 FT. OF COPPER WIRE AT 25°C |
|---|---|---|---|---|---|---|---|
| 1 | 289.3 | 83,690 | 0.1264 | 21 | 28.46 | 810.1 | 13.05 |
| 2 | 257.6 | 66,370 | 0.1593 | 22 | 25.35 | 642.4 | 16.46 |
| 3 | 229.4 | 52,640 | 0.2009 | 23 | 25.57 | 509.5 | 20.76 |
| 4 | 204.3 | 41,740 | 0.2533 | 24 | 20.10 | 404.0 | 26.17 |
| 5 | 181.9 | 33,100 | 0.3195 | 25 | 17.90 | 320.4 | 33.00 |
| 6 | 162.0 | 26,250 | 0.4028 | 26 | 15.94 | 254.1 | 41.62 |
| 7 | 144.3 | 20,820 | 0.5080 | 27 | 14.20 | 201.5 | 52.48 |
| 8 | 128.5 | 16,510 | 0.6405 | 28 | 12.64 | 159.8 | 66.17 |
| 9 | 114.4 | 13,090 | 0.8077 | 29 | 11.26 | 126.7 | 83.44 |
| 10 | 101.9 | 10,380 | 1.018 | 30 | 10.03 | 100.5 | 105.2 |
| 11 | 90.74 | 8,234 | 1.284 | 31 | 8.928 | 79.70 | 132.7 |
| 12 | 80.81 | 6,530 | 1.619 | 32 | 7.950 | 63.21 | 167.3 |
| 13 | 71 96 | 5,178 | 2.042 | 33 | 7.080 | 50.13 | 211.0 |
| 14 | 64.08 | 4,107 | 2.575 | 34 | 6.305 | 39.75 | 266.0 |
| 15 | 57.07 | 3,257 | 3.247 | 35 | 5.615 | 31.52 | 335.0 |
| 16 | 50.82 | 2,583 | 4.094 | 36 | 5.000 | 25.00 | 423.0 |
| 17 | 45.26 | 2,048 | 5.163 | 37 | 4.453 | 19.83 | 533.4 |
| 18 | 40.30 | 1,624 | 6.510 | 38 | 3.965 | 15.72 | 672.6 |
| 19 | 35.89 | 1,288 | 8.210 | 39 | 3.531 | 12.47 | 848.1 |
| 20 | 31.96 | 1,022 | 10.35 | 40 | 3.145 | 9.88 | 1,069. |

The size of a wire is specified by a special number in the land of electronics. This is called the Gauge number. The larger the number, the smaller the diameter of the wire, this is how this works. The number 20 and 22 are commonly used for hookup wire in electronics equipment. Numbers 12 and 14 will be found in light circuits in your home. Number 6 wire is used to connect an electric range. The size of the wire is determined by the amount of current the wire is required to carry.

If the wire is too small, it will heat-up, like in our little example above. The heat up is due to loss of energy as it overcomes the resistance of the wire. You should never apply more energy then what the wire is rated for.

The inch system in English is not used to measure wire size. Wire my friends is sized by CIRCULAR-MILS, which is its cross-sectional area. One circular-mill is the area of a circle one mil or .001 inch in diameter.

Incase you forgot your basic geometry laws here they are again to refresh your memory.

DIAMETER: the length of a straight line through the center of an object. RADIUS is: a line segment extending from the center of a circle or sphere to the circumference or bounding surface of the circle.

A wire that has a diameter of 1.00 inch would have a radius of .50 inch, right ? Please don't tell me that you are stuck on that one, if you are, please go back to elementary school and then come back here when you pass the grade.

By definition, a circular-mil is the area of a wire having a diameter of .001 inch or one mil same thing.  This wire then would contain .7854 square mils.

.7854 x (1)**2** = .7854 square mills, the **2** after the (1) is a power of two, 1 x 1 = 1

two square mills of .002 would be (2)**2** or 4 x .7854 = 1.57 square mills.

It's easier to work with mills then with inches, because 1 mills is .001 inch, 10 mills is .010 inch, get it ?  if you were working with inches then you have to use a complicated formula:

A = pie R**2** = pie (D/2)**2** = 3.1416 x D2/4 = 7854 D**2**

**2** = the sign for power of two

The best way to think about it for me atleast is to convert inch to mills and that is easy to do, because .001 = 1 mill, and then use the above first shorter formula to compute the square mills.

The most common way of designing a wire's resistance for everyday electronics or for electric use is to use ohms per circular-mil foot.  A circular-mil foot is a wire having one circular-mil cross sectional area and is one foot long.  Basically a one foot long piece of wire is one having one mil or .001 inch diameter.

For example a piece of wire that is 3.145 mils in diameter is not a piece of wire 3.145 inches long, it is a piece of wire 0.003124 inch in diameter or basically 3/100th of a inch in size.  That's pretty small and it's by the way Gage No. 40.

For example Gage No. 1 and remember that the smaller the number the larger the wire, is 289.3 diam. mils or 0.2893 inches in diameter which is a pretty big piece of wire.

If you think that 1/100th of an inch is small, then you should buy your self a pair of calipers.  They are capable of measuring 5/1000th of a inch in diameter.  If I remember regular paper used for a copy machine is 0.0035 inches thick.

Model No. 500-113

And to end this talk about Mils and remember that 1000 mils is 1.00 inch, and that should help you.

.999 mils is like .999 inches.

It's like this:

.001 inch is 1 mil, .005 inch is 5 mils.  Then to find the circular-mil area of this wire you would  use this formula.

.7854 x (5 mils)**2 = 19.64 square mils**

to find the circular-mil area of this wire, divide it's square mil area by .7854, and that would be 25.01 or 25.

Ok, so what is the diameter of a wire in inches that is 50.82 diam in mils ?

0.05082 inches or 2,582.67 or rounded to 2,583 circular mil area. How did I get that ? I used a power of 2 on the 50.82 and then rounded off the answer.

**AGAIN!** 1 circular-mil is the area of a circle one mil or .001 inch in diameter. And you know what that is, right ?

If you want to see the Wire gage Table, get a book on electronics or visit Radio Shack, they should have one. There are also Gauge wire instruments that you can use to quickly determine the Gauge No. of a wire. Radio Shack should sell it, or any other good electronic shop.

There are all kinds of wires; bare, insulated, twisted, used for different purposes. There are also wires that are stranded from many other wires to make one wire. This is done to provide the needed cross sectional area to carry more electric current. It also provide flexibility for better handling. Twisted wires don't automatically mean that they will be BIG wires, they can be small wires too. If you use wire that is made out of one strand, and if you need for this wire to be very flexible when bending without damaging it's self, then a stranded wire is the best one to get, otherwise over time the wire might break/snap in half if you use a single strand.

Also, the wire's resistance will increase as it's length is increased. For example, if you just finished calculating that your wire's resistance is 2 ohms per a foot, then this will increase to 20 ohms for 10 feet. 2 x 10 = 20 ohms. Incase you are confused about this, it means that the wire will oppose the electric current more as it's length increases and will oppose it less as it's length decreases, get it ? The same thing works in reverse. If the wire is shortened, it's resistance drops.

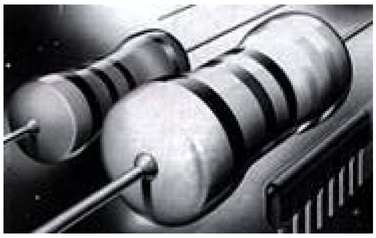
Hmm what else ? Ohh ya. Most of the time, the resistance of the wire will increase as the wire get's hotter. Before I go on and just incase you are still confused about what this resistance means it is simple. Resistance is opposition. More resistance means more opposition, less means less, think of it that way.

**Why doesn't the wire conduct better at higher temperatures ?**

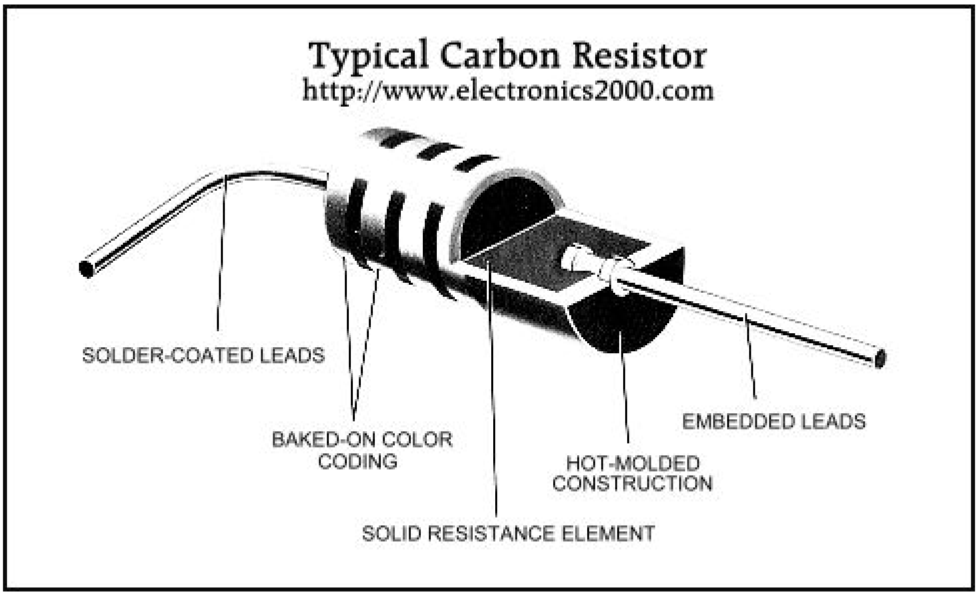
This has to do at the atomic level. To put it simply, at higher temperatures, there is many more free electrons and there are also many more collisions inside of the wire as the electrons jump from one atom to another. This disrupts the electric flow and lowers the conduction ratio of the wire. Cool or what ?

I say that this happens most of the time but not all the time. There is nothing ALWAYS in this world. Semiconductors will conduct better at higher temperatures. If you want to know why, that will be your research project. **Start reading and visit your local library,** I am not going to tell you.

Ok, that's enough about wire.  Now I will start to cover the actual electronics components.  I bet you waited for this moment ?  Ok.  The first one that you will get familiar with today is called a resistor.  The job of a resistor is to do just that, resist electricity.  There are many many many uses for resistors and they are used in almost everything from computers to televisions to radios, etc.

The following is a picture of a typical carbon resistor: 

Here is a better one, made by me :- )




Resistors are made from all type of different materials, from carbon to special film, etc. and there are as many different types of resistors and sizes and what they are designed to be used for.

I am not going to cover all of them, because if you made it this far, you must be a person who likes this stuff, so it is very safe to say that you will do a lot of investigating and learning on your very own.  Hooray!

I will list a brief description of the most common resistors that are used in hobby electronics and how they work and a little bit more.  Then I will finish this basics of electronics section and move on to mechanics and gears.

The resistor is labeled with a special sign in a schematic drawing that looks like this: 

CARBON RESISTORS are the most common type, (see picture above). Their resistance value is manufactured in a wide range of values from small fractions of an ohm to millions of ohms. Usually the larger the resistor the more heat it will be able to dissipate and therefore it will carry higher currents without melting down. Electronic components are rated for resistance just like our little friend the wire is. Make sure you use the right type of components or you will fry them if you use the wrong ones or even worse start a fire. Therefore, larger resistors, can resist larger amounts of current or AMPS, because that is what current in electricity is measured with.

POWER RESISTORS are used in high power circuits because they can carry a considerable amount of current, much more then the CARBON resistors can. These types of resistors are made out of ceramic material and usually wound with resistive wire around it. These types of resistors are made either with an adjustable slider to change the resistors value or a fixed value. Resistors that can have their value changed by our human hand by either moving a knob or a slider are called VARIABLE RESISTORS. The fixed type of power resistors are also called TAPPED Resistors, because the slider is tapped in a sense and you can't move it, it's fixed for good. I don't think that they actually make tapped sliders, but that is how that got its' name from.

To find out the schematic drawing for variable and tapped resistors, visit your local library.

One of the more popular variable resistors is called a POTENTIOMETER, which is a kind of a knob resistor that you can turn left and right, it looks like a switch but it is not. The carbon resistors have little color bands painted around them. They are there for a reason and not to look pretty.

This is called a color code. As I said earlier, electronic components are rated for resistance just as wire is. Everything resists electricity to some point. Instead of writing the number on the resistor, they paint them with the bands and you have to know the Standard Color code of the resistors to find it out.

# Basics of Electronics, Part II

You should not be reading this if you have not completely read Part I of the Basics of Electronics. If you have read it, no problem, let's continue.

**Understanding Basic Circuits, and studying the relationships between resistance, volts and amperes. More on WATTAGE. Conductance/MHOS/Siemens.**

First I will kinda talk about some quick facts and then we will go deeper into the heading of this chapter.

Most of the time when working with electronics you will be using batteries to make your projects work (D/C circuits) and I strongly recommend that you do until you have practiced and feel comfortable with all this tech ( not to mention safety ) talk before moving into A/C projects.  If you don't practice, you won't learn it.

While working with battery based or cell based projects you should be aware of the difference between SERIES and PARALLEL connected cells to the circuit.

One battery is called a cell, incase you missed that when coming in on the front page of this web site.  Two or more cells is called a BATTERY.

When cells or batteries are connected in SERIES, this means that they are connected end to end.  SERIES connections on batteries in electronics will increase the VOLTAGE of the battery above a single cell.  What that means is, if you connect two cells to a circuit in SERIES, and each of them is rated at 1.5 V, the voltage output will be 3 Volts.

If you connect two cells in parallel, this will keep the voltage output the same at 1.5 V but the total supply of energy and the capacity to produce a given current over a given time will be increased.

SERIES is when cells are connected from plus to minus.  I hope you know what parallel is :- ), but just incase you don't, it simply means, components are connected side by side, + with + and - with -.

One more way exists to connect batteries.  Cells can also be grouped as series of let's say 2 cells, and then connected in with other groups of the same series grouped in parallel.   Imagine that you have 6 batteries, each of them 1.5 V.

You divide these 6 cells into groups of three, you are left with 2 cells in each group which makes 6, right ? follow me ?

Now you connect each of these three groups which are 2 cells in series and then you connect these three series groups in parallel.  This gives you, 3 Volts total with an increased output capacity over time.

**George Simon Ohm, the German scientist who lived during the 19th century (1787-1854) is the man who has devoted a good part of his life into the study of PD in electric current and resistance using mathematical relationships.**

**His LAWS are the foundation of all circuit design and service.  The basics fundamental relationships between VOLTS, AMPERES and OHMS to all studies of electricity and electronics can be credited to him.**

**There is no more of an important lesson in this field then to understand this fundamental difference and the relationships between the three.**

**If you fail to understand them, you should stop and read it until you do.**

Ok, here we go.   **The first fact that you need to know is that:  Electric current in any circuit regardless if it is A/C or D/C;** BTW: A/C stands for Alternating Current and D/C stands for Direct Current. I will explain the difference later, but D/C is used mostly in batteries and A/C is used in high voltage circuits like in your home.

**-- is proportional to the applied voltage.** This simply means, that if the voltage is increased, the current will increase. If it is decreased, the current will decrease. Current is measured in AMPS, you are still awake, right ?

**Second:** The electric current in any circuit is INVERSELY Proportional to it's RESISTANCE. What that means is if the resistance in a circuit is increased, the current decreases. If it is decreased, the current increases.

What is the resistance in this circuit ? A resistor ? makes sense ? What type, doesn't really matter as I am only showing you an example here.

An example now with some numbers. We have a VERY SIMPLE CIRCUIT. 2 feet of wire, one 10V battery, and a resistor rated at 10 OHMS. If we measure the current with a meter, we get 1AMPS of current. If we remove the resistor and place a 5 OHMS in the other's place, what will the current increase to ?

2 AMPS You can get the same reading by simply increasing the voltage of the battery to 20V instead of replacing the resistor. If we increase the Voltage to 40V with a 10 OHM R, we get 4AMPS. I = E/R

You will really learn this once you start doing simple projects designed to teach you to take the right measurements and such. You should remember atleast one main fact out of all of this mambo jumbo. That fact is that our little three friends, the VOLT, AMPS and OHMS are kinda linked to each other. If one's value changes, it will change the other two.

Another new equation for you to study. This relationship is expressed in an equation like this:

I = E/R

I = intensity of the current in amperes or short AMPS

E = electromotive force in volts, or basically VOLTS

R = Resistance in OHMS

If you have any of the two values you can always find the third one. Depending on which two values you have you can use three different equations to help you solve for any of the three, they can only be either I, E or R. If you have I and E, then you are solving for R and you pick the equation with the R on the left side of the equal sign.

I = E/R, E = I x R AND R = E/I

Simple, right ? Good.

Ok, here is a problem if you think it is so simple:

**PROBLEM:** A current of .5 AMPS flows in a circuit that has a VOLTAGE of 500 VOLTS. What is the Resistance in the Circuit ?

Well ? PLEASE! Don't make this any harder then what it really is. This is ELEMENTARY. You can only have 3 VALUES, E, I or R. In the above example we have two values already given. AMPS is I, and Volts is E, so which one is missing ? R GOOD We solve for R, and we pick the equation with the R on the left side of the equal sign or R = E/I.

Now it's simple, you simply substitute the E for 500 and I for .5, you divide 500/.5 which gives you 1,000 OHMS.

And the answer is: The resistance in the circuit is 1,000 OHMS.

I got a question e-mailed to me by a reader, asking me how come everything that he saw in a Radio Shack magazine was rated in WATTS ?

The speakers were rated in watts and so were the CB radios and such. How come I didn't give more detailed explanation of WATTS and what for example a 1WATT CB Radio stand for ?

To be able to understand WATTS you have to understand this first and that is: VOLTS, AMPS, and OHMS. I did quickly introduce what WATTS are and such and if you go into PART I you will learn about it. Once I finish this I will explain in detail why they are rated in WATTS.

The WATT or WATTS is a common unit used to show how much electrical power has been used or a circuit uses. This brings me to another LAW, this law is called the CONSERVATION OF ENERGY LAW and it goes a little like this:

## CONSERVATION OF ENERGY LAW

## Energy can be only changed from one form to another, but it can not be created or destroyed.

For our poor human souls, this is the law that we have to follow for now. If you want to be politically correct, use it and you will be fine. I however don't believe it to be 100% true, but because I am some what of a Cyber Teacher, I want you to go by it and not what I think is correct.

Items like Radios or Light Bulbs are rated in WATTS. Did you ever noticed that ? Why, Why, WHY! ?

These devices are rated in WATTS to show how much power they consume at their maximum tolerance. A 60WATT light bulb operates at 60WATTS, which would be it's ideal power input. If you feed it too much WATTAGE or POWER, you will blow the bulb. Same thing with speakers and radios. They are rated by their maximum

WATTAGE capability. 1WATT speaker can operate at lower wattage, but if you exceed 1 WATT you are playing with fire and you will blow it if you pass it's tolerance.

Basically WATT is the unit of measurement of power. WATT-HOUR is the unit of energy measurement equal to one WATT per hour. A WATT-HOUR METER is a device that indicates instantaneous rate of power consumption of device or circuit. You have one of those meters in your home and the electric company reads off of that. To be more precise that is called a WATTMETER.

To figure out the circuits power at any given time of stable operation, and by that I mean, the VOLTS and AMPS are not moving in and out like crazy, simply multiply AMPS x VOLTS and you get = WATTS.

1 Horse Power = 746 WATTS, so if the circuit is operating at 460 VOLTS and uses 16 AMPS, it's power of consumption at that moment is ? 7360 WATTS. To get HP, simply divide 7360/746 to get approx. 9.8 HP, cool!

How many Volts and AMPS does a 1 WATT hand help CB (walkie talkie) radio use ? 1 VOLT and 1 AMP ?

Ummm, no. You can clearly see that it is using batteries that are of a little higher value then 1 VOLT, but the AMPS are less then 1 AMPS, much less then that.

I am purely guessing now, 9V and to get 1 WATT I would say it would have to be, about 0.11 AMP, because 0.11 x 9 = 1 WATT, makes sense.

Now when making the I, E, R equations, you must make sure that you use the same basic units: E in Volts, I in amperes and R in Ohms. You also have to remember about smaller or bigger values. What do I mean ?

Some bigger resistors are so big that it would be incorrect to use OHMS because of their high ratings, so we use kilohms or milliamperes in AMPS for smaller ratings. These must be changed to the basic units. This means that you will most likely have a decimal point to deal with, but that is necessary to get the right answer. Using KILO saves spaces when dealing with math.

100 milliamperes is not 100 AMPS, it is .10 AMPS. There is 1000 milliamperes to 1 AMP Similarly, 3.5 Kilohms is not 3.5 OHMS it is 3.5 to the 10(3) power or 3.5 times 1,000 = 3,500 OHMS.

So a circuit with a resistance of 3.5 Kilohms and with a current of 100 milliamperes would have a voltage of what ?

350 VOLTS of Potential Force, this is HIGH VOLTAGE! If you touch it, you will most likely die or be seriously injured.

**Pico** - one millionth of one millionth of basic unit / Pico = x 10(-12)
**Micro** - one millionth of basic unit / Micro = x 10(-6)
**Milli** - one thousandth of basic unit / Milli = x 10(-3)

( anything above this line is smaller then basic unit )
**Basic UNIT -----------------------------------------------------**
( anything below this line is larger then basic unit )

**Kilo** - one thousand times basic unit / Kilo = x 10(3)
**Mega** - one million times basic unit / Mega = x 10(6)

Everything in the ( ) is a power of ten. ( ) with a negative sign like this (-11) are negative powers of ten.

Think of it like this. Draw a straight line on a plain piece of paper. Find the middle, mark it with a point and name that 0, just like in math. Everything to the left is negative -0, everything to the right is positive +0.

0 is the basic unit of measure. Kilo is the first larger then basic unit of measure and then we use MEGA for even larger values when it becomes impractical to use KILO. And these two would be to the right side as + or bigger numbers.

Milli would be the first on the - negative side or smaller then basic unit of measure, then Micro and Pico.

**Series Circuits**

When you have two or more components in a circuit connected end to end, this is called a Series Circuit connection. In this type of a component connection, the current of electricity flows through each component.

If you had for example 3 resistors connected in SERIES they would be identified on a schematical drawing with little numbers besides them to identify one from the other. Like: R1, R2, R3, that is Resistor Number 1 and 2 and 3 and so on.

E = 10 VOLTS - | ------> R1 (300 OHM) ------> R2 (200 OHM) ------> R3 (100 OHM) ------> | +

What is the CURRENT in this Circuit ?

---> indicates electron flow, or polarity. R with a T, like this: RT is simply a way of writing the total resistance of all three of these resistors R1 through R3. The RT here would be 600OHM TOTAL.

Simply I = E/R We know that E = 10 and RT = 600 so 10/600 = 0.01666 AMPS or 16.66 milliamps

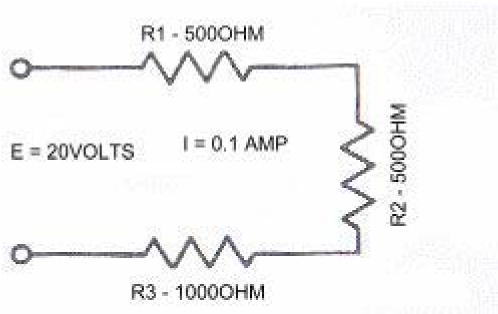
KIRCHOFF'S VOLTAGE LAW FOR SERIES CIRCUITS

The Sum of the voltage drops around a series circuit is equal to the applied voltage.

KIRCHOFF'S CURRENT LAW FOR SERIES CIRCUITS

The current is the same at all points in a series circuit.

How do you find the total circuit current if a series circuit has 3 resistors and each of them is of different value ?




( note on the picture I = 0.01 and not 0.10, will have to correct that later )

First you total all the resistances for all three resistors, 500 + 500 + 1000 = 2000OHM, so RT = 2,000OHM

Then you use the equation from above as I mentioned, we have R and E, so we are missing I. Then we solve for I and we pick I on the left side of the equal sign or like this I = E/R or 0.01APM = 20/2000, or 0.01APMS or 10 milliamperes

.

20 volts E or Volts

--------- divided by

2000 ohm R or Resistance

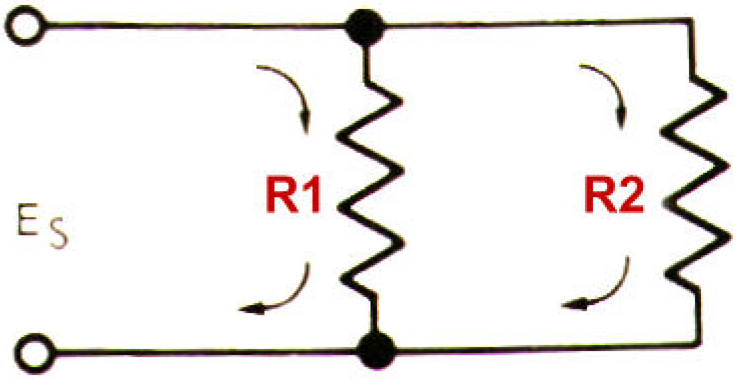
= 0.01 AMP I

There is much more to series circuits then what I mentioned here, please go to the LIBRARY and borrow a book or buy one. The best place to go for electrical books is to college stores. You do not have to be a student to buy them, just show some money and they will sell them to you.

Go into the electrical section. Or if you have lots of time and money, or maybe your parents are rich or have saved for your education since your beginning, go to a technical college for electronics. You will not! learn much about electronics if you just go for regular college courses, you are wasting your time and your parents money. Or borrow from a bank :- ) happy learning, they will lend to you, and you don't even have to have any credit at all.

## PARALLEL Circuits, MHOS and SIEMENS coming up.

In a parallel circuit, components are connected side by side and they also provide multiple paths for the current to flow through. If sometimes you see on a skematical drawing this right by the battery drawing < ES = 20 V > instead of just E which stands for VOLTS that simply means, Voltage source, the S stands for source.




KIRCHOFF'S VOLTAGE LAW FOR PARALLEL CIRCUITS

The voltages across all branches of a parallel circuit are equal.

KIRCHOFF'S CURRENT LAW FOR PARALLEL CIRCUITS

The current in a parallel circuit is equal to the sum of its branch currents.

This is going to sound strange but in parallel circuits the current will increase as you add more resistors in parallel. Why ? Because each time you add another resistor, that resistor it's self provides another path for the current to flow and the total current increases.

If you have two equal resistors of let's say 200 OHMS connected in the above circuit then the total circuit resistance may be found by this formula. This formula by the way can be used on any two or more resistors that are of same value.

**( the value must be same of all these resistors for this to be correct )**

RT = R / N, that mean Resistance Total equals = Resistor value divided by the number of resistors.

R = the value of any single resistor and N = the number of resistors in parallel.

So RT = 200OHMS / 2 = 100OHMS, then you simply find the voltage that is used by the circuit at any stable time of operation that you want this calculated for, let's say the above circuit uses 90 Volts, then you simply divide the volts by the 100ohms, like this 90/100 = 0.9 amps

To prove this you can simply divide 90 volts by each of the resistor's value 90/200 = 0.45 and then add the two together.

Power or WATTAGE can be found by multiplying AMPS x VOLTS or by multiplying OHMS or resistance by AMPS squared like this R x I(2)

To find the resistance in a parallel circuit that has two or more unequal resistors here is what you do.

Rt = R1 x R2 and so on divided by / R1 + R2 and so on = OHMS or the answer that you are seeking.

## IMPORTANT: The total resistance of any parallel circuit MUST BE LESS THAN the value of any simple resistor in the parallel circuit. Use this statement to check your mathematics when working with problems.

So let's say the two unequal resistors are 100OHM and 200OHM

100 x 200 / 100 + 200 = 20000 / 300 = 66.66666 ohms :- )

## Now here is something NEW! Hooray!

**CONDUCTANCE**

**The ability to conduct is opposite to the ability to resist. Either may be used in the computation of circuit values.**

Conductance of a circuit has been given the letter of G, as E is VOLTS and I is AMPS and R = OHMS.

So G = Conductance.

Conductance is measured in MHOS and if you look closely at this, MHOS is reverse of OHMS, only the S stays the same at the end of the word, basically OHMS spelled backwards.

The word SIEMENS is another term that you can use for MHOS. MHOS or SIEMENS, same thing.

G is exactly reverse of R, so if Ohm's law says that R = E/I, then G = I/E which makes some kind of sense.

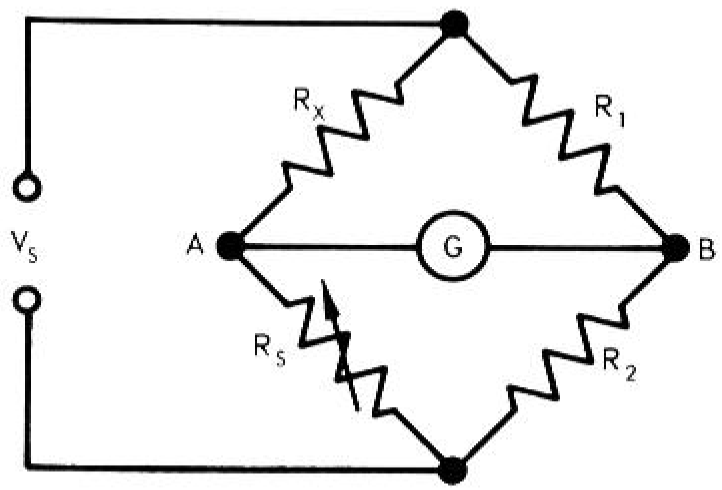
Conductance is really good to know about as it is later used in studies of transistors circuit parameters (controlling elements of a circuit such as voltage, current, resistance, inductance and capacitance).

# Basics of Electronics, Part III

I hope you have enjoyed Part I and Part II, and here is what I will write about in Part III.

Wheatstone Bridge Circuits, Switching, Rotary Switches, Capacitors, Magnetism;

**Let's begin.**




This is how the Wheatstone Bridge Circuit looks like. It is used for measuring unknown resistances. A circuit like this using resistors or as well as other components finds a wide range of usages in electronic circuits.

The above illustration is an example of a basic Wheatstone Circuit. The two input terminals are connected to a voltage source, Vs. The meter between points A and B is a sensitive galvanometer which is used to measure magnitude and direction of current. R1 and R2 represent the ratio arm of the bridge. Rs is a variable standard resistor and Rx is the unknown.

The bridge is in balance when the voltage drops across Rs and R2 are equal and there is a proportional division of voltage across the bridge.

In this "null" condition, the voltage at point A is equal to voltage at point B.

The meter reads ZERO since there is no difference in potential. A slight change in resistance Rx would cause an unbalance condition, and the proportional voltage division would be upset.

The differences in voltage between the points A and B would cause the meter to deflect. A small adjustment of Rs can bring the bridge back to balance.

As you can clearly see this stuff is getting much more involved then previous chapters I and II. So if you havn't read them, I would recommend that you do or you will be lost.  Also do a lot of research and reading on your own and together you will come out just fine.

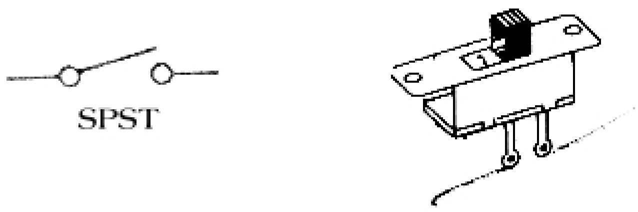
So, what is a Wheatstone Bridge the easy way ?  Here is the easiest way that I know of how to explain it.  Have you ever saw or maybe even used a VOLT meter ?  you know, one of those meters that you can buy at Radio Shack, they have these probes that you touch with, BLACK for negative and RED for positive ?

Well, this is something similar to it.  The input terminals can be compared to those probes.  With this circuit you can also find E, I AND R.

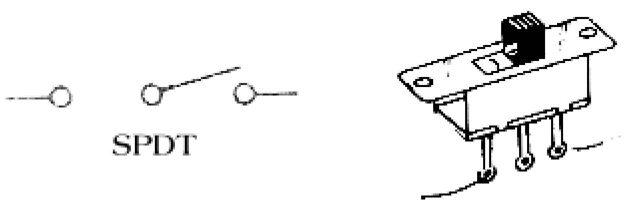
**SWITCHING -**

Switches in electronics, you guessed it are used to OPEN and CLOSE circuits, also to switch between circuits, but mainly to turn ON or OFF it's power supply.

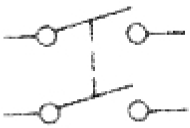
There are all kinds of switches for different type of purposes, here are some of them.



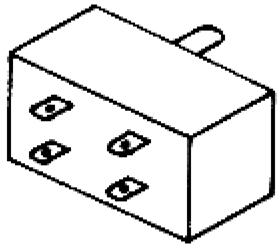

This type of switch is called an SPST, which stands for SINGLE POLE, SINGLE THROW.  The pole is the little piece of plastic that you move with your fingers to switch the switch ON or OFF.  This switch disconnects one side of a line in a single wire circuit.



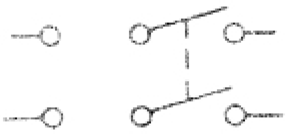

This is a SINGLE POLE, DOUBLE THROW switch used in switching from one circuit to another.  The OFF position is in the center and the ON's are on the left and right sides.



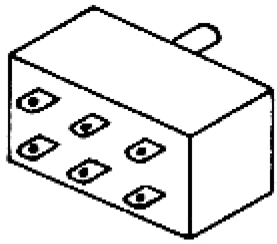
DPST



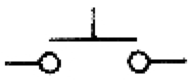
This is a DOUBLE POLE, SINGLE THROW used to switch both sides of a two wire circuit at the same time, similar to the SPST above.



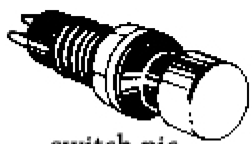
DPDT



This is a DOUBLE POLE, DOUBLE THROW switch used to switch between circuits and two of them at that.  Similar to SPDT, but you can switch between 2 circuits at a single throw meaning that if the center is OFF and the sides are ON, each side can turn ON or OFF two circuits, vs. only one in the SPDT.



open position



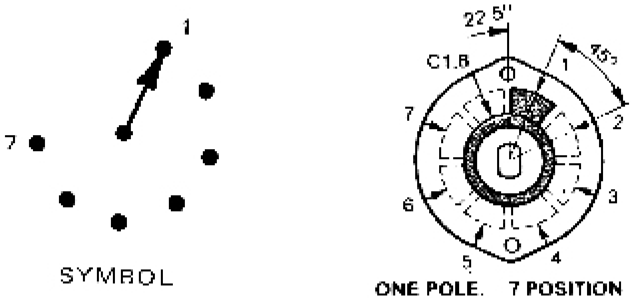
switch pic.

closed position

schematic signs above

This is a momentary switch, a push button switch to be more exact used in switching circuits momentarily.  Like your bell door, alarms or to momentarily close a circuit.

rotary switch symbol and section diagram




Rotary switches are devices that use a rotary switch. Above you can see a SPRS, SINGLE POLE, ROTARY SWITCH. There are different types of rotary switches and I am not about to cover every single one of them, so you will have to do some research on that. This is to show you only the basic diagram and how they look like. Some of the older television or radio sets still use them to this very day.

# MAGNETISM

Magnetism dates back a long time, before we even knew how and why it worked. It is said that a Chinese emperor used magnets as a direction finding device over five, that's 5,000 thousand years ago.

I even read somewhere that early ship navigators used this strange stone as a compass by attaching it to a small piece of floating wood and placing it into water. Since there was nothing holding the floating wood, the magnet would cause it to move towards the northerly direction, now that's really neat for their time.

But anyway, I am not going to talk about all the folklore and superstition that is associated with the magnet but instead will explain to you how and why it works the way it does, because it is very important in electronics.

Please again understand that if I didn't think this was important, I would not be writing about it. If you find this type of reading boring and this does not interest you enough to go out and do research on your own, then maybe electronics are not for you.

Scientists have discovered that our planet "the earth" is one big magnet. It's core, deep deep into the ground, in the middle is an enormous magnet. It's ends, like, imagine a football that is not round but more oval shaped, it's ends are pointing close to the earth's surface which happen to be in the north and south poles.

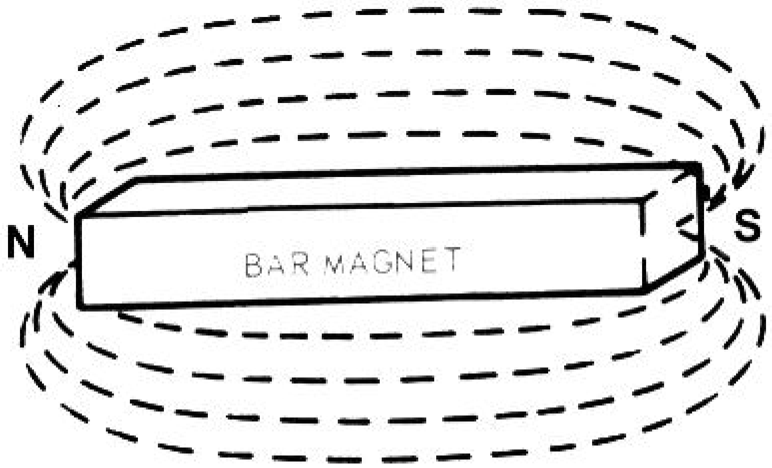
These magnetic forces can not be seen with the naked eye, but trust me they are there. That's why a compass is such a great direction finding device, because no matter where you stand on the surface of the planet it will always point towards NORTH.

As a matter of fact if you want to be more exact and for your information, here is the exact definition of magnetic North and South. The magnetic North that we know as North is in fact the south end of the earth's magnetic field and force. We in the early days were not yet that advanced about the knowledge of how this worked, so we called North because the compass always pointed in the Northern direction. But I do not think scientists quite understood how it worked back then.

Today, South would be North and North would be South. Cool or what ?

Further more, the magnetic north is not the true exact north. Why ? because of angular differences. The angular difference between magnetic north and the true NORTH POLE is called the ANGLE of DECLINATION or VARIATION.

Today magnets can and are artificially made using ferrous materials. The magnetic field has a name technically and that is called FLUX. If you take a magnet and place it under a piece of paper while you sprinkle some iron filings you can observe the particles aligning with the forces around the magnet. You will see that the bulk of the iron filings will concentrate at each ends of the magnetic poles. These are called the POLES, and each end is it's own POLE, either NORTH or SOUTH.




You can also observe that the filings align in the form of lines, and that the lines never cross each other. They also expand and separate more in the middle of the magnet.

These lines and their separation will depend on the power and strength of the magnet.

Here is the most important LAW for you to memorize about magnetism. They are as follows:

## UNLIKE POLES ATTRACT EACH OTHER, WHILE LIKE POLES REPEL EACH OTHER

This law is similar to the LAW of ELECTROSTATICS where, like forces repel and unlike attract.

If you want to learn about the MAGNETIC FIELDS in ATTRACTIVE or REPULSIVE POSITIONS, read a book :- ).

Anyway, since you know that like magnetic poles repel and unlike attract, you should also be aware that the distance between the magnets has a lot to do with that. The attractive or repulsive forces of poles varies inversely with the distance that the magnets are set apart. This difference is measured in distance squared or like this:

$$F = \frac{M_1 \ M_2}{\mu d^2}$$

M = magnet, strength of magnet

d = distance between magnets

The force is also directly proportional to the force of each acting magnet.

and that funny symbol that's u shaped is (mu) = **permeability:** is the ability of a material to conduct or carry magnetic lines of forces. It is the property of a material which permits easy distribution of magnetic force lines within the material. In magnetic circuits we use a greek letter of u, the funny shaped one above, (look at the picture) pronounced (mu) to permeability.

Permeability of different materials is assigned a number, this number has no unit of measurement and expresses the permeability of the material in respect to air, or more accurately, to vacuum. Vacuum has a permeability of 1.

That is why (mu) is included in the equation for magnetic force.

**retentivity:** is the ability of a material to hold it's magnetism after the material has been removed from a magnetic force or magnetism that remains after a magnetic force has been removed from is called **residual magnetism.**

Anyway, the most important magnetic materials used to date in electronics are called a FERROMAGNETIC materials because of their ease to magnetize and keep it's magnetism. These include iron, steel, cobalt, permalloy and alnico. If you think these are strange names then you are right. Alnico is a trade name for an alloy of iron, nickel and aluminum.

**PARAMAGNETIC** materials are the opposite, where they only hold a small fraction of the magnetism after passing through a strong magnetic force. These include aluminum, chromium and platinum, you know that very expensive metal.

A **DIAMAGNETIC** material is one that can also be slightly magnetized but it will assume a polarity opposite to the polarity of its magnetic force or magnet.  These include copper, silver, gold and mercury.  Some of the best conductors!, and which one is the best, do you remember ? Silver, that's right.  Most people still think it's gold, haha.

Ok, what else is there to say.  Magnetism plays a very important role in electronics, did I mention that yet ?  Motors work because of it and many other components and things in electronics.

Now, if you want to find out how exactly magnetism works, then look in more common textbooks under WEBER'S MOLECULAR THEORY or DOMAIN THEORY.  There is more then one.

What is **MAGNETIC INDUCTION** you ask ?

Very simple, when you bring a magnet close to any other material that has a high permeability like iron, steel, the force from the magnet will pass into the material and it will attach to the magnet.

So that material is in fact attracted to the magnet.  This magnetization of that material whatever that might be while in the FLUX or magnetic force of the magnet is called **MAGNETIZATION BY INDUCTION**.

Never heat a magnet and try not to drop them on the floor.  What is **MAGNETIC SHIELDING**? : There exist no 100% effective known shield against magnetism. Magnetism will pass through any material, and I mean anything, glass, plastic, water, insulation, even you.

Some materials basically conduct magnetism better then others, just like electricity.  If you want to shield something from magnetism, like your speakers, you would use a high permeability material and surround the item to be shielded to move the magnetism around it instead through the item.

Delicate instruments like meters, the ones with those dials have exactly this installed around the sensitive meter, because magnetism would interfere with a correct reading.

Anyway, a Scientist of the name Hans Christian Oersted, was the first to emphasize the relationship between electricity and magnetism in 1819.  He discovered that a compass would act very strange while very close to a flowing circuit and then it would go back to it's normal reading after the circuit was turned off.

From this we learned that you can also make a magnet by using electric current in a conductor.  One easy way is to take a nail and wind some wire around it and hook it up to a electric source.  You will in fact create an electromagnetic field and the reason why it is called an electromagnetic field and not a magnetic field is because the field was created using electricity and not a regular magnet.

When electric current flows through the wire, the current creates a clockwise circular magnetic field.  When you reverse it, it will produce a counterclockwise field.  As a matter of fact if you know how magnetism works you can quickly find out which way the electric current is flowing, up or down.

And you thought this was all boring :- )

When electric current flows through a wire that is wound around a nail for example, the magnetic field around the wire joins and reinforces each other.  The coil or nail will assume a magnetic Polarity just like a magnet.  One end becomes North and the Other South.  If you reverse the electric current, the poles will switch in force.

If you wind wire around an empty piece of coil, that is called a SOLENOID.  If the coil that you wound the wire around is made out of magnetic material, then you just made an electromagnet.

Here are a couple of points you should remember about electromagnets if you plan to make one and you should just for fun.

The number of turns of wire wound around the coil, more coil is better

The current flowing through the coil, stronger is better

The kind of core material

The ratio of coil length to its diameter

If you want to make the electromagnet more powerful there are only two ways to do it.  One, either wind more wire around the coil around the material that you are using to make the electromagnet or increase the current.

Another one can be by changing the type of wire you are using, silver will work much better then copper, because it resists less and is a better conductor.  Of course it is more expensive.  You do not need to use gold for even better conduction, because silver is a better conductor.

The magnetic field intensity of a coil will remain uniform, that means the same throughout the cross section of the coil if the length of the coil is ten times or more greater then its diameter or twenty times the coil radius.

Anyways, it's time to get familiar with the **electromagnetic terms and definitions.**

There is no one system in use when it comes to measuring electromagnetism.  The most accepted measurement systems are: the CGS (Centimetre-Gram-Second) system, the MKS system, and the English System units.

I will write about the English system and the CGS systems only.  As you already know FLUX is the measurement of the total number of lines of magnetic force.  The greater the FLUX reading, the more lines, the more powerful magnetic force, not that hard.

We use a Greek symbol of (phi)

$\Phi$ (phi)

to represent FLUX. In the English system, FLUX is measured in Kilolines or thousands of lines, as Kilo means thousand. In the other system (CGS), a single line is called a MAXWELL.

Another term called, FLUX DENSITY is used to measure the number of flux of field lines in the cross sectional area of the flux field. Density is expressed in KILOLINES per SQUARE INCH in the English system and MAXWELL PER SQUARE CENTIMETRE in the CGS system is called a GAUSS.

FLUX DENSITY has a symbol of B assigned in Electronics and the formula goes like this:

$$(\text{density})\, B = \frac{\Phi\,(\text{flux lines})}{A\,(\text{unit area})}$$

**MAGNETOMOTIVE FORCE** or (mmf) is the total force producing a magnetic field or FLUX. It's like this:

(flux) = mmf/R

$$\Phi(\text{flux}) = \frac{mmf}{R}$$

above is the formula for mmf.

Ok, a new term that I am going to teach you now is called **RELUCTANCE**: is the opposition to the establishment of flux lines in a material. RELUCTANCE is like RESISTANCE in electronics. Every time electricity flows through a conductor, it will be met with opposition or like friction, which is called RESISTANCE. Well, every time you create an electromagnet, you will be also creating opposition to the FLUX lines in that material that you used to create the magnet.

Also, **FIELD DENSITY** is the magnetic force that we use to describe unit length of the flux path. It is assigned a symbol of H. In the English System this is expressed with AMPERE TURNS PER INCH. In the CGS System it is expressed in GILBERTS PER CENTIMETRE.

$$\mu = \frac{B}{H}$$

Here is the formula for field density. U means what ? look above, anyways, u = B divided by H. Look above for those as well, I explained all of this already.

GILBERT is the unit of magnetomotive force in the CGS System. You can convert it to the English System by this following formula:

**ONE GILBERT = 1.256 AMPERE-TURNS**

Here is a to the point and easy to understand formula for calculating Magnetomotive force.

First you have to find out how many turns are around the coil that you use to produce your electromagnet. For example, if you gave it 250 turns, then you take that number and multiply it by the AMPS reading that is flowing into the circuit.

If you are feeding the electromagnet at 4 AMPS for example, then you multiply 4 x 250 = and you get 1,000 IN, the IN stands for AMPERE-TURNS.

Any good Electrician must understand this before he can work on motors, generators, relays and other electrical components.

Many times the electromagnets that you will work with are store bought, you will not be actually making them by hand and they have a fixed turns of wire around the coil. So the magnetomotive force can only vary by AMPS. You will therefore multiply AMPS x the fixed number of turns for each electromagnet to get a reading.

Field INTENSITY is also a very important term to understand more deeply. Field intensity is distributed more over the overall total length of the magnetic circuit or the electromagnet and it's core material.

So if the electromagnet is 5 inches long then here is what you do to find field intensity:

H = IN/inches

Or in our previous example,   H = 1,000/5 = 200 IN/inch

Field density works closely with Field Intensity or H.  Try not to confuse them, as they are not the same term.

According to ROWLAND'S LAW that states   (flux) = mmf/R, see formula above, if mmf is increased by an increase in AMPS will increase the magnetic flux.

Well, there is much, much more to magnetism then just what I have covered here. You know what to do if you want to learn more, right ?

BUT KNOW this, if you are planning a career in electronics or electronic engineering, MAGNETISM is VERY! important.  You will need to understand it very well, what terms like SATURATION means and how the characteristics of a magnetic material function within a coil.  You will need to understand this theory in order to work with chokes, transformers, memory cores of computers and many other electrical components.

Read a Book.

Next I will cover AC/DC and RELAYS to end chapter 3, and will begin chapter 4..

## **What is a RELAY ?** ha, ha

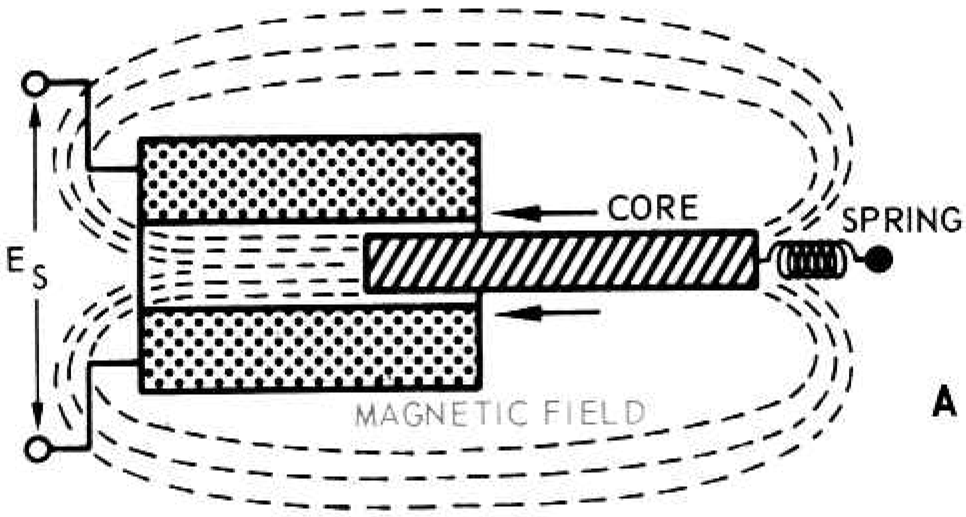
Now you will appreciate all the magnetism talk, and you will find out first hand why we learn it :- )

The key word here is: SOLENOID.  I covered what that is above, but to refresh your memory, here it is again.

Take a piece of pipe, and I do not mean pipe like in your plumbing system, but piece of coil, a round thing, you know ?

Make sure that it is made out of high permeability material, and I covered what metals are and are not.  Wind some wire around it to make a ELECTROMAGNET or SOLENOID.  Just keep in mind the major difference that of a SOLENOID and a ELECTROMAGNET.  The only minor difference is that a ELECTROMAGNET must be made out of magnetic material for it's core and a SOLENOID does not have to.

I believe that if I place this picture you will understand it much faster.

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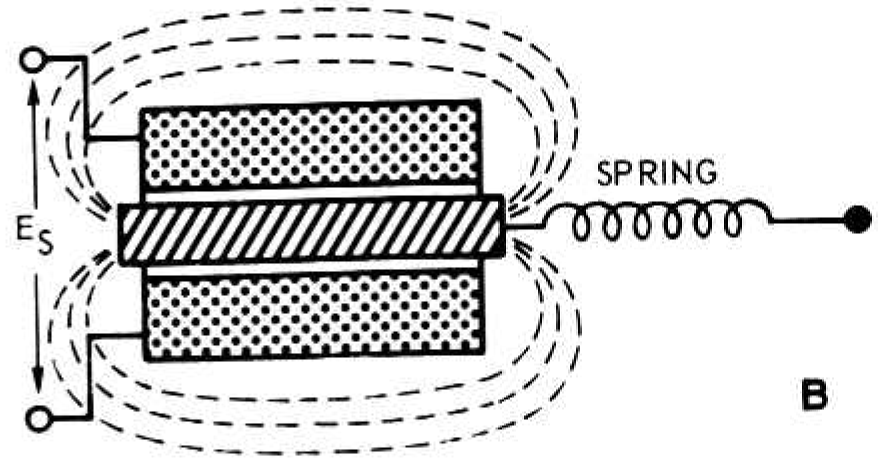



B

MAGNETIC FIELD

When you apply a voltage source, and ES stands for that, E stands for Volts and S stands for Source, you activate the coil or the electromagnet.  That rod that is connected to the spring first of all must be made out of a metal that falls within the good permeability metals, plastic won't work.  Once the electromagnet energizes and creates a magnetic field, the rod will become a part of it, like one big magnet and the FLUX lines will transfer into it as well.

Since the magnet lines are seeking the shortest path between the poles and since there is only a spring holding it, the electromagnet will cause the rod to move into the magnet to complete this shortest path as far as the magnetic field can pull it in.  This depends on the power of the electromagnet.

The electromagnet exerts a SUCKING IN FORCE and the core or rod moves in. When you turn off the voltage source from the electromagnet, the coil returns to it's previous place because the spring will exert or pull it back.

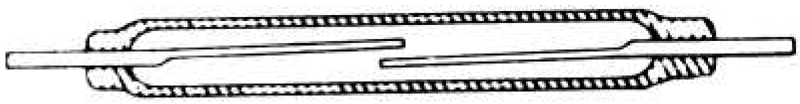
All that relays are, are MAGNETIC SWITCHES or to be more exact, ELECTROMAGNETIC SWITCHES. Relays are used in high power circuits where smaller conventional circuitry would be out of the question to use due to all kinds of heavy hazards.

Your washing machines uses relays to control the HOT and COLD water amongst other things and starters in cars also use a different type of relay. Your bell door alarm, uses a relay to hit the bell. The advantage of relays is that you can switch it ON and OFF from remote location via remote control or automatic programming and they are durable compared to TRANSISTORS which are very sensitive components and are not suitable for these types of jobs.

Well, now you know what a RELAY is, isn't that nice ? :- ) Relays can be connected in SERIES or in PARALLEL just like other components in electronics. PARALLEL connection are called SHUNT or SHUNTS.

Relays are made to be either voltage or current sensitive, depending on how you are planning to use them in a circuit. You must understand this difference. And relays that are used in parallel will differ from those made in series.

Basically what I mean is that they are made out of different materials and are not the same. Relays are also used as circuit brakers, you can compare them to a FUSE. And there exist very small relay FUSE like components where many people confuse them with FUSES, but in fact, they are relays. These are called REED relays.



Picture of a Reed Relay.

Well, that's it for relays, if you want to learn more about them, please read a book. Please keep in mind that these days relays come in all kinds of shapes and packages. Many look like SOLID STATE Circuits and are designed to work with printed circuits, others are not. There are heavy duty relays and light duty. It all depends. If you take a trip to Radio Shack and look at some of the electronic components, you will quickly have the opportunity to see what I am talking about.

Before I go I would also like to tell you to do some investigating on your own about FUSES and what they are, the different types and so on. Also read about BUZZERS and CHOPPERS, and BI-METAL THERMOSTATS.

## What is A/C ?

A big question, deserving a BIG, and LONG Answer and some more.

It doesn't take a genius to figure out what A/C stands for, it stands for Alternating Current. Now everything in electronics, most of the time has a reason for a certain name, just like A/C does.

From these two words, the key words here are, Alternating and Current :)

Let's begin. Another term that you will quickly get to know today is FREQUENCY. It is very important in Electronics :)

Ok, A/C Electricity or it's Current that flows through the wire is an alternating current and it alternates at 60Hz per second.

First some basics. One hertz or (Hz) same thing is one cycle per second of something of repetitive nature, and that is why it is called FREQUENCY. Like, how many times something is happening in how many cycles per second or time. For example, your car Engine cycles in RPM's, that is Revolutions per Minute. That is too FREQUENCY, it is just a different type of.

Before 1967 we did not use the term Hertz or (Hz) for FREQUENCY, we simply said, (cps) cycles per second. But then in 1967 in order to honor the memory of HEINRICH HERTZ, the German scientist who first discovered radiating waves, we switched from (cps) to (HERTZ) or (Hz).

Again:

One (Hz) = one cycle per second, not minute!

KILO stands for thousand and MEGA stands for million, GIGA stands for billion and so on.

One (KHz) = one thousand cycles per second

One (MKz) = one million cycles per second

One (GHz) = one billion cycles per second

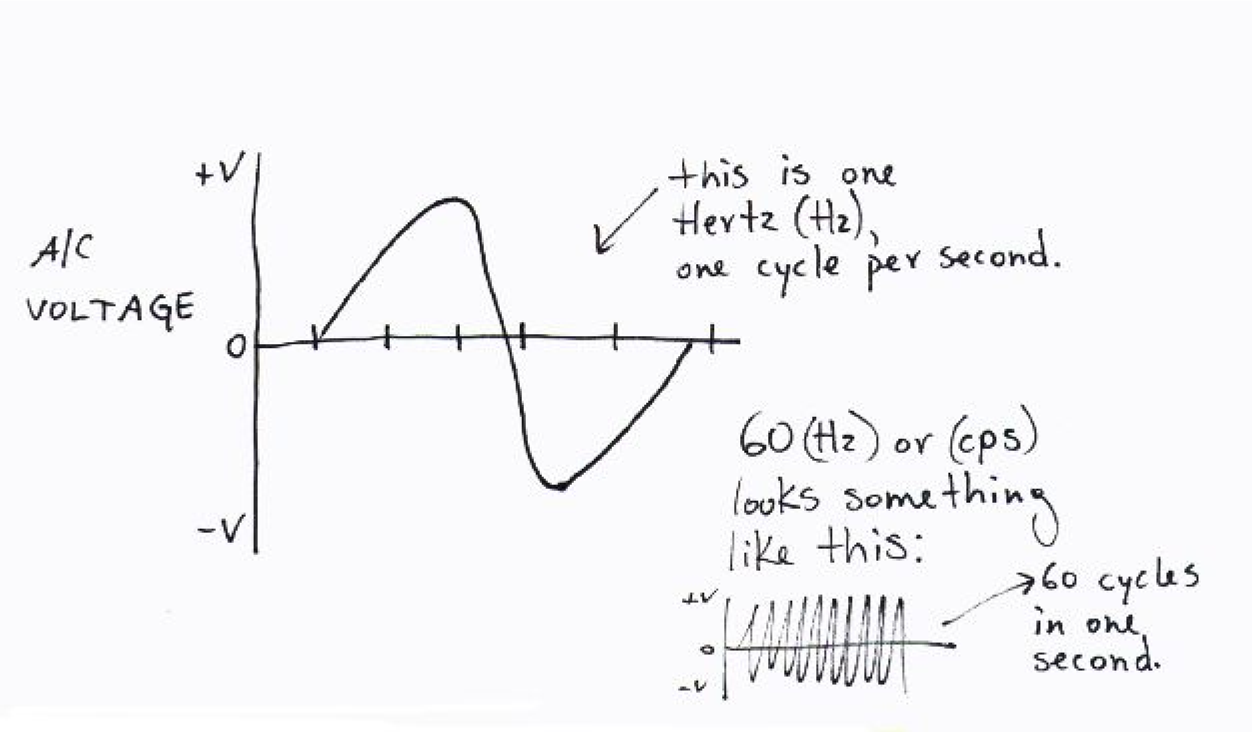
By LAW, yes it is true, A/C in America flows at 60Hz per second, that is, 60 cycles per second and the way it works is like this. Imagine a line, mark it 0 value, everything above it is + (plus) and everything below is - (minus).

The A/C current flows in one direction for a while and then flows in the opposite direction for a while, very different then D/C (Direct Current) which flows in the same direction all the time.

The VOLTAGE across this A/C line Goes from 0 to it's maximum value on the positive side, back to 0 and then to it's maximum value on the negative side and thus resulting in an Alternating current. Why this happens, is because of the way that this electricity is Generated and most of the time it is generated via. BIG GENERATORS, this is a new story in it's self. Basically you use Magnetism to produce electricity and because as the Generator turns around, it changes in polarity as it passes the North and

South POLES.  This Of course is the easy explanation, and right about now I am wondering, if maybe I should have covered GENERATORS first ? :) But because so many people have been begging for A/C here it is.

So anyways, this 0 to +, back to 0 and to -, is happening 60 times per second at 115VOLTS Fixed for normal A/C Values.  If you ever look at some GENERATORS or other equipment that is fed off of A/C Lines it will say 60Hz, 115VOLTS A/C be written right on the part.




The major different between A/C and D/C is that D/C while it can change in MAGNITUDE, it can not like it's Friend A/C change in direction.

Magnitude is the term we use for the value of current.  Like how strong, the bigger the Magnitude, the bigger the Value or MORE VOLTS.  But to make it easy, a generator can produce electricity if the conductor is moved through a magnetic field, this will produce a voltage.  Either the conductor or the magnetic field can be moved, it will result in the same effect.

If you hold a magnet in a fixed position and then move it up or down the coil, this will produce a current, or voltage.  First in one direction and then in the other.  That is why it alternates and thus why it is called Alternating Current.;

In Europe A/C is more then a mere 115 VOLTS, I think it is 230 VOLTS.  How do they produce more volts ?  Simple.  If you move the GENERATORS faster then 60cps or 60 Hz, the induced force on the electrons within the conductor will also be greater and a greater voltage will develop.  In Europe, they simply move the generators fasterrrrrr.

Also keep in mind that GENERATORS only convert Mechanical energy into Electrical Energy and not the other way around.  Later I will teach you about this as well.  You will know what a SIN WAVE is, and how a simple Alternator works.

I will also introduce you to some new formulas and laws, you will learn about such terms as PEAK VALUE, PEAK TO PEAK VALUE, WAVELENGTH.

To end this short introduction into A/C, know this too.  An A/C Wave, is made up on positive and negative ALTERNATIONS.  The average value of the wave is considered the average value of ONE ALTERNATION.

This value is considered at 63.7% percent of the peek value which I will teach you about later.  A/C is a complex subject, because it involves the time to learn many other subjects that are A/C related, Like Generators, which is a Subject all in it's own.

To confuse you further there also exist D/C Generators, wana learn more ? come back a later date and I will explain.  I will also explain to you about a very neato type of Tool called an Oscilloscope that is used to measure DC and AC Waveforms among other things.

# Basics of Electronics, Part IV

I don't know, I think that the subject of generators is so important, because it deals with A/C and FREQUENCY, that I might dedicate a whole chapter for it, will see.

So here we go.

One of very few but important people from the past and now in history books that you should know about is and was named, MICHAEL FARADAY.  He lived during the early part of the 19th Century, and he is mostly remembered for his work on DYNAMO's.  If you don't know what a DYNAMO is, don't worry, I will teach you about this later.

Anyways, he was one of the people who has spent an excessive amount of time working with electricity and magnetism and studding the relationship between them.  He reasoned that if Electricity could be used to create electromagnets with, why not then reverse the process and use electromagnets to produce electricity with.

Sounds reasonable to me : )

So, through his work and a major time effort devoted to this subject, Michael over time has discovered Magnetic Induction, I did explain what this is in Chapter 3.

Basically what his work lead to was to use MOTORS to produce electricity with.  If you take a conductor and move it inside a magnetic field, this will produce a voltage, more correctly, the voltage will be induced in the conductor.

Either the conductor can be moved or the magnetic field can be moved around the conductor to achieve the same effect.

If you take a small motor, you know, one of those hobby motors, you will see magnets around a moving COIL of wound wire that moves.    When you introduce an electric current to the motor, it will start to move.  If you remove the ES, Electric Source and then place the MOTOR over water so that the moving current of the water can make the bearings of the motor move, you can create electricity.

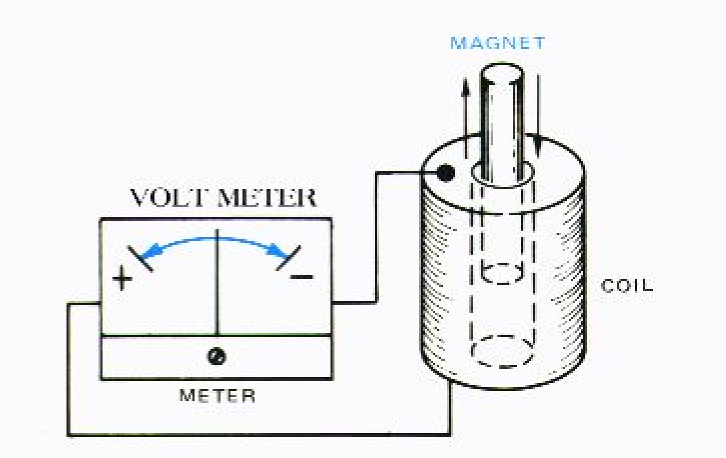
Here you are using, the moving force of the water, which is in it self a type of energy, then you transfer it into mechanical energy inside the MOTOR and that translates the mechanical energy into electrical energy that move down the wire and into the electric plant.

This is how Electric DAMS work, but a lot more complicated.

Anyways, Mr. FARADAY lived from (1791-1867) and came from England.  Hmm, if it wasn't for him, you would still be reading books under candle light :), and in order to honor this great in it's own way inventor, we named the unit of capacitance after his last name, FARAD.

As the COIL is moving around the SOUTH and NORTH POLE MAGNETS, it will produce DEFLECTION of current.  If you connect a VOLT meter, one of those ones with hand arms, you will observe the meter deflecting from 0 to positive, back to 0 and into negative territory.

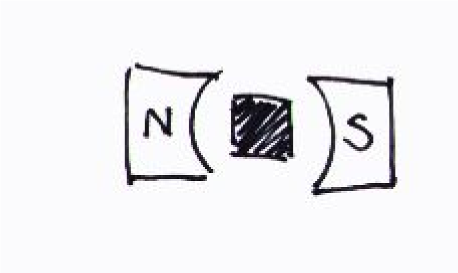
Relative motion must be present in the magnet or in the MOTOR, or current can not be produced.  This is how those WIND Propellers generate Electricity that you sometimes see mentioned on TV in the deserts of California and Arizona.




This should give you some hints about why A/C current Alternates.  Are you getting the idea right about now ? Great.

Anyways, here is an inside view of a typical MOTOR, doesn't matter what kind for now.

I am not an ARTIST, but try to imagine this.




The magnets reside around the moving coil of the motor.  How much VOLTAGE can be produced from a typical type of MOTOR or DYNAMO depend on the following factors:

- The SPEED at which the moving coil conductor cuts the magnetic field through.
- The STRENGTH of the magnetic field around the coil.
- The LENGTH or number of turns around the COIL.
- The ANGLE at which the conductor cuts the FLUX field.

So if the speed at which the conductor cuts through increases, that induces on the electrons within the conductor and result in a greater voltage output from the generators.

The big generators in Electric Power plants are huge and a lot of energy is required to make them move.  This is because the polarity of the fields opposes the movement of the conductor that cuts through them.   We need actual mechanical energy to move the generators, thus why we use water or atomic power to move the generators because a lot of energy is needed to move them.  So now you know how generators convert mechanical power into electrical.  Without mechanical power, electricity would not be possible.

Here is a LAW to memorize for you that provides the scientific explanation for this subject.

## "The polarity of an induced EMF-electron moving force, is such that it sets up a current, the magnetic field of which always opposes the change in the existing magnetic fields."

Now here I will explain why A/C Voltage moves in one direction for a while and then changes polarity and goes in a different direction.  This is tied to the generators that create the electricity at the electric plant.

The conductor that moves inside the generator is called an armature, at the end you have types of brushes, like in DC motors, these pass over the induced voltage to the two output terminals and then the electricity is let out of the generator and into some type of circuit where it is further processed.

First to induce the maximum voltage out of a generator, the ARMATURE must cut the FLUX in the proper degree angle, and for maximum this is at 90 deg.

As the armature is moving around inside the generator, the wire loops are cutting at right angles. In one quarter of a revolution, the armature will be moving parallel to the field, which in this case no voltage will be induced, but in yet another quarter of a full revolution, the armature will be cutting at 90 deg. again, So both sides of the armature are moving through the FLUX field but opposite of each other. The result is, an induced voltage opposite in polarity and the current or AMPS will flow in the opposite direction. Thus why the A/C current moves like waves. This wave by the way has a name, it is called a SINE wave.

This is called the Alternating Current or A/C Sine wave. The major difference between DC and AC is that AC is continually changing amplitude and polarity as such I just explained.

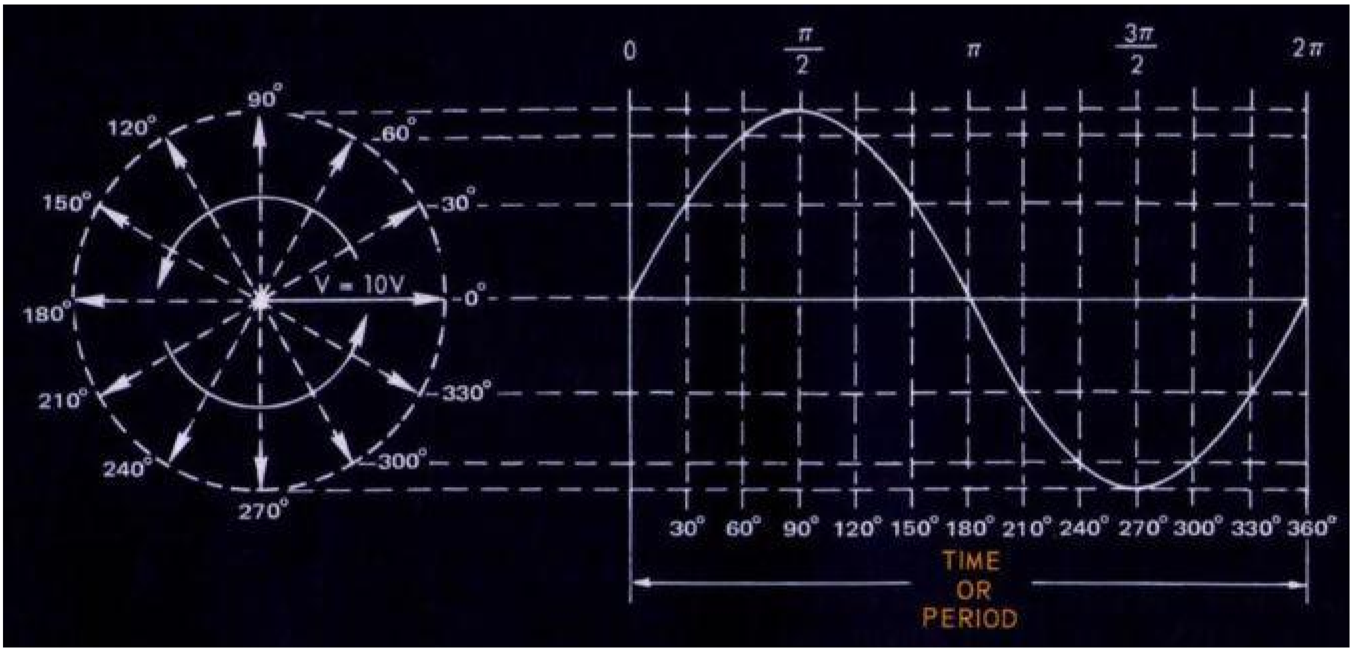
**A CYCLE** is described as this: The cycle of the wave starts at zero, it rises to a maximum of the positive polarity, or one polarity, drops to zero, goes exactly the same in the opposite direction or negative polarity, and then returns to zero. This constitutes one CYCLE. 60Hz, moves exactly like this 60 times per second.

Frequency I explained in Chapter 3. Now a **PERIOD** of a SINE wave is simple, even if the explanation sounds complicated. Period has the letter of T assigned in electronics. The formula is

T = 1 / f in Hz

The explanation is as follows. If you are trying to find out the PERIOD of a 60Hz wave, the typical wave at 115VAC, here is how you do it. The time in seconds for the durations of one CYCLE is PERIOD.

So 60Hz wave has a period of 1/60 sec. or 0.016666 sec. This is the PERIOD time for each cycle from 60Hz.




Here is an example of the SINE Wave chart, so that you can get a better idea of how it looks like.

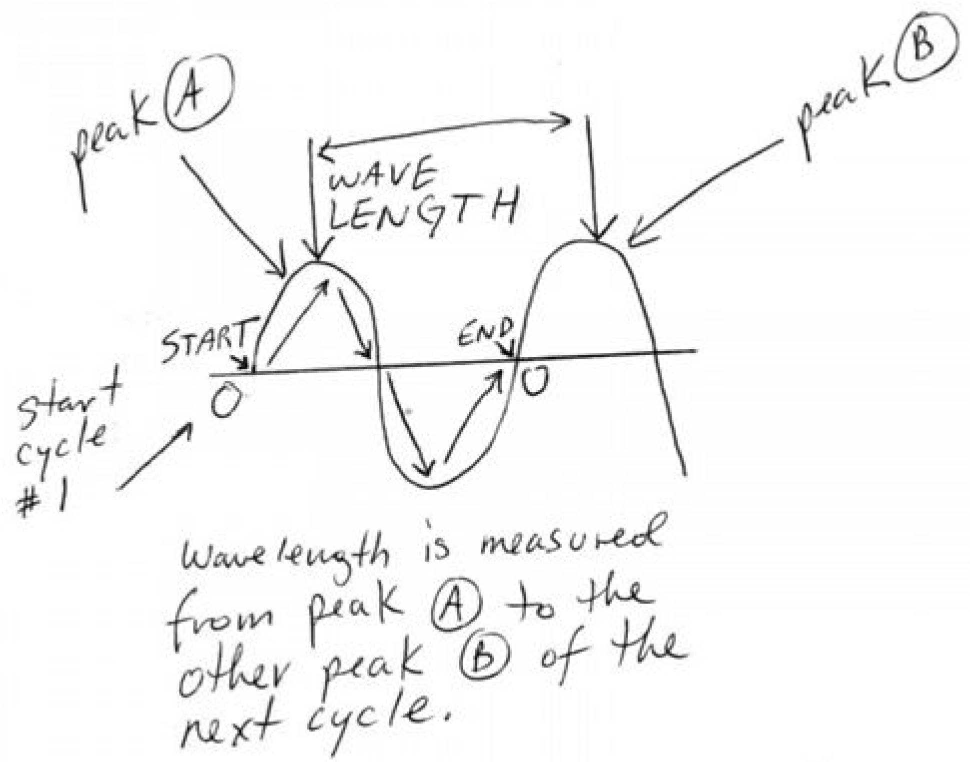
The circle with the arrows represent the armature that moves around the generator. It starts at 0 deg. and moves around one full cycles or a full revolution of 360 deg.

And based on where the armature is located inside the generator the SINE wave will be different, and again that is why it alternates.

You can find out what the PERIOD answer is for all frequencies like even in radio, by using that above example. Here is something else, try this. A radio station operates (only an example) at 99.9 KHz. Right off the bat, the K stands for thousand, so this in fact is 99,900 Hz, so that means that the frequency wave is moving at 99,900 cycles per second.

So, T = 1 / 99,900 = 0.00001 sec. So each individual CYCLE of each of the individual waves that make up the frequency is only 0.00001 sec. and if you take 0.00001 and multiply by 99,900 you get 1 or the value of 99,900 cycles per second for our frequency. The 1 stands for all the single CYCLES that make up the 99,900 freq. for a duration of one second.

The higher the frequency, the shorter the wave length. Here is how that works.




What's **PEAK VALUE** ?  To simply put it, it is the maximum amplitude of a wave in either positive or negative direction starting from zero.  A **PEAK TO PEAK VALUE** is the value of the frequency wave from the maximum positive peak of the wave to the maximum peak on the negative side or vice verse.  Another way to explain it is the value from both peaks, which represents two times the peak value.

What's **WAVELENGTH** ?  The length of a wave is measured from the peak of one cycle (from the top, see picture above), to the corresponding peak of the next value.  If you start having more cycles per second, less waves fit into the one second, so the WAVELENGTH becomes shorter and shorter.  If you reduce the frequency, the wavelength becomes wider and wider.

The Greek letter (lambda) : $\lambda$

is the letter in electronics that represents WAVELENGTH.

Frequency waves travel at light speed which just happens to be about 186,000 miles per second, that's:

$$3 \times 10^8$$

meters per second or again 186,000 miles per second, which is the same thing.

**wavelength calculation table**

f = frequency

$$\lambda \text{ in meters} = \frac{3 \times 10^8}{f \text{ in Hz}} \qquad \lambda \text{ in feet} = \frac{984}{f \text{ in MHz}}$$

for 1,000's → $\frac{3 \times 10^5}{f \text{ in KHz}}$

for 1,000,000's → $\frac{3 \times 10^2}{f \text{ in MHz}}$

: )

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If you know the wavelength, you can find out the frequency and vice verse.

**here is the formula for finding frequency if you know the wavelength:**

$$f \text{ in Hz} = \frac{3 \times 10^8}{\lambda \text{ in metres}}$$

← for KHz use 5 and for MHz use 2 in the power

Example is as follows: **What is the wavelength of a 10 KHz wave ?**

First you look what you are solving for, so we are dealing with K - thousands of HERTz. So we would use a power of 5 on the 10. So 3 times 10 to the Power of 5, divided by 10. That will give you 30,000 metres or meters.

Example is as follows: **What is the frequency of a 90 meter wave ?**

3 x 10 to the power 2 divided by 90 = 3.333 Mhz, to see if you are right, simply reverse the formula and solve for meters or.

3 x 10 to the power of 2, divided by 3.333 = 90 meters. So it works : ) You can reverse the same process for the first example. If you are confused, don't worry, it takes getting used to, read it a couple of times : )

Keep in mind that metre is not spelled wrong when refering to meters, it is the same thing, metres and meters = same. Metre is british. 1 metre is 39.37 inches.

I found this really good site that explains a lot of the Radio related and wireless terms and what they mean. For example, do you know what RF means ? no ? then please link here and you'll learn.

RF/Microwave Terminology - Glossary of Wireless, RF and Microwave Terms

Another interesting value to know is called the **Effective Value**, this value compares the A/C to D/C equivalent value of an A/C wave in order to produce the same power in a resistive load compared to a steady D/C SINE wave.

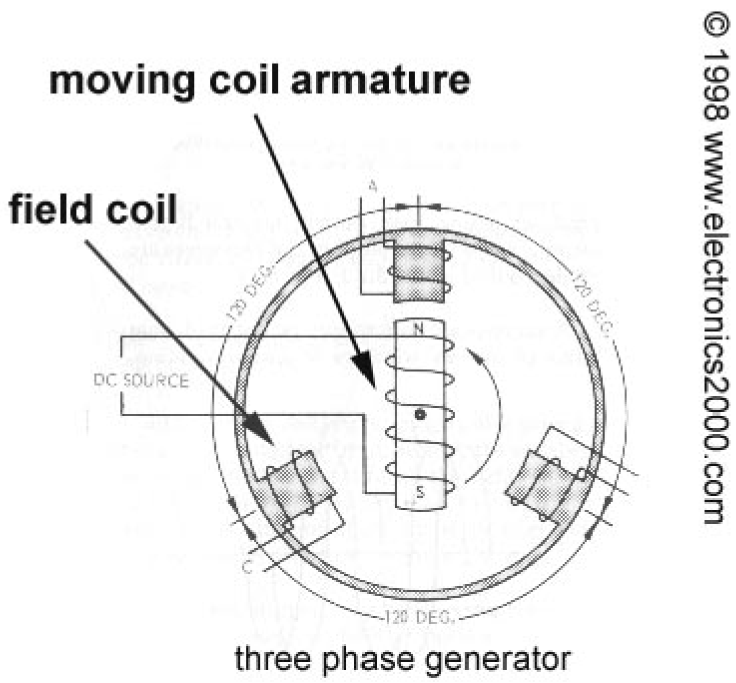
Some other terms you should be familiar with are **Amplitude**, which measures something similar to magnitude. The bigger the magnitude or something, the greater the size, or in this case the value reached by the SINE wave or waveform.

**Modulation**; the variation of a property that makes up the electromagnetic waves or signals such as it's frequency or phase.

Ok that's it about A/C Waves. There are many books dedicated to this subjects and the formulas can become quite complicated and lengthy, so if this interests you, do the research on your own. Let's move on to the subject of GENERATORS and some basic types that are out there.

I am going to explain several things here: SINGLE-PHASE Generators, Two-Phase, Three-Phase and Alternators.

To understand what I am about to explain to you, you must get some kind of an idea, a painted picture of what I am talking about, so here is a side view, of the inside from a typical generator.



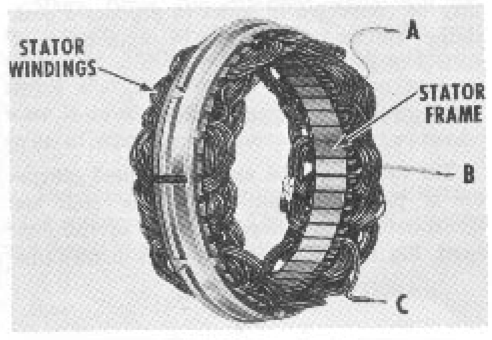

The above image is of an three phase generator, because the three field coils are spaced at 120 deg. apart, and each coil will produce its own sine wave. These three out of phase voltages can be easily put together or used singularly. A two-phase generator would have four field coils, and each coil is separated by 90 deg. apart., One might guess why then isn't it called a four phase generator ? because only two sine waves are produced. While there are four field coils, you have to remember that the armature will touch two fields at the same time, N end and S end, then it rotates and moves above the other two. So it produces only two sine waves. The Single phase one has two field coils, but so what, the armature produces only one single sine wave.

If you are having a hard time understanding this, don't worry about it. Get a book with lots of pictures and it should be able to show you what I mean. Solid state electronics don't use generators anyways, and I am only covering the basics here. But no matter how boring this might sound, you must understand this, because this will teach you a lot about the basics of rectifying and what a rectifier is and how it works on later.

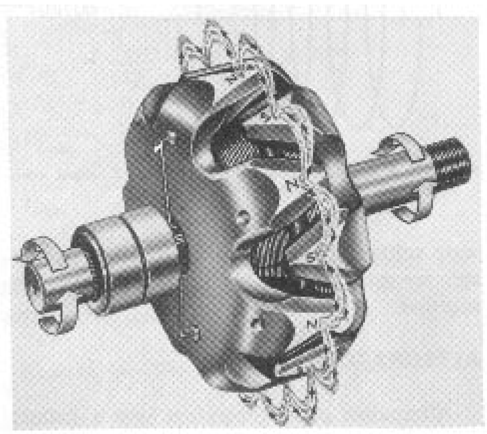
A quick note about a/c generators and alternators. Both of these devices have a disadvantage. What ? While in operation these devices produce high voltages/currents and then they are transferred to the rotating armature which connects to the external circuit by the form of sliding contacts also known as slip rings or brushes.

Because of high voltage, these contacts can and do spark and burning can and does result with time. Therefore engineers decided to induce the voltages in fixed coils called STATOR WINDINGS and revolve the magnetic field around the ROTOR WINDINGS, this way there is less friction. Because of this, the alternator or generator, becomes also a DYNAMO.

Below are pictures of these two items that are put together into a typical automobile alternator/generator : )

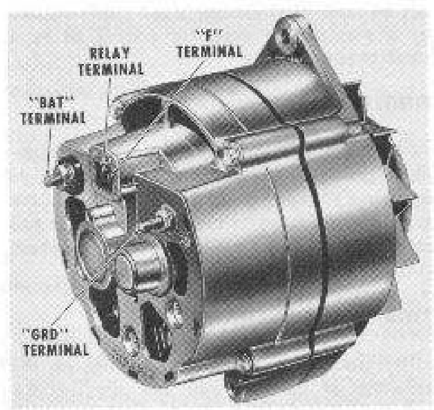



STATOR COIL



rotor winding

I let you guess what this is : )




Because of this setup, it is only necessary to supply enough electricity to the rotor to make the generator, generate electricity. The rotor kicks in and starts the magnetic field up and that makes it move. This generates the electricity, that's why they are called generators. The movement is transferred from the timing belt : ) another example of mechanical energy into electrical energy.

That's as much as I feel like writing about this subject, pick up a book and read more if you want to : )

Next chapter.

# Chapter 5

**Basic Volt Meter**

When you start to make electronics circuits or if you try to fix a problem, you will need and require measuring tools. It is said that the success of any technician or engineer is based on his/hers ability to measure precisely and to figure out how those measurements effect or will work in the circuit.

To do this we use measuring tools or instruments. Without instruments a technician becomes blind, because these tools are like gateway windows that show you the operation and performance of electronic circuitry.

One of the most basic instruments/tools in electronics is your everyday, basic voltmeter. If you don't atleast have a voltmeter on your hobby or professional bench, then you are no technician.

These days voltmeters are all digital, but I think it is important to understand how the old meter worked, and I am refering to the dial ones, that used a moving coil and magnets.

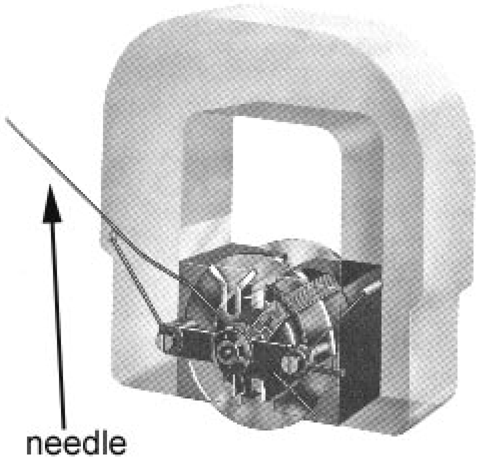
These were called the D'ARSONVAL meters, because they depend on the interaction of a moving magnetic coil which is in its self positioned inside another fixed magnetic field. There are volt meters for DC and AC.

When you introduce electrical current to the moving magnetic field, the one that the read dial is attached to, the current will produce a magnetic field around the conductor. So, when this current caring conductor is placed into a fixed magnetic field, these two magnetic fields will add together on one side and oppose on the other. Just like N and N will oppose and N and S will add.

Because of this, the moving coil conductor will move towards the weaker side when the current is introduced and the result will be that the arm will move with it and tell you the voltage. The coil is attached to a spring, and the current flowing will always make the arm move in the clockwise direction and against the tension of the spring.

Once the current is taken away from the meter, the spring pulls back the arm to read ZERO.

By arm, I am refering to the indicating needle of course.




Have you ever looked at one of these meters and wondered, hmmm, how do they determine about the reading on the scale, I mean how do they know if to measure 2 volts the indicating needle has to move a certain distance from 0 ?

By full scale deflection I am refering to the indicating needle moving from 0 to as far as it can go on the chart, as far as the spring that is pulling back on it will allow it to move away in the opposite direction without blowing up.

This is done by knowing several things before accurate meter movement can be printed.

- What is the DC ohmic resistance of the moving coil, because as we have learned from previous sections, all wire has resistance per foot, right ?
- What current is required in the moving coil to make it or cause it to move a full scale deflection of the indicating meter needle
- and what voltage applied across the moving coil will cause a full scale deflection to flow in coil

Anyways, the actual meter hardware is rated at a certain deflection ratio, and if you apply more energy then the meter can handle, you will blow it. That is why resistors are placed into them in various sizes and values so that you can select the voltage range that you will be measuring for, ever seen that on your meter ? well now you know.

This is called MULTIPLIER RESISTOR circuit. With a basic hardware meter that can only handle max. maybe 1 volt, you can expand to measure 5 volts, 50 volts and so on if you use the right multiplier resistor settings.

Go to the library to learn about that : )

Now lets talk about sensitivity of meters and circuit loading. Sensitivity of a voltmeter can be used to determine how much if any the meter will load a circuit when it is used to measure voltage. What I mean by this is the following.

If you are using a volt meter in a 5 volt circuit, and the volt meter is not of high quality, circuit loading will occur, where part of the voltage is transferred into the meter and incorrect reading is been taken. Very few people know this, but it is important to use high quality meters, the higher the meter resistance the better, and high resistance meters will barely give off any bad reading, circuit loading will be very low.

For how this works get a book. And the formula for finding out the meter sensitivity is OHMS PER VOLT.

Anyways I am going to skip a little bit to cover the rest of the chapter and in the future I will fill in some parts back with more information. So here we go.

**How A/C Voltage is measured with a meter ?**

A/C if you have forgotten is alternating current, and before a meter will tell you the correct reading, this A/C voltage must be rectified. What do I mean ? Rectification is when you change back A/C waves into pulsating direct or D/C waves.

I will tell you much more about rectification in later chapters, but will briefly fly across it here.

In simple meters this process of rectification can be simply accomplished by using a DIODE. A diode is an electrical component that allows current to flow in only one direction, it is unidirectional.

Because the A/C wave flows in one direction for some time and then in the other, the DIODE will only permit one direction to flow through it thereby cutting the A/C current basically in half.

This what I just described to you is called HALF WAVE rectification output, FULL WAVE rectification is where the waves that are under 0 and above 0, are simply neatly stacked above one side of the line, because they have to go only in one direction.

So in the previous chapters when I drew the line and there were waves above +0 and below -0, well you just draw the above waves normally, but the negative waves are drawn also in positive territory or on one side. It looks like when you are moving slowly and jumping up and down, but you aren't falling throught the floor into negative territory and back above the floor : ) I will draw a picture soon and scan it, if you are visually/imagination impaired.

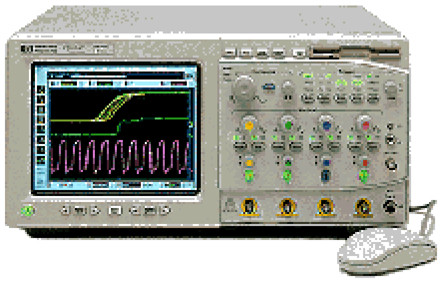
**What type of meters are there ?**

There are the manual armature meters, the old types and there are the newer digital multimeters. Multi, means a meter with more then one type of meter, like a volt meter, amp meter, ohm meter and so on.

**The Oscilloscope**

What the hell is it ? This instrument is used to measure signals waves of voltages. It is used by more advanced hobbies or professionals like technicians and engineers.

Here is a picture.

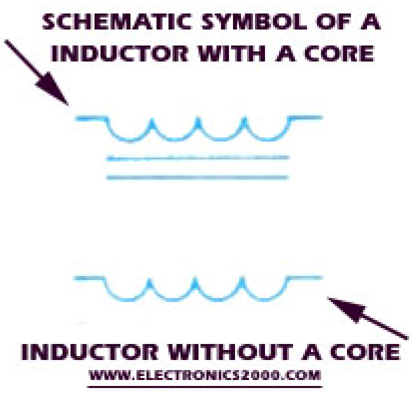


A good oscilloscope costs mucho money and even an entry level one will set you by more then couple of hundred dollars.  So learn about electronics first before wasting money on that.  These devices can get pretty fancy and very! expensive.

There are special models for students and if you look in the right place, maybe you can get a discount.

End of Chapter 5.

# Chapter 6




**What is INDUCTANCE ?**

Inductance is what opposes change in current in a circuit.  In electronics the letter **L** represents inductance.  Inductors are devices which oppose any change in current regardless in what direction.   Some inductors are primarily used in A/C circuits, like for example in power transformers, etc...

A coil that has wire wound around it will produce a magnetic field, if you let electric current flow through it, right ?  If you are confused about what a coil is, it's very simple, take some wire, wind it around your finger or a pencil and then remove it and you got a coil, the more layers you wind on top of each other the more layers you get and the more powerful of a coil you can make.  If you put a core inside, that's something that the coil is wound around all the time, like a pencil or a nail, that is exactly what a core is.  This is how you make electromagnets:

Here is a simple example of how a A/C inductor works. (Picture coming soon to help to illustrate the example.) Imagine a simple circuit, 6 volt A/C, and to it you connect a inductor, which can be as simple as a coil, with or without a core and nothing else, if you let the current run through the circuit, this is what happens; As the current flows, remember current is AMPS and current and volts are proportional to each other, most of the time if one rises so will the other. So, as the current flows through the circuit, a magnetic field will induce in the coil. This field will start from 0 and then will expand to it's fullest value or flux density.

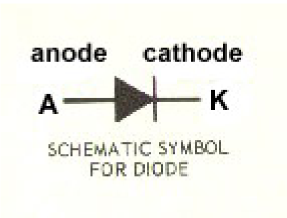
As this flux field moves outward, it cuts across the wires that make up the core or otherwise called windings of the coil. This will induce a voltage in the INDUCTOR coil and this voltage will OPPOSE the source voltage coming from the A/C source (whatever that might be). As it opposes the source voltage it will also oppose the rise in AMPS or current and kinda act as a resistor at the same time. And if you add a simple 6 volt lamp to our circuit and do this experiment in A/C and then the same in D/C, you will notice that in D/C the lamp will glow bright and in A/C it won't, it will glow dim because the inductor is constantly opposing the rise in current and opposing the voltage, although some voltage does get through, that's why it glows dimly.

The induced voltage inside of the COIL is called CEMF or counterelectromotive force. If you now let's say lower the source voltage to 3 volts A/C, the amps lower in the circuit, if there is less power in the circuit, the magnetic field previously induced can't sustain it's maximum value, so it will start to drop down, as it goes lower the decreasing magnetic field in the inductor will once again induce a voltage against the coil windings as it goes down to a lower value and because of this will tend to hold it's original current value. The opposite is also true.

Motors are inductive devices, even tho we don't think of them as such and don't use them in modern electronics to restrict current flow in one direction only.

**And what is a DIODE ?**

A diode is a two element unilateral conductor. UNILATERAL means that the diode has two parts to it or connections, "anode" and a "cathode" but the electric current will only flow in only one direction through this component.




To understand this process 100% you have to understand the semiconductor theory, which is what I am going to cover next.

Refer to Chapter 1 for Conductor, semiconductor and insulator basics. Remember that semiconductors are human made elements, they are designed on purpose to semi-conduct.

The impurities that are mixed into the making of the semiconductor make this possible.

You have to understand VALENCE and how this works in semiconductors.  The number of electrons in the outer shell minus the full permissible complement for that shell, determines the VALENCE of the atom.  That is why the outer shell in the atom is called the Valence Shell.  The amount of electrons in this VALENCE shell will determine how well this atom can carry free electrons or not.

An atom for example where the VALENCE shell that has a full complement of electrons in the shell, will easily gain electrons to complete its shell.  Once this electron is gained a very large amount of energy is required to free it.  So atoms with less electrons in the VALENCE shell will lose these electrons much easier.

The PERIODIC TABLE OF THE ELEMENTS, Any Chemistry Lab should have one or book, displays under what group the atom is registered under depending on how many electrons are in the VALENCE shell.  The higher number of complimented electrons that reside in the VALENCE shell, the harder it is to break those type of materials for conduction and a much greater amount of energy is required to make them conduct.

Most inorganic materials are of crystalline structure, that is how the atoms are arranged to make them like that.  Crystals can be arranged in either random fashion or lattice formation.

If you want to understand this 100% first read up on Basic Atomic structure and how that works. Then get familiar with how semiconductors are made, the type of different dopants that are used to make this material and what the combined mixture becomes.

But to summarize there are two types of crystals used in electronics. There is a N type and a P type.  Again to understand the following you need to understand the basics : )

N type crystals or semi-conductors conduct by adding a PENTAVALENT dopants, these are atoms with 5 electrons in the valence shells.  Once doped by mixing the dopants into pure crystal, the mix becomes an N type semi-conductor and it conducts by the extra electron.

It is called a N type crystal because the majority of carriers that transfer the electrical energy between the atoms are electrons.  P type crystals conduct by the opposite, by HOLE conduction where the majority are holes to be filled.

If you are confused about what a HOLE is, that is because you have failed to read the basics and you will not understand this and you will NEVER understand how basic components such as a diode operates or a transistor.

Getting back to N type, in it are holes too, but they are few compared to the majority and for this are called MINORITY carriers which do carry an electric current, but the amount is very little and insignificant.

The dopants that is used on a N type crystal is called a DONOR IMPURITY, where in the P type it is called a ACCEPTOR IMPURITY.

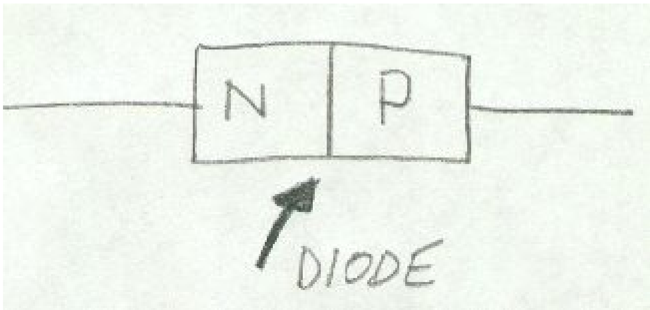
The dopants that are used in the P type crystals or mix are called TRIVALENTS and some of them are indium, gallium, and boron. On the other hand in the N type the most common ones are phosphorus, arsenic, bismuth, antimony to mention the common ones.

To get back to P type, the valence shell bond once mixed will result in a shortage to complete the covalent bonding structure.  This will leave off a HOLE and electricity is transferred by the HOLES. Majority carriers are HOLE and minority are electrons.

The crystal will end up N or P depending on the type of semiconductor material used with a mix of a dopants. This will all depend on both materials and the end mix result of the covalent bonding structure where the atoms meet in the outer shells. Excess will result in a free electron that will pass and exchange from atom to atom and shortage will result in HOLES, where electrons can be passed by when electric current is introduced into the semiconductor.

If you are confused  : )  learn physics basics and some chemistry wouldn't hurt. Otherwise you will never understand this : )

Now to answer the original question of the DIODE, it basically has two parts to it a N and P type crystal, 1/2 and 1/2 like this : )




A diode will resist electric current in the opposite direction and only allow it to run in the current direction. **Diodes must be correctly connected.** One end will have a + and the other -. If you connect it incorrectly, the plastic shielding will blow out and you will only be left with the wires. As a matter of fact a mini explosion will happen and if you are not wearing protective eye wear, those small pieces of plastic can flow right into your eye and leave you blind in one eye or cause serious damage. So wear eye protection if you are a newbie to this and aren't sure.

You can't replace an eye yet, but you can easily replace a diode.

The material in the diode as you can see from the above picture is separated into two sections, N type and P type crystals. Then the N type is alloyed with a metal base. Keep in mind that N and P type can also be determined by the rate growth at the time the crystal is grown. There are different ways of making N and P type, some of these methods include diffusion or the rate growth that I briefly mentioned.

Diffusion is more preferred in the manufacturing industry. At the separation or the junction where N and P are touching each other, electrons in the N type are attracted to the HOLES awaiting in the P type, this is also true where P is attracted to N. REMEMBER!, N works by electron, P by HOLES, electrons go into the HOLES to fill them : )

In any case, this attraction area is called the DEPLETION area or it is sometimes referred to as the transition or space charge region.

Because of this exchange, the area of exchange becomes void of carriers, whether they might be holes or electrons. Because of this attraction exchange a electrical potential develops and this potential is called a BARRIER. If you hook up a battery where the + lead is connected to the N type side, (note that: N = -, P = +), As the N electrons jump over to the P side, they or that area becomes positive and P holes becomes negative in that BARRIER area, picture coming up soon.

So if you hook up a battery + to - N, and battery - terminal to + end of diode, the depletion area or the barrier area increases in width and the source voltage join together to prevent current carriers from crossing over the junction where the N and P join. In order for the diode to conduct and let the electricity through you need to connect the - terminal of the diode to the negative terminal of the battery, - to - and + to +.

If you connect - to + and + to-, it will block. P type in semiconductors means Positive and N type means Negative just so you know.

How does it work by conduction ?

If you connect - to - and + to + of the diode terminals to the battery terminals then you get what is called FORWARD BIAS, blocking is called REVERSE BIAS.

In Forward Bias, where the gate is opened and the diode conducts and let the electric current go through, this happens:

The electrons from the P side are attracted to the + terminal of the battery, once they leave the P side to the battery + terminal a HOLE is created, and this hole is filled up on the N side, because the electrons are attracted to the positive side of the P crystal. The N side gets it's energy from the negative terminal of the battery. So the electricity flows from the negative terminal to the N junction, electrons are attracted in the P junction to the + terminal of the battery and when a whole is created N side fills it up and this process repeats over and over, and this is how a diode conducts.

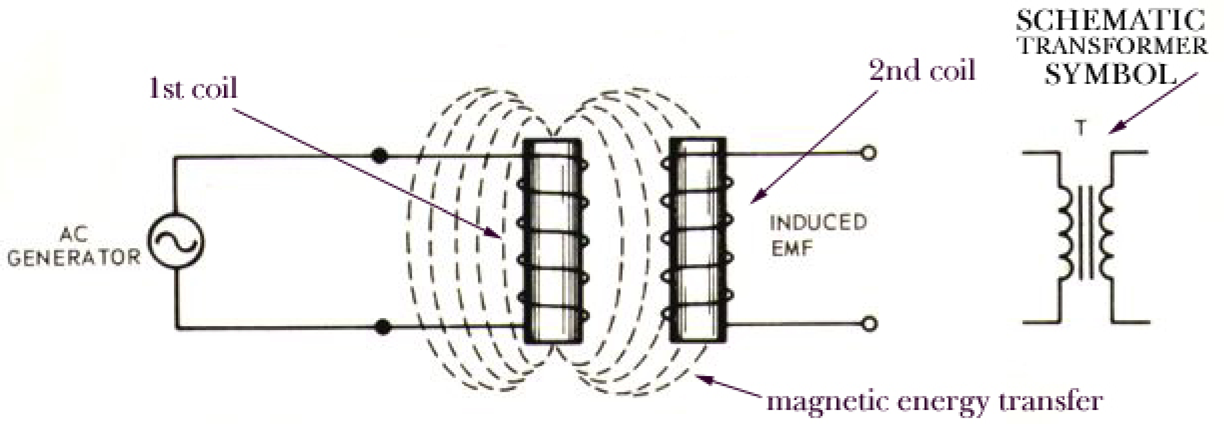
Hope I did not loose you. There are all kinds of diodes used for all kinds of different purposes : )

Next I will cover the TRANSFORMER!

# Chapter 7

Here I will try to explain to you how **TRANSFORMERS** work. Again, let me stress the importance of knowing the basics in this hobby. A lot of people can't wait to learn the basics and jump right into building things, later they wonder why they fail to work.

**TRANSFORMERS** use induction to work, something that I covered in Chapter 6, and you can always visit the local library to learn more about them if you like.




A term that you should be familiar with that plays an important role in understanding transformers is called **MUTUAL INDUCTANCE**. Mutual inductance is when you take two coils as described in Chapter 6, apply current to one coil only, don't matter which one as long as it is A/C current, and then place close together both coils (as long as they don't touch each other) and mutual inductance will take place. This is where the expanding and collapsing flux magnetic fields of the first coil with the current will cut across the winding of the second coil without the current, and voltage will be induced in the second coil.

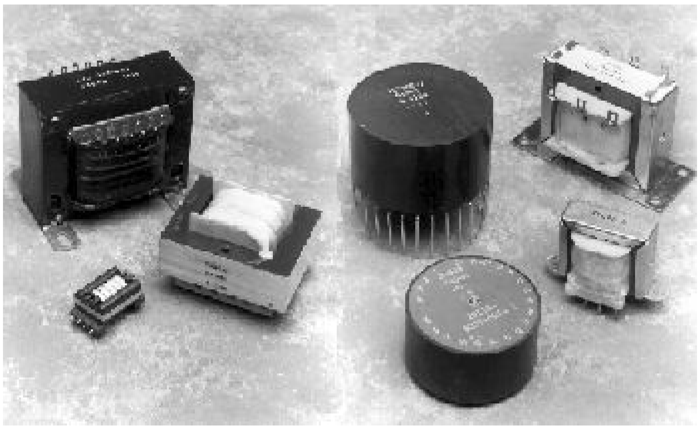
Energy will be transferred through AIR, these two coils never touch each other and electricity is transformed through INDUCTION through the AIR and the connection between these two coils is made by magnetic field only!

Interesting isn't it ? and if you didn't know what induction is, you might not fully understand this, now could you ?

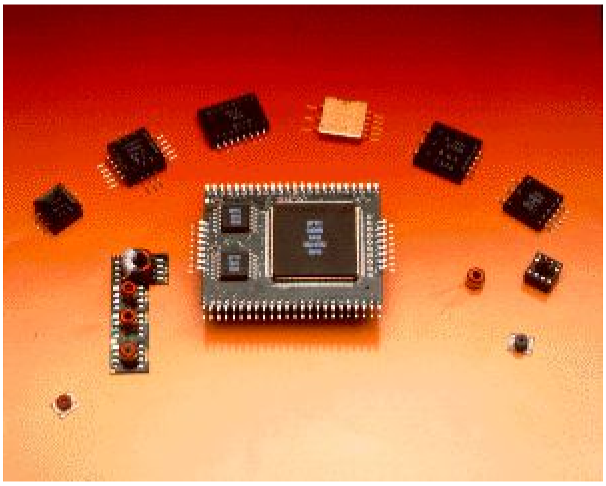
Ok, so...

The full assembly of these two coils is called a TRANSFORMER.

You might have seen transformers that may have looked like one of these:



these are POWER Transformers, but have you ever seen ones like these ?



these are surface mount transformers.  Do you see the BIG difference ? they can come in many different shapes and sizes.

If you want to get more familiar with different types of transformers that are available and description of each I recommend that you visit this company:

http://www.bttc-beta.com/  they manufacture many different transformers and are experts in this field.

**More about transformers:**

There are many different types of transformers, some won't even look like transformers, and it takes time to get familiar with the vast majority that are out there.  It took me some time to learn many of them and so too it will take you.

Looking at the picture above of a simple transformer here is some more information about it.  The simple assembly of the coils goes as follows;  The INPUT coil (this means the one where A/C is introduced into the first coil, and on that picture above, this is the one on the left side) is called the **PRIMARY** winding and the output coil is called the **SECONDARY** winding.

A transformers job by what is called the technical definition is to transfer electrical energy from one circuit to another by means of varying the magnetic field and transformer setup.

Don't forget that mutual induction works because of self-induction which I covered in chapter 6. If you don't know what self-induction is of a single coil while connected to a varying power supply, then you won't understand the above.

Anyways, all this conduction stuff is measured in electronics using a standard, and this magic word is called HENRY or measured in **HENRYS**.

It is said that if a primary coil induces a minimum one volt transfer into the secondary coil when the applied current to the primary coil is changing at a rate of ONE AMPERE per second, a mutual inductance of 1 HENRY takes place or inductance is ONE HENRY. The letter M represents Mutual inductance or HENRY. The complete formula is:

( SECONDARY voltage)

$$\mathbf{M\ (in\ henrys)} = \frac{e}{\Delta i / \Delta t}$$

(ROC or rate of change)

where:

e = how many volts in CEMF.

i = change of current in amperes

t = change of time in seconds

Here is a quick example of how to use this formula. Suppose you are given this information to find out the mutual inductance of a transformer.

The current applied to the primary coil changes at 2 amperes per second and it in turn induces 20 volts in the secondary coil ( remember coils do not touch each other, the electricity is transferred through the air only, no electrical connection of any kind is attached between the coils ), **What is the mutual induction ?**

You really don't even need to understand this to solve it, it's very simple, if you know the formula, anyone with very basic math skills can do this, it's a matter to fill in the blanks for corresponding info.

the 20 volts goes to = e

the 2 amperes goes to = i

and t gets 1, why 1 ? because we are told that it alternates 2 amperes every 1 second and t stand for time, so t gets a value of 1.

so M = 2/1 = 2 and 20/2 = 10, so the answer is 10 henrys. And what is 10 henrys again ? the answer lies in the question, but to be nice I'll tell you.

If a primary coil induces 20 volts in the secondary coil when the current in the primary coil is changing at the rate of two amperes per second, the mutual induction is 10 HENRYS.

And yet more information, **What is COUPLING ?**

While the word coupling might sound complicated, it is not. Coupling is a unit of measurement that is used in transformer technology to measure the effect of the position of the individual coils and how their position effect induction in the transformer circuit.

Let me give you an example. As you already might know by now, and I hope that you do, transformers work because of induction, and so the induction will be greater if the two coils are positioned closer together, right ? because the many magnetic lines will cut across the secondary coils with a greater force and a greater secondary voltage will be induced.

Yes, the opposite is true, if the coils are spread farther apart from each other, less of the magnetic energy will be transferred and so the induction in the secondary coil will decrease. Understand ? I hope so.

And so the effect of the PRIMARY and SECONDARY coils to each other based on their respective distance position from each other is called COUPLING. That's all coupling is.

If all the lines of the primary coils windings cut exactly perfect across the secondary, it is said that the COUPLING is at 1 or is UNITY COUPLING with a value of 1.

If the two coils are separated so that only half the magnetic energy is transferred from the primary to the secondary, the COUPLING is .5 The decimal point in the .5 indicates the number of flux lines available for mutual induction or the percentage, and in this case 50% and is called the **COEFFICIENT OF COUPLING** and is assigned a letter of ***k.***

Also know what the angle of the two coils and their respective positions, how that will affect their mutual induction. For a maximum mutual induction to take place, the right angles must be used. And right angles means that both coils are parallel to each other. If you turn one coil so that there is an angular different like by 45 or 90 degrees, the mutual induction will be decreased.

Ok, now for another formula. If you know the coupling or the coefficient of coupling and the inductance of each coil, you can find out what the mutual inductance is by following this equation or formula:

$$M = k \sqrt{L_1 \quad L_2} = \text{mutual induction}$$

So here is an example of this formula. **EXAMPLE:** Each of the two coils in the transformer are 8H and have a coupling of .5 **What is their mutual inductance ?**

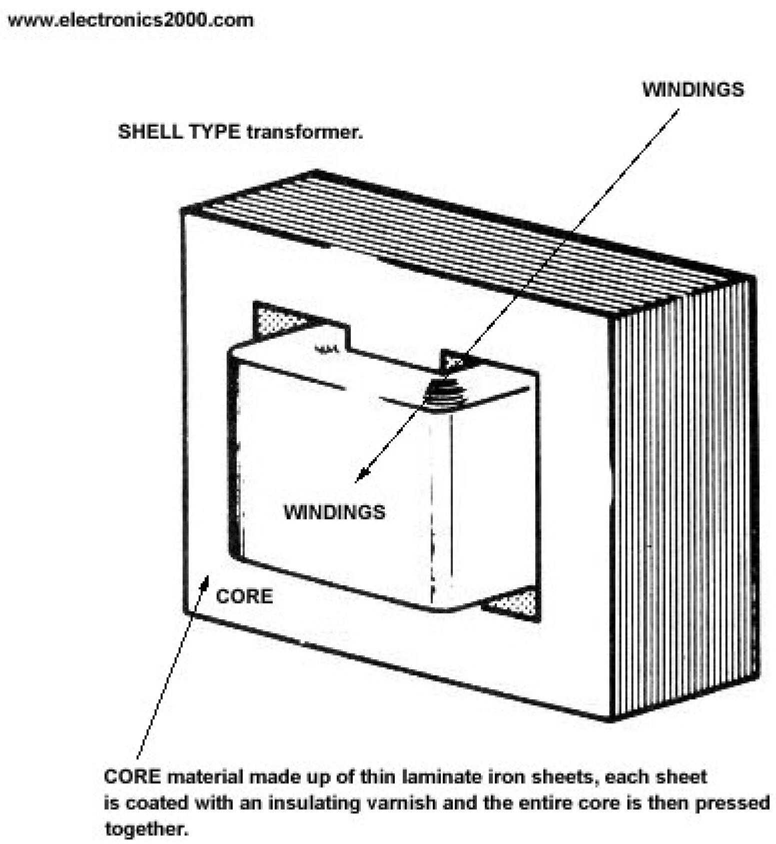
So the first L1 represents one of the coils in the transformer and the L2 the other, the example says that each coil has 8H, so 8 x 8 = 64 and what is then the square root of 64 ? 8 and then, k = .5, so 8 x .5 = 4 henrys.

**How do transformers work in real life ?**

One of the best ways to start out my transformer explanation is to introduce you to the power transformer first, because it is the most visible transformer type that you have probably in one time or another already seen even if you don't know how it works.

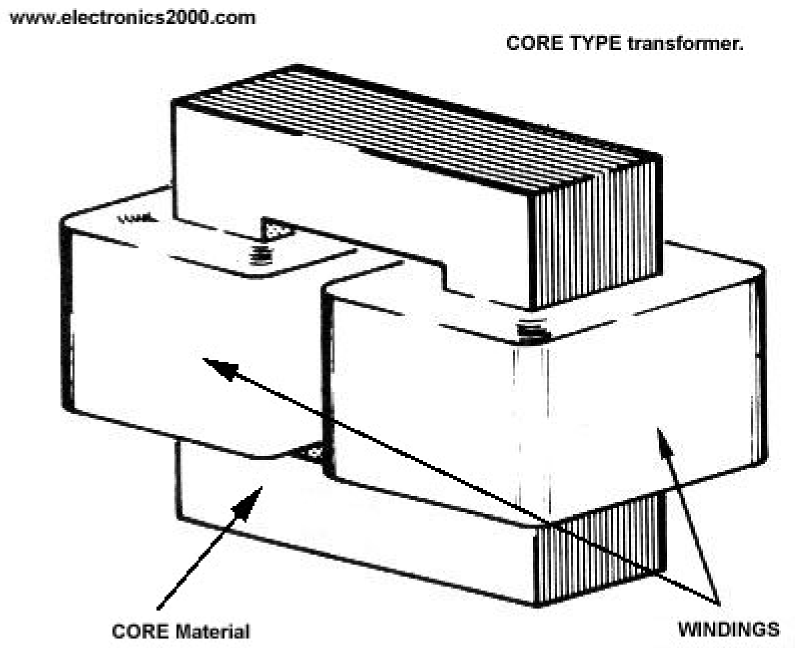
Basically there are two major types of POWER transformers out there, don't forget that power transformers are designed to work at power frequencies of between 30 to 500 Hz. The two major types are the CORE TYPE and the SHELL type:

The SHELL type which is the more popular model is shown below:




In the Shell type the windings are wound in layers and fit over the center of the core section.

The CORE type is the next model below:



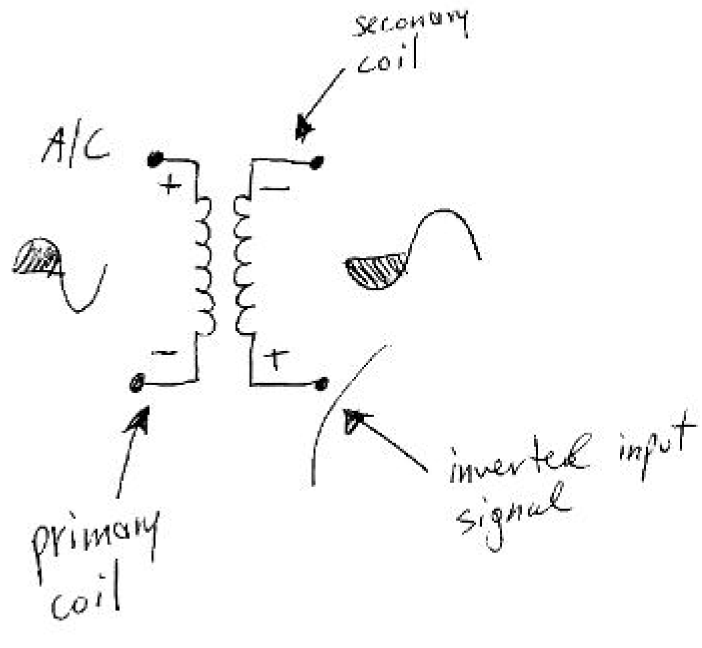
In the Core type the primary and secondary windings are placed on each side of the core.

Many other power transformers exist, and they may have more then one primary or secondary windings.

**Power Transformer Theory:**

When an A/C current/voltage is introduced to the primary winding of the transformer and the secondary winding is OPEN (that means no A/C current/voltage is applied to it), a magnetic field will be created in the primary coil or winding that will establish the magnetic fields necessary for transformer operation. The magnetized current in the primary coil depends on the A/C current/voltage applied and how many number of turns you wind around the coil. (I x N), I means current, N means number of turns on the winding/coil. The more is applied, the larger magnetic energy can be created in the primary coil/winding.

Now the expanding and collapsing magnetic fields of the primary coil cut across the secondary coil/winding and in turn induce a voltage in the secondary coil. The polarity outcome of the secondary coil will depend on the direction of the secondary coil winding and the external connections. Most of the time transformers invert the magnetic energy in the opposite direction to the secondary coil (see illustration below):




Hopefully you can read my hand writing. Inverted means made opposite, like inverting a picture, from a positive to a negative image. So it means that the + and - terminal location on the secondary side is reversed that from the positive input side.

Many of todays transformers are made in a way, especially the SHELL type transformers, where the unity coupling that exist between the primary and the secondary is at UNITY or very close to a COUPLING of 1. So therefore, since both the cores are wind closely together and the unit yis at almost a perfect 1 and are mounted on a common CORE, the available flux for the secondary coil is almost the same as for the primary.

Anyways, if the number of turns on the secondary coil are more then on the primary, this will increase the secondary voltage as it passes from the primary in the form of magnetic energy, but decrease current or AMPS. The opposite is also true. **THIS IS CALLED a STEP-UP transformer.** If the secondary has less turns in the coil then the primary, the secondary coil's voltage will decrease and the current or AMPS will increase. **This is called a STEP-DOWN transformer.**

# Chapter 8

**What is CAPACITANCE ?**

Capacitance plays a very important role in electronics together with resistance and other circuit properties. I will try to explain to you some basics about it and show you how important it really is in electronics.

This is were electronics begins to get a little more complicated and to some people this tutorial might not sound very exciting, but if you truly want to understand everything and make ideas work from scratch, you will need to understand it all, even the boring sections.

It takes a lot of reading and studding before you can start to design useful circuits.

First of, CAPACITANCE is represented with the letter C in electronics, just so you know.

An electronic device/component that sooner or later you will or might have already seen and worked with is a device that stores energy in an ELECTROSTATIC field inside of it and accepts a charge of electricity or returns the charge back to the circuit, depending on if it is charging or returning the constant feeding voltage.

Basically it is like a mini battery, it stores energy over short periods of time, temporarily, and some for longer periods of time, some devices charge and release on a regular interval.

It all depends on what type of capacitor you are using as there is many of them out there, different ones made for different purposes. Capacitors behave similar to inductors, they oppose the change in voltage in the circuit or release it back to the circuit depending on the situation.

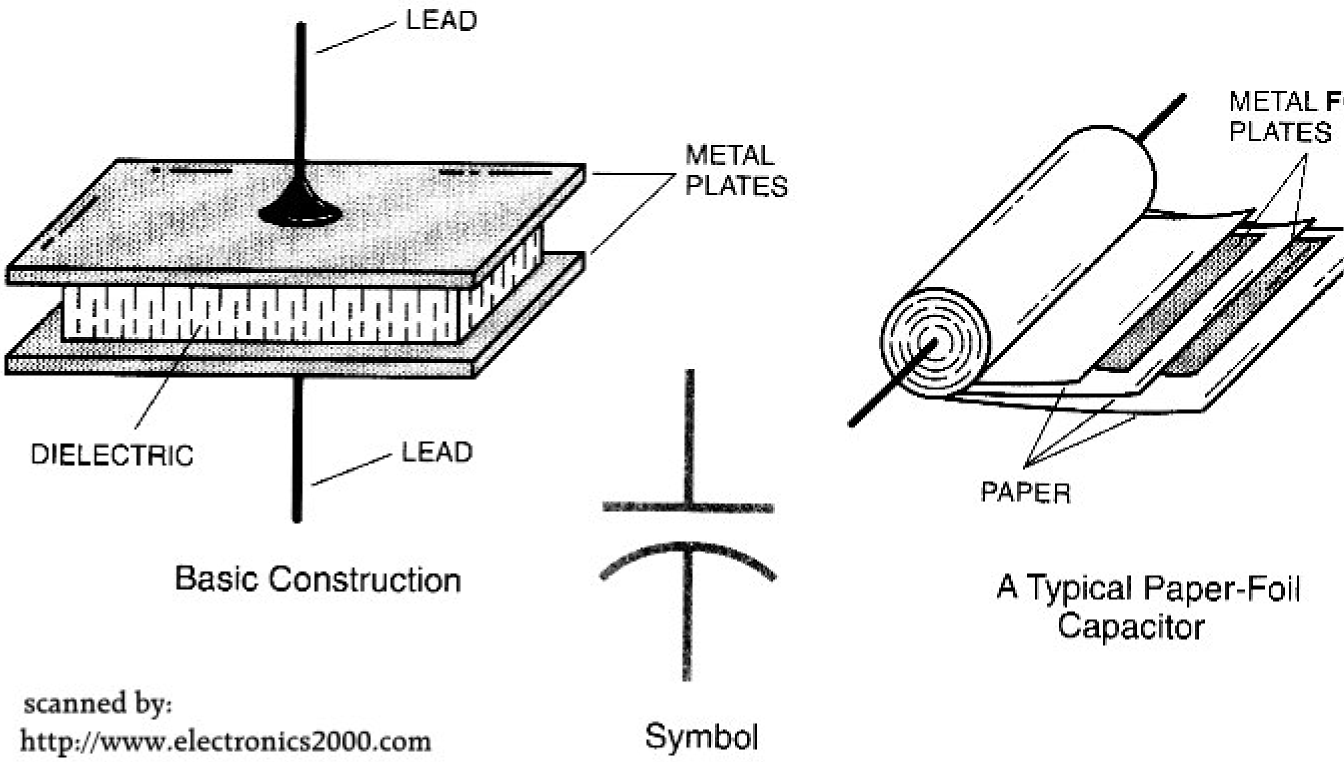
Most capacitors are solid state devices, this means they don't have any moving parts inside of them, but there are some that do have moving parts inside of them.  To give you an example, one such device is called a turning capacitor.  With this type of capacitor you use a knob to operate it.   You probably have one of these types of capacitors in your radio, and they are used to select frequencies with.  As you turn it, you can work with a different frequency at a time, but you can not hear others.

**What is a CAPACITOR ?**

In the old days the Capacitor was called a condenser, but we don't use that name anymore.  So what is a capacitor ?

A capacitor is a special electrical component that you can use to charge it with electrons, or energy in the circuit.  Once you charge the capacitor to it's maximum, it stays charged until you discharge it.  It was called a capacitor, because this device possesses capacitance.  Capacitance is the inherent property of electric circuit that opposes change in voltage.  Property of circuit whereby energy may be stored in electrostatic fields and use to do something with later on or immediately.

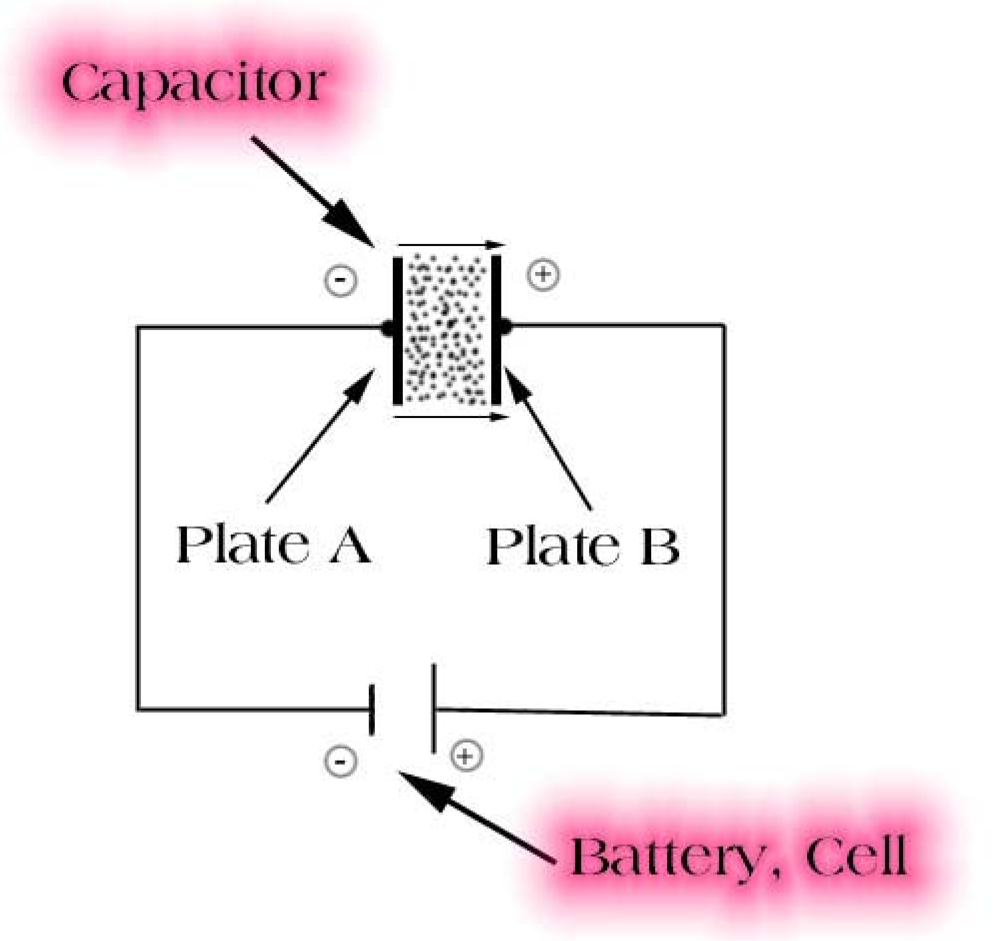
The schematic symbol for a capacitor is:




The basic capacitor is constructed out of two metal plates separated by an insulator or air.  **insulator:** substances containing very few free electrons and requiring large amounts of energy to break electrons loose from influences of nucleus.

This separator is called the DIELECTRIC.  A potential voltage connected across these plates produces the following action.

I did this picture below to illustrate my example better in Photoshop.




Ok, imagine that we took a small 9V cell, not a battery :- ), and connected two wires to it and those in turn are connected to our capacitor, what kind does not matter for now.

The electrons from the negative battery terminal or lower potential terminal flow through the wire instantaneously to the capacitor and hit plate A of the two plates, A and B or 1 and 2.

The plate on the other side of plate A, the one that is separated by the DIELECTRIC, actually both are, is very close, but not close enough to reach the plate A, so the current can't flow to the other side of the capacitor to plate B. However plate B is within the range of the established electrostatic field and that I will teach you about later.

The electrons on plate B are repelled by the electrons on plate A and are attracted to the positive terminal of the battery, the one with the higher terminal potential thus the reason why we have + and - on batteries.

The electrons are distorted toward the positive plate. This creates a potential difference between the two plates and the capacitor is said to be CHARGED. Please also note that the charge of the capacitor is opposite in polarity compared to the source voltage from the battery.

The AMPS or currents do flow or does flow in the circuit but only during the charging of the capacitor.  Once the capacitor is charged, or fully charged, the current stops flowing and is at zero and we of course still have volts in the battery.

If you are confused about the above, maybe if I refresh your mind about what repelled means you will understand it faster.  **repelled:** to drive back, turn away, reject, look it up in the dictionary.

If you removed the capacitor from our circuit, it would still remain charged and could be used as a source of voltage, not for very long, but could be used.

**Word of caution;** capacitors, especially the ones used in high powered circuits or voltage circuits can and most of the time do retain a great deal of energy when fully charged.  They are very dangerous and it is best to always discharge them by the process of shortening before handling them with your bare hands.

Capacitors are also used to act as filters, and are used in high frequency applications like radios and radio transmitters.  If you don't know what you are dealing with, don't touch it or it will be the last thing that you will ever touch.

All capacitors have a working voltage direct current or (WVDC) rating on them, which is the specified voltage the capacitor can handle or withstand without destructing it's self. There is also WVAC, for A/C circuits.

It is very important that the capacitors specification is obeyed and that the electrician replaces a bad capacitor with the right WVDC rating.

When a capacitor is discharged in the circuit, the energy stored within it is returned back to the circuit.  You have to keep in mind that capacitor components are made differently for different uses.  Some are rated to work within a certain Voltage ratings, if the applied voltage exceeds this rating, you will burn it up and damage the circuit.

If they fail to do so, sparks or arcing will result between the two plates and possibly start a fire, or explosion.

Some capacitors will and can remain charged very long after you turn off the circuit from the voltage source.  Again discharge them before handling with your bare hands, sometimes more then once to be on the safe side.  Use a insulated screwdriver and touch the LEAD of the capacitor, this will discharge it.

**What is the FARAD ?**

The unit of measure FARAD is used in capacitors to tell how much electrical energy that capacitor can store.  It was named in honor of Michael Farad.

A value of 1 FARAD is a very large unit, and that is why most of the time you will be working with much smaller units of measure.

1 FARAD (F) is 1
1 microfarad is 1/1,000,000  or  basically 1 millionth of a farad
1 picofarad is (1/1,000,000 of 1/1,000,000 of a farad)

And a FARAD is ?

When one ampere of charging current flows and when the applied voltage is changing at a rate of one volt per one second we have 1 FARAD.

Looking at it from a mathematical angle, here is the equation to figure out Capacitance.

C = unit of measure in Farads
**i** = charging current in amps
**v** = the change in volts
**t** = the change in time in seconds

C =

i
----- divided by
v/t

or i divided by  ( v divided by t )

Example:

**Question:** What is the capacitance of a capacitor when:

Charging current is 350 milliamperes  <-- this is **i**
Voltage changes at a rate of 35 volts  <--  this is **v**
Frequency is 185 hertz  <--  this is **t**

**The i and v** SHOULD BE OBVIOUS, the little twist that you might be confused is the 185 hertz as that doesn't sound like a unit of seconds that you probably would expect, but hertz are cycles of frequency and you will many time see this in examples instead of a time values like 5 seconds or 60 seconds.

The first thing you need to do is change all given values to the basic number.

350 milliamperes is 0.35 amps, remember there is 1000 milliamperes to 1 amp.
35 volts is already in a basic number.
and 185 hertz is 0.0185 seconds.

10,000 hertz or 10 Kilohertz is 1 second, not really sure why, but this is how I learned it and it is correct as far as I know.

C =

.35
-------- divided by
35 / 0.0185

= 0.000185 farads or 185 microfarads

Another way to find out Capacitance is with a method of finding out the charge or quantity of electrons that the capacitor can accept per volt of potential applied to it in a circuit.

in this example:

C = capacitance in farads
Q = coulombs **( you should know what that is by now, if you don't remember, please look it up in my previous chapters or the local library, also physics books and chemistry books should have this )**
V = volts

Working example:

You know that a capacitor that you hooked up to a circuit will accept a charge of .35 coulombs with an applied voltage of 350 volts, to find out the capacitance, you do this:

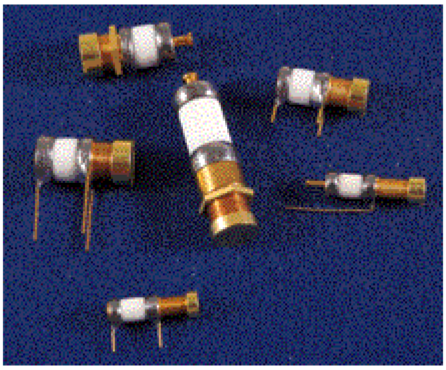
C =

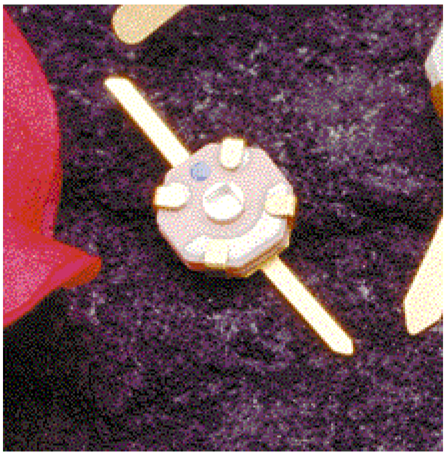
.35 coulombs
------- divided by
350 volts

= 0.001 farads or 1000 microfarads ( Remember that it takes 1,000,000 microfarad units to make 1 FARAD )  1 FARAD can kill you.

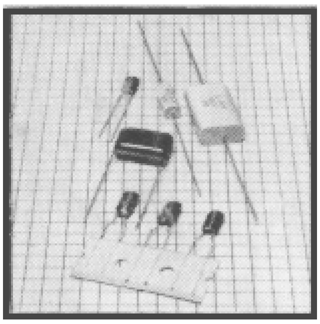
**TYPES of Capacitors ?**

There are many different types of capacitors made for different applications in the electronics fields, and to be honest with you I don't know them all.  Some of the most common types are:

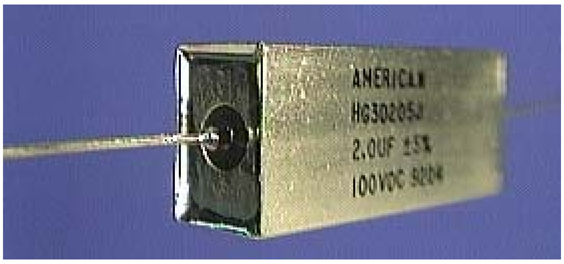




VARIABLE CAPACITORS

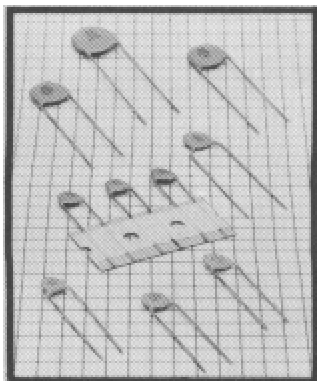


FILM CAPACITORS

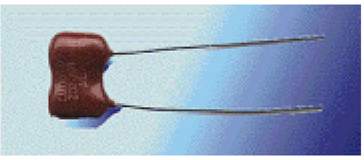


HERMETIC SEAL

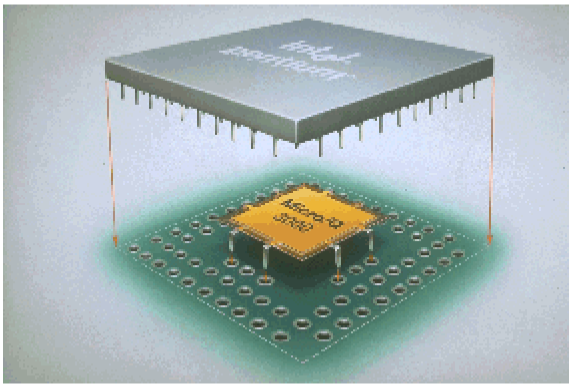
PAPER CAPACITORS


CERAMIC CAPACITORS


ELECTROLYTIC CAPACITORS


MICA CAPACITORS

Large industrial type CAN CAPACITORS



MINIATURE CAPACITORS, used in computer manufacturing of all kinds of circuit boards, like motherboards.

MICROWAVE OVEN CAPACITORS

As you start to make projects you will get familiar with many different ones over time, don't try to learn them all now, real life experience will teach you a lot in addition to reading books.

**What are the "CHARACTERISTICS" that make up a Capacitor ?**

You can make your own capacitor if you want, as a matter of fact that is how they were invented by scientists making them in the lab first before they go to any sort of production.

The 3 major characteristics are:

PLATE AREA

- SPACING BETWEEN THE PLATES

- and KIND OF Dielectric used to separate the plates

**Plate Area:** The capacitance of a capacitor will be increased as you increase the plate area, simply because you can store more energy into them. One good example that will show you this in real time without making any type of capacitor and comparing it with a smaller one is to use a variable capacitor.

This is the one that has rotating plates, as you turn the knob the plates move against the other stator plates and a larger area is being covered or used. Turn it the other way and a smaller area is used, cool isn't it ?

These types of capacitors almost give you many different ones all in one, by turning the knob it's like changing a capacitor without doing so, you should use this type of capacitor whenever this circuit effect is needed.

**Spacing between the plates:** Spacing is not the dielectric, it is simply the distance used to separate the two plates from each other, in addition to spacing there is also dielectric material used, that's next.

To put it into simple words, as the plates are closer together, capacitance is increased, as they are moved apart more, capacitance is decreased. Molecular distortion and the ability for the plates to store more energy will be less as the plates are separated more, more if separated less.

**And now the DIELECTRIC:** The dielectric values of different materials are all compared back to AIR or Vacuum. In the beginning simple air capacitors were used. Later it was found that other materials worked better then AIR and they could increase the capacitance of the capacitor.

Because of how different materials are made and of their molecular formation, they work better storage abilities when used as a dielectric.

Because AIR or Vacuum was used first, the below chart show these two basic values comparing the other materials all back in respect to Air or Vacuum.

So Air/Vacuum is our basic Value of 1, just like FARAD is our basic value of 1 in capacitance.

| Material | Dielectric Constant (k) |
|---|---|
| Vacuum | 1.0000 |
| Air | 1.0006 |
| Waxed Paper | 3 to 5 |
| Glass | 5 to 10 |
| Mica | 3 to 6 |

( note that some capacitors are named Mica because of the material used in dielectric )

| | |
|---|---|
| Rubber | 2.5 to 30 |
| Wood | 3 to 8 |
| Pure Water | 81 |

FIXED FILM CAPACITOR DIELECTRICS examples:

Polyester (Mylar) Film:

A good general purpose plastic dielectric with relativity low cost and high volumetric efficiency.
Still the most popular of the capacitor dielectrics. Available in both Metallized Polyester Film and
Polyester Film & Foil designs.

Combination Film:

Combination Polyester (Mylar) and Polypropylene. Extremely low temperature coefficient in the
0° C to 85° C temperature range. Volumetric efficiency similar to Polycarbonate. Available in
both Metallized and Foil designs.

KF (Polymer) Film:

Extremely high volumetric efficiency with about 4 times the "K Factor" of mylar, making it about
1/4 the size. Higher DF and lower IR are its disadvantages along with cost.

Polycarbonate Film:

Lower DF, higher IR, better temperature coefficient and better stability than mylar with a slightly
lower volumetric efficiency. Second most popular Dielectric. Available in both Metallized
Polycarbonate Film and Polycarbonate Film & Foil designs. Polycarbonate capacitors have a
100% voltage rating from -55° C to +125° C.

Kapton Film:

Electrical properties similar to Mylar with a much higher operating temperature going up to 250°
C. A higher cost than mylar limits its use.

Polypropylene Film:

Very good temperature coefficient high IR, and low DF make it good for AC operation. Usable to

105° C without derating. Has become increasingly popular for AC applications. Available in both
Metallized Polypropylene Film and Polypropylene film & Foil constructions.

Polysulfone Film:

Electrical properties similar to polycarbonate with a very good temperature coefficient and
higher operating temperature. Very limited availability in the last few years has limited its use.
Available in both Metallized Polysulfone Film and Polysulfone Film & Foil designs.

Polystyrene Film:

Very good electrical properties and excellent stability are its advantages. Its big disadvantage is
its operation is limited to below 85° C and it is available in Polystyrene Film & Foil construction
only.

SuperMetallized Polypropylene Film:

A very high current design for very high frequencies up to 1 Megahertz. The ultimate in high
current capacitors. They are used for input filtering, high frequency transformer DC blocking and
output filtering. They are dry-section non-polar metallized film dielectric with special high current
end terminations resulting in very low ESR values and very high DV/DT ratings. Larger than
SuperMetallized Polypulse. Also popular in snubber applications.

SuperMetallized Polypulse Film:

Developed by American Capacitor specifically for switching power supply type applications.
They are used for input filtering, high frequency transformer DC blocking and output filtering.
They are dry-section non-polar metallized film dielectric with special high current end
terminations resulting in very low ESR values and very high DV/DT ratings. They are
significantly smaller than metallized polypropylene capacitors and have a 100% voltage rating
from -55° C to +125° C. Capacitance change over temperature is 4 times better than with
polypropylene.

Teflon Film:

The best electrical properties of all the Dielectrics. Extremely high IR, low DF and operation to
250° C. Available in both Metallized Teflon Film and Teflon Film & Foil constructions.

Paper Film:

Paper or Kraft Paper is the oldest of the film capacitor dielectrics. It is available in both
Metallized Paper and Paper & Foil constructions. The paper must be impregnated with Epoxy,
Wax, Oil, or other suitable impregnate. It is still popular for high voltage and AC rated capacitors
operating at lower frequencies. Paper is also wound with plastic dielectrics in combination
dielectric capacitors.

There are many different materials that can be used for the dielectric, I can't remember them all.

If you know of any others that I missed, please let me know, I am not sure if silicone is used and what it's value is, if you know, contact me so that I can put this into this Table. The materials used in dielectric are called dielectric constants. Some capacitors have several different constants mixed and used as the dielectric.

If you make a home made capacitor and want to know what it's capacitance is, here is the equation to find that out with:

k = dielectric constant
A = area of one plate in square inches
n = number of plates
d = distance between the plates in inches
.2249 = a factor used to convert from metric to British units of measurement.

C =

k * A (n-1)
-------------- divided by
d

**TECHNICAL TERMS**

**These technical terms were taken off of the http://www.AmericanCapacitor.Com web site for reference only, I thought it was very usefull information, so it's here also, but not as easy to understand as my examples :- )**

Capacitance:

A measure of the energy storage ability of a capacitor, given as C = K A/D, where A is the area of the electrodes, D is their separation, and K is a function of the dielectric between the electrodes. The formula yields a result in farads (F ), but a farad is so large that the most commonly used values are expressed in microfarads ( µf = 10-6F ) or picofarads ( pf = 10-12F ).

Working voltage (Wvdc, Wvac):

The maximum continuous voltage that should be applied to a capacitor. Rated voltages for DC and AC operation are usually not the same.

Temperature Coefficient (TC):

The change in capacitance with temperature expressed linearly as parts per million per degree centigrade (PPM/°C), or as a percent change over a specified temperature range. Most film capacitors are not linear and TC is expressed in percent.

Dissipation Factor (DF):

A measure of the power factor (or losses) of a capacitor, given as DF = 2 P fRC X 100%, where R is the equivalent series resistance of the capacitor, f is the frequency, and C is capacitance. Dissipation factor varies with frequency and temperature.

Equivalent Series Resistance (ESR):

A measure of the total lossiness of a capacitor which includes the leads, electrodes, dielectric losses, leakage (IR) and most important, the end spray connecting the leads to the metallized film. The lower the ESR the higher the current carrying ability the capacitor will have.

Insulation Resistance (IR):

A measure of the resistance to a DC current flow through the capacitor under steady state conditions. Values for film and ceramic capacitors are usually expressed in megohm-microfarads for a given design and dielectric. The actual resistance of the capacitor is obtained by dividing the megohm-microfarads by the capacitance.

Dielectric Absorption (DA):

An apparent "recovery voltage" measured after the capacitor is discharged and expressed as apercent of the initial charge voltage. DA is due largely to the dipole moment of the dielectric and to lesser degree the migration of free electrons to the surface of the dielectric.

Volumetric efficiency:

Energy density in µf-volts per cubic inch, from: (capacitance) X (working voltage) ÷ (volume).

Longer capacitors are more efficient than shorter units, because of volume used by encapsulation and unused dielectric at the capacitor ends (The margins). Cylindrical units have a smaller volume than rectangular units, although rectangular units can be stacked more compactly.

Corona:

Any electrically detectable, field intensified ionization that does not result immediately in complete breakdown of the insulation and electrode system in which it occurs. Its incidence can be reduced or avoided through special designs.

Pulse Operation:

Capacitors subjected to DC pulses or non-sinusoidal voltages with fast rise or drop times (High DV/DT) will be exposed to high current. This current must be limited to within the maximum peak current allowed.
These peak currents refer to an unlimited number of pulses charging or discharging the capacitors.

AC VOLTAGE:

The sum of the DC and Peak AC voltage applied to the capacitor should not exceed the rated DC voltage, nor should the RMS voltage exceed the Corona Start Voltage.

I RMS:

The maximum RMS ripple current in amps at a given frequency.

I PEAK:

The maximum peak current in amps @ +25° C for non-repetitive pulses or where the pulse time off is sufficient to allow cooling so overheating will not result.

DV/DT:

Is the maximum allowed change in volts per microsecond at the rated voltage.