Thus far, you have learned about electrical currents that flow in one direction at a constant rate. These currents were called direct currents or simply DC. During this conference you will be introduced to magnetism, magnetic effects of a magnet, and their uses. You will be introduced to a current which alternately flows in one direction, then in the other. In other words, an alternating current or AC. The principles of AC were first discovered in 1831 by Michael Faraday and Joseph Henry. Without AC, communication as we know it today would not exist; however, both AC and DC are used in electronics since each has distinct advantages.

To be able to understand the basic principles of AC generation, you will need to be familiar with magnets and magnetic properties.

A substance is said to be a magnet if it has the property of magnetism; that is, if it has the power to attract such substances as iron, and steel, which are known as magnetic materials.

There are three kinds of magnets.

Natural magnets - This magnetic material is found in the natural state in the form of a mineral called magnetite.

Permanent Magnets - This type of magnet consist of bars of hardened steel (or some form of alloy such as alnico) that has been permanently magnetized.

Electromagnets - This type of magnet is composed of a soft iron core, around which are wound coils of insulated wire. When an electric current flows through the coil, the core becomes magnetized. When the current is removed, the core loses most of its magnetism.

Permanent magnets are sometimes referred to as bar magnets that are magnets that remain or are permanently magnetized. When two bar magnets are brought together, they will align themselves according to their poles.

As the earth has a north pole and south pole, so does the magnet. All magnets have a north and a south pole.

It has been discovered that like poles repel each other and unlike poles attract each other.

If a bar magnet were cut in half, it would produce two bar magnets. It stands to reason that if the bar magnet were divided until the smallest particle, the atom, remained it would still have a north and south pole.

Atoms in a material, such as a bar of steel, are small magnets. If they are out of alignment, the magnetic effects are cancelled and the material is said to unmagnetized.

When the atoms (or small magnets) within the material are aligned, it is said to be magnetized.

Magnets will have one effective north pole, and one effective south pole. The ends of the magnets where the attractive force is greatest are called the poles of the magnet.

There exist forces sometimes referred to as lines of force, directed from the south pole to the north pole. These lines of force make up the magnetic field of the magnet and have been named flux lines.

The magnetic lines of force (flux lines) leave the north pole and enter the south pole as closed loops.

Lines of force never cross each other, and can penetrate any known material. Materials similar to the magnet materials make a good path for the flux to travel in.

The loops formed by the lines of force tend to become larger and increase in length as they develop away from the magnet.

Current flowing through a conductor produce electromagnetic fields around the conductor as shown in FIGURE 3.

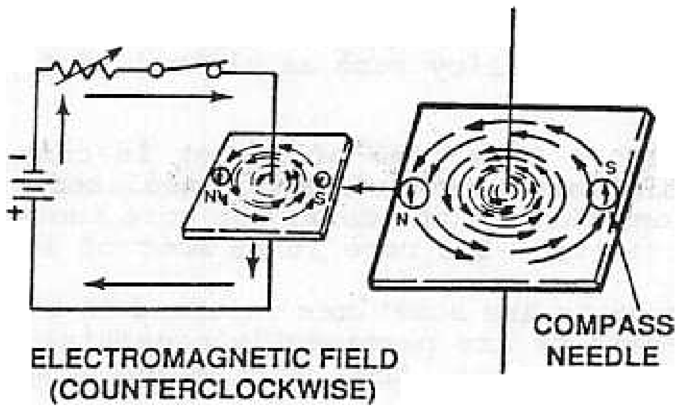

FIGURE 3

If a small magnet were placed close to the conductor, it would align its north and south poles with the lines of force pointing in the direction that the lines of force are traveling. See Figure 4.

It must be remembered that like poles repel and unlike poles attract.

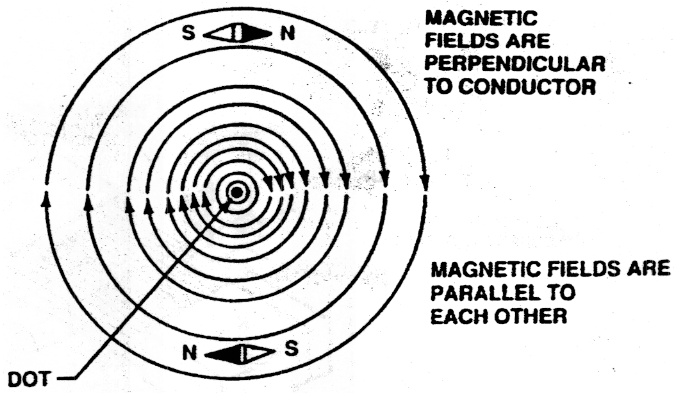

FIGURE 4

The force of attraction or repulsion existing between two magnetic poles decreases rapidly, as the poles are separated from each other. When the poles are brought together, the repulsion will be stronger. The further apart the poles are removed, the weaker the repulsion will be.

The requirements for the generation of AC is determined by the following: a Magnetic Field, a Conductor, and Relative motion - This is the result of either the magnetic field rotating about the conductor or the conductor moving through the mag- netic field.

A generator is a device which transforms mechanical energy into electrical energy.

Alternating current (AC) is a current that continually changes in amplitude and periodically reverses direction.

A simple rule can be used to determine the direction of current flow or induced voltage within a conductor. This rule requires the use of the thumb and first two fingers of your left hand and is commonly referred to as the left-hand generator rule. When the left hand is positioned as shown, the thumb points in the direction of conductor motion; while the forefinger points in the direction of magnetic flux and the middle finger (which is bent out from the palm at 90°) points in the direction of induced current. If you examine the position of the fingers shown in FIGURE 5 and compare them to the conductor and magnetic field shown, you will find that the left hand rule verifies the fact that the induced current (assuming a complete circuit) will flow in the direction shown.

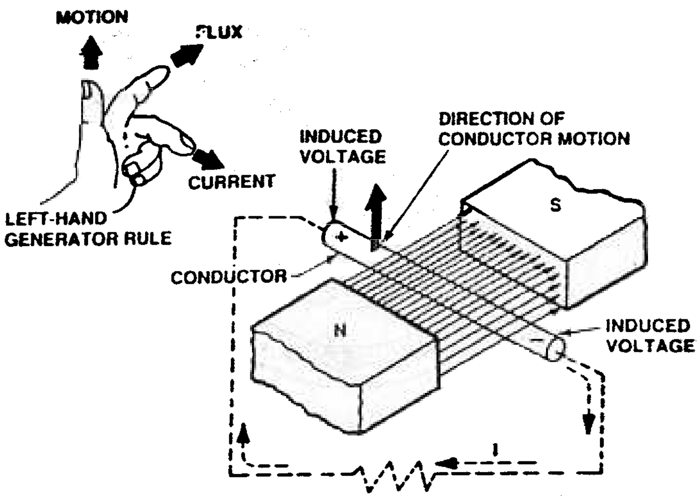

FIGURE 5

As may be seen in FIGURE 6, the basic AC generator with a coil of wire for a conductor can be used at various points or angles of rotation to show the generation of an AC sine wave.

Position A shows that the rotor moving parallel to the flux lines is actually not cutting the flux lines, thus the output is zero volts.

Position B shows the rotor cutting maximum lines of force or at 90° perpendicular to the lines of force. Thus maximum voltage is generated at this point and is positive.

Position C shows the rotor at 180° or again it is moving parallel to the flux lines. Thus no voltage is being generated.

Position D shows the rotor at 270° or perpendicular to the flux lines, thus the generator is producing maximum output. Note that position B and D are 180° out of phase, position D being maximum negative.

Position E brings the rotor back to the starting point or parallel to the flux lines generating zero output.

The waveform generated by the rotor of the generator in FIGURE 6, is called a SINE WAVE. The sine wave is so called because the amount of voltage generated at any point on the circle of the generator is equal to the sine of the angle times the maximum the generator can produce.

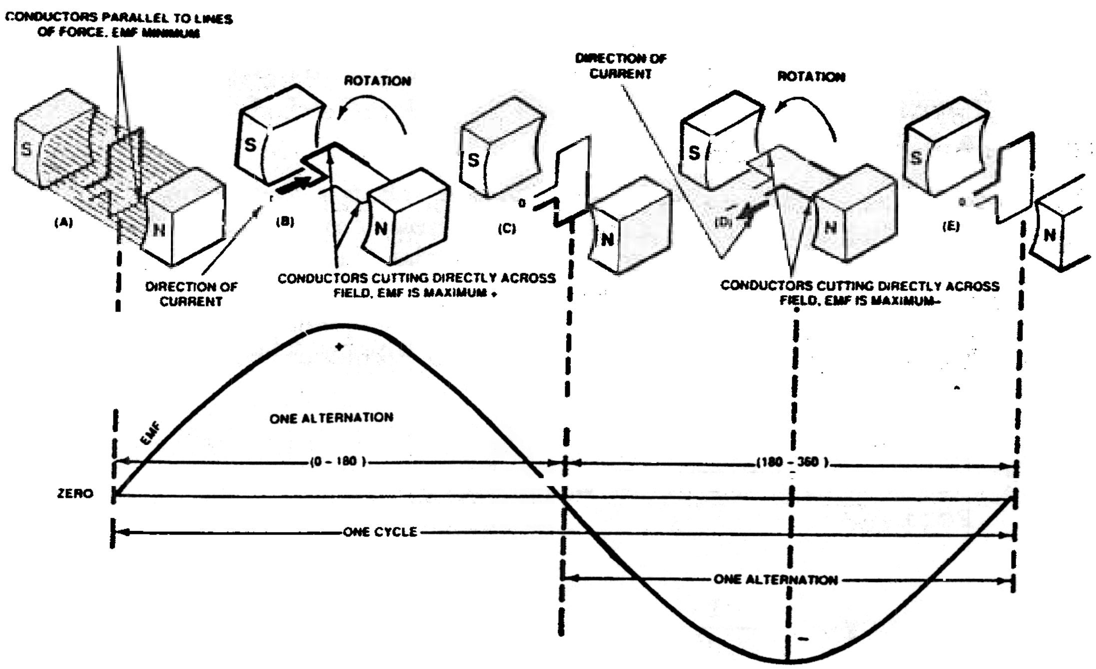

FIGURE 6

E_{max} x sin Ø = E_{out}.

EXAMPLE:

If the generator can produce an output of one (1.0) volt;

E_{max} x Sin Ø = E_{out} Ø = The Angle

1.0 x Sin 0° = 1.0 x 0 = 0V, Sin Ø = 0

1.0 x Sin 45° = 1.0 x .707 = .707V, Sin 45° = .707

1.0 x Sin 90° = 1.0 x 1.0 - 1.0V, Sin 90° = 1.0

1.0 x Sin 135° = 1.0 x .707V, Sin 135° = .707

1.0 x Sin 270° = 1.0 x -1.0 = -1.0V, Sin 270° = -.707

1.0 x Sin 360° = 1.0 x 0 = 0V, Sin 360° = 0

At this time it may be recognized that the sine wave produced in FIGURE 6, was the result of one revolution of the generator rotor.

The length of <u>TIME</u> that it takes for the rotor to make one complete revolution is called the <u>PERIOD</u>. The faster the rotor turns the shorter the period. The period is measured in time-hours, minutes, seconds. It can be expressed in revolutions per hour, minute, second. If the rotor is turning one (1.0) Rev./sec., it can be written 1.0 RPS.

The speed that the rotor is turning or how fast the rotor is turning is called the frequency. Frequency can be expressed as Rev./sec. The terminology is expressed in Hertz/sec., usually 1.0 Hertz or 1.0 Hz. The HERTZ is an expression of the rate or speed, like miles per hour for an automobile.

In the above discussion the period (time for one revolution) was determined by the speed or frequency (how fast it is turning). Note, as frequency (speed) increases, the period (time) decreases. As frequency (speed) decreases, period (time) increases. Thus it may be said; frequency and period are inversely proportional and may be expressed mathematically; Frequency/Time, where time is equal to PERIOD.

Example:

$$\frac{\text{Frequency}}{\text{Period}} = \frac{\text{Frequency}}{1} = \frac{1}{\text{Period}}$$

$$\text{Frequency} = \frac{1}{\text{Period}}; \quad \text{Period} = \frac{1}{\text{Frequency}}$$

OR

$$F = \frac{1}{\;} \quad \text{AND} \quad P = \frac{1}{\;}$$

The sine wave shown in FIGURE 6, is divided into two parts called the ALTERNATION. There are two alternations in one period. One is positive and one is negative. Thus we may say the time for one alternation is one half the period. This will later be referred to as the PULSE WIDTH (PW).

$$PW = \frac{1}{2} P$$

S

In previous discussions it was shown that the voltage at any point along the sine wave could be calculated by using the sine of the angle at that point, times the maximum. This maximum swing of the sine wave positive is called the POSITIVE PEAK (P). The maximum swing of the sine wave negative is called the NEGATIVE PEAK (P). The distance from maximum positive to maximum negative is called PEAK-TO-PEAK (PP).

This all goes to show that AC voltage is positive one half the time and negative one half the time.

The multimeter will not measure A.C. on the D.C. position because the positive voltage equals the negative voltage resulting in zero voltage. Thus a method of measurement using the DC meter was developed.

The experimental circuits A and B shown in FIGURE 7, will be used to illustrate how to determine the RMS (root-mean-square) or EFF (effective value) value of a sine wave.

Circuits A and B are identical except for the power supplies. Circuit A uses a DC supply, and Circuit B uses an AC supply. Both circuits were adjusted until one ampere of current was measured in each circuit. The temperature of each resistor was measured and the resistor in Circuit A, measured 100°C. Circuit B, measured 70.7°C.

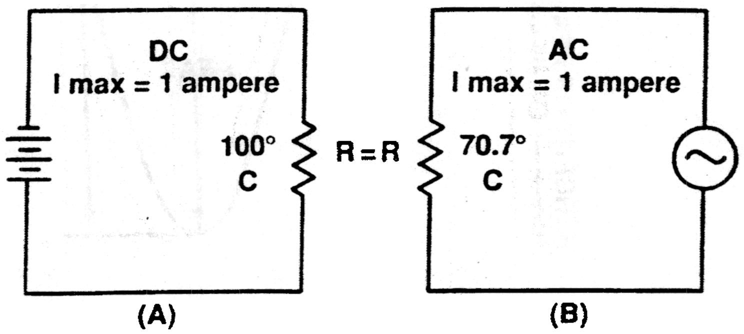

FIGURE 7

The relationship between 100°C and 70.7°C is used to establish an equivalent relationship. 100°C is equal to 1 ampere of DC current. 70.7°C is equal to 1 ampere of AC current. Thus we have a ratio of equivalent current and temperatures.

Example:

I_{AC} is to 70.7°C

I_{DC} is to 100°C

OR

$$\frac{I_{AC}}{I_{DC}} = \frac{70.7°C}{100°C}$$

$I_{AC} = .707\ I_{DC}$ $I_{AC} = I_{Eff} = I_{RMS}$

Thus

$I_{RMS} = .707\ I_{peak}$

From FIGURE 8, we can see the values projected on the sine wave.

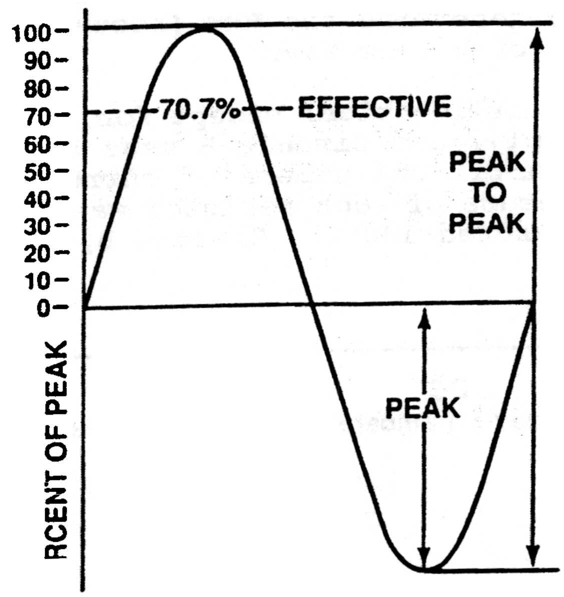

FIGURE 8

Example:

$$\frac{RMS}{707} \times 2$$

$$\frac{\text{Peak to Peak}}{2} \times .707$$

Given any one value, Peak to Peak (PP), Peak (P), RMS (eff) the other two can be calculated.

Example:

Given; a sine wave that has a RMS value of $115V_{RMS}$ calculate the PP value.

$$E_{pp} = \frac{115\ V_{RMS}}{} \times 2 = 162.66 \times 2 = 325.32\ V_{pp}$$

NOTE: 115 V_{RMS} is the AC voltage measured at the output of the outlet of your work station.

The effective or RMS value for AC may be used in both current and voltage calculations. From FIGURE 11, we may see both current and voltage waveforms plotted on the same axis.

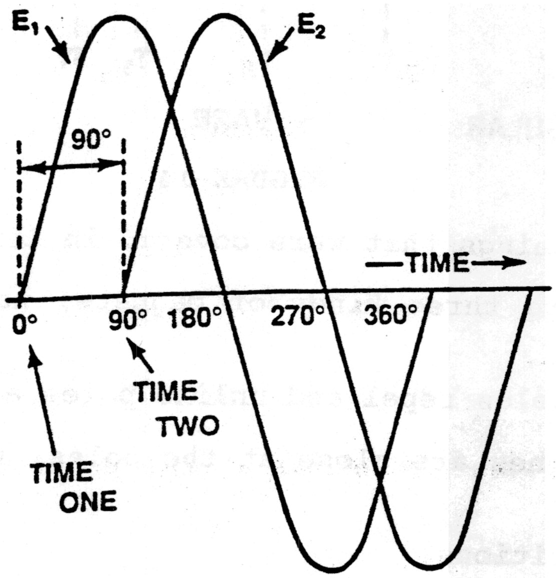

FIGURE 11

Even though the values of the waves may be different in amplitude, the RMS values of current and voltages may be calculated.

From FIGURE 11, it may be said that current and voltage are in phase. Notice that the waveforms cross 0°, 180° and 360° at the same points. Notice also the positive and negative peaks occur at the same time, 90° and 270°. These are the conditions for being in phase.

There are more complex mathematical methods for dealing with AC currents and voltages, however, for less formal methods we will be using approaches easier to work with.

Working with AC values will become more complex. Thus far we have been able to add currents, voltages and resistance directly, however, as phases come into use we can only add those values that are in phase or that have zero phase shift.

As we proceed in lessons that involve resistive, capacitive, and inductive components, we will discuss the phase relationships of each when we encounter these individually.

Some other types of waveforms you will see are shown in FIGURE 14.

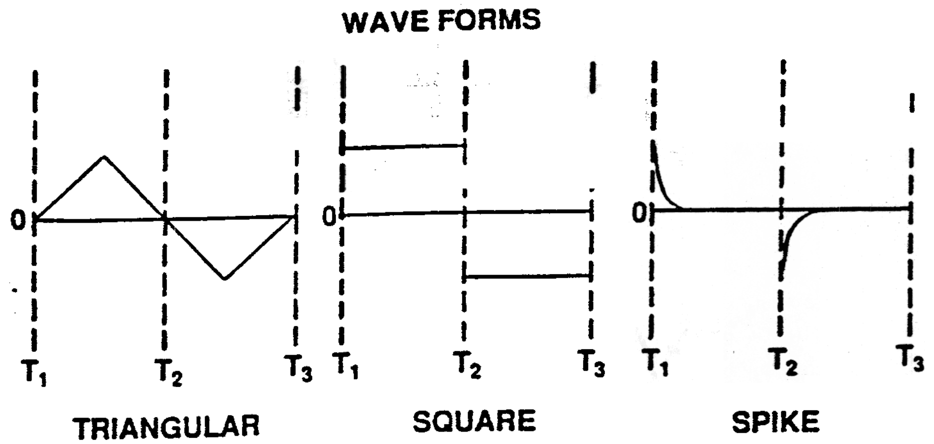

FIGURE 14

To summarize the things that were covered in this lesson:

First there are three kinds of magnets; natural, permanent, and electromagnet.

Second, like poles repel and unlike poles attract.

Third, flux lines are close at the poles, providing the greatest force.

Now some definitions:

The generator is a device which changes mechanical power into electrical power.

The Left Hand Rule, the thumb represents motion - the forefinger represents the flux - the second finger represents current.

AC is a current that continually changes in amplitude and periodically reverses direction.

The requirements for the generation of AC is a magnetic field, a conductor and relative motion.

AC waveforms consist of sine waves, square waves, triangular (sawtooth) waves, and spike waves.