**Basic Electronics**

**AC-DC: (Refer PPT)**

Emphasize that current type comes only from how the current flows in a wire. If it flows only in one direction, the current is Direct Current (DC), if the current alternates from flowing in one direction one moment and then reversing to the other direction the next moment, the current is Alternating Current (AC). Also emphasize that current magnitude (amplitude) is not a determinant of current type. DC does not have to be constant, as is normally the case of current flowing from a battery, DC only flows in one direction even if the amplitude varies.

Discuss the sources of DC and AC. Make note that both types of current are used in electronic devices. DC is generally used as sources of power for circuits. AC is generally used as signal sources to transfer energy or intelligence (information like voice, media like radio waves).

Point out that there are dedicated circuits within an electronic device that converts AC to DC and DC to AC, and from one AC current to another AC current.

Circuit is a word to describe a pathway for the flow of electrons. A good analogy is a race track for motor vehicle races. The vehicles run on the track. If there is a blockage or cut in the track, the race stops. If there is a shortcut, some of the vehicles will take that shortcut and get to the finish line by cheating. The path concept will become more important in future units to understand parallel and series circuits.

**Circuit: (Refer PPT)**

**In electronics, there are three types of circuits. Open, Closed, and Short.**

In an open circuit, the pathway (the conductor) is broken by some means and there is no complete pathway for the electrons to flow, and so they do not flow. A good example of an open circuit is an on/off switch. When the switch is in the off position, a portion of the switch mechanism that connects the electronic components to the power source is disconnected creating an open circuit.

Alternatively, if the on/off switch is closed, the switch mechanism connects the electronic components to the power source and the circuit is completed or closed. The electrons are free to flow through the circuit.

The short circuit is usually a bad thing. In this case, a failure in the path results in a more direct circuit path being formed that goes around the electronic components that are intended to be energized. The short circuit path can cause dangerous electron flows through areas (like your body) where the flow is not intended. Special safety components called circuit breakers or fuses are placed in the pathway to sense when a short circuit occurs and then open the circuit to stop the dangerous flow of current. Provide the audience with examples of circuits and safety devices in the classroom.

**Measuring Current & Voltage using Multimeter**

**Reading assignment: Instruction manual for the VOM: (Refer PPT)**

Discuss with the students the various functions of the Volt-Ohm-Meter and the ones that you will be covering in the class (measuring voltage, current, and resistance).

Have the audience take a close look at their VOM as you take a tour of the basic meter and the meter functions.

At the top of the meter is the reading display screen. The big round know in the middle of the meter is the function selection know. Ask the audience to turn the pointer on the function selection know to left from the OFF position one click to the 600 DC volt scale. Notice that there are 3 zeros displayed and no decimal point. The meter can now read up to 600 volts DC. Ask the students to continue to rotate the function selection know one click left through the other DC voltage ranges and note the change in the decimal point location. Ask the student to return the meter to the OFF position to turn off the power to the meter (and conserve battery power).

Point out to the audience the location of the two voltage ranges, DC and AC. Note that the AC ranges are fewer and cover only 200 and 600 volts AC. The wavy line indicates AC voltage, the solid/dashed line indicates DC voltage and current ranges.

Finally point out the location of the probe jacks. There are three jacks. The bottom most jack is the common or grounding jack. By convention the audience should insert the black probe lead in the common jack.

The middle jack is for accessing the voltage, resistance and low current ranges and the most commonly used jack. Ask the students to insert the red probe lead in the middle jack. The meter is now ready to read most of the voltages/currents/and resistances the audience will encounter.

The upper jack is for high current levels about 200 milliamps up to a maximum of 10 amps. If the user is not sure what the current level that they will be measuring, it is prudent to start with the red probe lead in this jack and get an approximate current reading. If the current is less than 200 milliamps, then the user can return the probe lead to the center jack to get a more accurate reading.

Explain to the audience the purpose of the high current jack and the fuse protection that is internal to the meter to provide some over-current protection. Also inform the audience that the meter is powered by a replaceable 9-volt battery. The batteries will last a long time with wise use of the VOM (I.e., don’t forget to turn it off when not in use).

Use this slide to highlight the two current ranges. Also discuss the fuse protection that is internal to the VOM to prevent damage in the event of trying to measure too much current with the probe setting. The low current (up to 200 milliamps) can be measured with the center jack position, and up to 10 amps for high current with the upper jack position.

During this program, the audience will not be using the transistor checker function of the VOM which is a more advanced function.

Point out that other VOMs have additional functions such as measuring AC current, measuring capacitance, and some have frequency counters for measuring low (up to the high audio range) frequencies.

Now on to actually using the meter. These are the three functions that will be covered in detail.

Emphasize that when measuring voltage, the VOM is used to sample the voltage **across** the source, which is different than when measuring current where the current in the circuit must flow **through** the VOM to be measured. This makes it far easier to measure voltage in a circuit because the operator can simply place the probes across the component as it is wired in the circuit. In measuring current, the operator must physically interrupt the circuit (i.e., un-solder and connection) an insert the VOM into the circuit.

Point out on the VOM the two voltage measurement ranges, one for DC and the other for AC. During this program the audience will be using only the DC range.

Recall with the student that AC voltages have peaks and troughs on the waveform, this makes it difficult to measure a specific voltage because the voltage is constantly changing.

One approach is the measure the peak-to-peak voltage.

The preferred approach is to determine a voltage value for an AC wave will do an equivalent amount of work to a DC voltage. Measuring AC voltages in this way allows the user to compare voltages using a known standard, and more importantly, use the voltage readings in Ohm’s law to calculate circuit performance. Ohm’s law of course will be covered in future units. The preferred means to measure AC voltage is to measure the Root Mean Square (RMS) voltage. RMS is a weighted average voltage that compensates for the plus and minus nature of an AC wave. Without using RMS, the average voltage would be zero and the equivalent DC voltage would be too high for the amount of actual work that could be accomplished with the voltage. A detailed look at RMS would come in a more advanced study of basic electronics. This particular VOM measures pseudo-RMS which is a gross approximation. More expensive meters would read True-RMS.

You will now take the audience through the process of measuring a voltage.

Point out that they need to ensure the probes are in the middle and lower jacks, by convention the black lead is the common or ground lead.

Initially set the voltage scale to the highest scale – 600 volts

Using a 9 volt battery for the voltage source, note that the male clip is the positive pole of the battery.

Go through with the audience how to set up the VOM to make a voltage measurement.

One technique to use if you are going to measure an unknown voltage is to use the highest scale, in this case the 600 volt DC scale. (Emphasize the difference between using the DC and the AC scale while measuring DC voltages)

While using the 600 volt scale, the resolution of the VOM is one volt.

The purpose of this exercise is to show that the VOM can tell the difference between negative and positive voltages. Point out to the audience that some VOMs, particularly analogue types will not be as forgiving, that putting the probes on reverse voltages can damage the meters.

Using a voltage scale that is closer to the actual voltage shows an improvement in resolution, in this case the voltage value is to one decimal point or 1/10th of a volt.

Again, using a scale a little closer to the actual voltage results in additional resolution this time to 1/100th of a volt.

Do the same exercise using the 1.5-volt battery.

Emphasize to the audience that when they are using the 2000 millivolt scale, they actually are using the 2 volt scale because 2000 millivolts is the same as 2 volts. But because the display is in millivolts, there is no decimal point in this case. A reading of 1527 millivolts is the same as 1.527 volts.

Note: The 200 millivolt scale is actually the .2 volt scale.

So what happens if you use a scale that is too low for the voltage being measured. As long as you do not exceed the maximum voltage value for the meter, in this case 600 volts, there will be no physical damage to the meter. The meter indicates an over voltage situation by displaying a single digit “1” at the far left. This “overage” indication is consistent with the other functions to be looked at later.

Spend some time with the audience discussing safety considerations particularly when working around high voltages and high currents. The operators of the volt meter could be exposed to lethal voltage and current levels. Also when probing a live circuit, careless cross contacts and the resulting short circuits could route equipment damaging levels of voltage and current to the circuit under test. Personal experiences will help illustrate the point.

A good technique is the do a “dry run” of probe placement with power turned off. During the dry run, the operator can see if the probe placement is correct and not short circuiting to damaging voltages and currents. Practice probe placement, and once confident, turn on the power source to make the measurement.

Another good technique is to start all measurements at the highest scaling level and then adjust the scale downward to the appropriate level. There are usually automatic protection features in VOMs, but it is best not to consistently depend on them doing their intended jobs.

What is current? Current is the flow of electrons through a conductor, the water analogy is that current is like the water flowing through a hose. Current is measured in amperes, and show from this illustration, 1 ampere is a large number of electrons flowing past a spot in the conductor in 1 second. Current in normal electronics can be in the range of hundreds of amps to millions of an amp (micros) to billionths of an amp (nano). You will generally work with 10s of amps down to micro amps in the typical electronic device.

Continue your discussion of safety, particularly equipment safety, when measuring current.

Re-emphasize the difference between AC and DC voltages and currents.

Finally, spend some time to amplify the final bullet. To measure current, the current must flow through the meter as opposed to measuring voltage when it was only necessary to sample the voltage surrounding the source (or component of interest). Generally, to have the current flow through the VOM, an existing circuit must be broken (i.e., un-soldered) and the meter probes connected to either side of the “break.” The VOM then becomes part of the path through which the current must flow.

While the audience is looking at the VOM, point out the two current scales and the associate probe jacks. Most situations the user will use the center jack and the low current scale. There may be rare occasions when higher than 200 milliamps will be measured, this will require switching the probe jack along with selecting the high current range on the meter.

In the event of an over current situation, the internal fuse will blow. To return the VOM to operation, the fuse must be replaced, with the same size fuse, by opening the VOM case and replacing the fuse. If the user is going to be making frequent current measurements, particularly in high current situations, it is advisable to have spare fuses handy at the workbench.

This might be a good time to talk about how fuses operate and the cautions surrounding replacing fuses (use the same current rated fuse as the one blown).

With no resistance in the circuit, the voltage source will provide the full current available to the circuit. There is essentially no resistance in the VOM probe lines, therefore if the probes are connected directly across the battery poles, the full current in the battery will flow through the VOM, and probably blow the fuses.

So emphasize to the audience, that during the following current measurement exercises, they must be careful to ensure that the suggested resistance is in the circuit and that the VOM probes are placed as will be illustrated. The previous suggestion on meter safety applies and this might be a good place to practice … do a dry run on probe.

Resistors will be covered in detail in a later section. The audience will need help in identifying different resistance values, from the color codes, that are used in the exercises. The audience will want to learn more about resistors and the color codes at this point, try to keep the audience focused on the lesson at hand and that is the learn how to use the VOM to measure current. They need to be patient and wait for the more detailed discussion on resistors until later.

**Basic Understanding of Resistors in Detail: (Refer PPT)**

Begin by having your audience rub the palms of their hands together and noting what they observe. Point out that their hands do not move freely across the surface of the other palm. In the process of rubbing their hands back and forth, heat is generated. This heat comes from the friction between the palm surfaces which resists the movement of the hands … in the process of resisting, the energy of movement (kinetic energy) is converted into heat.

The same thing happens as electrons try to move through a conductor or other material. The electrons run into things as they move, and each collusion causes the electron’s movement to be impeded in some way, and the resulting lost of kinetic energy is converted into heat. In the majority of the cases in electronics, this heat is imperceptible. In other cases, the heat is desirable as is the case with a stove top. In still other cases, the generated heat must be moved away from the electronic device to prevent damage (fans on a computer).

In summary, resistance is friction toward moving electrons. All materials provide some level of resistance. The unit of resistance is the Ohms. Resistance measurements can be incredibly small to incredibly large.

Discuss with the audience the various types of resistors and the application of each type. Stress the concepts and the differences between the resistance value and the power rating value. Resistors with power rating values of 1/8th watt up to 10s of watts can all have the same resistance value. In this case, physical size doesn’t matter as far as resistance is concerned.

Also point out the composite resistors are generally used when close tolerance and wide ranging values are required. Wire wound resistors are used generally where low resistance but high power handling capabilities are required. As a side note point out that because wire wound resistors are actually large and long coils of wire, the wire wound resistor can and does act like an inductor under AC conditions and therefore care and caution should be exercised when using wire wound resistors in AC applications (for instance, do not use a wire wound 52 ohm resistor as a dummy load).

Model how to read a resistor color code with the audience. Use a 1K resistor (brown, black, red, and tolerance band). Have the audience follow along with their own 1K resistors.

1. Orient the resistor with the tolerance band to the right (the gold or silver band). If there is no band (20% tolerance resistor), orient the resistor so the bands are toward the left.
2. Take note that the 2 significant digits of the resistor value are going to be represented by the two left most color bands.
3. Note that the left most band is brown, which translates to a value of 1.
4. Moving left to right, note that the next band is black, which translates to a value of 0.
5. Continue moving left to right, note the multiplier band is red, which translates to a multiplier of 100.
6. Multiply the 10 times 100 = 1000 or 1K ohm.

**Basic Understanding of Capacitor in Detail: (Refer PPT)**

Emphasize with the audience that you will not be going into as much detail as you discuss the remaining basic electronic components. The purpose of this course is to give a very basic overview of electronics and a just a basic understanding of what these components do in a circuit is part of that understanding. If more information is desired, additional study materials and in-depth reading is available on the subject.

In this next section you will cover what a capacitor is, what it does, the physical characteristics that influence the amount of capacitance, and how capacitors react differently in series and parallel circuits from resistors.

Bring to the audience the analogy of static electricity when they comb their hair or take clothing out of a dryer. Apposing charges build up on the comb and hair. When the comb is brought into proximity to the hair, the hair is attached to the comb and stands on end. Everyone has experienced static discharge with an unexpected spark. The phenomena is basically how a capacitor works, by storing that change.

The basic unit of capacitance is the farad. A single farad in reality can hold a very large amount of charge and in electronic circuits, and the amount of capacitance is usually in the millionths and billionths of a farad (micro-farad, pico-farad, nano-farad).

Capacitors are identified by the type of insulating materials between the conductive plates, I.e., air, mica, tantalum, ceramic, polystyrene, etc.

The value of the capacitor is determined by 3 physical factors:

1. The mount of surface area of the conductive plates. The larger the surface area, the more charge, and therefore the higher capacitance value.
2. The distance between the plates. The closer the conductive plates are to each other, the stronger the electrostatic field that is developed. When the plates are close together, the attraction between the opposing poles is stronger. The closer the plates are together the higher the capacitance.
3. The insulating material between the plates. Certain materials are more conducive to separating the poles than others, this allows capacitors to handle higher voltages or to hold a charge longer. Certain materials are very thermally stable and will not expand or contract as much with temperature changes therefore making the capacitance value more stable over wide operating temperatures.
4. Spend some time talking about how a capacitor is charged. Go back and use the water analogy to help explain how a capacitor works. In this illustration water (electrons) is entering the tank (capacitor) from the right. The rate that the water (electrons) enters the tank (capacitor) depends on how much pressure (voltage) pushing on the water. The outlet valve on the right is closed so water (electrons) can not escape. When there is no water (electrons) in the tank (capacitor), the reverse pressure (voltage) from the water (electrons) in the tank (capacitor) would be zero and the water (electrons) would rush into the tank (capacitor) un-impeded. When the tank (capacitor) has all the water (electrons) it can hold, the reverse pressure (voltage) of the water (electrons) would equal the pressure (voltage) pushing the water (electrons) in to the tank (capacitor) and the flow of water (electrons) would stop and remain constant. The tank (capacitor) is in a charged state with the pressure (voltage) inside the tank (capacitor) equal to the pressure (voltage) of the water (electron) supply.
5. In the beginning the water (electrons) rush in at a rapid rate because there is no opposing pressure (voltage) built up. As the opposing pressure (voltage) builds as more water (electrons) enters the tank (capacitor), the rate of water (electron) flow slows until it virtually stops when the tank (capacitor) is full.
6. Describe to the audience the physical arrangement of the conductive plates within their electrolytic capacitor. There are two sheets of conductive material separated by a chemically active past dielectric (insulating) material. The two sheets are connected to the leads that come out the bottom of the capacitor. The sheets are rolled up, much like a sleeping bag, and put into the container they are holding.
7. Ensure with your audience that the voltage and current levels of the capacitor they are using are very, very low and safe. This may not always be the case. Capacitors are main components in power supplies in consumer electronic devices. In some cases, power supply capacitors can be charged with high voltages and high currents that could be harmful. So cautions is generally advised when working with large capacitors that are installed in power supply circuits.
8. The voltages measured should be virtually zero.
9. Emphasize with the audience to take note of the polarity of the capacitor and attach the + or – side of the capacitor to the appropriate pole of the battery. There is little danger that reversing the polarity will damage the capacitor in this case, but they should get into the habit of watching polarities.
10. The audience will have to experiment to find the appropriate range on the VOM, the capacitor will be charged to approximately 9 volts, therefore the 20 volt range would be appropriate. The audience should observe that the voltage quickly bleeds off and they can continue to monitor the lower voltages by switching to lower VOM ranges.
11. Discuss with the audience what they are observing. Emphasize that the rate of discharge varies over time explain that this is caused by the decrease in voltage is resulting in a decrease in electron flow from the capacitor. This will be reinforced in the next few slides.
12. This illustration returns to the water tank analogy to help show what happens after the capacitor is charged and allowed to discharge. The intake valve on the left is closed, and the outlet valve on the right is opened. In the previous activity, when the VOM was connected to the capacitor, a path was opened for the electrons to flow from the capacitor (the VOM does take a little bit of the current to make the readings). Initially when the capacitor was fully charged, there was approximately 9 volts of pressure pushing the electrons down the conductor. As the voltage drops in step with the reduced charge, the pressure pushing the electrons also decreases causing a decrease in electron flow. How this showed up on the VOM was an initial, rapid voltage drop that slowed down to a crawl. In reality, a capacitor loses its charge only after a prolonged period of time, the voltage drop is asymptotic to zero (never reaches zero).
13. Point out to the audience that they used DC to charge the capacitor. Once the capacitor reaches full charge (the forward voltage equals the reverse pressure), the current ceases to flow, it stops, it is essentially blocked.
14. This is going to take a little more explaining. Talk the audience thorough the process after you review what AC is.
15. During the positive portion of the cycle, electrons are drawn from plate 1 and added to plate 2, the capacitor is charged with plate 2 being negative and plate 1 being positive.
16. After the peak of the positive cycle, the capacitor begins to discharge. When the cycle begins to go negative, electrons are added to plate 1 and drawn away from plate 2. The capacitor is charged with plate 1 being negative and plate 2 being positive.
17. If the audience looks at just one plate, the plate goes from positive to negative and back again … just as if the plate were a source of AC!
18. In summary, cover that the capacitor blocks the passage of DC and passes AC. You can add an additional tidbit that depending on the value of capacitance, a capacitor more readily passes certain frequencies, this concept is called the capacitive reactance.
19. Point out to the audience the wide range of capacitance values. The most common values are micro and pico farad though sometimes you will see values listed as nano farad.

Capacitor identification can be a little tricky and complicated. These two illustrations show the typical numbering system. Here are some common examples:

1uf = 105

.1uf = 104

.01us =103

1000pf = 1nf = 102

.047uf = 473

.022uf = 223

The audience should already be familiar with parallel, series, and mixed circuits from the previous discussion. There is a little twist that is important when dealing with capacitors in circuits, the mathematics is the opposite of what they use with resistance, i.e., parallel capacitances are a simple sum, series capacitance is the reciprocal sum.

It is fairly easy to see why there is a difference if the audience goes back to what physical factors affect the amount of capacitance, or the amount of charge the device can hold. There are two physical factors, the surface area of the conductive plates and the distance between the conductive plates.

In a series circuit, take a look at the plate closest to the negative pole of the source and the plate closes to the positive pole of the source. These plates are physically more separated from each other than if there was a single capacitor. Since the plates appear to be wider apart, the electrons on the negative plate, and the positive charge (lack of electrons) on the positive plate cannot influenced each other as much, and therefore the electric field is weaker, and the capacitance is less.

The surface area of the conductive plates in parallel capacitors add together. The electrons on the plates connected to the negative pole of the source spread out across both capacitor’s plate, the positive change (absence of electrons) on the plates attached to the positive pole of the source also spread out, the plates are still only separated by the same distance as if there was just a single capacitor. So there is more electrons are exposed over a greater surface but at the same distance, therefore the capacitance will be more. The simple sum.

The two formulas should look familiar. Emphasize with the students that even though the formulas look the same as the ones used for series and parallel resistances, the mechanism that these formulas represent are different between resistors and capacitors. The important thing to remember, that the formulas are applied opposite between resistors and capacitors.

**Basic Understanding of Inductor in Detail: (Refer PPT)**

Now turning to inductors. Inductors are essentially coils of wire that are used to store energy temporarily in a magnetic field. Inductors when combined with capacitors are used in many different kinds of electronic circuits because of their property to oscillate or “ring”, energy in one component feeds the other, back and forth in an oscillating or “ringing” manner at a specific frequency. This phenomena is called resonance. Additionally, paired inductors in close proximity, with overlapping magnetic fields, allow energy to flow from one inductor to the other, by “inducing” a current in the other inductor. This is basically how a transformer works. These concepts are beyond the scope of this basic course, however, the audience should be aware of the basic function of the inductor.

A very good demonstration of the two fundamental principles is to drop a strong magnet through a conductive pipe (such as copper or aluminum and a non conductive pipe such as PVC). The magnet falls right through the non conductive pipe as expected, but drops slowly though the aluminum pipe, and even more slowly through the copper pipe. What is happening is that the moving magnetic field tries to cause the electrons in the conductor to move, those electrons in turn create and opposing magnetic field that slows the magnet's decent. The magnet falls through copper slower because copper is a better conductor than aluminum.

A good source of magnets for this demonstration is at:

**http://www.gaussboys.com/product\_info.php?products\_id=31**

Discuss with the audience the concept of magnetic fields related to the two fundamental principles of electronics. Give some examples that they may be familiar with, like the coil in a car or the electro-magnets they made in school or played with as children.

Emphasize that like capacitors, inductors temporarily store energy, but unlike capacitors the energy is stored in a different form, a magnetic field.

Discuss with the audience the physical makeup of the typical inductor … a coil of wire. The permeable material (meaning it accepts and concentrates magnetic fields) helps to generate a larger magnetic field in the inductor without adding wire. The permeable materials are metallic mixtures that usually include iron. The magnetic field created by an inductor surrounds the inductor. The toroid, or doughnut form, helps to keep the magnetic field contained within the immediate vicinity of the inductor. This is sometimes desirable so that inductors near each other will not interact.

As in capacitance and the Farad, a single Henry is a huge amount of inductance and would require a very large component. In electronics, the values of inductance are generally in the milli and micro ranges.

All of these factors contribute to the value of inductance. All of these factors are mathematically related and an inductors value can be predicted pretty well if these dimensions are known. The math and the formulas are beyond the scope of this course, but they are by no means too difficult for those in the audience that are interested.

Take some time to talk your audience through the process as a DC current flows through the inductor. During the building of the magnetic field, that process actually impedes the growth of the field, but the current flow will prevail to build up the field to the maximum. But when the current is suddenly taken away, the field immediately begins to collapse with a resulting high voltage across the inductor. This is how the high voltages are generated in a car to cause the ignition spark.

Now with AC current, the current and the magnetic field are constantly reversing. The inductor causes a “delaying action” for the reacting current. These properties actually act against each other. The result is that collapsing magnetic field and the reverse generated current all combine to act like resistance to the current flow, this type of resistance is called reactance. As the frequency of the AC current increases, the apparent resistance (reactance) increases. This makes sense, a straight wire, one with no coiled turns, would only exhibit pure resistance to the flow of electrons through the wire. But once you start to coil the wire and focusing the induced magnetic field, the inductor properties and the changing magnetic field will add additional resistance (reactance) to the flow of electrons.

Pairs of inductors in close proximity is another important use of inductors in electronics. The household transformer that converts 120V AC wall current into current that will run a 12V DC radio probably uses a transformer and other circuits to do the conversion. It is important to go back to the two fundamental principles stated earlier in this unit (moving electrons create magnetic fields, changing magnetic fields cause electrons to move). This would be a good opportunity to walk your audience through the process while discussing how a transformer works.

**Basic Understanding of Diode in Detail: (Refer PPT)**

The diode is a devise that allows current to flow in only one direction. There are specialized diodes, the light emitting diode (LED) and the Zenier diode that will be discussed later. However, the basic principal is the same, the current will flow in one direction, if current flow is attempted in the opposite direction, the flow will be blocked. Diodes find use in may electronic circuits.

The audience probably have heard that diodes convert AC to DC. This is an over simplification of how a diode operates, you will be clearing this misconception up the the following discussion.

The material presented in the first section, the semi-conductor phenomena will be used later during the discussion of transistors, so encourage your audience to make sure they are comfortable with the material in the diode discussion.

Take a moment to discuss the schematic symbol and how it relates to the physical diode. The cathode end is associated with the negative pole of the diode, the term also refers to an element inside a vacuum tube that was the source of electrons in the tube. The banded end of the diode is the cathode end. The anode end of the diode is associated with the positive pole of the diode, the term also refers to an element inside a vacuum tube that was called the plate. The plate is connected to the positive side of the power source accepted the stream of electrons that flowed within the vacuum tube from the cathode to the place.

You will be covering later the confusing convention in semiconductors that current flow referees to the movement of hole or electron holes. The arrow in this case is pointing in the direction of positive current flow.

Refresh your audience's memory about the basic structure of an atom. The center nucleus is made up of protons (positive changes) and neutrons (no charge, just mass). Surrounding the nucleus are electrons (negative charges) that are contained in shells of varying energy levels. In an atom with no net charge, the number of protons equals the number of electrons. For numerous reasons, some atoms hold their associated electrons very tightly and the outer “shell” of electrons are not free to roam from one atom to the next. These atoms make up materials called insulators because electricity does not flow readily through the material. Other atoms do not hold on to the outer shell of electrons very tightly and allows these collective out electrons to form a sea of electrons that freely move from one atom to the next. These atoms make up materials called conductors. The overall net charge of the material is still neutral because the number of protons equals the number of electrons. However, if one electron is injected into the material on one end, one electron is ejected from the material from the other end.

There is a certain class of material called semiconductors. The electrons are held tightly, but not too tightly. Under certain conditions, the other shell of electrons can move from one atom to the next, in other conditions, the electrons are held firm. If impurity materials are added to the semiconductor material the properties of the material are changed. Adding impurities is called “doping.” For instance, if an impurity is added that does not hold on to it’s outer shell of electrons very tightly, these atoms become a source of free electrons that can move through the material. This material is called “N” type material. Alternatively, if an impurity is added that holds very tenaciously to it’s outer shell of electrons, the atoms become a source of electron holes or spaces where electrons will be drawn to as they move into the material. This material is called “P” type material.

This would be a good time to discuss with your audience the concept of electrons holes. By historical convention in semiconductor electronics, current movement refers to the movement of electrons holes versus the movement of electrons. The electron holes are unfilled spaces that could hold an electrons. The arrows noted on semiconductor device schematic diagrams indicate the direction that the holes travel, from the positive pole to the negative pole. Think of the ball moving across a hole pocked surface, as the ball (electron) moves from one hole to the next, the vacant holes in turn move the opposite direction of the moving ball.

The left side of the Silicon bar is doped with impurities that have excess electrons, this side of the bar then has “N” type material. The right side of the bar is doped with impurities that have excess holes, or unfilled space for electros to reside. This side of the bar is “P” type material. In between the N and P material is a thin layer of just plain old Silicon material that keeps the P and N materials separated by its relative neutrality.

Now you will take a look at what happens inside a diode when current is applied.

In the first case, a current source is applied to the diode so that the negative pole, a source of electrons, is connected to the anode (the P material side) and a source of electron holes, is connected to the cathode (the N material side). The free electrons within the N material are drawn further away from the P-N Junction by the positive pole of the source. The electron holes are drawn further away from P-N Junction by the negative pole of the source. (One way of looking at this is that the electrons from the source actually fill in the holes … same thing as the holes moving.) The P-N Junction now in essence has expanded and includes even more simple Silicon material that is holding on to the outer shell of electrons keeping them from moving. Current therefore does not flow. This diode is turned off, this condition is called reverse biased.

Now in this second case, the poles of the source are reversed. The electrons from the negative pole of the source add to the excess electrons in the N material. The electrons from the P material are drawn to the positive pole of the source to crease more holes in the P material. The result is that the N-P Junction is no longer a no-mans land and the excess electrons and the holes come together allowing the current to flow. This situation is called forward biasing of the diode.

The following two activities reinforce what has just been presented. Work with the audience to ensure they can identify the banded (Cathode) end of the diode. This would be a good place to talk about the purpose of the current limiting resistor. When the diode is reversed biased, current will not flow through the diode and the protective resistor would not be needed. However, when the diode is forward biased, the diode conducts and is essentially a closed switch or closed circuit with very little internal resistance and the full current available would flow through the circuit potentially damaging the components within the circuit.

Ask the audience to identify if the diode is reverse or forward biased. In turn as them to predict what type of meter indication they would expect. If the current were to flow in this circuit, what would be the expected current. This type of calculation should be done ahead of time, before making the measurement, so that the proper meter range could be used.

This circuit is reverse biased and no current flows. Using a 9 volt battery and a 330 ohm resistor, assuming no resistance within the diode, using Ohm’s law the current will be 27 milliamps. The 200m range would be appropriate in the next activity.

In this case, the diode is forward biased and current will flow through the circuit. The predicted current flow is 27 milliamps, but the actual current flow through the circuit is 24 milliamps.

You can use this difference to discuss with the audience what is going on. They should come to the conclusion that there is less than predicted current flow because there is additional resistance somewhere in the circuit. You can lead them to the conclusion that perhaps there is resistance in the diode. How could that go about determining if the diode is the source of resistance?

One strategy is to use the circuit in the next activity.

In this circuit, the VOM is connected to read the voltage across the diode. On the test bed, the voltage drop was .709 volts. Using the current measured in the previous activity, 24 milliamps, and this voltage drop of .709 volts in Ohm’s law results in a resistance within the diode of 29 ohms. Taking this a step further, the total resistance of the circuit is 330 + 29 = 359 ohms. Using Ohm’s law, the current through this circuit with a 9 volt battery should be 25 milliamps … a little closer to the value observed.

Here is where you can discuss with the audience that although the diode is forward biased and is conducting electrons (or holes depending on your point of view), there is some inherent internal resistance in the diode. The typical voltage drop they will experience with a conducting diode is approximately .7 volts.

The current carrying capacity of a diode must be considered in circuit design. While there is a .7 volt drop across the diode due to the internal resistance, this resistance will in turn create heat when current is flowing through the diode, and this heat must go someplace. Therefore diodes a rated by their ability to handle current as well as their ability to hold back voltage (maximum reversed bias voltage before failure). It is up to the designer to consider the current capabilities and limit the current by proper current limiting resistor choice.

Diode rectifiers are primary components in power supplies. The diodes are arrange to clip the negative cycle of an AC wave and allow the positive side of the AC wave to pass to filter circuits that fill in the gaps to create a smoothed DC current. You can, depending on the level of the audience elect to go into the various types of rectifier circuits, their advantages and disadvantages.

This graphic represents the input and output pattern of a half wave dipole. Use this graphic to explain that current flows during one part of the cycle and is cut off during the other part of the cycle, creating a pulsating current that travels in one direction … DC.

Emphasize to the audience that although the limiting resistor controls brightness, the builder has to keep the maximum current rating in mind when determining the minimum value (maximum brightness) of the resistor.

A Zener diode is constructed so that it will conduct when reversed bias above a certain voltage. The excess voltage and current then is conducted to ground and the energy is dissipated as heat. A Zener acts as a simple voltage regulator. In the case illustrated, a 9 volt source is passed through a current limiting resistor to drop the voltage somewhat (to take the pressure off the Zener). If the Zener was not in place, the amount of voltage drop across the resistor would depend on the amount of current being drawn from the circuit. With the Zener in place, the 4.7 volts would be maintained by the Zener acting as a path for the excess current that is not being drawn off. This excess current has to be dissipated as heat therefore there are current limits on Zeners that the designer needs to consider.

**Basic Understanding of Diode in Detail: (Refer PPT)**

Though you can not make a transistor simply by putting two diodes together back-to-back, it is useful to look at the transistor as made up of diodes to better understand what is happening inside.

Take a look at this representation of the inner workings of a PNP transistor. Close inspection reveals there are two diodes with their P poles connected together. The P-N Junction is represented by the narrow black line. In an actual transistor, the P material would really be just a very narrow strip of material, not as represented in this graphic.

In this circuit, a power source is applied between the base and the emitter, the positive pole to the base, negative to the emitter. An additional power source is applied between the collector and the base, the negative pole to the base, the positive pole to the collector.

The base-emitter diode is forward biased, which remember cause that diode to conduct electrons allowing the electrons to move left to right, and the holes right to left. The base-collector diode in turn is reverse biased, which means the diode is turned off and not necessarily conducting.

Something interesting happens in this case though, the transistor effect. As the electrons from the base-emitter diode go across the P=N Junction, the P layer is so thin, and there are so few holes to accept the electrons, that the electrons continue to flow right on past and cause the base-collector diode to start conducting and allowing the current to pass through the transistor to the collector. In effect, a small forward bias on the base-emitter diode causes the transistor to turn on and pass current through the emitter to the collector.

Now take a look at what happens when the base-emitter diode is reverse biased and the base-collector is also reverse biased. The base-emitter diode is no-conducting along with the base-collector diode, no current flows and the transistor is turned off.

Point out to the audience that the symbols for PNP and NPN transistors have a subtle difference, the direction of the arrow. Remember the arrow, by convention, shows the direction that the holes move, not the flow of electrons.

The two types of transistors are used throughout an electronic circuit. The choice is usually due to the polarity of the power sources surrounding the transistor. The circuits are basically the same except the polarities of the power sources are reversed.

Spend some time with the audience to make sure they have the pin out of the transistor correct before building the circuit, it will save some time during the activity.

The audience will need some help in first determining the transistor pin outs and then installing the LED. Reminded them that the positive side (anode) of the LED is the longer lead.

In this circuit, the 330 ohm resistor in the collector circuit limits the current through the LED. Remember when the transistor begins to conduct, the path through the transistor is very low resistance. Without the current limiting resistor, too much current could flow and damage the components.

Additionally, the 1000 ohm resistor in the base circuit also limits current. In this case, when the base-emitter diode conducts, there is a low resistance path. Without current limiting, the transistor could be damaged.

When this circuit is completed, nothing should happen because the base-emitter diode of the transistor is not biased so the transistor does not conduct.

When the base is connected to 9 volts, the base-emitter diode is forward biased and conducts. This in turn turns on the transistor and the current flows through the LED to turn it on. The audience should note that LED goes off when the base voltage is removed.

When the voltage is positive on the base, the transistor conducts and the LED is lit. Point out to the audience that in this case, they are controlling a much larger voltage with a small voltage. This will become more important in the following circuits when a transistor amplifier is explored.

Take some time to explain to the audience how the variable resistor works and what is going on here.

The voltage across the variable resistor is the battery voltage. The wiper of the variable resistor taps off the resistor at different places depending on how the screw control on the variable resistor set. The variable resistor become a voltage divider so that the voltage on the base can range from ground (no voltage) to 9 volts and all voltages in between.

When the circuit is wired, task the audience to adjust the variable resistor through its range and stop when the LED is fully lit. Using the VOM, measure the voltage on the base of the transistor and record the value. On the test bed the voltage was .78 volts.

Next, decrease the voltage by adjusting the variable resistor until the LED is just barely visible and again measure the base voltage. On the test bed the voltage was .68 volts.

Finally, move the variable resistor until the LED is fully off and record the voltage. On the test bed the voltage was .63 volts.

Discuss with the audience what the voltages mean in relation to the operation of the transistor as a switch.