

A Student’s Guide To:

Multi-Meters, Test Lights, Oscilloscopes & More…

**By:**

Brian Green

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**Introduction:**

*How can you effectively and properly use electronics technology test equipment, when analyzing electrical circuits?*

I have been asking this question for quite some time now. When I was a student, learning about the different concepts of electricity and engineering there was a lot of information to digest. So many tools and theories needed, each achieving something different. In my opinion, all of the information comes at you very fast and it becomes a bit overwhelming to comprehend. When building an electrical circuit, or creating something with an electrical charge, something will go wrong.

On occasions, as a student you might get flustered or even get a bit angry when building an electrical circuit or a mechanical mechanism and it does not seem to work the way you intend it to work. With this guide, I hope to help you navigate through the various kinds of testing equipment in order to analyze and determine what is going on within your circuit and possibly correct any mistake and even help you prevent any mishap.

The purpose of this guide is to assist you in class while you are completing labs or assigned activities. Use this reference resource to your advantage; learn about the features and functions of the test equipment that will be used in this laboratory. Always remember, safety first above all else!

**Electrical Circuit Basics:**

The test equipment that we will be using, measures various elements of electricity. We will begin by reviewing the basic concepts of building a circuit and converting electricity to ensure a thorough understanding before we proceed to testing our connections. Electricity in my opinion is what makes the world go round. Electricity is too broad of a term; it is usually defined as, “energy made available by the flow of electric charges through a conductor. Limitless things can be done with electricity and humans are just becoming to harness the capabilities of the power”. (Wolfram Alpha)

When building an electrical circuit you must always keep in mind the three main sections that comprise electricity. These sections or components are known as the **Current**, **Voltage**, and **Resistance**. Current is known as the flow of free electrons through the conductor of an electrical circuit. The voltage is the push, or the driving force of the flow of free electrons. Resistance in an electrical circuit is known as the, opposition to the flow of free electrons.

**Application:**

* *Please define the following terms:*
  + **Current:**
  + **Resistance:**
  + **Voltage:**

These three sections are all related and have a direct correlation. Resistance is indirectly proportionate to current to the point that if resistance increases, current decreases or vice-versa. Current is directly proportional to voltage, as one of them increases, so does the other. The relationship between current and voltage can be defined and calculated through mathematical formulas known as Ohm’s law. When designing electrical circuitry, engineers will incorporate components, and then determine expected outputs through the use of ohm’s law. This would allow for the opportunity to test electrical circuits in theory before it is actually built. If the calculations match the actual number output; this allows for you to see if either, there was an error in your design or a malfunction in the procedure of your creation.

**Question:** *What is ohms law? Why is it important for the use in electronics technology?*

In application today we can classify electricity into two different categories. These categories are: **Alternating Current** *(AC)* and **Direct Current** *(DC)*. Both types have advantages as well as many disadvantages when it comes to electrical circuits.

DC is used in handheld electronic devices because it provides a continual stream of current. These devices need the reliable flow to operate appropriately. The significance to *DC* is that if the current must travel long distances it electro-static interference (ESI) causing it to drops very quickly. This is why it is commonly used in small or handheld devices. *AC* is a great way to have current travel over long distances. The current creates a wave that can carry the electricity for a longer amount of time and distance. For this reason our homes are usually powered. The electricity comes from a power plant and travels many miles into our homes and places of work.

Since this is a Robotics Technology course, you will unsurprisingly be working with DC. AC plays an essential part in electrical circuits as well and should be understood in order to efficiently and effectively test your circuits. During this course you will become astonished at some ways current is used in our electronic devices and modern day robots.

**Testing Equipment:**

Multi-meters are one of the most commonly used tool when diagnosing and testing an electrical circuit. It is a device that is capable of calculating immediate values of electrical components in a circuit. There are various categorizations for meters. Two types you will be using in this class will be Analog Multi-meter and a Digital Multi-meter. The analog Multi-meter has become obsolete within the industry, but it is still capable of gauging voltage, current, and resistance. This type of multi-meter can function with predetermined measurements and an indicator that moves accordingly.

Digital Multi-meters have Liquid Crystal Display (LCD) screen, a control to select what you are evaluating, and a buzzer. Higher-end Multi-meters have something called auto range. When analyzing values in electrical circuits it is common to use the metric system to help calculate readings. The auto range helps you finding which prefix you are trying to get. This will automatically range through the settings.

It is very important to observe what settings you have set your multi-meter to. You must ensure you are reading the correct number. For example, the 5-ohm resistance you are reading may actually be 5,000,000 ohms because the “M” for mega failed to be observed. Always keep in mind your engineering notation.

Once you get a Multi-meter, make sure you have two leads connected to it. We will begin by testing the voltage in a circuit. Always make sure you have the leads connected to the corresponding ports in order to get the appropriate readings.

The control on the multi-meter is what helps you select the function you are attempting to measure. Turn your control towards the DC or AC voltage selection; this all depends on the type of circuit you are testing. DC is represented on multi-meters as straight line with a dotted line above it. AC is represented by a sine wave. Once the control is on the correct voltage option, plug the red lead into the port labeled V for *voltage*. Take the black lead will plug into the COM port. COM stands for Common Ground. No matter what you are testing the black lead will always go to COM (Multimeter). Once you have your leads in the corresponding ports, you can begin to test the current in parallel.

**Application: Quick review**:

* What is a simple circuit?
* *What is a series circuit?*
* *What is a parallel circuit?*

When you plug your lead in parallel this means you may examine an electrical circuit without disturbing its flow of current, it also allows for an accurate reading or measurement. Make sure solid contacts are made with the conductor on the electrical circuit and do not, I repeat do not touch the metal of the test leads with your fingers, or your tongue, even if your partner says nothing will happen. After you make a connection with the live circuit, a measurement will appear on the LCD screen of meter. You should always record your readings to compare and contrast if in case you get inconsistent measurements.

**Application: Please answer:**

* *What is the difference between the digital and analog mutli-meters?*
* *Do the test leads have to go in a specific way? Why or why not?*
* *What does LCD stand for?*

At this point you should be able to measure the push or the driving force of the current within your electrical circuit.

Resistance is known as the opposition to the flow of free electrons, it is very significant when analyzing an electrical circuit. Equivalent to the voltage, the red test lead is connected to the port, labeled with an omega symbol (Ω). The omega symbol represents the unit of resistance called ohms. So once the red lead is connected and the black lead is connected to the COM port, turn the control to the resistance portion. When you have the resistance portion set, you should always test the leads by touching them together as your first step. Your measurements should be below 1 ohm (Multi-meter Tutorial, 2002). This measurement represents the original resistance that exists in the conductive wire and connections of your test leads. If your measurement is higher then 1 ohm, something is most definitely wrong and should be addressed immediately. You may want to troubleshoot this problem before moving on.

**Application:**

* *When measuring for resistance where should your test leads be connected to on the multi-meter?*

To correctly measure resistance in an electrical circuit, remove the power source from the circuit. If you do not do so you will experience unreliable readings and measurements. After the power source is removed from the electrical circuit you may use the multi-meter to measure the opposition to the electrons. The leads should be in parallel to the circuit in order to prevent from interrupting the flow of the current.

If there is no constant flow of current between the test leads, the meter will show “OL”. “OL” stands for open loop, usually known as an open circuit. When you have an open loop, or an open circuit this indicates that there is not electrical current running between the two test leads, causing the open.

A great option provided on the Multi-meter is the audible continuity buzzer. By pressing this button, when calculating for resistance, whenever continuity happens across the two test leads, the meter will make a noticeable beep to signal that there is constant flow. The display will continue to show the calculation for you to visually see it but since you have the sound no need to look at the display. This feature is great when working in loud shops, or when you are outside especially useful when there is an uncomfortable position. When testing your circuit.

**Very Important:** *When you are using the test leads, especially while measuring resistance, always keep your hands away from anything conducting electricity. As human beings we conduct electricity. At times our body has too high of a resistance that limits the amount of current that can actually effect us, but since some of these electrical circuits have a high level of current and voltage.*

When measuring current while using a meter it gets a bit more complicated. Current is always measured in amperes, which is abbreviated to amps. On most electronic components and devices amperes is displayed simply using the letter A.

The first step you should take to measure for current using a meter is to remove the power source from the electrical circuit you are attempting to measure. The meter should be placed in series unlike when measuring for voltage or resistance. In order to get the most accurate measurement, you should make sure that your meter is in the direct path for current. Once, you have completed those steps you are now ready to calculate the current in the circuit. Once you have the meter in the direct path for current, re-connect the power source; make sure to be very carful when attempting this. Now you should be able to dial the settings on the meter for amperes. After the circuit is charged, you are now ready to begin the calculating.

Another type of measuring device you should become familiar with is the Oscilloscope. The Oscilloscope measures the voltage, which correlates to its frequency. Oscilloscopes have a grid-lined screen. This display has a X-axis, Y-axis, and a Z-axis.

The X-axis is the horizontal centered line on the grid, the Y-axis is the vertical centered line on the grid just like on a graph. The Z-axis is a distinctive axis, which represents the strength of the light that is being shot to the screen. The light that is shot through the screen is known as the cathode ray, which is sent through a cathode-ray tube (CRT). The vacuum tube that shoots the beam of electrons is used to represent the waveform image (Oscilloscope Terminology, 2005). The functioning of this relies on the components of the cathode-ray tube. The CRT includes four plates, an anode or positively charged electrode, focus grid, a cathode ready to heat the cathode or negatively charged electrode and a fluorescent screen. The anode is also known as an electron gun. It supposes to generate the light beam, which can vary in both its sharpness and strength.

Often the waveforms can be in the form of a sine, cosine, square, and triangle wave. The basics needed in order to measure these waves using an oscilloscope includes the usage of the controls for volts per division, the sweep time per division control. The volts per division control, allows waveforms reading to be adjusted to be able to calculate certain amount of volts per line on the grid. This can be any where between 6V all the way to a six thousandth of a volt (6mV), the amount of the wave can be elevated or dropped.

The sweep time per division control lets a waveform calculation be adjusted at the period of the frequency itself (Oscilloscope Terminology, 2005). Often there will be either be a straight waveform or several small waves displayed on the screen.

To appropriately get these amounts, the oscilloscope must be wired in parallel to the electrical components of the circuit. When you wire the leads so that the push of electrons is not divided but the flow of the electrons will separation.

After you’ve made the adjustments you will get a proper waveform and accurate reading measurement (Oscilloscope Terminology, 2005). Depending on the kind of oscilloscope you are using it can measure two or more waveforms at the same time.

On higher end oscilloscopes there are features known as the dual channel, on these models there are other settings called, “Chop mode” or “Alternate mode”. Chop mode, on an oscilloscope will show you the wave with the lowest frequency, by switching between each waveform input.

Alternate mode is better for calculating the higher frequencies. The Chop mode will display both waveforms in most cases, where alternate modes may only display one wave at a time.

You can switch these using another setting known as the “Source mode”. The source mode allows you to choose which channel’s waveform to display on your grid.

Other settings on the oscilloscope, as you will see, will be the positive and negative slope controls. There will also be a button to invert your waves, a trigger, and a vertical adjustment control switch for each channel.

The vertical adjustment control switch, allows you to move the waveform along the Y-axis to any position you want. The trigger allows you to calibrate the waves by using a signal within itself, in order to precisely place the wave. The invert button is used in order to reverse the signals you are receiving from positive to negative or vice-versa.

Using all of these options on the oscilloscope, you can accurately, measure the voltage of an AC source, with a corresponding frequency. You are able to determine whether the waveform is closer to a **DC** (*direct current*) system, or an **AC** (alternate current) system. It is recommended that you use the oscilloscope for mainly AC sources, being that you may use a digital Multi-meter to measure DC constructed circuits.

**\*\*Important Note**: *an oscilloscope will not and should not measure resistance, or current. It is not recommended you try to do so!*

An oscilloscope can be used to hypothetically determine the resistance, and current of a circuit, using the voltage displayed on the waveform. Since you are able to view a waveform, you can calculate the values of Root Mean Square (*RMS*) voltage, Average Voltage, Peak-to-Peak Voltage, and Peak Voltage (*maximum*). Those are values that a Multi-meter cannot give you.

In order to effectively and properly measure current in your circuits, you must first understand how these mechanisms work. The analog Multi-meter may not always provide you with the best accurate results, it will be able to give you measurements. The digital Multi-meter, is very accurate and with the proper usage and handling, you will get measurements that will allow you to check any circuit for voltage, current, and/or resistance. The double channel, or single channel, oscilloscopes are capable of measuring the voltage in accordance with frequency, and will give you a more specific value of an AC circuit.

**Wattmeter**

Another type of advance tools used in electronics and test equipment would be the Wattmeter. The Wattmeter measures electric power, in units of Watts. This meter is used to measure the total amount of electricity used in a residence, by all electronic devices and daily home appliances. This process is most useful in order to calculate the cost of the usage by the energy company.

Many companies like, National Grid and ConEdison use this tool to charge their customers usage. However, this tool is also useful in taking statistics in so that electricity usage can be greatly reduced in the future. Like the Multi-meter, there are two types of Wattmeter: Digital Wattmeter and Analog Wattmeter.

**Question:**

**1.** What unit of measurement for ***Power***?

**2**. What is the main use for the Wattmeter?

**3**. What are two types of Wattmeter?

The Analog Wattmeter is used to show the measurements with a needle and scale indicator. These meters are what is known as electro-dynamic and have three internal coils, two of which provide static current, and the third, which is on a pivot, is a potential coil with an indicator needle connected to it (Scott, 2014). As current flows through these coils, the electromagnetic field generated, forces on the potential coil in order to move in accordance to the value of the electricity.

In order to use and read the analog Wattmeter effectively, you must understand how the dial on the tool works. There are five dials on the analog Wattmeter; The first, third, and fifth dials are all clockwise, whereas the second and fourth are counter-clockwise in rotation.

\***Keep in Mind*-*** *You must try to remember that odd goes clockwise, and the even are counter-clockwise.*

When the needle is in between two numbers, it is essentially read as the smaller number. If the needle is directly pointing to a number, then the number is taken only if the needle pointer on the dial to the right is on or past zero.

The digital Wattmeter is a device that uses a liquid crystal display to show how much electrical energy is being consumed. The digital Wattmeter can include additional features like; coil taps that allow multiple voltages to be read. These meters use a microprocessor to obtain current and voltage values from an electrical circuit at frequencies of many thousands of samples per second (Scott, 2014). With these samples, the meter calculates the average power factor, finally placing the reading on the digital display. Unlike its analog meter, it is relatively easy to read, with its straightforward numerical values placed on a digital screen.

**Question**: *What is the difference if any between a Digital Wattmeter and an Analog Wattmeter?*

Another type of meter that is used, related to the Wattmeter, is a portable version called “**Kill-A-Watt**” or Kilowatt meter. These meters have the same function as the Wattmeter, except it is more for personal and flexible to use (Scott, 2014). The Kilowatt meters are small just like multi-meter but hold the function to measure wattage from devices and even outlets.

To use the meter you must first plug it into the outlet of your choice. Afterwards, plug in the device that you wish to measure wattage from, once that is done, you may press the corresponding buttons to get the appropriate values and you have now measured how much electricity the device consumes.

**Application**: Using the instructions above draw and describe how you would set up to measure the amount of electricity used by an electronic device in your home?

There are some differences between both of these wattage measure devices. Some of the most notable difference are as follows:

**1**. The location of their application; The Wattmeter is usually placed in a location on the side of a household or residential or commercial building. Energy companies mainly use these in order to calculate the cost for the amount of electricity consumed by the building. The Kilowatt meter is a more portable device that can be used by the average consumer and electrician to measure the wattage coming from any small device. The Wattmeter is a device used for more large-scale usages, thus it doesn’t individually tell you how much electricity you would have used with your refrigerator. However, there is another type of meter that can be used to even further benefit the consumer and reduce their electric bill.

The Smart Meter is the latest type of electricity meter. These are made to replace the current Wattmeters, and have no need for any employee from a company to check how much electricity you have used. These meters automatically send the electric consumption readings to the company that supplies your electricity. The additional features they have are in-home displays, and they function as a smart gas meter as well. Another reason why it is considered “smart” is because it can send the data of electric consumption to the consumer a well, through even mobile devices. Using this type of meter can help lower the cost of one’s electric bill, thus it is important that you know how to use it, as more people tend to make the switch.

In order to read the Smart Meter one must be aware of the Power Status Display and Cumulative Electric Usage Display. On the meter it will tell you whether they are being supplied with electricity or not. The two identifiers for this are OPN and CLS ("AEP Texas - How To Read A Smart Meter"). OPN status means that the energy is not being supplied, while CLS means it is. On the other hand, the Cumulative Electric Display shows the cumulative kilowatt-per-hour usage to the current billing period. This is the number used to calculate an electric bill. At the bottom of the meter there is a meter number and device code, which is used to identify ones personal meter.

The three meters used to measure wattage are the Wattmeter, Kilowatt meter and Smart Meter. They are fundamental to electric measurement, and serve a similar purpose to that of the multimeter, ammeter, ohmmeter, and voltmeter (Chavis, 2014). Wattage is defined as a measure of electrical power, and using mainly current and voltage, it is very easy to find out these values theoretically. However, with the help of the Wattmeters, this isn’t necessary, and you are able to figure out the power values for any electronic device. In addition to that, there are always analog and digital variations, but in this case both types prove accurate and appropriate for taking measurements.

As mentioned before, in accordance with the Smart Meters, it measured natural gas as well. However, there is a certain meter used to measure the amount of natural gas used in a home for heating. These are Gas Meters or Natural Gas meters; companies, which provide the natural gas, use the meter for large residences and buildings. Just like the other meters there is a specific way to read this one, in order to appropriate the total usage. On this meter there are four dials, the first and third being counter clockwise, and the second and fourth being counter-clockwise. Just like the Wattmeter, the pointers are read to the smallest and closest number it is directed at.

Another meter used for measurements is the Lux Meter. The Lux meter is used to measure the brightness in an area. It can also be put that it measures the intensity of how the brightness appears to the human eye. It does not however, measure the light energy being used. Lux is the unit of measure for illuminance or brightness, and it stems from the Candela, which is a standard unit of measurement for power of light ("What Is a Lux Meter?"). One lux is equal to one lumen of light that is dispersed across the surface area of a square meter.

This meter works by using a photocell to ascertain the light within the area. By converting the light into electric current, the device is able to calculate the lux value of it and display it as a reading. Although it is used for photography and filmography, it is used for health and safety regulations, these being to check if rooms are bright enough, and even to see if there is a problem with the circuitry for lighting.

In order to use a lux meter one must set the appropriate setting for measuring in lumens on the meter. Then take piece attached to it, called the light sensor, and hold it near the area in which you wish to measure. In order to get an accurate reading the sensor must be held in that location only, and very still. To make sure it doesn’t vary, pressing the hold button on the meter, will keep it at the current value that you see. It is very important that you understand the fact that even being a centimeter off from the first location can drastically change the readings on the meter. Light dispersion varies from place to place, thus the sensor will accurately depict such.

Pertaining to electricians, this is a very valuable meter to have and use. There are often times where there is old circuitry in homes, leading to faulty light fixtures, and inaccurate displays of light for certain light bulbs. Using a light meter can help determine whether there is a problem in the home, and notify the electrician that such needs to be fixed. Therefore, it is important that you remember the fundamental principles when working with the light meter, and think outside the box in order to solve complex or unknown problems. These meters are portable, durable, and very useful in many ways ("What Is a Lux Meter?"). One can use these meters for more than what it may be said it is used for. It all depends on how you use it, and make it become a useful tool for ascertaining problems in a home and with your work.

Now after measuring many units, there is another one to take in consideration, temperature. Temperature is a very important factor; when it comes to all sorts of things, such as materials, power dissipation, and determining the safety of light exposure. The Infrared Thermometer is a screening tool that is used for measure surface temperatures. It usually takes form of an Infrared Gun, which shoots out a laser beam in order to measure the particular surface. Once it obtains the reading, it is displayed on a screen for the user to see in either degrees Celsius or degrees Fahrenheit.

The major concern with using the Infrared Thermometer is its safety because there is a laser beam. When using the device it is imperative that one does not look directly into the laser light. If one were to look directly into the light severe eye damage would occur, and potentially blindness. The laser should never be pointed at other people, into mirrors, and should be kept out of the hands of children. The damage is irreparable, thus it is the first instruction given to the user. In addition to that warning, the light emitted also gives out a degree of radiation that, with enough exposure, can cause certain side effects.

Now when it comes to actually measuring temperature with the Infrared Gun, there are only a few steps to take into consideration. The first step is to properly aim the device at the desired surface area. Afterwards, press the trigger, or any button associated with the device, to obtain the desired measurement. Momentarily the measurement will be displayed on the screen as the desired value.

Other factors to take in consideration when using the device are the requirements for its usage. The Infrared Thermometer Gun cannot measure through transparent surfaces like plastic or glass, but the surface only. The sensor can be affected by steam, dust, smoke, or vapor, that block the optics unit. Proceed with caution that you do not measure reflective surfaces, due to the laser light, and also because the device is not made to measure such types of surfaces. Lastly, the Infrared Thermometer is not made to measure in very humid environments, and that should be taken into consideration.

The Infrared Thermometer is a very useful tool when it comes to safety and efficiency. It can measure mostly all types of surfaces, in both Fahrenheit and Celsius, and uses a highly effective laser light to do so. When exercising the appropriate caution, it can aid in finding problems when it comes to heating, dissipation, and circuitry. With crafty intuition and skill this device can be utilized wisely, and prevent any unsafe conditions from occurring as well as producing the most efficient results with any device or system created. However, all should take in mind the hazards that come with using the device.

The next device you will be instructed on is the Electrometer. The Electrometer is a measuring device for charge, potential difference, or voltage of electricity. However, this device does differ from the voltmeter in that it is used to determine the level of the electromagnetic interactions of subatomic particles, along with voltage. Although it is used for those purposes, they have been modernized to have other functions, a common one being to also record ionizing radiation (Chavis, 2014).

The Electrometer is designed with a vibrating reed, which has a moving electrode, which vibrated in accordance with the fixed electrode. These two pieces successfully create a capacitor, a device that stores electric charge. In contrast to the voltmeter, this device can be created to be extremely small and compact. Another electrometer features a vacuumed tube, which has current flowing through a grid with high levels of input resistance (Chavis, 2014). It is then amplified with an anode circuit, or polarized electrical device. If allows for there to be low amounts of current leakage, but can be damages from salt that can accumulate from the hand of a human. The latest Electrometer has a solid-state amplifier, which magnifies small currents for measurement. With this there can be connections to external devices, which log data and have a display for viewing. It is the most accurate of the Electrometer designs and can measure smaller levels of electric charge.

Now to use the Electrometer is a simple process, much like the voltmeter, ammeter, and multimeter. First the user much make sure that it is set to zero, or change it themselves by using a Mechanical Zero Adjust Screw. Next they must connect the leadoff the input and ground to the Electrometer to the corresponding places. Once this is done, you are now ready to turn the Electrometer on. The range switch LEDs will blink twice in quick succession, indicating that the device is functioning properly. Next press the Zero button on the meter and any charge, current, or voltage can be measured. The range switch must be changed to appropriate the proper measurement; there are basic ranges such as 3, 10, 30 and 100 Volts.

There are many types of meters that are used in order to measure certain things, such as temperature, voltage, current, resistance, charge, natural gas, electricity or power, light, and luminescence. Along with these come basic instructions that all users should follow, without following them the devices are in danger of being used incorrectly and inaccurately. For best results it is highly recommended that you follow all instructions and warnings carefully and use the devices for the proper utility. As discussed there is the Voltmeter, Ohmmeter, Ammeter, Multi-meter, Oscilloscope, Wattmeter, Kilowatt Meter, Lux Meter, Light Meter, Infrared Thermometer, Gas Meter, Smart Meter, and Electrometer. It is wise that you take in consideration all of the instructions placed here for you, as they are for the safety of the user handling them.

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