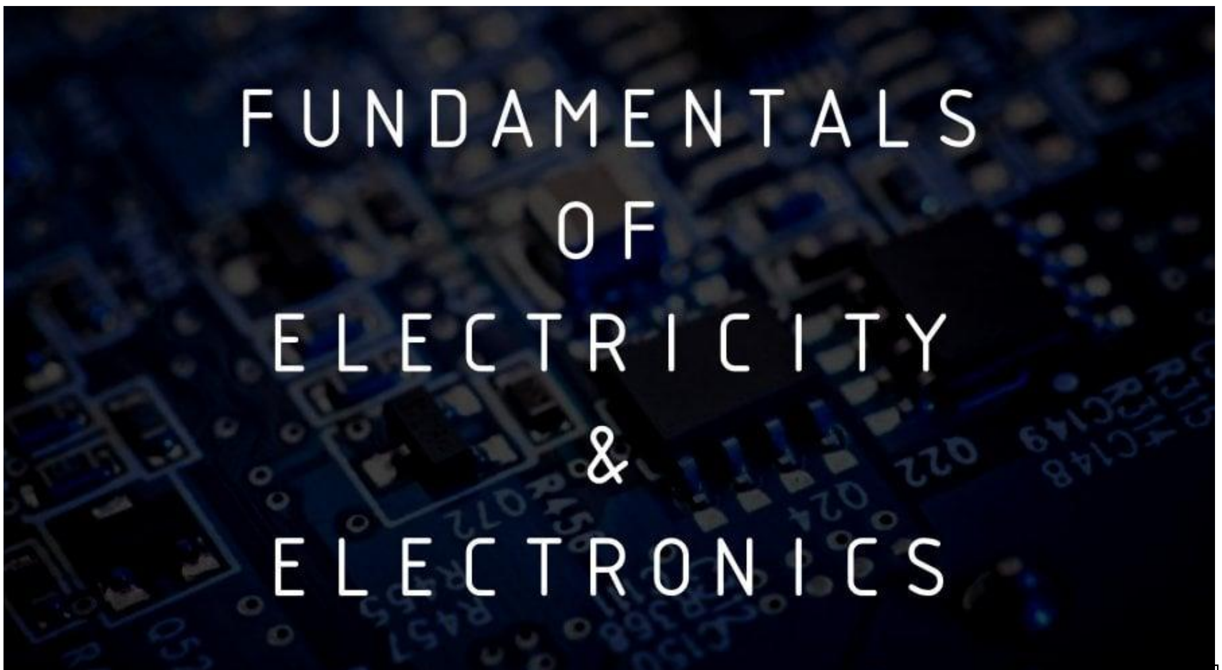

# Competency Based Learning Material




| Module Title: |
| --- |
| **Fundamentals in Electricity and Electronics** |
| Sector: |
| **Electronics** |

**Learning Competencies (ELC724331)**

1. Recognized the Basic Concepts of electricity
2. Learning its role and function.
3. Develop a willingness to explore more about electricity.

**General Instructions in Accomplish the Module:**

1. Activities and Performance Tasks contained in this module are for Enhancement of Learning purposes only. Students can answer them for mastery learning but it is not required to be answered.
2. Answer Assessment only (last page of the module). This is ONLY required to be answered by the students since the scores are to be recorded for the computation of grades. Please detach the page if you are done answering it. You can also attach additional sheet of paper if needed. Then, submit it to the class adviser. Thanks.

**TO OUR DEAR STUDENT**

A BLESSED DAY!

This module contains different instructional materials with activities that will help you in stepping forward to next level.

If you complete with workmanship exposing in constant practice and familiarization of the instruction and theory, this will grant you an excellent mastery of the course that lead you in identifying fundamentals in electricity and electronics.

Please be guided accordingly, you may approach your respective teacher for any question and clarification.

**HOW TO USE THIS MODULE**

Fundamentals in Electricity and electronics module used to build a basic foundation of all devices using electricity as well as its role and function.

In this module, you will read and comprehend all information and complete the learning activities in order to achieve the expected learning Outcome. In each learning outcome are Information Sheets, Self checks, operation sheets and task/job sheets. Perform the activities accordingly. Approach your teacher for any further question and clarification.

Please Note:

1. Read and understand the data information in each section Complete the “what I understand”.

2. Please be guided accordingly in performing of all things on the way.

**Introduction**

This module is designed to develop Knowledge, Skills, attitudes and Passion of learners in accordance with industry standards. Mastery of this will lead you to get the National Certificate level II.

It provides Data information and activities to develop desirable values, skills and understanding by providing concrete information about what electricity and electronics all about.

**INFORMATION 1.1.1**

**ELECTRICAL SAFETY IN WORKPLACE**

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to identify the electrical safety in workplace.(TESDA CODE- 5 00 311108 )
- Align with TCEC;( TLE_IAEPAS9-12TCEC-IIIa-20)

  2.1 Observe safety procedures in using tools and use personal protective equipment.

  2.2 Undertake work safely in accordance with the workplace and standard procedures.


| Sec | Content | Objective |
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| 1 | **Introduction to Electrical Safety** | Participants will be able to:<br><br>• Explain the issues (statistics) associated with poor electrical safety in the workplace.<br>• Recall key electrical terms which are essential to understanding and meeting the requirements of key electrical safety standards; i.e. OSHA 29 CFR 1910.331-.335, NFPA 70E, NEC (NFPA 70)<br>• Define and differentiate between qualified and unqualified persons under OSHA Sub Part S. and the training requirements for each.<br>• Describe the intent of an Electrical Safety Program and list the essential elements of an effective program.<br>• Use a “Status Check” survey to assess the facility’s electrical safety program and where necessary develop strategies for improvement. |
| 2 | **Identifying the Hazards** | Participants will be able to:<br><br>• List types of electrical hazards to personnel and describe the nature of the hazards related to:<br>  ○ Electric shocks, arcs and blasts<br>  ○ Fault current and potential difference<br>  ○ Electrical safety in industrial plants<br>• List the characteristics of an arc flash hazard<br>• List the characteristics of an arc blast hazard<br>• Explain how other injury hazards are related to shock, flash, and blast |
| 3 | **OSHA Requirements** | Participants will be able to:<br><br>• Identify requirements specified in OSHA 29 CFR 1910.301-.308 and NFPA 70E- 2004 Chapter 4 and describe similarities and differences in OSHA and 70E.<br>• Explain how NFPA 70E is used in OSHA compliance and enforcement.<br>• Determine training for workers in accordance with OSHA Sub Part S requirements.<br>• Recall Safe Installation Practices including:<br>  ○ Guarding<br>  ○ Identification<br>  ○ Flexible cords and cables<br>  ○ System grounding<br>  ○ Location of overcurrent protection devices |

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| | | ○ Workspace clearance requirements<br>• Assess an electrical installation for compliance with OSHA regulations.<br>• Explain the reasons for doing a site assessment to determine arc flash hazard potential for equipment and electrical enclosure. |
| 4 | **Safety Related Work Practices** | Participants will be able to:<br><br>• Identify requirements for electrical safe work practices specified in OSHA 29 CFR 1910.331-.335 and NFPA 70E Chapter 1<br>• Define an “Electrically Safe Work Condition” and list specific steps to be taken to ensure an electrically safe work condition.<br>• Explain how the creation of an electrically safe work condition can involve hazards |

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| | | and the methods to protect against them.<br>• Describe the facility’s lockout/tagout (LO/TO) procedure including requirements and activities in the procedure and identify the persons responsible for each activity.<br>• Determine the LO/TO procedure applicable to a given facility, operation, equipment or activity.<br>• Describe other safety related work practices to protect from electrical hazards including:<br>○ Selection and use of work practices<br>○ De-energized work practices<br>○ Energized work practices<br>○ Approach boundaries and approach distances<br>○ Requirements for use of test instruments and equipment<br>○ Requirements for insulated tools<br>○ Other equipment such as ladders, |

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| | | barricades, signs |
| 5 | **Working On or Near Live Parts** | Participants will be able to:<br><br>• Identify persons who may be exposed to a source of electrical energy directly or indirectly.<br>• List the conditions under which “hot work” is allowed.<br>• Describe the purposes of an energized electrical work permit.<br>• Recall three types of approach boundaries and define the dimensions of each approach boundary, given all necessary information.<br>• Describe the essential parts of a Flash Hazard Analysis and list the data required analysis.<br>• List the information, including Hazard Risk Category, provided to a worker by a Flash Hazard Analysis and describe its use. |
| 6 | **Personal Protective Equipment (PPE)** | Participants will be able to:<br><br>• List the basic types of personal protective equipment (PPE) for tasks involving electrical hazards.<br>• Describe how each type protects against hazards and identify the limitations of PPE.<br>• Explain the need for flame resistant (FR) clothing and layering of clothing for protection and list clothing prohibited where electrical hazards are present.<br>• Select PPE for a given Hazard Risk Category including gloves, eye, head, face protection and (FR) clothing. |

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| | | • Describe the requirements for use, care, maintenance and storage of PPE. |
| 7 | **Action Planning and Course Wrap-up** | Participants will be able to:<br><br>• Outline an Action Plan to achieve compliance with OSHA Subpart S and NFPA 70E.<br>• Provide assistance to help achieve workplace goals of OSHA Subpart S and NFPA 70E compliance. |

## HISTORY OF ELECTRICITY

600BC: Static electricity

Thales, a Greek, found that when amber was rubbed with silk it attracted feathers and other light objects. He had discovered static electricity. The Greek word for amber is elektron', from which we get electricity' and electronics'.

1600: William Gilbert invented the term electricity

William Gilbert, scientist and physician to Queen Elizabeth I, coined the term electricity. He was the first person to describe the earth's magnetic field and to realize that there is a relationship between magnetism and electricity.

1752: Franklin proved that lightning is a form of electricity

Benjamin Franklin, famous U.S. politician, flew a kite with a metal tip into a thunderstorm to prove that lightning is a form of electricity.

1820: Hans Christian Oersted discovered magnetic fields caused by electricity Hans Christian Oersted of Denmark found that when electricity flows through a wire, it produces a magnetic field that affects the needle of a nearby compass.

1821: Michael Faraday's discovery that led to the invention of electric motors

Michael Faraday discovered that when a magnet is moved inside a coil of copper wire, a tiny electric current flows through the wire. This discovery later led to the invention of electric motors.

1826: André Ampère explained the electro-dynamic theory

André Ampère published his theories about electricity and magnetism. He was the first person to explain the electro-dynamic theory. The unit of electric current was named after Ampère.

1827: Georg Ohm published his complete mathematical theory of electricity

German college teacher Georg Ohm published his complete mathematical theory of electricity. The unit of electrical resistance was later named after him.

1831: The First Telegraph Machine

Charles Wheatstone and William Fothergill Cooke created the first telegraph machine.

1838: Samuel Morse invented Morse Code

At an exhibition in NewYork, Samuel Morse demonstrated sending 10 words a minute by his new telegraph machine. He used a system of dots and dashes, which later became standard throughout the world, known as Morse code.

1870s: Thomas Edison built a DC electric generator

Thomas Edison built a DC (direct current) electric generator in America. He later provided all of New York's electricity.

1876: Alexander Graham Bell invented the telephone

Alexander Graham Bell, inventor of the telephone, used electricity to transmit speech for the first time.

1878: Joseph Swan demonstrated the first Electric Light

Thomas Edison demonstrated the first electric light with a carbon filament lamp.

1879:

First fatal accident due to electric shock.

1800's: Nicola Tesla devised the AC (Alternating Current) system for electrical transmission that is used in homes, businesses and industry today. He also invented the motors that run on AC and designed the world's first Hydroelectric Plant (in Niagara Falls, NY).

1895: The first electric hand drill

The first electric hand drill became available, invented by Wilhelm Fein.

1918-19: Washing machines and refrigerators electric washing machines and refrigerators first became available.

1926: First National Grid was introduced electricity Supply Act - the first National Grid was introduced.

1930-40s: Electrical household appliances introduced mains powered radios, vacuum cleaners, irons and refrigerators were becoming part of every household.

1936: John Logie Baird pioneered the television.

<u>**Hazards Associated With Electricity**</u>

Electricity is widely recognized as a serious workplace hazard, exposing employees to electric shock, burns, fires, and explosions. According to the Bureau of Labor Statistics, 250 employees were killed by contact with electric current in 2006. Other employees have been killed or injured in fires and explosions caused by electricity.

It is well known that the human body will conduct electricity. If direct body contact is made with an electrically energized part while a similar contact is made simultaneously with another conductive surface that is maintained at a different electrical potential, a current will flow, entering the body at one contact point, traversing the body, and then exiting at the other contact point, usually the ground. Each year many employees suffer pain, injuries, and death from such electric shocks.

Current through the body, even at levels as low as 3 milliamperes, can also cause injuries of an indirect or secondary injuries in which involuntary muscular reaction from the electric shock can cause bruises, bone fractures and even death resulting from collisions or falls.

Burns suffered in electrical accidents can be very serious. These burns may be of three basic types: electrical burns, arc burns, and thermal contact burns. Electrical burns are the result of the electric current flowing in the tissues, and may be either skin deep or may affect deeper layers (such as muscles and bones) or both. Tissue damage is caused by the heat generated from the current flow; if the energy delivered by the electric shock is high, the body cannot dissipate the heat, and the tissue is burned. Typically, such electrical burns are slow to heal. Arc burns are the result of high temperatures produced by electric arcs or by explosions close to the body. Finally, thermal contact burns are those normally experienced from the skin contacting hot surfaces of overheated electric conductors, conduits, or other energized equipment. In some circumstances, all three types of burns may be produced simultaneously.

If the current involved is great enough, electric arcs can start a fire. Fires can also be created by overheating equipment or by conductors carrying too much current. Extremely high- energy arcs can damage equipment, causing fragmented metal to fly in all directions. In atmospheres that contain explosive gases or vapors or combustible dusts, even low-energy arcs can cause violent explosions.

# Information Sheet 5.1-1

# (Tools: Function, Operation)

Learning Objectives:

After reading this INFORMATION SHEET, YOU MUST be able to: ( ELC724202)

1. Identify hand tools and its operations and functions.
2. Identify four types of Hardware tools
3. Align with TCEC; ( TLE_IAEPAS9-12TCEC-IIIa-20)

    2.1 Observe safety procedures in using tools and use personal protective equipment.

    2.2 Undertake work safely in accordance with the workplace and standard procedures.

**Hardware Tools**

To complete hardware repairs, it is important to have a toolkit that should contain all of the necessary tools. As you gain experience, you will learn which tools to have available for different types of jobs. Hardware tools are grouped into these four categories:

- Electro-Static Discharge (ESD) tools
- Hand tools
- Cleaning tools
- Diagnostic tool

**Electro-Static Discharge (ESD**)

Tools Static electricity is easily generated by friction on carpets, tile flooring, clothing, hair, fabric, and etc. The friction of moving air alone will charge suspended particles and cause the buildup of static electrical charges on people and objects in the environment. Grounded antistatic work mats used with antistatic wrist straps provide the most basic means for the controlled discharge of electrostatic electricity. Examples of ESD Tools:

Anti-static wrist strap – used to prevent ESD damage to computer equipment

Anti-static mat – used to stand on or place hardware on to prevent static electricity from building up.

**Hand Tools**

Hand Tools - A hand tool is a device for performing work on a material or a physical system using only hands. The hand tools can be manually used employing force, or electrically powered, using electrical current. Examples of Hand Tools:

Flat head screwdriver – used to loosen or tighten slotted screws.

Philip’s head screwdriver – used to loosen or tighten crosshead screws.

Torx screwdriver - used to loosen or tighten screws that have a star-like depression on the top, a feature that is mainly found on laptop.

Hex driver – sometimes called a nut driver, is used to tighten nuts in the same way that a screwdriver tightens screws.

**Computer Systems Servicing: Intermediate**

Needle-nose plier – used to hold small parts.

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Wire cutter – used to strip and cut wires

Tweezers – used to manipulate small parts.

Part retriever- used to retrieve parts from location that are toosmall for your hand to fit.

Flashlight – used to light up areas that you cannot see well.

## Cleaning Tools

Having the appropriate cleaning tools is essential when maintaining or repairing computers. Using these tools ensures that computer components are not damaged during cleaning. Examples:

Lint-free cloth – used to clean different computer components without scratching or leaving debris.

Compressed air – used to blow away dust and debris from different computer parts without touching the components.

Parts organizer – used to hold screw,jumpers, fasteners and other small parts and prevents them from getting mixed together.

Diagnostic Tools

Computers are easier to use and more dependable with each new generation of hardware and operating system update, but that doesn't mean they're problemfree. Here are the most popular tools for diagnosing your computer problems:

Multimeter – used to test the integrity of circuits and the quality of electricity in computer components.

Loopback Adapter – used to test the functionality of computer ports.

## Self-check: 1.1.2

## (Tools: Function, Operation)

**Direction: Identify the tool being described in the following items.**

**1. Used to stand on or place hardware on to prevent static electricity from building up.**

**2. It is a type of hand tool that is used to loosen or tighten screws that have a star-like depression on the top, a feature that is mainly found on laptop.**

**3. This type of tool is used to strip and cut wires.**

**4. Used to hold screw, jumpers, fasteners and other small parts and prevents them from getting mixed together.**

**5. A diagnostic tool that is used to test the integrity of circuits and the quality of electricity in computer components.**

**6. Used to clean different computer components without scratching or leaving debris.**

**7.**

**INFORMATION SHEET 1.2.1**

**BASIC CONCEPT OF ELECTRICITY**

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to identify the basic concept of electricity. ( ELC724202)
- Align with TSEC, Check wiring and circuits using specified testing procedures. (TLE_IAEPAS9-12TCEC-IIId-e-2)

**DIRECT CURRENT**

Modern life could not exist if it were not for electricity and electronics. The history of electricity starts more than two thousand years ago, with the Greek philosopher Thales being the earliest known researcher into electricity. But it was Alessandro Volta who created the most common DC power source, the battery (for this invention the unit Volt was named after him).

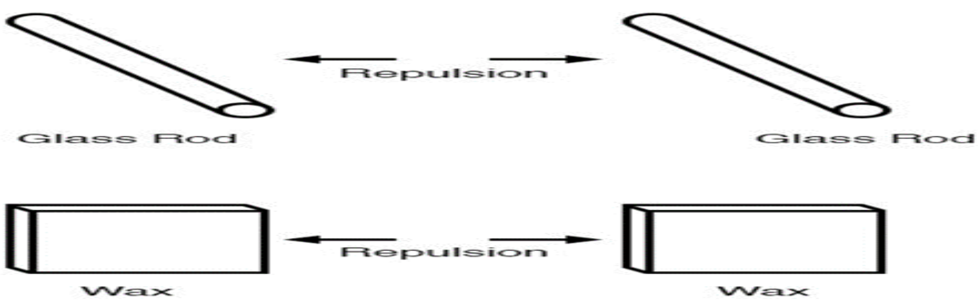
Direct current (also known as DC) is the flow of charged particles in one unchanging direction (most commonly found as electron flow through conductive materials). DC can be found in just about every home and electronic device, as it is more practical (compared to AC from power stations) for many consumer devices. Just a few of the places where you can find direct current are batteries, phones, computers, cars, TVs, calculators, and even lightning

STATIC ELECTRICITY

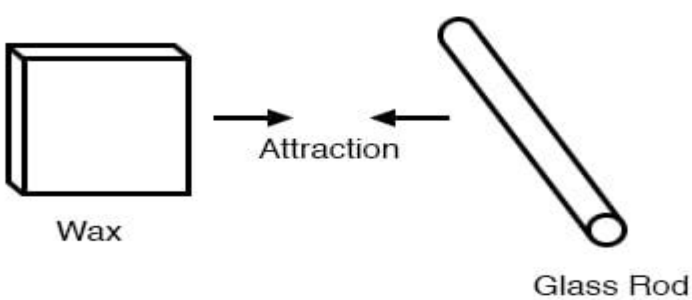
It was discovered centuries ago that certain types of materials would mysteriously attract one another after being rubbed together. For example, after rubbing a piece of silk against a piece of glass, the silk and glass would tend to stick together. Indeed, there was an attractive force that could be demonstrated even when the two materials were separated:


Glass and silk aren't the only materials known to behave like this. Anyone who has ever brushed up against a latex balloon only to find that it tries to stick to them has experienced this same phenomenon. Paraffin wax and wool cloth are another pair of materials early experimenters recognized as manifesting attractive forces after being rubbed together:


This phenomenon became even more interesting when it was discovered that identical materials, after having been rubbed with their respective cloths, always repelled each other:

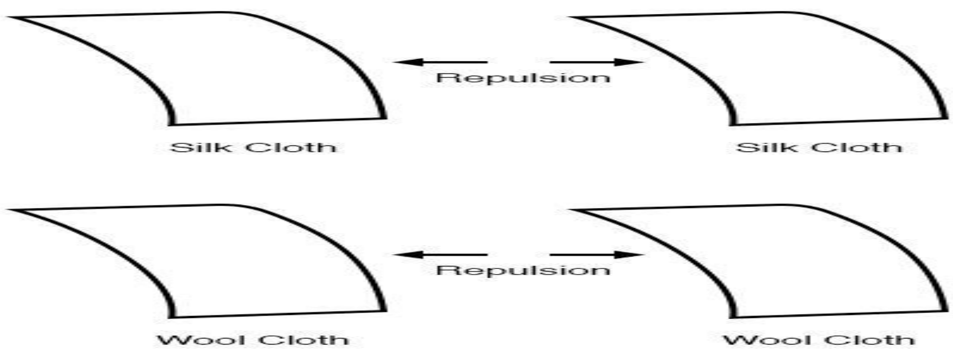



It was also noted that when a piece of glass rubbed with silk was exposed to a piece of wax rubbed with wool, the two materials would attract one another:




Furthermore, it was found that any material demonstrating properties of attraction or repulsion after being rubbed could be classed into one of two distinct categories: attracted to glass and repelled by wax, or repelled by glass and attracted to wax. It was either one or the other: there were no materials found that would be attracted to or repelled by both glass and wax, or that reacted to one without reacting to the other.

More attention was directed toward the pieces of cloth used to do the rubbing. It was discovered that after rubbing two pieces of glass with two pieces of silk cloth, not only did the glass pieces repel each other but so did the cloths. The same phenomenon held for the pieces of wool used to rub the wax:




Now, this was really strange to witness. After all, none of these objects were visibly altered by the rubbing, yet they definitely behaved differently than before they were rubbed. Whatever change took place to make these materials attract or repel one another was invisible.

Charles Dufay was one of the early experimenters who demonstrated that there were definitely two different types of changes wrought by rubbing certain pairs of objects together. The fact that there was more than one type of change manifested in these materials was evident by the fact that there were two types of forces produced: attraction and repulsion. The hypothetical fluid transfer became known as a charge.

One pioneering researcher, Benjamin Franklin, came to the conclusion that there was only one fluid exchanged between rubbed objects, and that the two different “charges” were nothing more than either an excess or a deficiency of that one fluid. After experimenting with wax and wool, Franklin suggested that the coarse wool removed some of this invisible fluid from the smooth wax, causing an excess of fluid on the wool and a deficiency of fluid on the wax. The resulting disparity in fluid content between the wool and wax would then cause an attractive force, as the fluid tried to regain its former balance between the two materials.

Postulating the existence of a single “fluid” that was either gained or lost through rubbing accounted best for the observed behavior: that all these materials fell neatly into one of two categories when rubbed, and most importantly, that the two active materials rubbed against each other always fell into opposing categories as evidenced by their invariable attraction to one another. In other words, there was never a time where two materials rubbed against each other both became either positive or negative.

Following Franklin's speculation of the wool rubbing something off of the wax, the type of charge that was associated with rubbed wax became known as "negative" (because it was supposed to have a deficiency of fluid) while the type of charge associated with the rubbing wool became known as "positive" (because it was supposed to have an excess of fluid). Little did he know that his innocent conjecture would cause much confusion for students of electricity in the future!

Precise measurements of electrical charge were carried out by the French physicist Charles Coulomb in the 1780s using a device called a torsional balance measuring the force generated between two electrically charged objects. The results of Coulomb's work led to the development of a unit of electrical charge named in his honor, the coulomb. If two "point" objects (hypothetical objects having no appreciable surface area) were equally charged to a measure of 1 coulomb, and placed 1 meter (approximately 1 yard) apart, they would generate a force of about 9 billion newtons (approximately 2 billion pounds), either attracting or repelling depending on the types of charges involved. The operational definition of a coulomb as the unit of electrical charge (in terms of force generated between point charges) was found to be equal to an excess or deficiency of about 6,250,000,000,000,000,000 electrons. Or, stated in reverse terms, one electron has a charge of about 0.00000000000000000016 coulombs. Being that one electron is the smallest known carrier of electric charge, this last figure of charge for the electron is defined as the elementary charge.

It was discovered much later that this "fluid" was actually composed of extremely small bits of matter called electrons, so named in honor of the ancient Greek word for amber: another material exhibiting charged properties when rubbed with cloth

**<u>WHAT IS STATIC ELECTRICITY?</u>**

The result of an imbalance of this "fluid" (electrons) between objects is called static electricity. It is called "static" because the displaced electrons tend to remain stationary after being moved from one insulating material to another. In the case of wax and wool, it was determined through further experimentation that electrons in the wool actually transferred to the atoms in the wax, which is exactly opposite of Franklin's conjecture! In honor of Franklin's designation of the wax's charge being "negative" and the wool's charge being "positive," electrons are said to have a "negative" charging influence. Thus, an object whose atoms have received a surplus of electrons is said to be negatively charged, while an object whose atoms are lacking electrons is said to be positively charged, as confusing as these designations may seem. By the time the true nature of electric “fluid” was discovered, Franklin’s nomenclature of electric charge was too well established to be easily changed, and so it remains to this day.

Michael Faraday proved (1832) that static electricity was the same as that produced by a battery or a generator. Static electricity is, for the most part, a nuisance. Black powder and smokeless powder have graphite added to prevent ignition due to static electricity. It causes damage to sensitive semiconductor circuitry. While it is possible to produce motors powered by high voltage and low current characteristics of static electricity, this is not economic. The few practical applications of static electricity include xerographic printing, the electrostatic air filter, and the high voltage Van de Graaff generator.

**CONDUCTORS ,INSULATORS, AND ELECTRON FLOW**

The electrons of different types of atoms have different degrees of freedom to move around. With some types of materials, such as metals, the outermost electrons in the atoms are so loosely bound that they chaotically move in the space between the atoms of that material by nothing more than the influence of room-temperature heat energy. Because these virtually unbound electrons are free to leave their respective atoms and float around in the space between adjacent atoms, they are often called free electrons.

CONDUCTORS AND INSULATOR

In other types of materials such as glass, the atoms’ electrons have very little freedom to move around. While external forces such as physical rubbing can force some of these electrons to leave their respective atoms and transfer to the atoms of another material, they do not move between atoms within that material very easily.

This relative mobility of electrons within a material is known as electric conductivity. Conductivity is determined by the types of atoms in a material (the number of protons in each atom’s nucleus determines its chemical identity) and how the atoms are linked together with one another. Materials with high electron mobility (many free electrons) are called conductors, while materials with low electron mobility (few or no free electrons) are called insulators. Here are a few common examples of conductors and insulators:

| Conductors | Insulators |
|---|---|
| silver | glass |
| copper | rubber |
| gold | oil |
| aluminum | asphalt |
| iron | fiberglass |
| steel | porcelain |
| brass | ceramic |
| bronze | quartz |
| mercury | (dry) cotton |
| graphite | (dry) paper |
| dirty water | (dry) wood |
| concrete | plastic |
| | air |
| | diamond |
| | pure water |

It must be understood that not all conductive materials have the same level of conductivity, and not all insulators are equally resistant to electron motion. Electrical conductivity is analogous to the transparency of certain materials to light: materials that easily “conduct” light are called “transparent,” while those that don’t are called “opaque.” However, not all transparent materials are equally conductive to light. Window glass is better than most plastics, and certainly better than “clear” fiberglass. So it is with electrical conductors, some being better than others.

For instance, silver is the best conductor in the “conductors” list, offering easier passage for electrons than any other material cited. Dirty water and concrete are also listed as conductors, but these materials are substantially less conductive than any metal.

It should also be understood that some materials experience changes in their electrical properties under different conditions. Glass, for instance, is a very good insulator at room temperature but becomes a conductor when heated to a very high temperature. Gases such as air, normally insulating materials, also become conductive if heated to very high temperatures. Most metals become poorer conductors when heated, and better conductors when cooled. Many conductive materials become perfectly conductive (this is called superconductivity) at extremely low temperatures.

SELF CHECK 1.2.1

BASIC CONCEPT OF ELECTRICITY

DIRECTION: FILL IN THE BLANKS

1. ________________ is the flow of charged particles in one unchanging direction (most commonly found as electron flow through conductive materials).

2. ________________was one of the early experimenters who demonstrated that there were definitely two different types of changes wrought by rubbing certain pairs of objects together.

3. The result of an imbalance of this “fluid” (electrons) between objects is called __________.

4. While the normal motion of “_____” electrons in a conductor is random, with no particular direction or speed, electrons can be influenced to move in a coordinated fashion through a conductive material.

5. A relative mobility of electrons within a material is known as ________.

INFORMATION SHEET 1.3.1

ELECTRICAL CONTINUITY AND ELECTRIC CIRCUITS

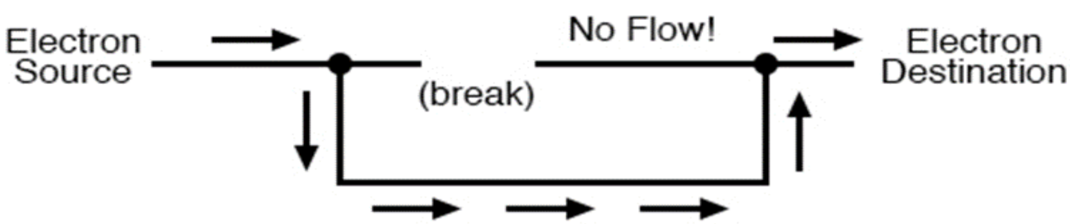
**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to identify the electrical continuity and electric Circuits. ( ELC724202)
- Align with TSEC, Check wiring and circuits using specified testing procedures. (TLE_IAEPAS9-12TCEC-IIId-e-2)

**ELECTRICAL CONTINUITY**

Since air is an insulating material, and an air gap separates the two pieces of wire, the once-continuous path has now been broken, and electrons cannot flow from Source to Destination. This is like cutting a water pipe in two and capping off the broken ends of the pipe: water can't flow if there's no exit out of the pipe. In electrical terms, we had a condition of electrical continuity when the wire was in one piece, and now that continuity is broken with the wire cut and separated.

If we were to take another piece of wire leading to the Destination and simply make physical contact with the wire leading to the Source, we would once again have a continuous path for electrons to flow. The two dots in the diagram indicate physical (metal-to-metal) contact between the wire pieces:



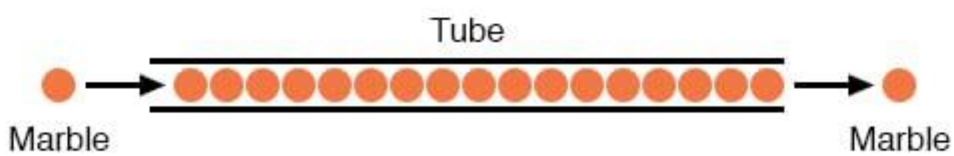

Now, we have continuity from the Source, to the newly-made connection, down, to the right, and up to the Destination. This is analogous to putting a "tee" fitting in one of the capped-off pipes and directing water through a new segment of pipe to its destination. Please take note that the broken segment of wire on the right-hand side has no electrons flowing through it because it is no longer part of a complete path from Source to Destination.

It is interesting to note that no "wear" occurs within wires due to this electric current, unlike water-carrying pipes which are eventually corroded and worn by prolonged flows. Electrons do encounter some degree of friction as they move, however, and this friction can generate heat in a conductor. This is a topic we'll explore in much greater detail later.

**ELECTRON FLOW / ELECTRIC CURRENT**

While the normal motion of "free" electrons in a conductor is random, with no particular direction or speed, electrons can be influenced to move in a coordinated fashion through a conductive material. This uniform motion of electrons is what we call electricity or electric current. To be more precise, it could be called dynamic electricity in contrast to static electricity, which is an unmoving accumulation of electric charge. Just like water flowing through the emptiness of a pipe, electrons are able to move within the empty space within and between the atoms of a conductor. The conductor may appear to be solid to our eyes, but any material composed of atoms is mostly empty space! The liquid-flow analogy is so fitting that the motion of electrons through a conductor is often referred to as a "flow."

A noteworthy observation may be made here. As each electron moves uniformly through a conductor, it pushes on the one ahead of it, such that all the electrons move together as a group. The starting and stopping of electron flow through the length of a conductive path is virtually instantaneous from one end of a conductor to the other, even though the motion of each electron may be very slow. An approximate analogy is that of a tube filled end-to-end with marbles



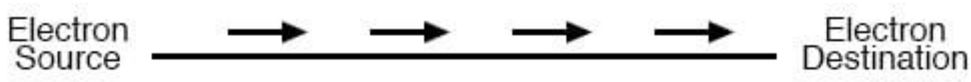

The tube is full of marbles, just as a conductor is full of free electrons ready to be moved by an outside influence. If a single marble is suddenly inserted into this full tube on the left-hand side, another marble will immediately try to exit the tube on the right. Even though each marble only traveled a short distance, the transfer of motion through the tube is virtually instantaneous from the left end to the right end, no matter how long the tube is. With electricity, the overall effect from one end of a conductor to the other happens at the speed of light: a swift 186,000 miles per second!!! Each individual electron, though, travels through the conductor at a much slower pace.

**ELECTRON FLOW THROUGH WIRE**

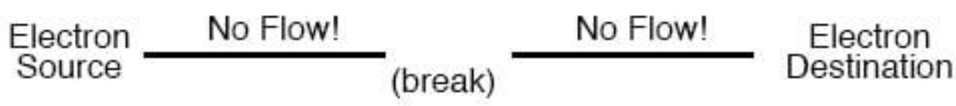
If we want electrons to flow in a certain direction to a certain place, we must provide the proper path for them to move, just as a plumber must install piping to get water to flow where he or she wants it to flow. To facilitate this, wires are made of highly conductive metals such as copper or aluminum in a wide variety of sizes.

Remember that electrons can flow only when they have the opportunity to move in the space between the atoms of a material. This means that there can be electric current only where there exists a continuous path of conductive material providing a conduit for electrons to travel through. In the marble analogy, marbles can flow into the left-hand side of the tube (and, consequently, through the tube) if and only if the tube is open on the right-hand side for marbles to flow out. If the tube is blocked on the right-hand side, the marbles will just “pile up” inside the tube, and marble “flow” will not occur. The same holds true for electric current: the continuous flow of electrons requires there be an unbroken path to permit that flow. Let’s look at a diagram to illustrate how this works:

A thin, solid line (as shown above) is the conventional symbol for a continuous piece of wire. Since the wire is made of a conductive material, such as copper, its constituent atoms have many free electrons which can easily move through the wire. However, there will never be a continuous or uniform flow of electrons within this wire unless they have a place to come from and a place to go. Let’s add a hypothetical electron “Source” and “Destination:”




Now, with the Electron Source pushing new electrons into the wire on the left-hand side, electron flow through the wire can occur (as indicated by the arrows pointing from left to right). However, the flow will be interrupted if the conductive path formed by the wire is broken:



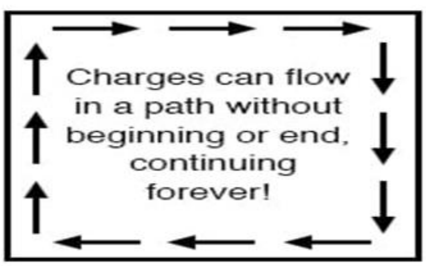
INFORMATION 1.3.2
ELECTRIC CIRCUITS

ELECTRIC CIRCUITS

You might have been wondering how charges can continuously flow in a uniform direction through wires without the benefit of these hypothetical Sources and Destinations. In order for the Source-and-Destination scheme to work, both would have to have an infinite capacity for charges in order to sustain a continuous flow!
Using the marble-and-tube analogy from the previous page on conductors, insulators, and electron flow, the marble source and marble destination buckets would have to be infinitely large to contain enough marble capacity for a “flow” of marbles to be sustained.

WHAT IS CIRCUIT

The answer to this paradox is found in the concept of a circuit: a never-ending looped pathway for charge carriers. If we take a wire, or many wires, joined end-to-end, and loop it around so that it forms a continuous pathway, we have the means to support a uniform flow of charge without having to resort to infinite Sources and Destinations:

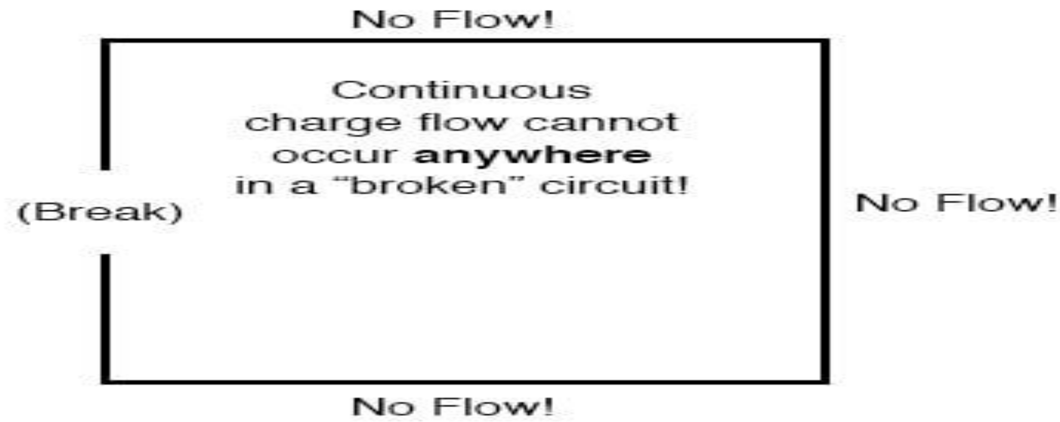




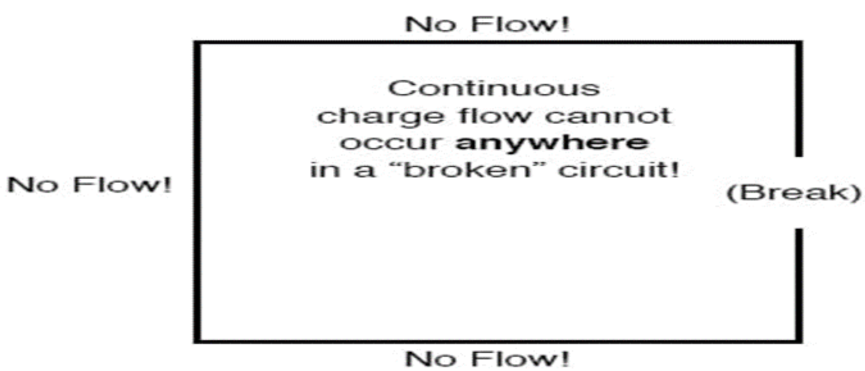
Each charge carrier advancing clockwise in this circuit pushes on the one in front of it, which pushes on the one in front of it, and so on, and so on, just like a hula-hoop filled with marbles. Now, we have the capability of supporting a continuous flow of charge indefinitely without the need for infinite supplies and dumps. All we need to maintain this flow is a continuous means of motivation for those charge carriers, which we’ll address in the next section of this chapter on voltage and current.

WHAT DOES IT MEAN IF THE CIRCUIT IS BROKEN

Continuity is just as important in a circuit as it is in a straight piece of wire. Just as in the example with the straight piece of wire between the Source and Destination, any break in this circuit will prevent charge from flowing through it




An important principle to realize here is that it doesn’t matter where the break occurs. **Any discontinuity in the circuit will prevent charge flow throughout the entire circuit.** Unless there is a continuous, unbroken loop of conductive material for charge carriers to flow through, a sustained flow simply cannot be maintained.



SELF CHECK 1.3.1-2

ELECTRICAL CONTINUITY AND CIRCUITS

TRUE OR FALSE

DIRECTION: WRITE TRUE IF THE STATEMENT IS TRUE AND WITE FALSE IF THE STATEMENT IS FALSE.

1. Once-continuous path has now been broken, and electrons can flow from Source to Destination.
2. If the continuous path is broken, put another piece of wire serve as conductor to make the electrons flow.
3. In order for the Source-and-Destination scheme to work, both would have to have an infinite capacity for charges in order to sustain a continuous flow.
4. Any discontinuity in the circuit will prevent charge flow throughout the entire circuit.
5. Electrons do encounter some degree of friction as they move, however, and this friction can generate heat in a conductor.

INFORMATION SHEET 1.4.1

VOLTAGE

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to identify the voltage. ( ELC724202)
- Align with TSEC, Check wiring and circuits using specified testing procedures. (TLE_IAEPAS9-12TCEC-IIId-e-2)

WHAT IS VOLTAGE?

Voltage (also known as electric potential difference, electromotive force emf, electric pressure, or electric tension) is defined as the electric potential difference per unit charge between two points in an electric field. Voltage is expressed mathematically (i.e. in formulas) using the symbol “V” or “E”.

Otherwise, we’ll continue below with a more formal definition of voltage.

In a static electric field, the work required to move per unit of charge between two points is known as voltage. Mathematically, the voltage can be expressed as,

VOLTAGE(V)=Work Done (W) /Charge (Q)

Where work done is in joules and charge is in coulombs.

Thus Voltage (V)= Joule / Coulomb

We can define voltage as the amount of potential energy between two points in a circuit.

One point has a higher potential and the other points have lower potential. The difference in charge between higher potential and lower potential is called a voltage or potential difference.

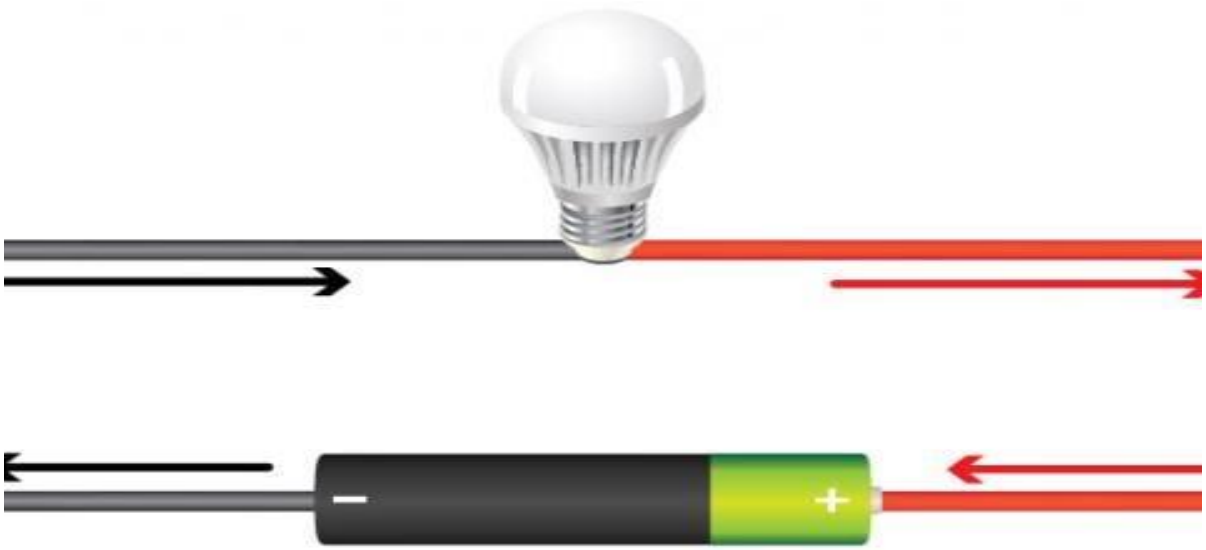
The voltage or potential difference gives the force to the electrons to flow through the circuit.

The higher the voltage, the greater the force, and hence the more electrons flowing through the circuit. Without voltage or potential difference, electrons would move randomly in free space.

Voltage is also sometimes referred to as “electric tension”. For example, the voltage handling capacity of cables such as 1 kV, 11 kV, and 33 kV are referred to as low tension, high tension, and super tension cables respectively.

In brief, voltage = pressure, and it is measured in volts (V). The term recognizes Italian physicist Alessandro Volta (1745-1827), inventor of the voltaic pile—the forerunner of today's household battery.

In electricity's early days, voltage was known as electromotive force (emf). This is why in equations such as Ohm's Law, voltage is represented by the symbol E.

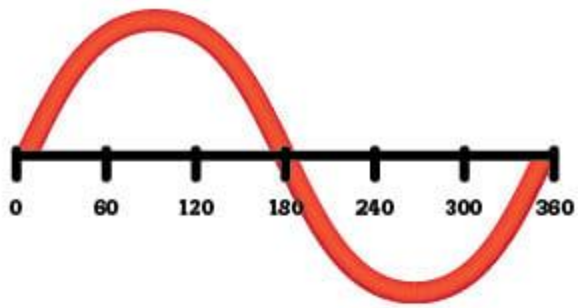


1. In this dc circuit, the switch is closed (turned ON).
2. Voltage in the power source—the "potential difference" between the battery's two poles—is activated, creating pressure that forces electrons to flow as current out the battery's negative terminal.
3. Current reaches the light, causing it to glow.
4. Current returns to the power source.

Voltage is either alternating current (ac) voltage or direct current (dc) voltage. Ways they differ:

Alternating current voltage (represented on a digital multimeter by):

Flows in evenly undulating since waves, as shown below:




- Reverses direction at regular intervals.
- Commonly produced by utilities via generators, where mechanical energy—rotating motion powered by flowing water, steam, wind or heat—is converted to electrical energy.
- More common than dc voltage. Utilities deliver ac voltage to homes and businesses where the majority of devices use ac voltage.
- Primary voltage supplies vary by nation. In the United States, for example, it's 120 volts.
- Some household devices, such as TVs and computers, utilize dc voltage power. They use rectifiers (such as that chunky block in a laptop computer's cord) to convert ac voltage and current to dc.

What is potential difference?

Voltage and the term "potential difference" are often used interchangeably. Potential difference might be better defined as the potential energy difference between two points in a circuit. The amount of difference (expressed in volts) determines how much potential energy exists to move electrons from one specific point to another. The quantity identifies how much work, potentially, can be done through the circuit.

A household AA alkaline battery, for example, offers 1.5 V. Typical household electrical outlets offer 120 V. The greater the voltage in a circuit, the greater its ability to "push" more electrons and do work.

Voltage/potential difference can be compared to water stored in a tank. The larger the tank, and the greater its height (and thus its potential velocity), the greater the water's capacity to create an impact when a valve is opened and the water (like electrons) can flow.

Why measuring voltage is useful

Technicians approach most troubleshooting situations knowing how a circuit should customarily perform.

Circuits are used to deliver energy to a load—from a small device to a household appliance to an industrial motor. Loads often carry a nameplate that identifies their standard electrical reference values, including voltage and current. In place of a nameplate, some manufacturers provide a detailed schematic (technical diagram) of a load's circuitry. Manuals may include standard values.

These numbers tell a technician what readings to expect when a load is operating normally. A reading on a digital multimeter can objectively identify deviations from the norm. Even so, the technician must use knowledge and experience to determine the factors causing such variances.

SELF CHECK 1.4.1

VOLTAGE

FILL IN THE BLANKS

1. __________also known as electric potential difference, electromotive force emf, electric pressure, or electric tension) is defined as the electric potential difference per unit charge between two points in an electric field.
2. We can define voltage as the amount of _________ between two points in a circuit.
3. Without voltage or potential difference, electrons would move ______ in free space.
4. ___________Is the inventor of the voltaic pile—the forerunner of today's household battery.
5. Commonly produced by utilities via generators, where mechanical energy—rotating motion powered by flowing water, steam, wind or heat—is converted to _____________.

**INFORMATION SHEET 1.5.1**

**ELECTRIC CURRENT**

**Learning Objective:**

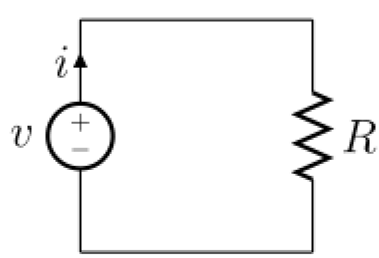
- After reading this INFORMATION SHEET, YOU MUST be able to identify the electric current. ( ELC724202)
- Align with TSEC, Check wiring and circuits using specified testing procedures. (TLE_IAEPAS9-12TCEC-IIId-e-2)

What is Electric Current?

An electric current is a flow of charged particles, such as electrons or ions, moving through an electrical conductor or space. It is defined as the net rate of flow of electric charge through a surface. The moving particles are called charge carriers, which may be one of several types of particles, depending on the conductor. In electric circuits the charge carriers are often electrons moving through a wire. In semiconductors they can be electrons or holes. In an electrolyte the charge carriers are ions, while in plasma, an ionized gas, they are ions and electrons.

The SI unit of electric current is the ampere, or amp, which is the flow of electric charge across a surface at the rate of one coulomb per second. The ampere (symbol: A) is an SI base unit. Electric current is measured using a device called an ammeter.

Electric currents create magnetic fields, which are used in motors, generators, inductors, and transformers. In ordinary conductors, they cause Joule heating, which creates light in incandescent light bulbs. Time-varying currents emit electromagnetic waves, which are used in telecommunications to broadcast information.



| | |
|---|---|
| A simple electric circuit, where current is represented by the letter *i*. The relationship between the voltage (V), resistance (R), and current (I) is V=IR; this is known as Ohm's law. | |
| **Common symbols** | *I* |
| **SI unit** | ampere |
| **Derivations from other quantities** | |

CONVENTIONS

The electrons, the charge carriers in an electrical circuit, flow in the opposite direction of the conventional electric current.

**The symbol for a battery in a circuit diagram.**

The conventional direction of current, also known as conventional current, is arbitrarily defined as the direction in which positive charges flow. In a conductive material, the moving charged particles that constitute the electric current are called charge carriers. In metals, which make up the wires and other conductors in most electrical circuits, the positively charged atomic nuclei of the atoms are held in a fixed position, and the negatively charged electrons are the charge carriers, free to move about in the metal. In other materials, notably the semiconductors, the charge carriers can be positive or negative, depending on the dopant used. Positive and negative charge carriers may even be present at the same time, as happens in an electrolyte in an electrochemical cell.

A flow of positive charges gives the same electric current, and has the same effect in a circuit, as an equal flow of negative charges in the opposite direction. Since current can be the flow of either positive or negative charges, or both, a convention is needed for the direction of current that is independent of the type of charge carriers. Negatively charged carriers, such as the electrons (the charge carriers in metal wires and many other electronic circuit components), therefore flow in the opposite direction of conventional current flow in an electrical circuit.

## ALTERNATING AND DIRECT CURRENT

In alternating current (AC) systems, the movement of electric charge periodically reverses direction. AC is the form of electric power most commonly delivered to businesses and residences. The usual waveform of an AC power circuit is a sine wave, though certain applications use alternative waveforms, such as triangular or square waves. Audio and radio signals carried on electrical wires are also examples of alternating current. An important goal in these applications is recovery of information encoded (or modulated) onto the AC signal.

In contrast, direct current (DC) refers to a system in which the movement of electric charge in only one direction (sometimes called unidirectional flow). Direct current is produced by sources such as batteries, thermocouples, solar cells, and commutator-type electric machines of the dynamo type. Alternating current can also be converted to direct current through use of a rectifier. Direct current may flow in a conductor such as a wire, but can also flow through semiconductors, insulators, or even through a vacuum as in electron or ion beams. An old name for direct current was galvanic current.

**OCCURRENCES**

Natural observable examples of electric current include lightning, static electric discharge, and the solar wind, the source of the polar auroras.

Man-made occurrences of electric current include the flow of conduction electrons in metal wires such as the overhead power lines that deliver electrical energy across long distances and the smaller wires within electrical and electronic equipment. Eddy currents are electric currents that occur in conductors exposed to changing magnetic fields. Similarly, electric currents occur, particularly in the surface, of conductors exposed to electromagnetic waves. When oscillating electric currents flow at the correct voltages within radio antennas, radio waves are generated.

In electronics, other forms of electric current include the flow of electrons through resistors or through the vacuum in a vacuum tube, the flow of ions inside a battery, and the flow of holes within metals and semiconductors.

A biological example of current is the flow of ions in neurons and nerves, responsible for both thought and sensory perception.

**Measurement**

Current can be measured using an ammeter.

Electric current can be directly measured with a galvanometer, but this method involves breaking the electrical circuit, which is sometimes inconvenient.

Current can also be measured without breaking the circuit by detecting the magnetic field associated with the current. Devices, at the circuit level, use various techniques to measure current:

- Shunt resistors
- Hall Effect current sensor transducers
- Transformers (however DC cannot be measured)
- Magnetoresistive field sensors
- Rogowski coils
- Current clamps
- Resistive heating

Joule heating, also known as ohmic heating and resistive heating, is the process of power dissipation by which the passage of an electric current through a conductor increases the internal energy of the conductor converting thermodynamic work into heat. The phenomenon was first studied by James Prescott Joule in 1841. Joule immersed a length of wire in a fixed mass of water and measured the temperature rise due to a known current through the wire for a 30 minute period. By varying the current and the length of the wire he deduced that the heat produced was proportional to the square of the current multiplied by the electrical resistance of the wire.

$P \propto I^2 R$

This relationship is known as Joule's Law. The SI unit of energy was subsequently named the joule and given the symbol J. The commonly known SI unit of power, the watt (symbol: W), is equivalent to one joule per second.

SELF CHECK 1.5.1

ELECTRIC CURRENT

MULTIPLE CHOICE

DIRECTION: Choose the letter of your choice.

1. What do you call a flow of charge particles?
   a. Voltage
   b. Current
   c. Electrons
   d. Ampere

2. What do you call the unit of current?
   a. Ampere
   b. Volts
   c. Ohms
   d. Farad

3. What do you call a arbitrarily defined as the direction in which positive charges flow?
   a. Conventional Current
   b. Directional Current
   c. Alternating Current
   d. Direct Current
4. What do you call the movement of electric charge periodically reverses direction?
   a) Conventional Current
   b) Directional Current
   c) Alternating Current
   d) Direct Current
5. What do you call refers to a system in which the movement of electric charge in only one direction (sometimes called unidirectional flow?
   a) Conventional Current
   b) Directional Current
   c) Alternating Current
   d) Direct Current

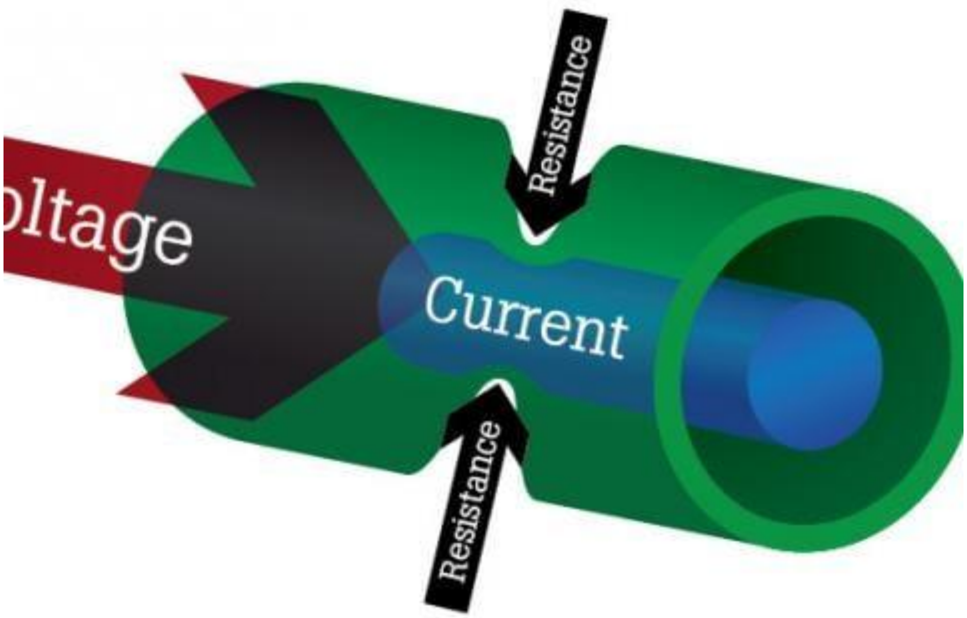
INFORMATION SHEET 1.6-8

RESISTANCE

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to identify the electrical resistance. ( ELC724202)
- Align with TSEC, Check wiring and circuits using specified testing procedures. (TLE_IAEPAS9-12TCEC-IIId-e-2)

Resistance



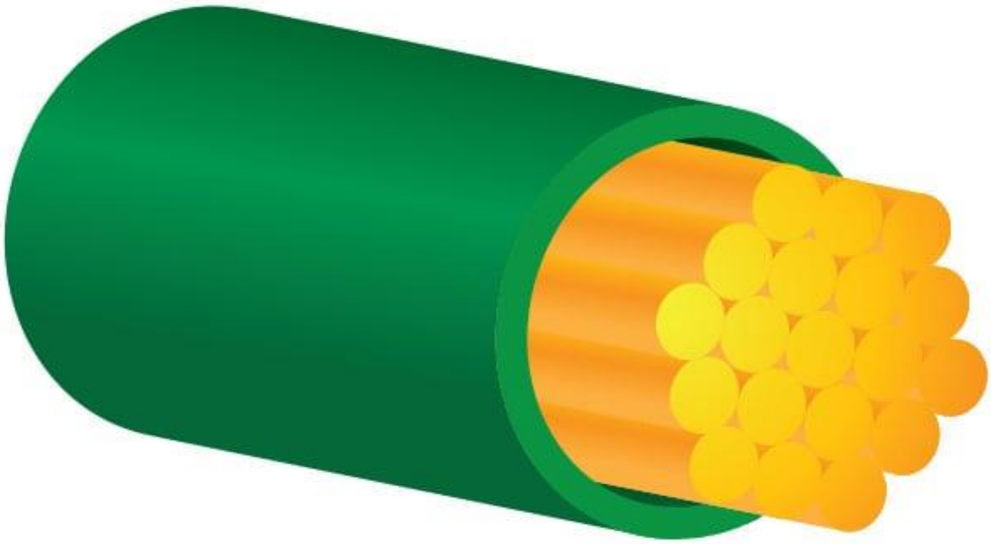

Resistance is a measure of the opposition to current flow in an electrical circuit.

Resistance is measured in ohms, symbolized by the Greek letter omega (Ω). Ohms are named after Georg Simon Ohm (1784-1854), a German physicist who studied the relationship between voltage, current and resistance. He is credited for formulating Ohm's Law.

All materials resist current flow to some degree. They fall into one of two broad categories:

Conductors: Materials that offer very little resistance where electrons can move easily. Examples: silver, copper, gold and aluminum.

Insulators: Materials that present high resistance and restrict the flow of electrons. Examples: Rubber, paper, glass, wood and plastic.



Resistance measurements are normally taken to indicate the condition of a component or a circuit.

The higher the resistance, the lower the current flow. If abnormally high, one possible cause (among many) could be damaged conductors due to burning or corrosion. All conductors give off some degree of heat, so overheating is an issue often associated with resistance.

The lower the resistance, the higher the current flow. Possible causes: insulators damaged by moisture or overheating.

Many components, such as heating elements and resistors, have a fixed-resistance value. These values are often printed on the components' nameplates or in manuals for reference.

When a tolerance is indicated, the measured resistance value should be within the specified resistance range. Any significant change in a fixed-resistance value usually indicates a problem.

"Resistance" may sound negative, but in electricity it can be used beneficially.

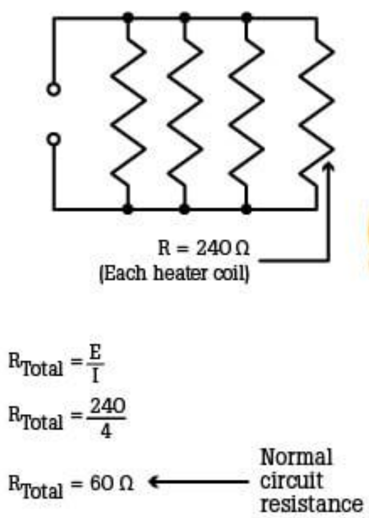
Examples: Current must struggle to flow through the small coils of a toaster, enough to generate heat that browns bread. Old-style incandescent light bulbs force current to flow through filaments so thin that light is generated.

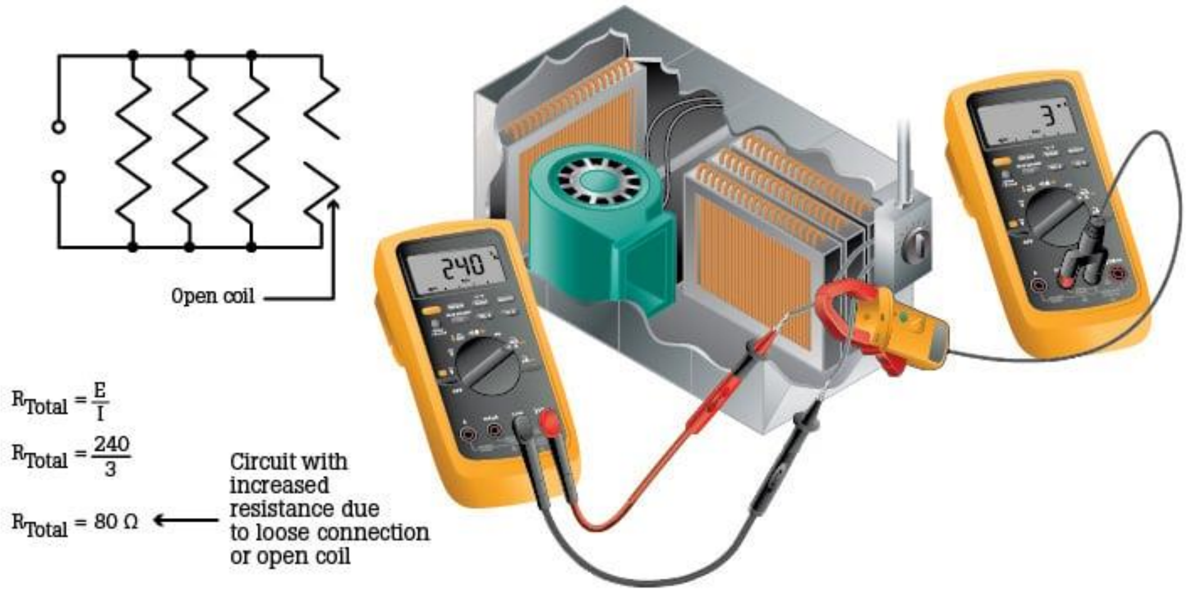
Resistance cannot be measured in an operating circuit. Accordingly, troubleshooting technicians often determine resistance by taking voltage and current measurements and applying Ohm's Law:

E = I x R

That is, volts = amps x ohms. R stands for resistance in this formula. If resistance is unknown, the formula can be converted to R = E/I (ohms = volts divided by amps).

Examples: In an electric heater circuit, as portrayed in the two illustrations below, resistance is determined by measuring circuit voltage and current, then applying Ohm's Law.




In the first example, total normal circuit resistance, a known reference value, is 60 Ω (240 ÷ 4 = 60 Ω). The 60 Ω resistance can help determine the condition of a circuit.

In the second example, if circuit current is 3 amps instead of 4, circuit resistance has increased from 60 Ω to 80 Ω (240 ÷ 3 = 80 Ω). The 20 Ω gain in total resistance could be caused by a loose or dirty connection or an open-coil section. Open-coil sections increase the total circuit resistance, which decreased current.

# SELFCHECK 1.6.1

# RESISTANCE

FILL IN THE BLANKS

DIRECTION: Write the correct answer in the Blanks.

1. ________ a German physicist who studied the relationship between voltage, current and resistance.
2. ________ Materials that offer very little resistance where electrons can move easily. Examples: silver, copper, gold and aluminum.
3. ________ Materials that present high resistance and restrict the flow of electrons. Examples: Rubber, paper, glass, wood and plastic.
4. The higher the resistance, the _______ the current flow.
5. When a tolerance is indicated, the measured resistance value should be within the specified _______________.

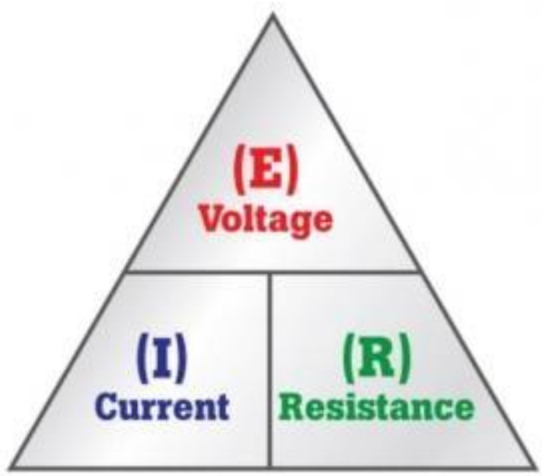
INFORMATION SHEET

OHM'S LAW

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to understand OHM's Law. ( ELC724202)
- Align with TSEC, Check wiring and circuits using specified testing procedures. (TLE_IAEPAS9-12TCEC-IIId-e-2)

Ohm's Law




Ohm's Law is a formula used to calculate the relationship between voltage, current and resistance in an electrical circuit.

To students of electronics, Ohm's Law (E = IR) is as fundamentally important as Einstein's Relativity equation ($E = mc^2$) is to physicists.

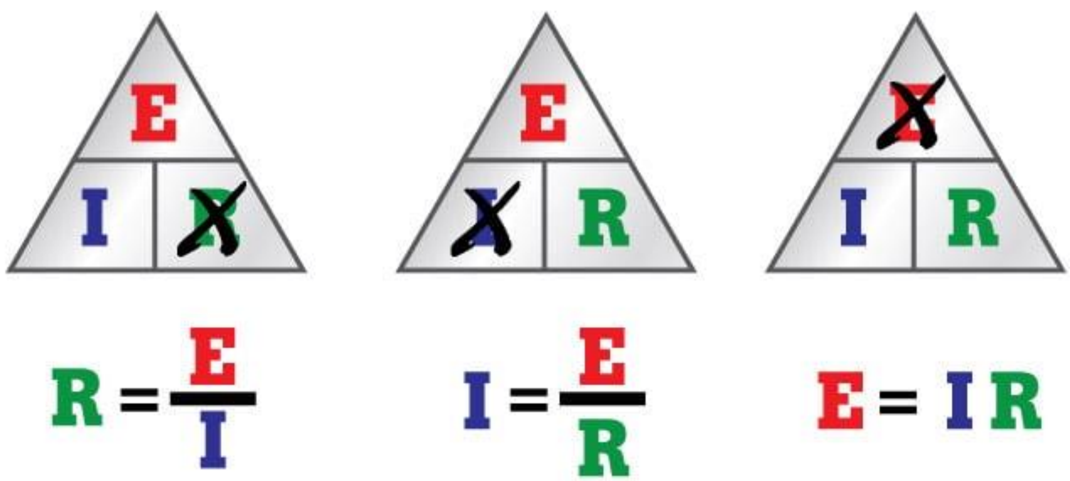
E = I x R

When spelled out, it means voltage = current x resistance, or volts = amps x ohms, or V = A x Ω.

Named for German physicist Georg Ohm (1789-1854), Ohm's Law addresses the key quantities at work in circuits:

| Quantity | Ohm's Law symbol | Unit of measure (abbreviation) | Role in circuits | In case you're wondering: |
|---|---|---|---|---|
| **Voltage** | E | Volt (V) | Pressure that triggers electron flow | E = electromotive force (old-school term) |
| **Current** | I | Ampere, amp (A) | Rate of electron flow | I = intensity |
| **Resistance** | R | Ohm (Ω) | Flow inhibitor | Ω = Greek letter omega |

If two of these values are known, technicians can reconfigure Ohm's Law to calculate the third. Just modify the pyramid as follows:




If you know voltage (E) and current (I) and want to know resistance (R), X-out the R in the pyramid and calculate the remaining equation (see the first, or far left, pyramid above).

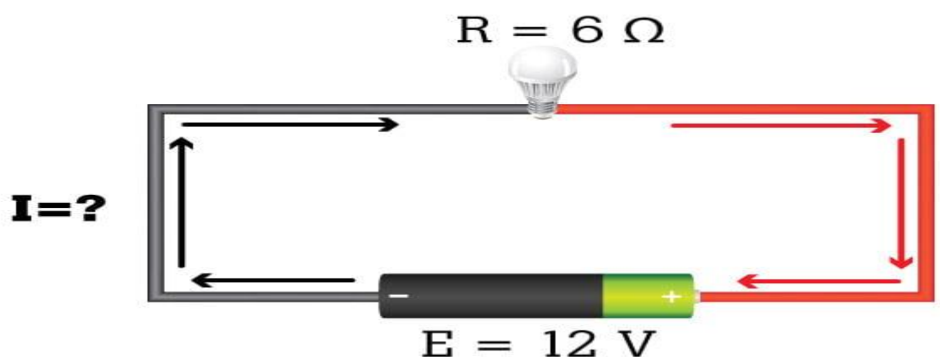
Note: Resistance cannot be measured in an operating circuit, so Ohm's Law is especially useful when it needs to be calculated. Rather than shutting off the circuit to measure resistance, a technician can determine R using the above variation of Ohm's Law.

Now, if you know voltage (E) and resistance (R) and want to know current (I), X-out the I and calculate the remaining two symbols (see the middle pyramid above).

And if you know current (I) and resistance (R) and want to know voltage (E), multiply the bottom halves of the pyramid (see the third, or far right, pyramid above).

Try a few sample calculations based on a simple series circuit, which includes just one source of voltage (battery) and resistance (light). Two values are known in each example. Use Ohm's Law to calculate the third.

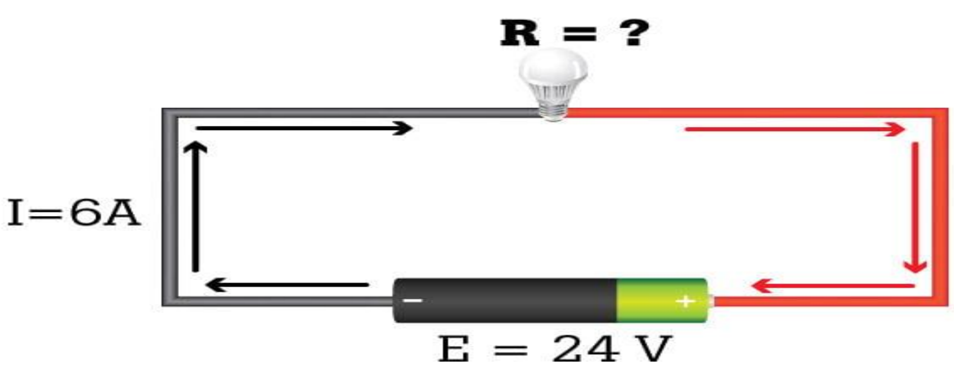
Example 1: Voltage (E) and resistance (R) are known.




What is the current in the circuit?

I = E/R = 12V/6Ω = 2A

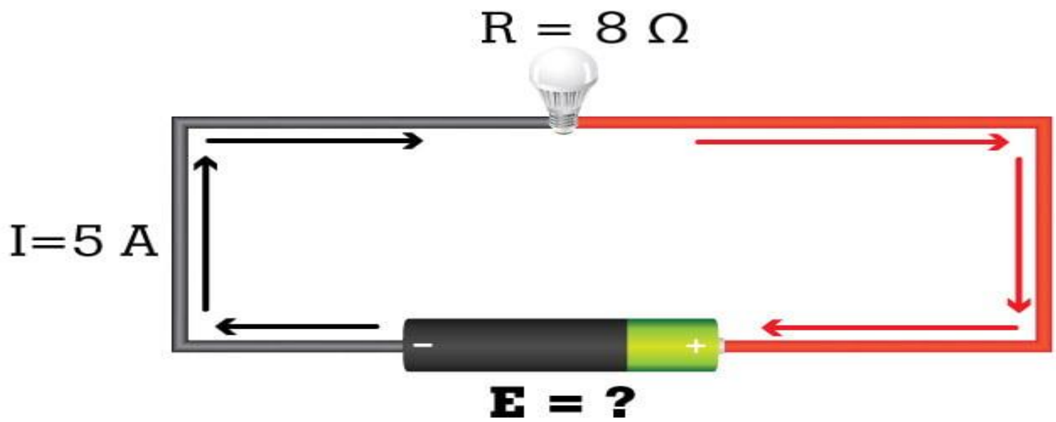
Example 2: Voltage (E) and current (I) are known.




What is the resistance created by the lamp?

R = E/I = 24V/6A = 4Ω

Example 3: Current (I) and resistance (R) are known. What is the voltage?




What is the voltage in the circuit?

E = I x R = (5A)(8Ω) = 40 V

When Ohm published his formula in 1827, his key finding was that the amount of electric current flowing through a conductor is directly proportional to the voltage imposed on it. In other words, one volt of pressure is required to push one amp of current through one ohm of resistance.

What to validate using Ohm's Law

Ohm's Law can be used to validate the static values of circuit components, current levels, voltage supplies, and voltage drops. If, for example, a test instrument detects a higher than normal current measurement, it could mean that resistance has decreased or that voltage has increased, causing a high-voltage situation. This could indicate a supply or circuit issue.

In direct current (dc) circuits, a lower than normal current measurement could mean that the voltage has decreased, or circuit resistance has increased. Possible causes for increased resistance are poor or loose connections, corrosion and/or damaged components.

Loads within a circuit draw on electrical current. Loads can be any sort of component: small electrical devices, computers, household appliances or a large motor. Most of these components (loads) have a nameplate or informational sticker attached. These nameplates provide safety certification and multiple reference numbers.

Technicians refer to nameplates on components to learn standard voltage and current values. During testing, if technicians find that customary values do not register on their digital multimeters or clamp meters, they can use Ohm's Law to detect what part of a circuit is faltering and from that determine where a problem may lie.

The basic science of circuits

Circuits, like all matter, are made of atoms. Atoms consist of subatomic particles:

Protons (with a positive electrical charge)

Neutrons (no charge)

Electrons (negatively charged)

Atoms remain bound together by forces of attraction between an atom's nucleus and electrons in its outer shell. When influenced by voltage, atoms in a circuit begin to reform and their components exert a potential of attraction known as a potential difference. Mutually attracted loose electrons move toward protons, creating a flow of electrons (current). Any material in the circuit that restricts this flow is considered resistance.

# SELF CHECK 1.6-8

## OHMS LAW

True or False

Direction. Write **True** if the statement is true and write **False** if the statement is false.

1. Ohm’s Law is a formula used to calculate the relationship between voltage, current and resistance in an electrical circuit.
2. Einstein's Relativity equation ($E = mc^2$) is to physicists.
3. Resistance can be measured in an operating circuit.
4. The amount of electric current flowing through a conductor is directly proportional to the voltage imposed on it. In other words, one volt of pressure is required to push one amp of current through one ohm of resistance.
5. When influenced by voltage, atoms in a circuit begin to reform and their components exert a potential of attraction known as a potential difference.

JOBSHEETS 1.3-6-8

PROBLEM SOLVING

DIRECTION: Solve the following using Ohm's Law.

| NO. | VOLTAGE (V) | CURRENT (I) | RESISTANCE (Ω) |
|---|---|---|---|
| 1. | 110 | | 330 |
| 2. | | 1.8 | 500 |
| 3. | 230 | 2.6 | |
| 4. | 200 | 1.3 | |
| 5. | 600 | | 380 |
| 6. | 220 | | 375 |
| 7. | 80 | | 70 |
| 8. | | 4.2 | 640 |
| 9. | | 3.2 | 590 |
| 10. | | 0.5 | 200 |

INFORMATION 2.1.1

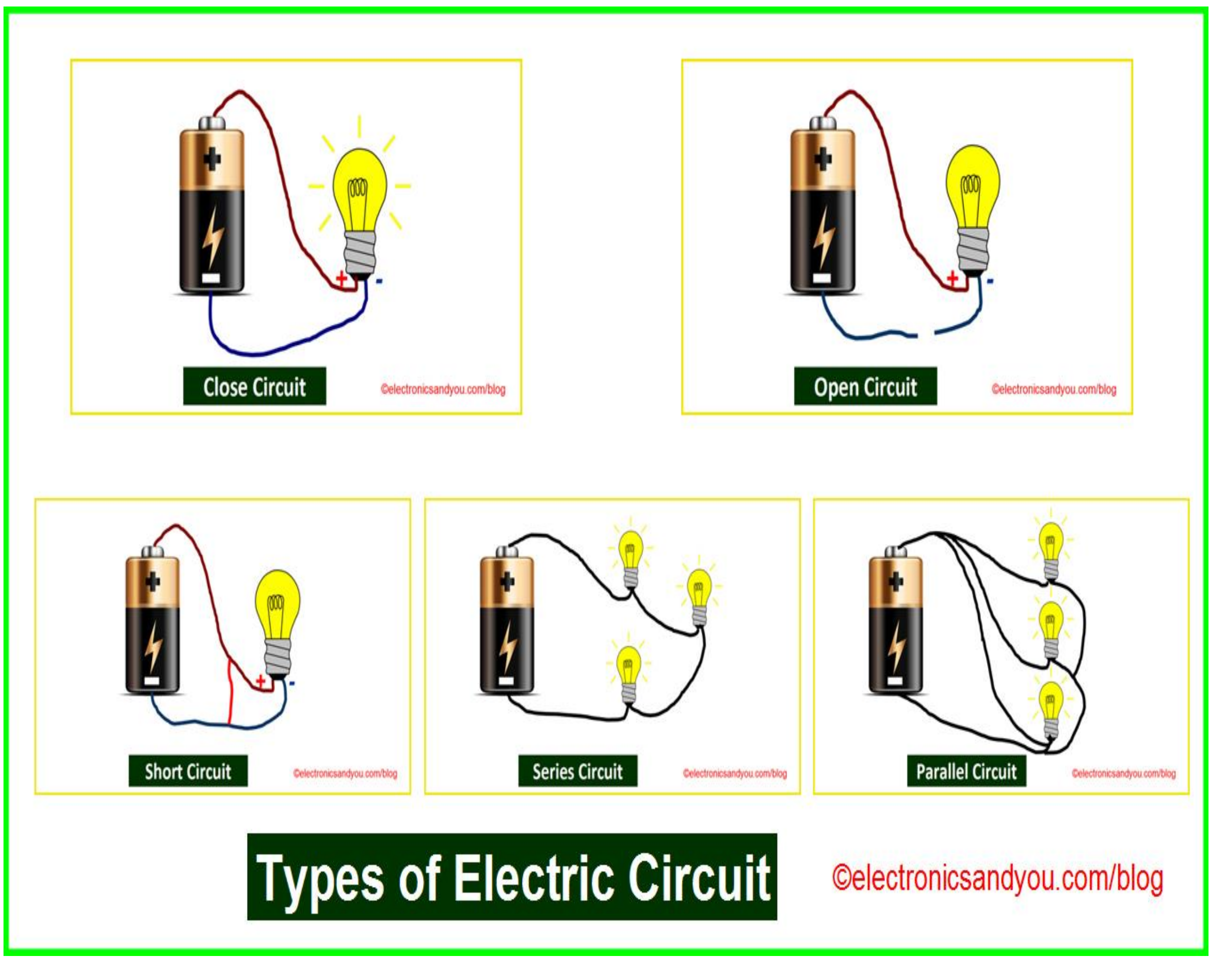
ELECTRICAL CIRCUITS

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to identify electrical circuits. ( ELC724202)
- Align with TSEC, Check wiring and circuits using specified testing procedures. (TLE_IAEPAS9-12TCEC-IIId-e-2)

ELECTRICAL CIRCUITS

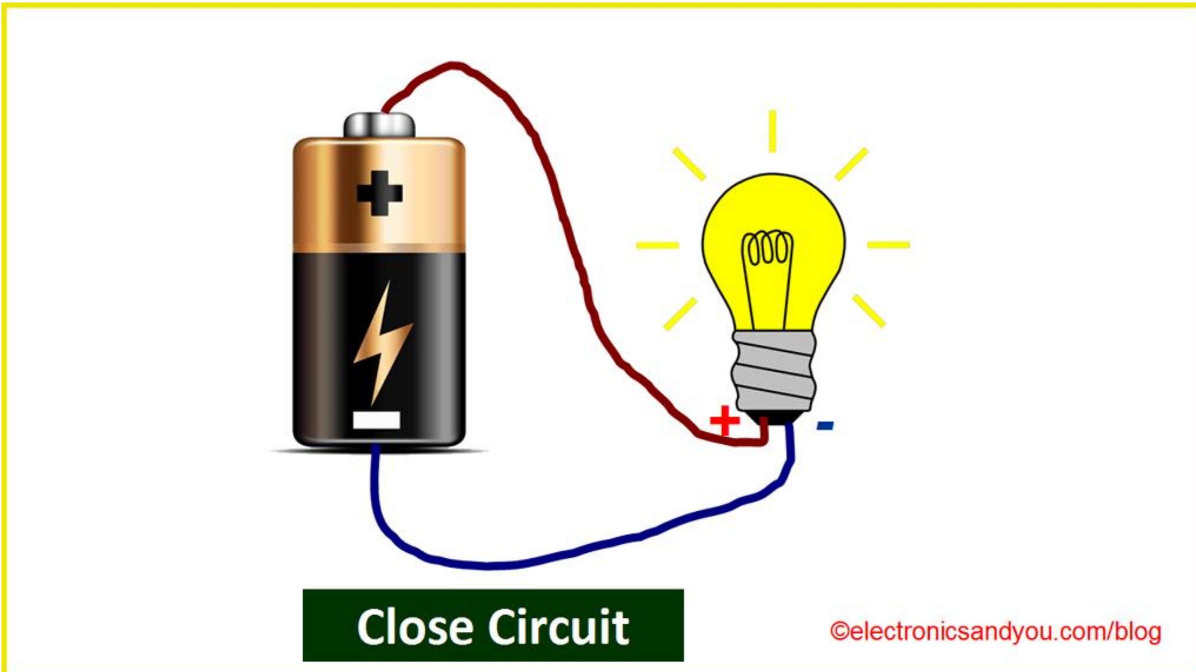
An Electric Circuit is the conductive path for flow of current or electricity is called electric circuit or electrical circuit. A conductive wire is used to establish relation among source of voltage and load. An ON / OFF switch and a fuse is also used in between the source and load.



COMMON TYPES OF ELECTRICAL CIRCUITS

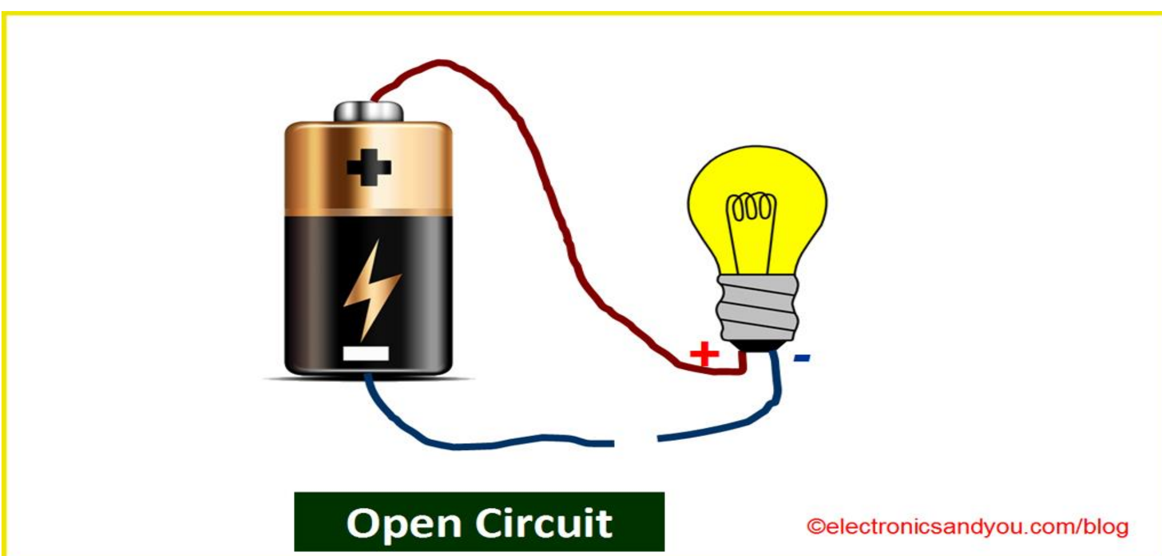
1. Close Circuit

When load works on its own in a circuit then it is called Close Circuit or Closed Circuit. Under this situation, the value of current flow depends on load.



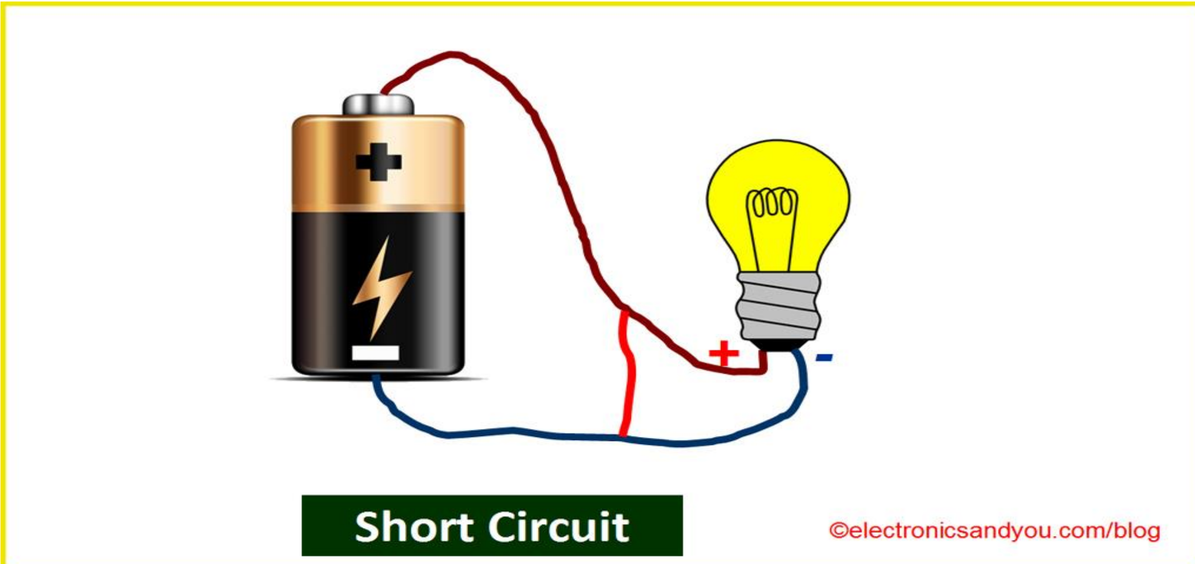

2. Open Circuit

When there is a faulty electrical wire or electronic component in a circuit or the switch is OFF, then it is called Open Circuit. In the below diagram you can see that the Bulb is Not glowing because either the switch is OFF or there is fault is the electrical wire.



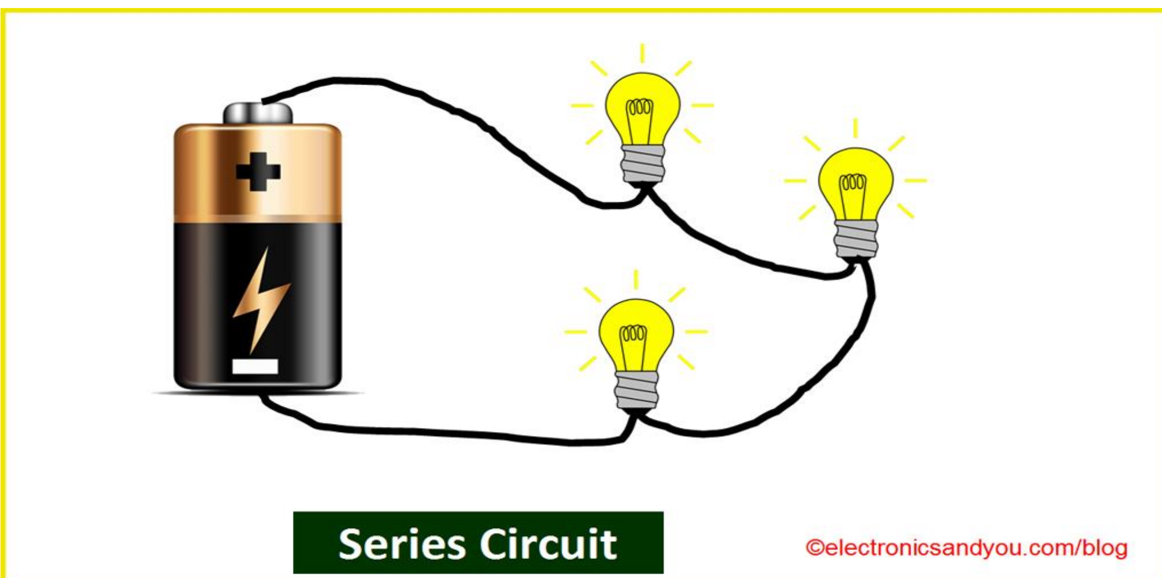
3. Short Circuit

When both points (+ & –) of voltage source in a circuit gets joint with each other for some reason then it is called Short Circuit. Maximum current starts to flow under this situation. Short circuit generally happens when the conducting electrical wires get joint of even because of shorting in the load.



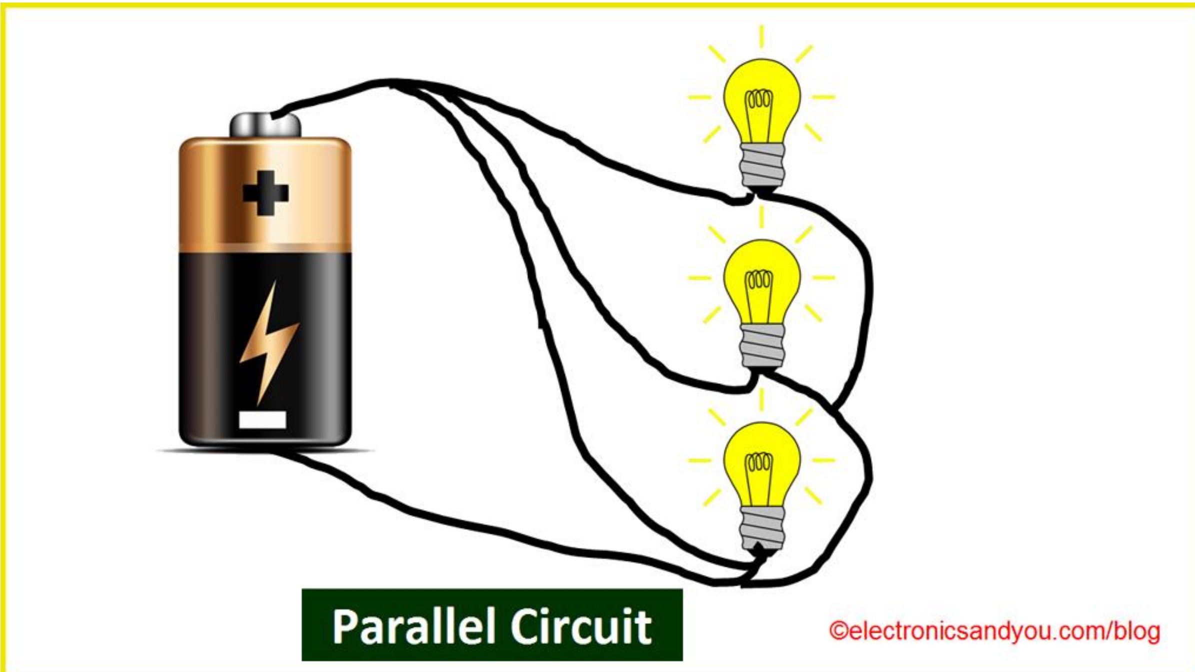

4. Series Circuit

When 2 or more loads (Bulb, CFL, LED, Fan etc) are connected to each other in a series, then it is called a Series Circuit. In a series circuit, if one load or bulb gets fuse, then rest of the bulbs will not get power supply and will not glow. Look at the example below.




5. Parallel Circuit

When 2 or more loads (Bulb, CFL, LED, Fan etc) are connected to each other in parallel, then it is called Parallel Circuit. In this type of circuit, the voltage capacity of all loads must be equal to input supply. Power of “load” can be different. In a parallel circuit, if one load or bulb gets fuse, then rest of the bulbs will still get power supply and will glow. Look at the example below.




SELF CHECK 2.1.1

ELECTRIC CIRCUITS

MATCHING TYPE

| TYPES OF ELECTRICAL CIRCUITS | DEFINITION |
|---|---|
| 1. PARALLEL CIRCUIT<br><br>2. SERIES CIRCUIT | A. When load works on its own in a circuit then it is called Close Circuit or Closed Circuit. Under this situation, the value of current flow depends on load<br><br>B. When 2 or more loads (Bulb, CFL, LED, Fan etc) are connected to each other in a series, then it is called a Series Circuit. In a series circuit, if one load or bulb gets fuse, then rest of the bulbs will not get power supply and will not glow. Look at the example below. |

| | |
|---|---|
| 3. CLOSE CIRCUIT<br><br>4. OPEN CIRCUIT<br><br>5. SHORT CIRCUIT | C. When there is a faulty electrical wire or electronic component in a circuit or the switch is OFF, then it is called Open Circuit. In the below diagram you can see that the Bulb is Not glowing because either the switch is OFF or there is fault is the electrical wire.<br>.<br>D. When both points (+ & –) of voltage source in a circuit gets joint with each other for some reason then it is called Short Circuit. Maximum current starts to flow under this situation. Short circuit generally happens when the conducting electrical wires get joint of even because of shorting in the load.<br><br>E. When 2 or more loads (Bulb, CFL, LED, Fan etc) are connected to each other in parallel, then it is called Parallel Circuit. In this type of circuit, the voltage capacity of all loads must be equal to input supply. Power of “load” can be different. In a parallel circuit, if one load or bulb gets fuse, then rest of the bulbs will still get power supply and will glow. |

**INFORMATION SHEET 2.2-3**

**HOW ELECTRICAL/ELECTRONICS CIRCUIT WORKS**

**Learning Objective:**

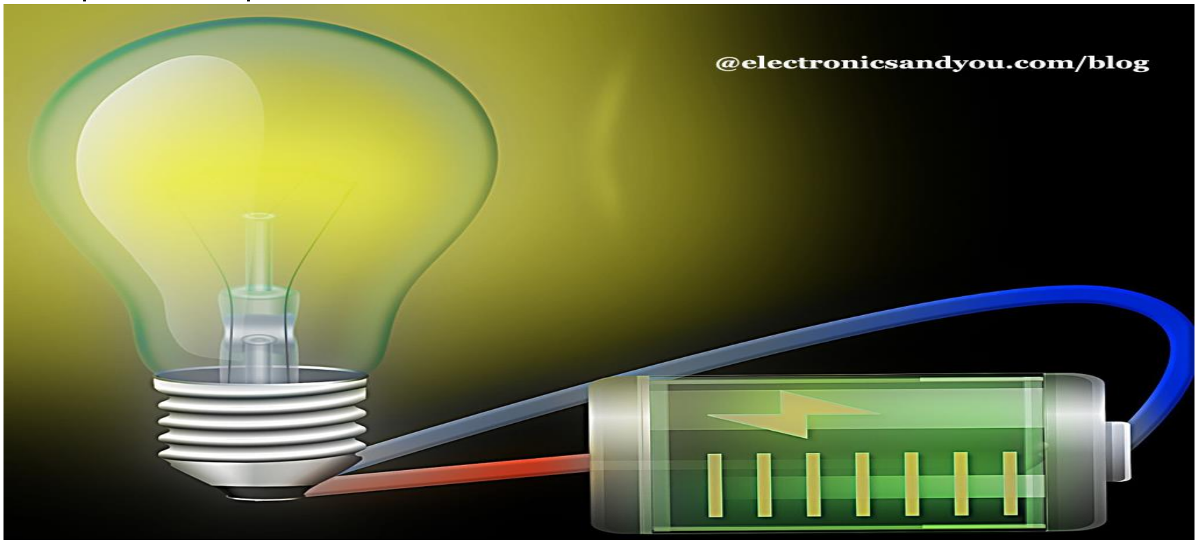
- After reading this INFORMATION SHEET, YOU MUST be able to understand how electrical/electronics circuit works. ( ELC724202)
- Align with TSEC, Check wiring and circuits using specified testing procedures. (TLE_IAEPAS9-12TCEC-IIId-e-2)

What is Electricity or Electric Charge?
Electric charge is nothing but flow of electrons from one object to another. We all know that an atom is made up of electrons, protons and neutrons. Electrons are negatively charged and protons are positively charged while neutrons are neutrally charged. At the same time the number of electrons and protons in an atom is always same.

Now, if, by any means, few electrons can move away from the atom of object A to atom of object B, then object A will get positively charged due to deficiency of electrons while object B will get Negatively charged due to excess electrons. In such case object A will be called Positively Charged and object B will be called Negatively Charged. This is how electricity is generated.

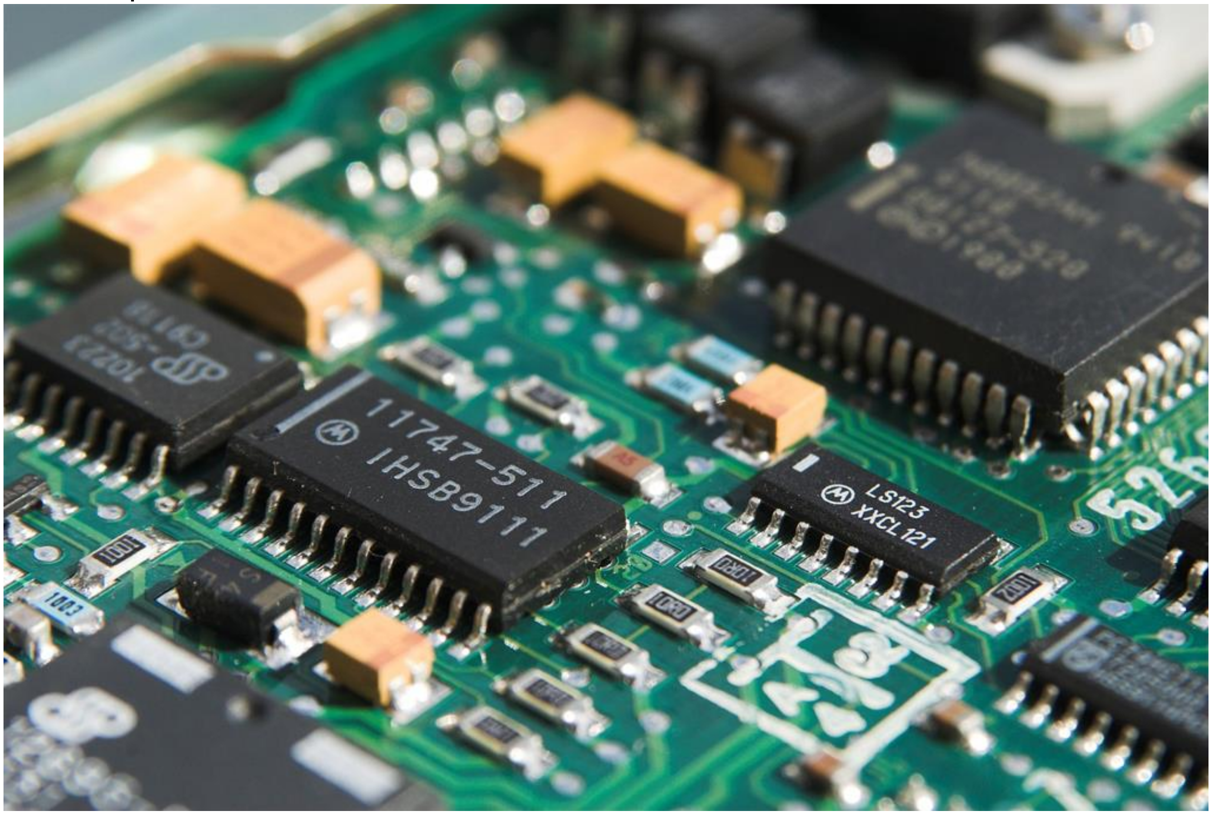
**What is Electrical Circuit?**

Electrical circuit or power circuit is arrangement of electrically conductive path for flow and movement of electric charge or electricity. A home electrical wiring system is good example of a simple electrical circuit.




**What is an Electronic Circuit?**

An electronic circuit is path made out of electronically conductive material such as metal, with electronic components on the path for controlled flow of electricity of electric charge. A printed circuit board is an example of electronic circuit. Electronic gadgets such as the TV, Computer, and Mobile Phones etc all have electronic circuits.




How Electrical Circuit Works?

As I mentioned above, an electrical circuit or power circuit is arrangement of electrically conductive path for flow and movement of electric charge or electricity. To make an electrical circuit, we need a path for the electrons to flow, and a power-source to push them along. Electrons travel well through metals. Therefore, in an electrical circuit, a path is made out of thin metal in the form of wire.

Power source for the circuit could be a switch from a home wiring or a battery. Let us take an example of a light-bulb connected to a battery. In order to glow the bulb, electrons have to be pushed out of the battery. This is done through electric field. The electrons then pass through the light-bulb, and back to the other end of the battery. During this process, the wire (normally tungsten) in the light-bulb get so hot that it glows and emits bright light.

How Electronic Circuit Works?

Printed Circuit Board of a computer, laptop, TV, cell phone etc are all examples of electronic circuit. These circuit boards have predefined metallic path for electricity to flow with electronic components on the way. These active and passive electronic components (Through Hole and SMD) help to control the flow of electricity as and when required.

Design of the circuit and arrangement of electronic components determines how an electronic appliance or gadget will work.

SELFCHECK 2.2-3

HOW ELECTRICAL/ELECTRONICS CIRCUIT WORKS

Fill in the blanks

Direction: Write your answer in the blanks.

1. ___________ flow of electrons from one object to another.

2-3. __________ are negatively charged and ________ are positively charged while neutrons are neutrally charged.

4.___________ is arrangement of electrically conductive path for flow and movement of electric charge or electricity.

5. ___________ is path made out of electronically conductive material such as metal, with electronic components on the path for controlled flow of electricity of electric charge.

II. Essay

1. What is the difference between Electrical Circuit and Electronics Circuits?

INFORMATION SHEET 2.4-6

ELECTRICAL POWER/ENERGY

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to recognize electrical power and energy. ( ELC724202)
- Align with TSEC, Check wiring and circuits using specified testing procedures. (TLE_IAEPAS9-12TCEC-IIId-e-2)

ELECTRICAL POWER

Electrical Power Definition

Electrical power arises from the flow of charge, known as current, due to the electrical energy arising from a potential difference.

Electric power is defined as the electrical energy transferred in a circuit per unit of time.

The unit of electric power is the Watt (W) and it is denoted by the symbol (*P*). It is often measured in kW(1kW=1000W). The power rating that we see in our home appliances defines how much energy is being transferred from the grid to power the device. A mobile phone charger has a power rating in the range of 2W-6W. This means that the charger draws 6W or 6 Joules per second from the mains. An electric kettle on the other hand has a power rating of 3kW. That is 3000 Joules per second which is 500 times the power consumed by the charger! This makes it 500 times more expensive to use than your typical mobile charger. Let us now look at how to calculate the power using the current drawn and the voltage.

Factors of electrical power

The electrical power used by an electrical component depends on two main factors. These factors are:

- ✓ The current passing through the component.
- ✓ The potential difference/voltage across the two ends of the component

increasing either one of these variables will increase the power proportionally. This can be formulated as an equation for power in terms of these two variables which we demonstrate in the next section of this explanation.

**Electrical power formula**

The electric power transferred to an electrical component in a circuit can be calculated using the electric power formula:

$P=VI$

Power=Potential Difference x Current

Where ***P*** is the electrical power, ***V*** is the potential difference across the component and ***I*** is the current passing through the component.

The electric power can also be calculated by knowing the current and resistance using the following equation

$P=I^2R$

Where R is the resistance of the electrical component.

Therefore,1W of electric power can be defined as the energy transferred when a current of 1A flows through a potential difference of 1V.

Unit of Electrical Power

The unit of electrical power is Watt.

$$V = 1\ volts\ and\ I = 1\ ampere$$

$$P = 1\ watt$$

If, Thus, the power consumed in an electrical circuit is said to one watt if one ampere current flows through the circuit when a potential difference of 1 volt is applied across it. The bigger unit of electrical power is the kilowatt (kW), it is usually used in the power system

$$1kW = 1000W$$

INFORMATION SHEET 2.5.1

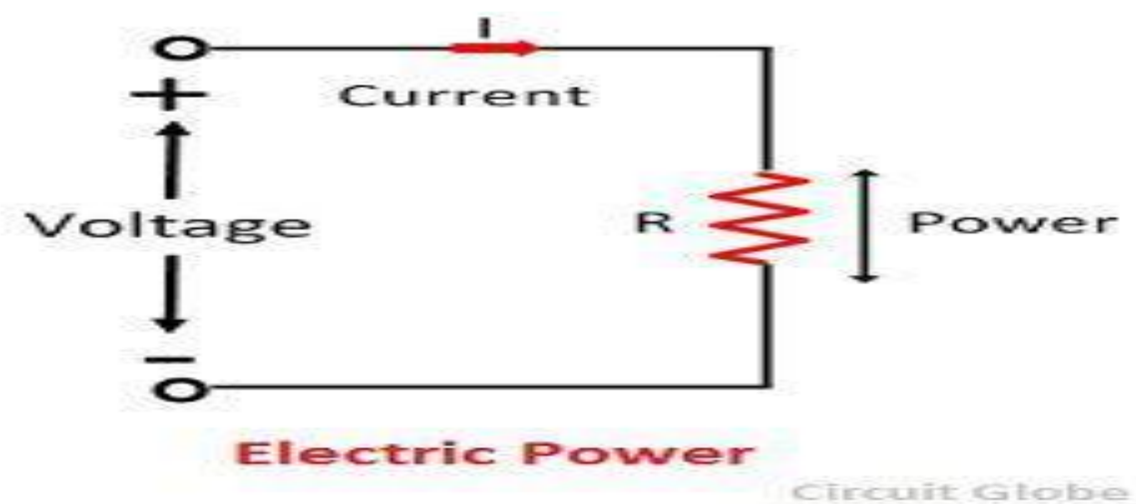
TYPES OF ELECTRICAL POWER

**Types of an Electric Power**

The electrical power is mainly classified into two types. They are the DC power and the AC power.

1. DC POWER

The DC power is defined as the product of the voltage and current. It is produced by the fuel cell, battery and generator.



$$P = V \times I$$

Where P – Power in watt.
V – voltage in volts.
I – current in amps.

2. AC POWER

The AC power is mainly classified into three types. They are the apparent power, active power and real power.

**1. Apparent Power –** The apparent power is the useless power or idle power. It is represented by the symbol S, and their SI unit is volt-amp.

$$S = V_{rms} I_{rms}$$

Where S – apparent power
$V_{rms}$ – RMS voltage = $V_{peak}\sqrt{2}$ in volt.
$I_{rms}$ – RMS current = $I_{peak}\sqrt{2}$ in the amp.

Φ – impedance phase angle between voltage and current.

The relation between the apparent, active and reactive power is shown below.

$$S^2 = Q^2 + P^2$$

The ratio of the real to the apparent power is called power factor, and their value lies between 0 and 1.

INFORMATION SHEET 2.6.1

## ELECTRICAL ENERGY

Electrical energy

Figure 1: Within this image there different examples of electrical energy: the electricity to light the well-lit buildings, and the lightning strike.

Electrical energy is the most convenient form of energy for most human uses. Electrical energy is easy use and move from one location to another, but it is almost impossible to store in any large quantity. It can be used for running computers and most appliances, home heating, and even transportation. Electricity is used by industry, households, and businesses—accounting for 18% of end use energy worldwide.

The energy itself is held in the movement and configuration of electric charge. The flow of electric charge (usually electrons) is electric current. Charge can build up on a capacitor and store electrical energy. This energy is physically carried in the electric fields and magnetic fields associated with how charges are arranged and moving, but can easily be turned into most energy services.

Electrical conduction is the physical phenomenon that allows electricity to be transported easily. Wires, materials made out of conductors (usually metals), are capable of transporting this energy hundreds of kilometers. This system of transporting electrical energy is called the electrical grid.

Electrical energy is not a primary energy source, but rather an energy currency (read more in the article electricity as an energy currency). Primary energy (like wind or natural gas) goes into an electric generator to make electricity for easy use and transport. The energy that is transported and used by so much of the modern high energy society must come, fundamentally, from some primary fuel or primary flow.

Electrical energy is very convenient, and as a result more and more of the energy used by a high energy society is in the form of electricity, see figure 1. The rate of electrical energy use is growing faster than the rate of electricity use, see figure 2.

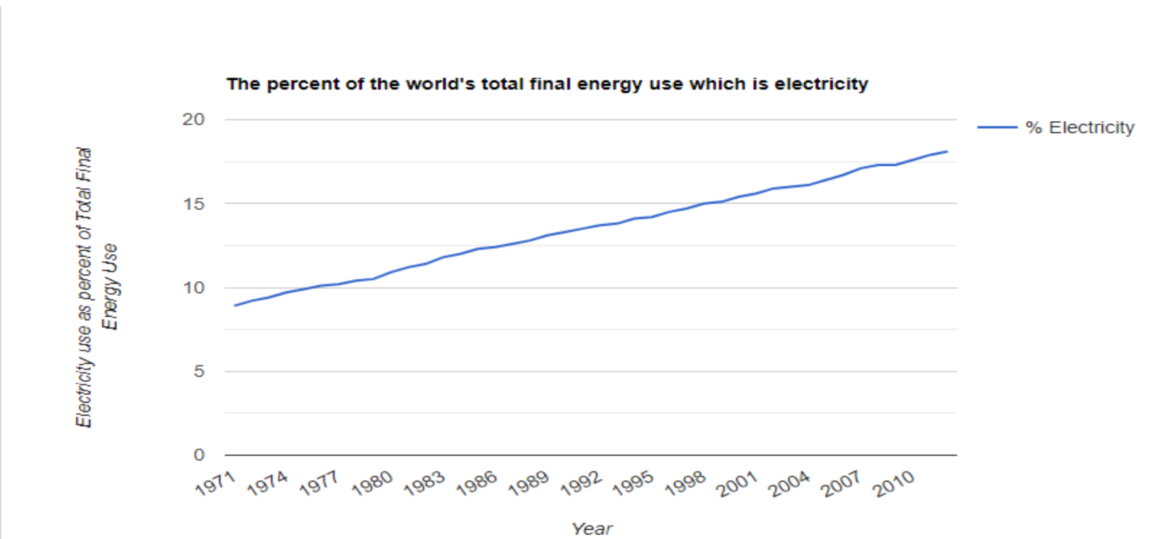
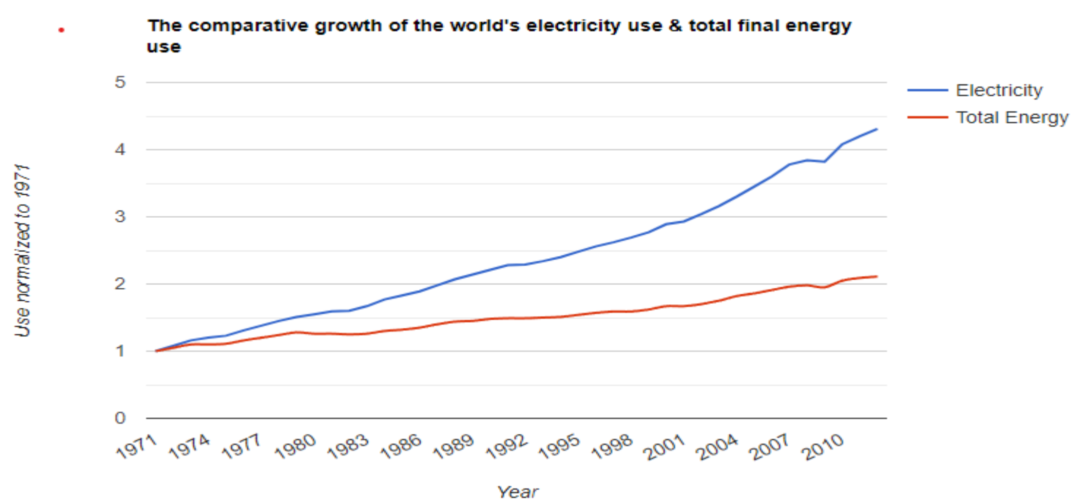


Figure 1. The above graph shows how electricity use is growing as a percentage of the total final energy use in the world.[2] This shows that the flexibility of electricity creates a strong incentive to have as great a fraction of energy produced in that form as is possible.

Figure 2. The above graph shows how electricity use is growing faster than the total final energy use in the world.[2] This shows that the flexibility of electricity creates a strong incentive to have as great a fraction of energy produced in that form as possible.



SELF CHECK 2.4.6

ELECTRICAL POWER/ENERGY

I. FILL IN THE BLANKS

Direction: Write your answer in the blanks.

1.______________ arises from the flow of charge, known as current, due to the electrical energy arising from a potential difference.
2. The unit of electric power is the _______ and it is denoted by the ________.
3. Electrical Power Formula is_______________.
4-5. The electrical power used by an electrical component depends on two main factors. These factors are:

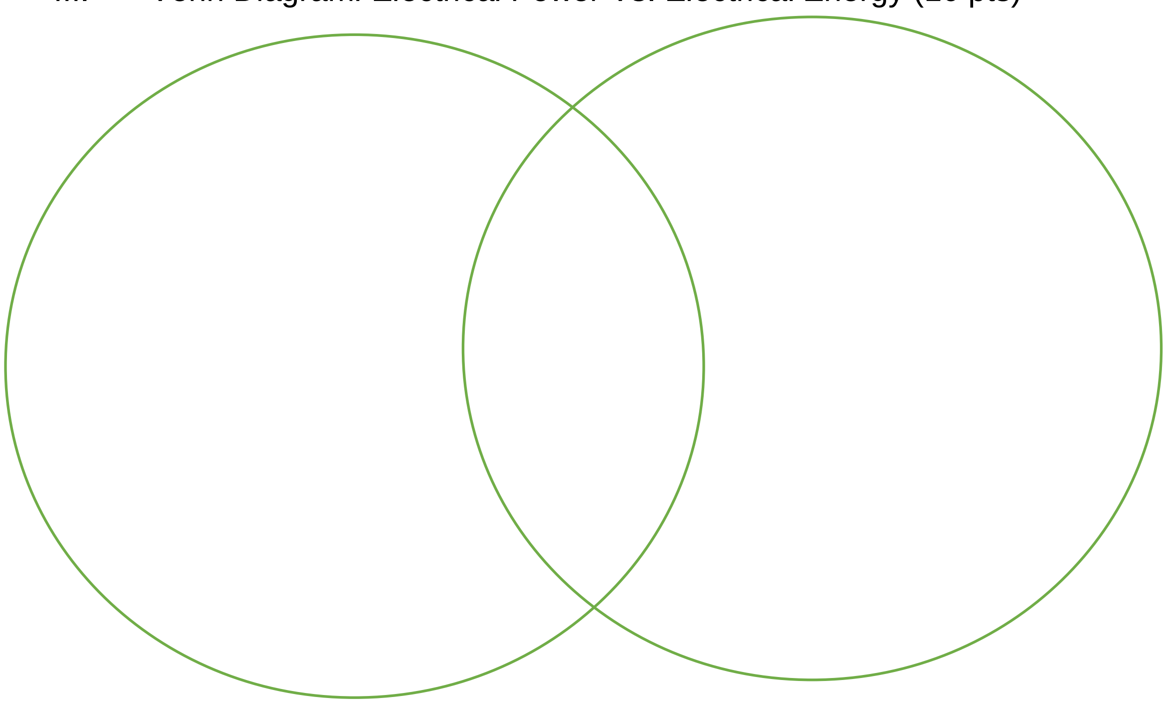
______________________________________________________________________

___________________________________________________________________

II. Enumeration: (5pts)

1. Enumerate the types of electrical power and its definition.

III. Venn Diagram: Electrical Power Vs. Electrical Energy (10 pts)



INFORMATION SHEET 2.7-8

ELECTRICAL CIRCUIT PROTECTION

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to identify electrical circuit protection. ( ELC724202)
- Align with TSEC, Check wiring and circuits using specified testing procedures. (TLE_IAEPAS9-12TCEC-IIId-e-2)

## ELECTRICAL CIRCUIT PROTECTION

Fuses, MCBs, RCDs, and RCBOs are all devices used to protect users and equipment from fault conditions in an electrical circuit by isolating the electrical supply. With fuses and MCBs only the live feed is isolated; with RCDs and RCBOs both the live and neutral feeds are isolated.

### Fuses


A fuse is a very basic protection device which is destroyed (i.e. it 'blows') and breaks the circuit should the current exceed the rating of the fuse. Once the fuse has blown, it needs to be replaced.

In older equipment, the fuse may just be a length of appropriate fuse wire fixed between two terminals (normally screw terminals). These are becoming rarer as electrical installations are updated - the presence of such fuses usually indicates that it is about time that the installation is updated.

Modern fuses are generally incorporated within sealed ceramic cylindrical body (or cartridge) and the whole cartridge needs to be replaced.

Cartridge fuses are used in older type consumer units, fused sockets, fused plugs etc.

### Miniature Circuit Breaker (MCB)

Miniature Circuit BreakerAn MCB is a modern alternative to fuses used in Consumer Units (Fuse Boxes). They are just like switches which switch off when an overload is detected in the circuit. The advantage of MCBs over fuses is that if they trip, they can be reset - they also offer a more precise tripping value.

### Residual Current Device (RCD)

Modern alternatives (better) to Earth Leakage Circuit Breakers and fuses in the Consumer Unit. RCDs are tripped if they detect a small current imbalance between the Live and Neutral wires above the trip value - this is typically 30mA.

RCDs can be wired to protect a single or a number of circuits - the advantage of protecting individual circuits is that if one circuit trips, it will not shut down the whole house, just the protected circuit.

**RCDs are available in at least 4 basic configurations:**

**Residual Current Device** - in circuitAs hard wired in units, where both the inputs and outputs are wired into the unit - ideal for a workshop etc where all the sockets within can be protected. Each individual circuit taken from the RCD is protected by a MCB of an appropriate value.

RCD socket outlet As protected outlets - normally a protected socket can be fitted as a direct replacement for a standard, no protected outlet socket.

**Plug in RCDAs a plug** -in unit which can convert any socket into to a protected circuit - this gives good flexibility as, for example, a lawn mower or a hedge trimmer can be plugged in at different times. However, as the individual appliance could still be plugged into an unprotected socket, you need to remember to fit the plug-in unit when it is required.

**Residual Current Device** - Plug inAs a plug for wiring on to the lead of an individual appliance, this does make it less flexible than the plug-in unit above but it does ensure that the piece of equipment is always protected. One very usefully use to to fit it to the end of an extension cable, then whatever you plug into the extension lead is protected.


**Residual Current Breaker with Overload protection (RCBO)**

Residual Current Breaker with Overload protectionA RCBOs combines the functions of a MCB and a RCD in one unit. They are used to protect a particular circuit, instead of having a single RCD for the whole building. Generally these are used more often in commercial building than domestic ones.

SELF CHECK 2.7-8

ELECTRICAL PROTECTION DEVICES

I. TRUE OR FALSE

Direction: Write T if the statement is True and write F is the statement is false.

1. Fuses, MCBs, RCDs, and RCBOs are all devices used to protect users and equipment from fault conditions in an electrical circuit by isolating the electrical supply.
2. A Circuit breaker is a very basic protection device which is destroyed (i.e. it 'blows') and breaks the circuit should the current exceed the rating.
3. An MCB is a modern alternative to fuses used in Consumer Units (Fuse Boxes).
4. RCDs are tripped if they detect a small current imbalance between the Live and Neutral wires above the trip value - this is typically 30mA.
5. RCDs can be wired to protect a single or a number of circuits.

II. Essay (5pts)

Why electrical protection device is important?

INFORMATION SHEET 3.1-2
INTRODUCTION OF ELECTRONICS

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to recognize electronics. (ELC724335)
- Align with AEP,
    1.6 Obtain parts and components needed to complete the work in accordance with requirements.( TLE_IAEPAS9-12AEP-IVa-27)

The term electronics thus deals with electrical circuits that have electrical components. These common electrical components are vacuum tubes, transistors, diodes, integrated circuits, optoelectronics, and sensors. All of them are associated with passive electrical components and interconnection technologies.

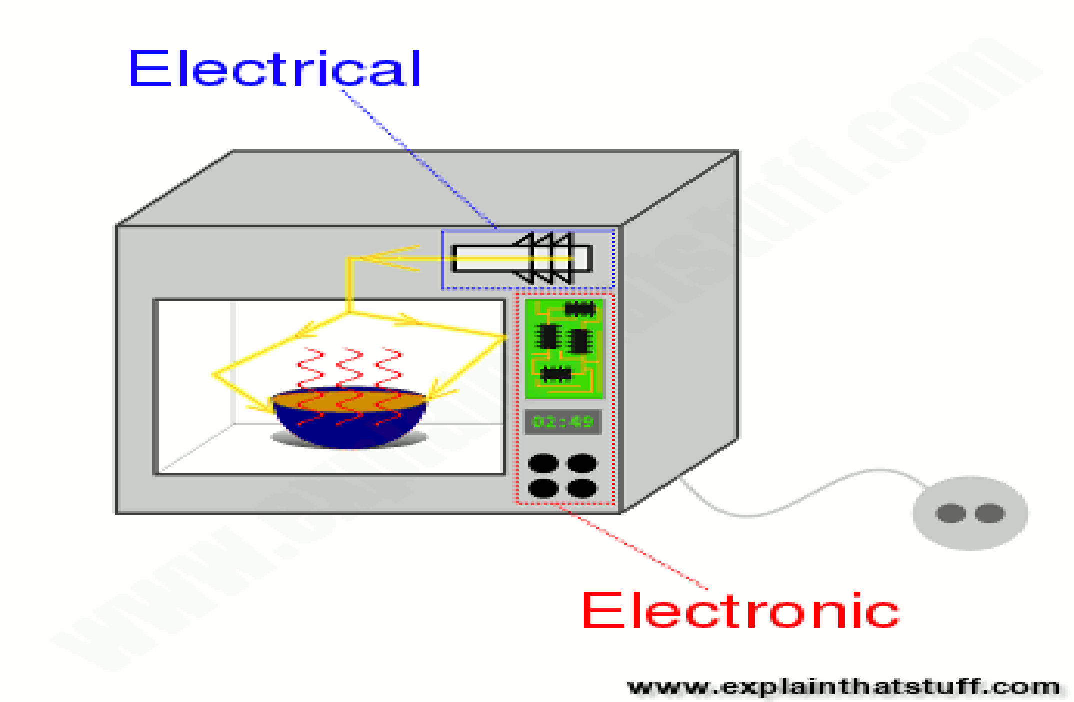
ELECTRICITY

Electricity is the flow of electrical power or charge. Electricity is both a basic part of nature and one of the most widely used forms of energy.

**What's the difference between electricity and electronics?**

A very versatile kind of energy that we can make in all sorts of ways and use in many more. Electricity is all about making electromagnetic energy flow around a circuit so that it will drive something like an electric motor or a heating element, powering appliances such as electric cars, kettles, toasters, and lamps. Generally, electrical appliances need a great deal of energy to make them work so they use quite large (and often quite dangerous) electric currents. The 2500-watt heating element inside an electric kettle operates on a current of about 10 amps. By contrast, electronic components use currents likely to be measured in fractions of milliamps (which are thousandths of amps). In other words, a typical electric appliance is likely to be using currents tens, hundreds, or thousands of times bigger than a typical electronic one.

Electronics is a much more subtle kind of electricity in which tiny electric currents (and, in theory, single electrons) are carefully directed around much more complex circuits to process signals (such as those that carry radio and television programs) or store and process information. Think of something like a microwave oven and it's easy to see the difference between ordinary electricity and electronics. In a microwave, electricity provides the power that generates high-energy waves that cook your food; electronics controls the electrical circuit that does the cooking.




*Artwork: Microwave ovens are powered by electric cables (gray) that plug into the wall. The cables supply electricity that powers high-current electrical circuits and low-current electronic ones. The high-current electrical circuits power the magnetron (blue), the device that makes the waves that cook your food, and rotate the turntable. The low-current electronic circuits (red) control these high-powered circuits, and things like the numeric display unit.*

Analog and digital electronics

There are two very different ways of storing information—known as analog and digital. It sounds like quite an abstract idea, but it's really very simple. Suppose you take an old-fashioned photograph of someone with a film camera. The camera captures light streaming in through the shutter at the front as a pattern of light and dark areas on chemically treated plastic. The scene you're photographing is converted into a kind of instant, chemical painting—an "analogy" of what you're looking at. That's why we say this is an analog way of storing information. But if you take a photograph of exactly the same scene with a digital camera, the camera stores a very different record. Instead of saving a recognizable pattern of light and dark, it converts the light and dark areas into numbers and stores those instead. Storing a numerical, coded version of something is known as digital.


*Photo: Analog and digital electronics. The radio (back) is analog: it "soaks" up radio waves and turns them back into sound with electronic components like transistors and capacitors. The camera (front) is digital: it stores and processes photos as numbers.*

Electronic equipment generally works on information in either analog or digital format. In an old-fashioned transistor radio, broadcast signals enter the radio's circuitry via the antenna sticking out of the case. These are analog signals: they are radio waves, traveling through the air from a distant radio transmitter, that vibrate up and down in a pattern that corresponds exactly to the words and music they carry. So loud rock music means bigger signals than quiet classical music. The radio keeps the signals in analog form as it receives them, boosts them, and turns them back into sounds you can hear. But in a modern digital radio, things happen in a different way. First, the signals travel in digital format—as coded numbers. When they arrive at your radio, the numbers are converted back into sound signals. It's a very different way of processing information and it has both advantages and disadvantages. Generally, most modern forms of electronic equipment (including computers, cell phones, digital cameras, digital radios, hearing aids, and televisions) use digital electronics.



**Electronic components**

If you've ever looked down on a city from a skyscraper window, you'll have marveled at all the tiny little buildings beneath you and the streets linking them together in all sorts of intricate ways. Every building has a function and the streets, which allow people to travel from one part of a city to another or visit different buildings in turn, make all the buildings work together. The collection of buildings, the way they're arranged, and the many connections between them is what makes a vibrant city so much more than the sum of its individual parts.

The circuits inside pieces of electronic equipment are a bit like cities too: they're packed with components (similar to buildings) that do different jobs and the components are linked together by cables or printed metal connections (similar to streets). Unlike in a city, where virtually every building is unique and even two supposedly identical homes or office blocks may be subtly different, electronic circuits are built up from a small number of standard components. But, just like LEGO®, you can put these components together in an infinite number of different places so they do an infinite number of different jobs.

These are some of the most important components you'll encounter:

**Resistors**


These are the simplest components in any circuit. Their job is to restrict the flow of electrons and reduce the current or voltage flowing by converting electrical energy into heat. Resistors come in many different shapes and sizes. Variable resistors (also known as potentiometers) have a dial control on them so they change the amount of resistance when you turn them. Volume controls in audio equipment use variable resistors like these.

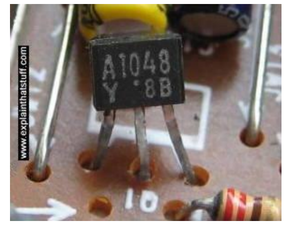
**Diodes**


The electronic equivalents of one-way streets, diodes allow an electric current to flow through them in only one direction. They are also known as rectifiers. Diodes can be used to change alternating currents (ones flowing back and forth round a circuit, constantly swapping direction) into direct currents (ones that always flow in the same direction).

**Capacitors**


These relatively simple components consist of two pieces of conducting material (such as metal) separated by a non-conducting (insulating) material called a dielectric. They are often used as timing devices, but they can transform electrical currents in other ways too. In a radio, one of the most important jobs, tuning into the station you want to listen to, is done by a capacitor.

## Transistors




Easily the most important components in computers, transistors can switch tiny electric currents on and off or amplify them (transform small electric currents into much larger ones). Transistors that work as switches act as the memories in computers, while transistors working as amplifiers boost the volume of sounds in hearing aids. When transistors are connected together, they make devices called logic gates that can carry out very basic forms of decision making. (Thyristors are a little bit like transistors, but work in a different way.)

**Opto-electronic (optical electronic) components**


There are various components that can turn light into electricity or vice-versa. Photocells (also known as photoelectric cells) generate tiny electric currents when light falls on them and they're used as "magic eye" beams in various types of sensing equipment, including some kinds of smoke detector. Light-emitting diodes (LEDs) work in the opposite way, converting small electric currents into light. LEDs are typically used on the instrument panels of stereo equipment. Liquid crystal displays (LCDs), such as those used in flatscreen LCD televisions and laptop computers, are more sophisticated examples of opto-electronics.

SELF CHECK 3.1-2

INTRODUCTION IN ELECTRONICS

MATCHING TYPE

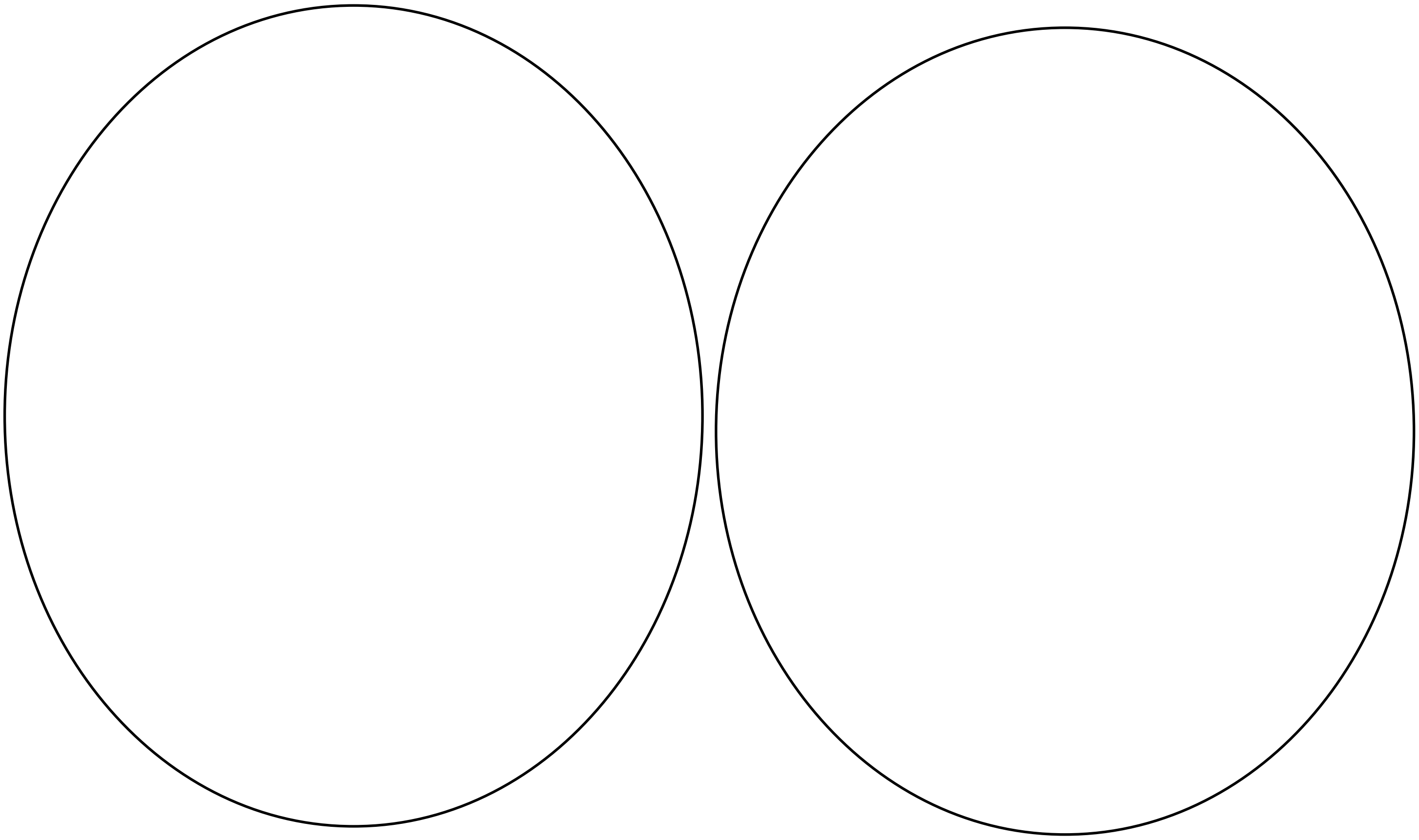
Direction: Match Column A with Column B

| COLUMN A | COLUMN B |
| --- | --- |
| 1. Resistors | Photocells (also known as photoelectric cells) generate tiny electric currents when light falls on them and they're used as "magic |

| | |
|---|---|
| | eye" beams in various types of sensing equipment, including some kinds of smoke detector. |
| | working as amplifiers boost the volume of sounds in hearing aids. |
| 2. Diodes | |
| 3. Capacitors | These relatively simple components consist of two pieces of conducting material (such as metal) separated by a non-conducting (insulating) material called a dielectric. |
| | allow an electric current to flow through them in only one direction. |
| 4. Transistors | |
| 5. Opto Elctronics Components | Their job is to restrict the flow of electrons and reduce the current or voltage flowing by converting electrical energy into heat. |

III. Venn Digram

Difference between electronics and electricity



INFORMATION SHEET 3.3.1

COMMON ELECTRONIC COMPONENTS

**Learning Objective:**

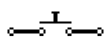
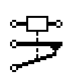
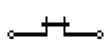
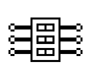
- After reading this INFORMATION SHEET, YOU MUST be able to recognize common electronics components. (ELC724335)
- Align with AEP,

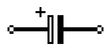
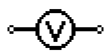
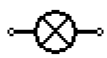
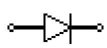
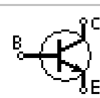
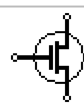
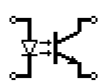
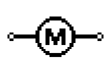
  1.6 Obtain parts and components needed to complete the work in accordance with requirements.( TLE_IAEPAS9-12AEP-IVa-27)

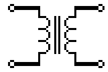
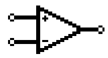
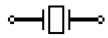
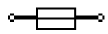
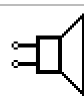
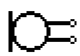
Electronic Components

Electronic components are parts of electrical & electronic circuits. Each component has typical functionality according to its operational characteristics.

Electrical and electronic components table

| Component Image | Component Symbol | Component Name |
|---|---|---|
|  | | Wire |
|  |  | Toggle switch |
|  |  | Pushbutton switch |
| |  | Relay |
| |  | Jumper |
| |  | Dip switch |
|  |  | Resistor |
| |  | Variable resistor / Rheostat |

| | | |
|---|---|---|
| |  | Potentiometer |
|  |  | Capacitor |
|  |  | Variable capacitor |
|  |  | Electrolytic capacitor |
|  |  | Inductor |
|  |  | Battery |
| |   | Voltmeter |
|  |  | Lamp / Light bulb |
|  |  | Diode |
|  |   | BJT Transistor |
|  |  | MOS transistor |
| |  | Optocoupler / optoisolator |
|  |   | Electric motor |

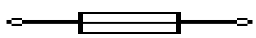
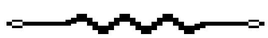
| | | |
|---|---|---|
| |  | Transformer |
| |  | Operational amplifier / 741 |
| |  | Crystal oscillator |
|  |  | Fuse |
|  |  | Buzzer |
| |  | Loudspeaker |
|  |  | Microphone |
| |  | Antenna / aerial |

SELF CHECK 3.3.1

COMMON ELECTRONIC COMPONENT

IDENTIFICATION:

Direction: Identify the common Electronic components according to its symbol.

| Component Symbol | Component Name |
|---|---|
|  | |
|  | |
|  | |
|  | |
|  | |

INFORMATION SHEET 3.4.1

# INTRODUCTION TO CAPACITOR

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to identify capacitor. ( ELC724335)
- Align with AEP,
  5.2 Perform mechanical and electrical/electronic testing in accordance with quality standards, procedures, and requirements. (TLE_IAEPAS9- 12AEP-IVa-27)

## Introduction to Capacitors

Capacitors are simple passive device that can store an electrical charge on their plates when connected to a voltage source

In this introduction to capacitors tutorial, we will see that capacitors are passive electronic components consisting of two or more pieces of conducting material separated by an insulating material. The capacitor is a component which has the ability or "capacity" to store energy in the form of an electrical charge producing a potential difference (Static Voltage) across its plates, much like a small rechargeable battery.

There are many different kinds of capacitors available from very small capacitor beads used in resonance circuits to large power factor correction capacitors, but they all do the same thing, they store charge.

In its basic form, a capacitor consists of two or more parallel conductive (metal) plates which are not connected or touching each other, but are electrically separated either by air or by some form of a good insulating material. This insulating material could be waxed paper, mica, ceramic, plastic or some form of a liquid gel as used in electrolytic capacitors.

As a good introduction to capacitors, it is worth noting that the insulating layer between a capacitors plates is commonly called the Dielectric.

Due to this insulating layer, DC current can not flow through the capacitor as it blocks it allowing instead a voltage to be present across the plates in the form of an electrical charge.

The conductive metal plates of a capacitor can be either square, circular or rectangular, or they can be of a cylindrical or spherical shape with the general shape, size and construction of a parallel plate capacitor depending on its application and voltage rating.

When used in a direct current or DC circuit, a capacitor charges up to its supply voltage but blocks the flow of current through it because the dielectric of a capacitor is non-conductive and basically an insulator. However, when a capacitor is connected to an alternating current or AC circuit, the flow of the current appears to pass straight through the capacitor with little or no resistance.

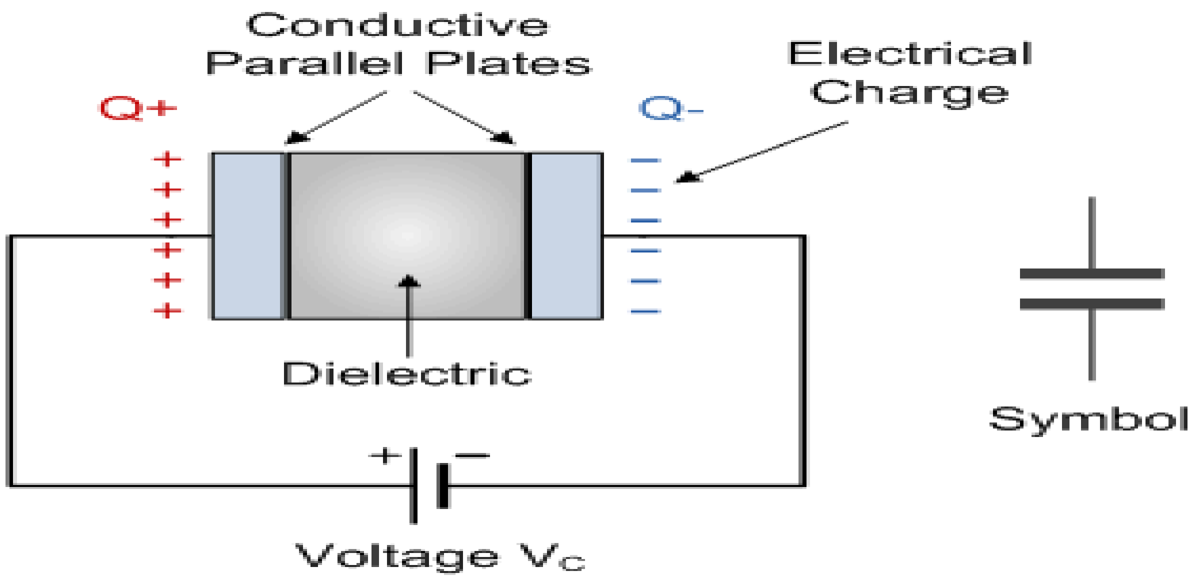
There are two types of electrical charge, a positive charge in the form of Protons and a negative charge in the form of Electrons. When a DC voltage is placed across a capacitor, the positive (+ve) charge quickly accumulates on one plate while a corresponding and opposite negative (-ve) charge accumulates on the other plate. For every particle of +ve charge that arrives at one plate a charge of the same sign will depart from the -ve plate.

Then the plates remain charge neutral and a potential difference due to this charge is established between the two plates. Once the capacitor reaches its steady state condition an electrical current is unable to flow through the capacitor itself and around the circuit due to the insulating properties of the dielectric used to separate the plates.

The flow of electrons onto the plates is known as the capacitors Charging Current which continues to flow until the voltage across both plates (and hence the capacitor) is equal to the applied voltage Vc. At this point the capacitor is said to be “fully charged” with electrons.

The strength or rate of this charging current is at its maximum value when the plates are fully discharged (initial condition) and slowly reduces in value to zero as the plates charge up to a potential difference across the capacitors plates equal to the source voltage.

The amount of potential difference present across the capacitor depends upon how much charge was deposited onto the plates by the work being done by the source voltage and also by how much capacitance the capacitor has and this is illustrated below.




The parallel plate capacitor is the simplest form of capacitor. It can be constructed using two metal or metallised foil plates at a distance parallel to each other, with its capacitance value in Farads, being fixed by the surface area of the conductive plates and the distance of separation between them. Altering any two of these values alters the the value of its capacitance and this forms the basis of operation of the variable capacitors.

Also, because capacitors store the energy of the electrons in the form of an electrical charge on the plates the larger the plates and/or smaller their separation the greater will be the charge that the capacitor holds for any given voltage across its plates. In other words, larger plates, smaller distance, more capacitance.

By applying a voltage to a capacitor and measuring the charge on the plates, the ratio of the charge Q to the voltage V will give the capacitance value of the capacitor and is therefore given as: $C = Q/V$ this equation can also be re-arranged to give the familiar formula for the quantity of charge on the plates as: $Q = C \times V$

Although we have said that the charge is stored on the plates of a capacitor, it is more exact to say that the energy within the charge is stored in an "electrostatic field" between the two plates. When an electric current flows into the capacitor, it charges up, so the electrostatic field becomes much stronger as it stores more energy between the plates.

Likewise, as the current flowing out of the capacitor, discharging it, the potential difference between the two plates decreases and the electrostatic field decreases as the energy moves out of the plates.

The property of a capacitor to store charge on its plates in the form of an electrostatic field is called the Capacitance of the capacitor. Not only that, but capacitance is also the property of a capacitor which resists the change of voltage across it.

**The Capacitance of a Capacitor**

Capacitance is the electrical property of a capacitor and is the measure of a capacitors ability to store an electrical charge onto its two plates with the unit of capacitance being the Farad (abbreviated to F) named after the British physicist Michael Faraday.

Capacitance is defined as being that a capacitor has the capacitance of One Farad when a charge of One Coulomb is stored on the plates by a voltage of One volt. Note that capacitance, C is always positive in value and has no negative units. However, the Farad is a very large unit of measurement to use on its own so sub-multiples of the Farad are generally used such as micro-farads, nano-farads and pico-farads, for example.

Standard Units of Capacitance

Microfarad (μF) 1μF = 1/1,000,000 = 0.000001 = 10-6 F

Nanofarad (nF) 1nF = 1/1,000,000,000 = 0.000000001 = 10-9 F

Picofarad (pF) 1pF = 1/1,000,000,000,000 = 0.000000000001 = 10-12 F

Then using the information above we can construct a simple table to help us convert between pico-Farad (pF), to nano-Farad (nF), to micro-Farad (μF) and to Farads (F) as shown.

| Pico-Farad (pF) | Nano-Farad (nF) | Micro-Farad (μF) | Farads (F) |
|---|---|---|---|
| 1,000 | 1.0 | 0.001 | |
| 10,000 | 10.0 | 0.01 | |
| 1,000,000 | 1,000 | 1.0 | |
| | 10,000 | 10.0 | |
| | 100,000 | 100 | |
| | 1,000,000 | 1,000 | 0.001 |
| | | 10,000 | 0.01 |
| | | 100,000 | 0.1 |
| | | 1,000,000 | 1.0 |

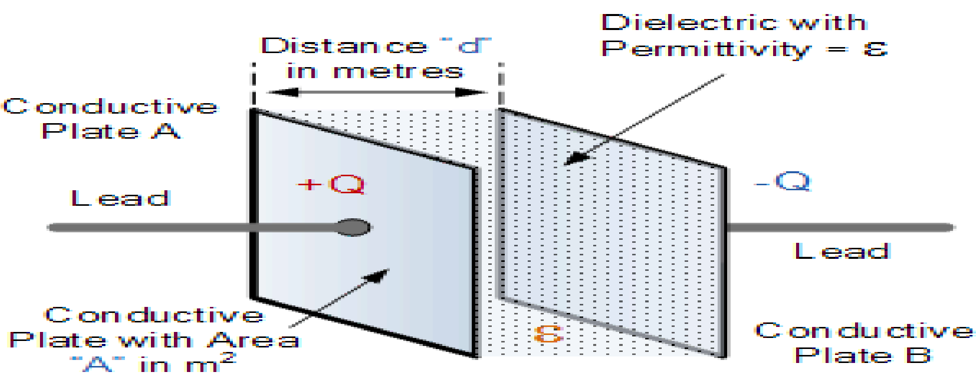
**Introduction to Capacitors – Capacitance**

The capacitance of a parallel plate capacitor is proportional to the area, A in metres2 of the smallest of the two plates and inversely proportional to the distance or separation, d (i.e. the dielectric thickness) given in metres between these two conductive plates.

The generalised equation for the capacitance of a parallel plate capacitor is given as: C = ε(A/d) where ε represents the absolute permittivity of the dielectric material being used. The dielectric constant, εo also known as the "permittivity of free space" has the value of the constant 8.854 x 10-12 Farads per metre.

To make the maths a little easier, this dielectric constant of free space, εo, which can be written as: 1/(4π x 9×109), may also have the units of picofarads (pF) per metre as the constant giving: 8.85 for the value of free space. Note though that the resulting capacitance value will be in picofarads and not in farads.

Generally, the conductive plates of a capacitor are separated by some kind of insulating material or gel rather than a perfect vacuum. When calculating the capacitance of a capacitor, we can consider the permittivity of air, and especially of dry air, as being the same value as a vacuum as they are very close.



SELF CHECK 3.4.1

INTRODUCTION TO CAPACITOR

FILL OUT THE TABLE

Direction: Convert the given value and fill out the table.

| PICO FARAD(pF) | NANO FARAD (Nf) | MICRO FARD (µF) | FARD (F) |
|---|---|---|---|
| 2500 | | | |
| | 15.0 | | |
| | | | 1.5 |
| | | | 20 |
| | | | 26 |
| | | | 14 |
| | | 1,500,000 | |

INFORMATION 3.5.1

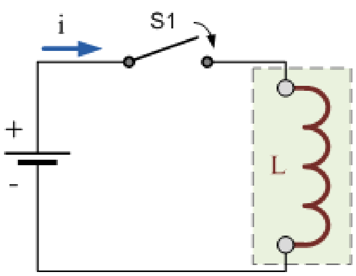
INDUCTORS

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to identify inductors. (ELC724335)
- Align with AEP,

    1.6 Obtain parts and components needed to complete the work in accordance with requirements.( TLE_IAEPAS9-12AEP-IVa-27)

## The Inductor




An Inductor is a passive electrical component consisting of a coil of wire which is designed to take advantage of the relationship between magnetism and electricity as a result of an electric current passing through the coil

In this tutorial we will see that the inductor is an electrical component used to introduce inductance into a circuit which opposes the change of current flow, both magnitude and direction, and that even a straight piece of conductive wire can have some amount of inductance in it.

In our tutorials about Electromagnetism, we saw that when an electrical current flows through a wire conductor, a magnetic flux is developed around that conductor. This affect produces a relationship between the direction of the magnetic flux, which is circulating around the conductor, and the direction of the current flowing through the same conductor. This results in a relationship between current and magnetic flux direction called, “Fleming’s Right Hand Rule”.

But there is also another important property relating to a wound coil that also exists, which is that a secondary voltage is induced into the same coil by the movement of the magnetic flux as it opposes or resists any changes in the electrical current flowing it.

A Typical Inductor

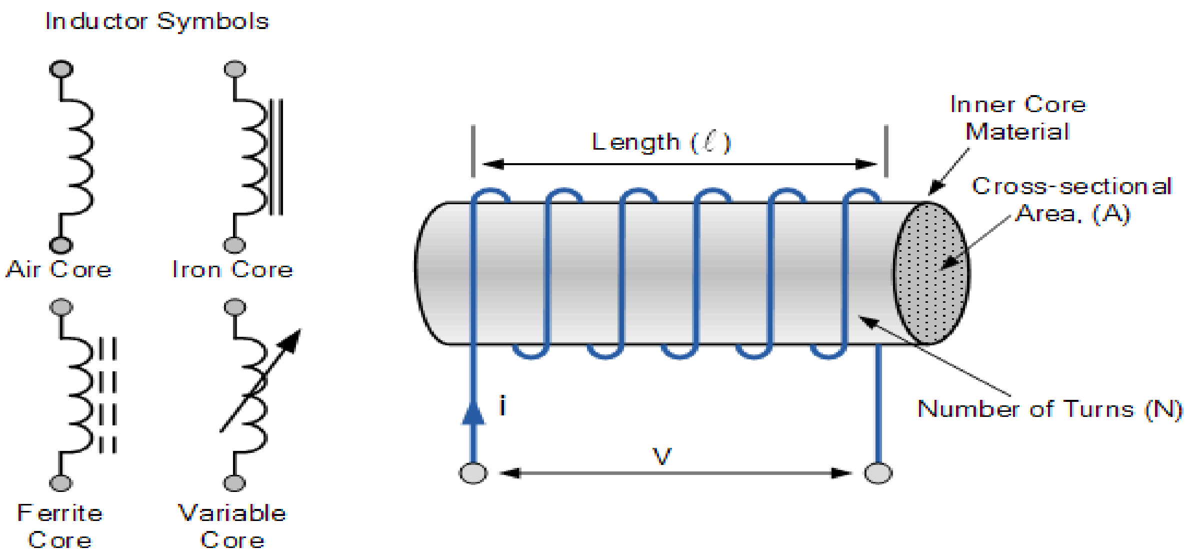
In its most basic form, an Inductor is nothing more than a coil of wire wound around a central core. For most coils the current, ( i ) flowing through the coil produces a magnetic flux, ( NΦ ) around it that is proportional to this flow of electrical current.

An Inductor, also called a choke, is another passive type electrical component consisting of a coil of wire designed to take advantage of this relationship by inducing a magnetic field in itself or within its core as a result of the current flowing through the wire coil. Forming a wire coil into an inductor results in a much stronger magnetic field than one that would be produced by a simple coil of wire.

Inductors are formed with wire tightly wrapped around a solid central core which can be either a straight cylindrical rod or a continuous loop or ring to concentrate their magnetic flux.

The schematic symbol for a inductor is that of a coil of wire so therefore, a coil of wire can also be called an Inductor. Inductors usually are categorised according to the type of inner core they are wound around, for example, hollow core (free air), solid iron core or soft ferrite core with the different core types being distinguished by adding continuous or dotted parallel lines next to the wire coil as shown below.

INDUCTOR SYMBOL




The current, *I* that flows through an inductor produces a magnetic flux that is proportional to it. But unlike a Capacitor which oppose a change of voltage across their plates, an inductor opposes the rate of change of current flowing through it due to the build up of self-induced energy within its magnetic field.

In other words, inductors resist or oppose changes of current but will easily pass a steady state DC current. This ability of an inductor to resist changes in current and which also relates current, i with its magnetic flux linkage, NΦ as a constant of proportionality is called Inductance which is given the symbol L with units of Henry, (H) after Joseph Henry.

Because the Henry is a relatively large unit of inductance in its own right, for the smaller inductors sub-units of the Henry are used to denote its value. For example:

INDUCTANCE PREFIXES

| Prefix | Symbol | Multiplier | Power of Ten |
|---|---|---|---|
| milli | m | 1/1,000 | $10^{-3}$ |
| micro | µ | 1/1,000,000 | $10^{-6}$ |
| nano | n | 1/1,000,000,000 | $10^{-9}$ |

So to display the sub-units of the Henry we would use as an example:

1mH = 1 milli-Henry – which is equal to one thousandths (1/1000) of an Henry.

100μH = 100 micro-Henries – which is equal to 100 millionth's (1/1,000,000) of a Henry.

Inductors or coils are very common in electrical circuits and there are many factors which determine the inductance of a coil such as the shape of the coil, the number of turns of the insulated wire, the number of layers of wire, the spacing between the turns, the permeability of the core material, the size or cross-sectional area of the core etc, to name a few.

An inductor coil has a central core area, ( A ) with a constant number of turns of wire per unit length, ( l ). So if a coil of N turns is linked by an amount of magnetic flux, Φ then the coil has a flux linkage of NΦ and any current, ( i ) that flows through the coil will produce an induced magnetic flux in the opposite direction to the flow of current. Then according to Faraday's Law, any change in this magnetic flux linkage produces a self-induced voltage in the single coil of:

$$V_L = N\frac{d\Phi}{dt} = \frac{\mu N^2 A}{\ell}\frac{di}{dt}$$

Where:

N is the number of turns

A is the cross-sectional Area in m2

Φ is the amount of flux in Webers

μ is the Permeability of the core material

l is the Length of the coil in meters

di/dt is the Currents rate of change in amps/second

A time varying magnetic field induces a voltage that is proportional to the rate of change of the current producing it with a positive value indicating an increase in emf and a negative value indicating a decrease in emf. The equation relating this self-induced voltage, current and inductance can be found by substituting the μN2A / l with L denoting the constant of proportionality called the Inductance of the coil.

The relation between the flux in the inductor and the current flowing through the inductor is given as: NΦ = Li. As an inductor consists of a coil of conducting wire, this then reduces the above equation to give the self-induced emf, sometimes called the back emf induced in the coil too:

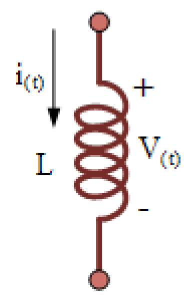
Back emf Generated by an Inductor

back emf of an inductor

$$V_L(t) = \frac{d\phi}{dt} = \frac{dLi}{dt} = -L\frac{di}{dt}$$

Where: L is the self-inductance and di/dt the rate of current change.

So from this equation we can say that the "Self-induced emf equals Inductance times the rate of current change" and a circuit has an inductance of one Henry will have an emf of one volt induced in the circuit when the current flowing through the circuit changes at a rate of one ampere per second.



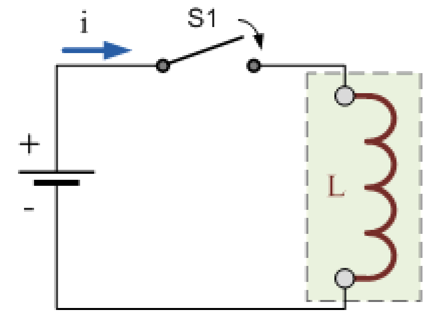

One important point to note about the above equation. It only relates the emf produced across the inductor to changes in current because if the flow of inductor current is constant and not changing such as in a steady state DC current, then the induced emf voltage will be zero because the instantaneous rate of current change is zero, di/dt = 0.

With a steady state DC current flowing through the inductor and therefore zero induced voltage across it, the inductor acts as a short circuit equal to a piece of wire, or at the very least a very low value resistance. In other words, the opposition to the flow of current offered by an inductor is very different between AC and DC circuits.

**The Time Constant of an Inductor**

We now know that the current can not change instantaneously in an inductor because for this to occur, the current would need to change by a finite amount in zero time which would result in the rate of current change being infinite, $di/dt = \infty$, making the induced emf infinite as well and infinite voltages do no exist. However, if the current flowing through an inductor changes very rapidly, such as with the operation of a switch, high voltages can be induced across the inductors coil.

Consider the circuit of a pure inductor on the right. With the switch, ( S1 ) open, no current flows through the inductor coil. As no current flows through the inductor, the rate of change of current (di/dt) in the coil will be zero. If the rate of change of current is zero there is no self-induced back-emf, ( VL = 0 ) within the inductor coil.




If we now close the switch (t = 0), a current will flow through the circuit and slowly rise to its maximum value at a rate determined by the inductance of the inductor. This rate of current flowing through the inductor multiplied by the inductors inductance in Henry's, results in some fixed value self-induced emf being produced across the coil as determined by Faraday's equation above, VL = -Ldi/dt.

This self-induced emf across the inductors coil, ( VL ) fights against the applied voltage until the current reaches its maximum value and a steady state condition is reached. The current which now flows through the coil is determined only by the DC or "pure" resistance of the coils windings as the reactance value of the coil has decreased to zero because the rate of change of current (di/dt) is zero in a steady state condition. In other words, in a real coil only the coils DC resistance exists to oppose the flow of current through itself.

Likewise, if switch (S1) is opened, the current flowing through the coil will start to fall but the inductor will again fight against this change and try to keep the current flowing at its previous value by inducing a another voltage in the other direction. The slope of the fall will be negative and related to the inductance of the coil as shown below

SELFCHECK 3.5.1

INDUCTOR

FILL IN THE BLANKS

Direction: write your answer on the blanks.

1. The current, *I* that flows through an inductor produces a _______flux that is proportional to it.
2. The relation between the flux in the inductor and the current flowing through the inductor is given as_________.
3. 1mH = 1 milli-Henry – which is equal to one thousandths (________) of an Henry.
4. 100μH = 100 micro-Henries – which is equal to 100 millionth's (_______) of a Henry.
5. This results in a relationship between current and magnetic flux direction called, "______________".

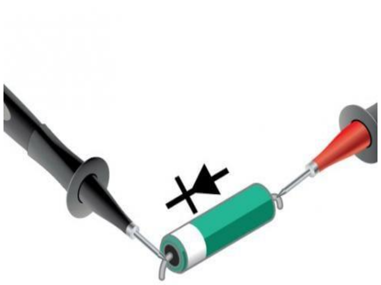
INFORMATION SHEET 3.6.1

DIODE

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to recognize diode. (ELC724335)
- Align with AEP,
    1.6 Obtain parts and components needed to complete the work in accordance with requirements.( TLE_IAEPAS9-12AEP-IVa-27)

What is Diode?



A diode is a semiconductor device that essentially acts as a one-way switch for current. It allows current to flow easily in one direction, but severely restricts current from flowing in the opposite direction.

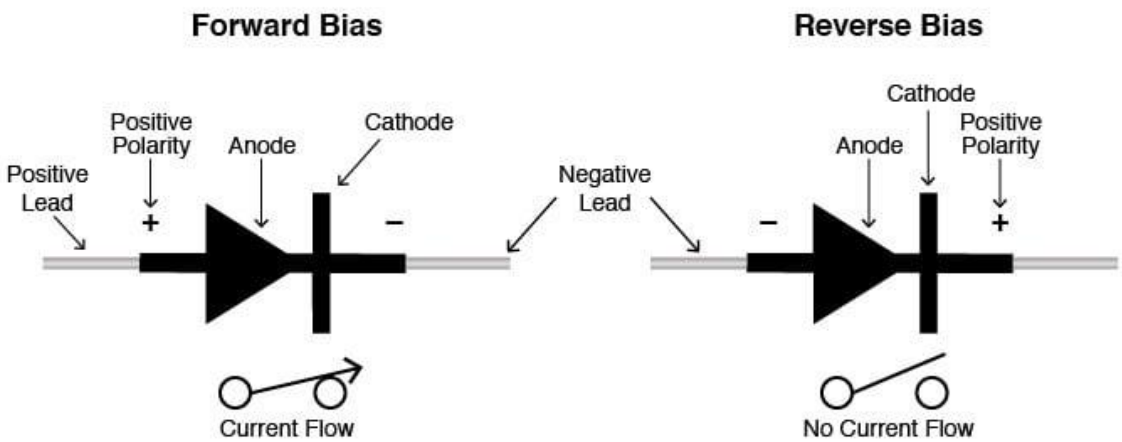
Diodes are also known as rectifiers because they change alternating current (ac) into pulsating direct current (dc). Diodes are rated according to their type, voltage, and current capacity.

Diodes have polarity, determined by an anode (positive lead) and cathode (negative lead). Most diodes allow current to flow only when positive voltage is applied to the anode. A variety of diode configurations are displayed in this graphic:

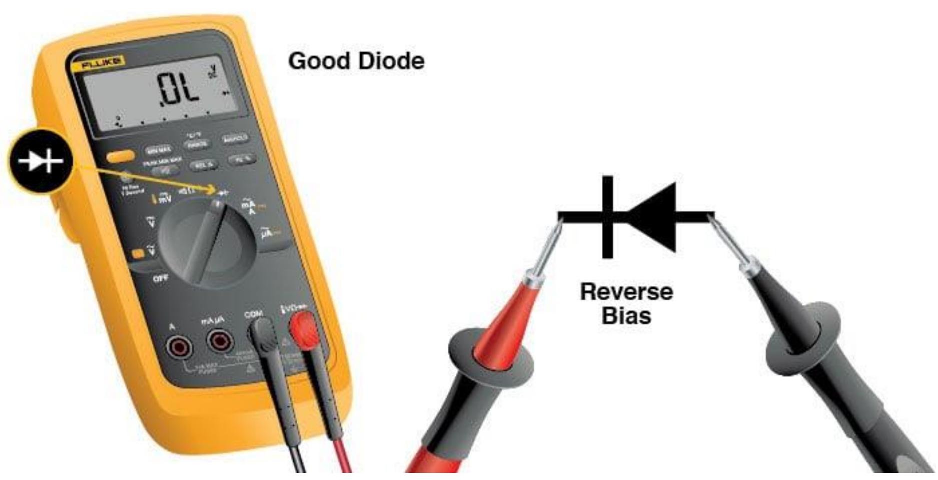
*Diodes are available in various configurations. From left: metal case, stud mount, plastic case with band, plastic case with chamfer, glass case.*

When a diode allows current flow, it is forward-biased. When a diode is reverse-biased, it acts as an insulator and does not permit current to flow.

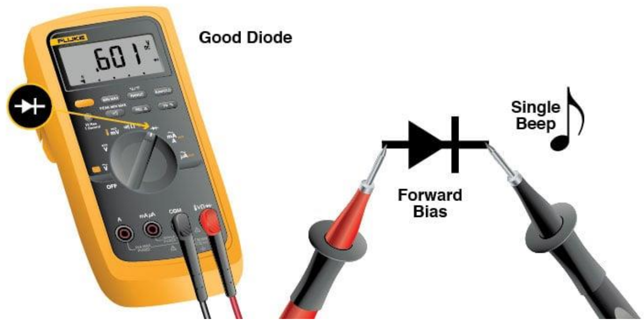
Strange but true: The diode symbol's arrow points against the direction of electron flow. Reason: Engineers conceived the symbol, and their schematics show current flowing from the positive (+) side of the voltage source to the negative (-). It's the same convention used for semiconductor symbols that include arrows—the arrow points in the permitted direction of "conventional" flow, and against the permitted direction of electron flow.



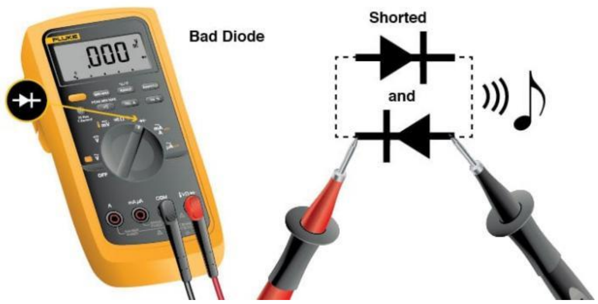

A digital multimeter's diode test diode produces a small voltage between the test leads enough to forward-bias a diode junction. Normal voltage drop is 0.5 V to 0.8 V. The forward-biased resistance of a good diode should range from 1000 ohms to 10 ohms.

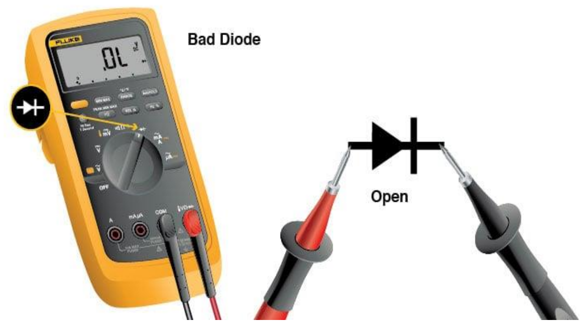



When reverse-biased, a digital multimeter's display will read OL (which indicates very high resistance).




Diodes are assigned current ratings. If the rating is exceeded and the diode fails, it may short and either a) allow current to flow in both directions or b) halt current from flowing in either direction.



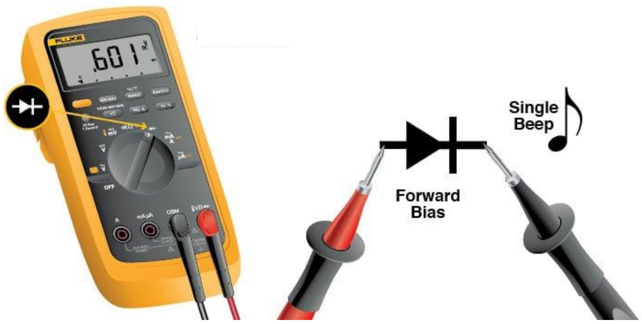

SELFCHECK 3.6.1

DIODE

IDENTIFICATION

Direction: Identify each pictures and write on the blank if the diode is Good or Bad and explain why. (5pts)

1.

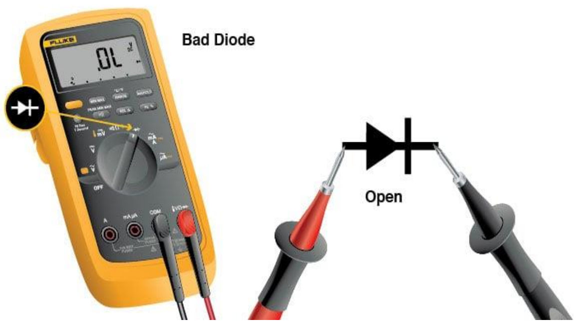



______________________________

____________________________

______________________________________

2.




______________________________

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__________________________________________________________________________________

INFORMATION SHEET 3.7-8

ELECTRONIC FUSE (EFuse)

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to recognize EFuse. (ELC724335)
- Align with AEP,
  1.7 Obtain parts and components needed to complete the work in accordance with requirements.( TLE_IAEPAS9-12AEP-IVa-27)

What is an eFuse?

An integrated circuit protection solution called “eFuse” can overcome the limitations with discrete circuit protection realizations. An eFuse is an “active circuit protection device with an integrated FET used to limit currents, voltages to safe levels during fault conditions”. It embeds various functions to protect system against inrush current, overcurrent, overvoltage, reverse current, reverse polarity and short circuit faults.

The eFuse is more accurate, faster and can ‘repair’ itself without user intervention. Most of the TI eFuses are recognized as Solid State Overcurrent Protectors under the UL2367 standard. Also these are certified under safety standard UL 60950 and are safe to use.

Advantages of using eFuse IC

Possible advantages of using the eFuse IC are as follows.

**Reduction in maintenance costs and time due to no need for replacement**

Since the built-in MOSFET is turned off to cut off the current, the IC will not be destroyed by a single overcurrent. If the FET is turned on again, the IC can return to normal operation by applying the current as before. Unlike conventional fuses that fuse irreversibly, they can be used repeatedly, eliminating the need to replace parts and reducing the cost and time required for maintenance, such as repair.

**Realization of robust protection performance by high-precision current and voltage protection functions**

Conventionally, fuses utilize fusion insulation and thermal expansion, so the current to shut off current cannot be determined strictly. Therefore, there is a risk of breakage because the current rating is selected so that the current rating is a certain

range to avoid malfunction with respect to the current assumed in the load. On the other hand, in eFuse IC, the sensing current can be set with an external resistor, allowing the optimum current values to be set with high accuracy. In addition, for TCKE805/812 series, etc., voltage clamps can be applied with high accuracy against overvoltage. These features provide robust protection against current and voltage.

**Higher reliability thanks to high-speed protection operation**

With conventional fuses, it takes time for the temperature rise due to the Joule heat to reach the melting point of the fuse material, so there is a time lag from the occurrence of overcurrent to the interruption. During this time, overcurrent continues to flow. However, since the e-Fuse IC can turn off the switch and shut off the current at almost the same time as detecting the overcurrent, the time for the overcurrent to flow can be drastically shortened. This reduces damage to the equipment and improves long-term reliability.

**Cost reduction and miniaturization through the use of one-package for various protection functions**

Since the eFuse IC is an IC, in addition to the overcurrent protection function, various functions such as the overvoltage protection function, the inrush current suppression (slew rate control) function, the overheat protection function, and the reverse current prevention function, which cannot be realized by conventional fuses, can be packaged in one package.

Compared to the realization of functions by combining discrete passive components and multiple ICs, this technology dramatically reduces the number of components and man-hours, and reduces the mounting area, thus contributing to lower costs and downsizing.

**Simplification of equipment design by acquiring international safety standards**

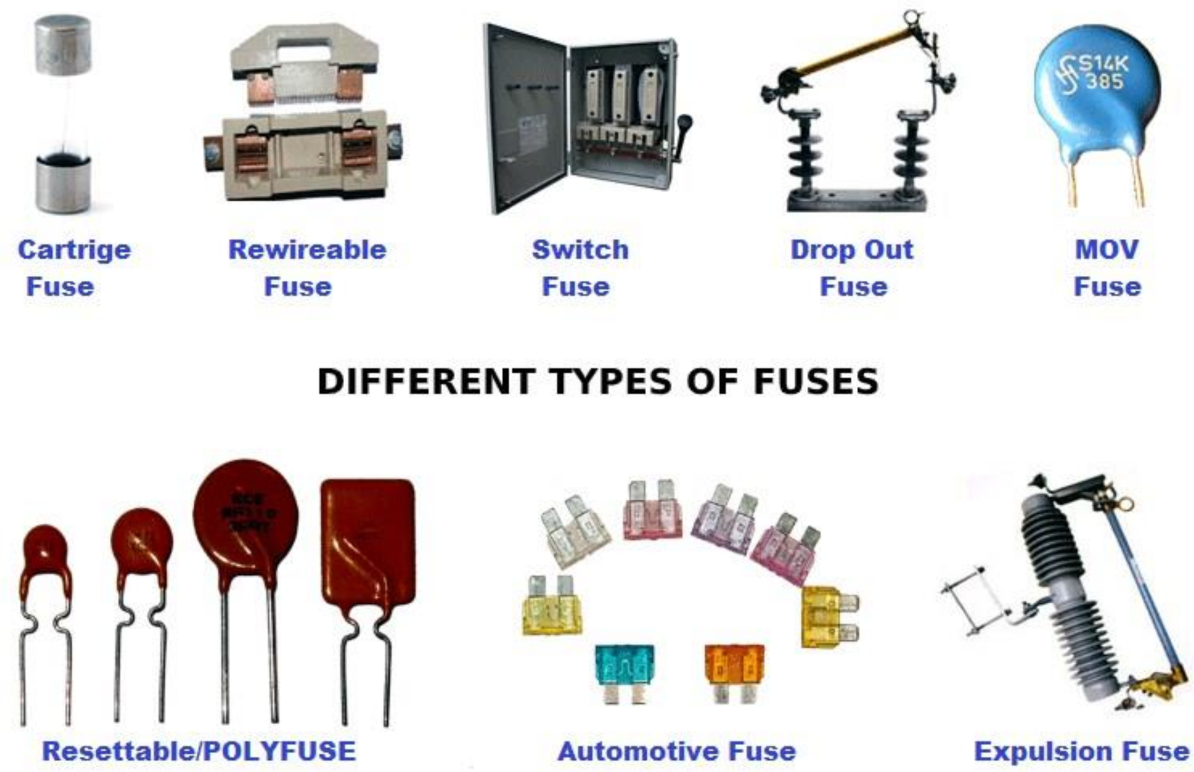
Testing required to comply with internationally recognized safety standards takes time. ICTs and audio/video equipment, which are widely used in commercial equipment such as consumer and industrial equipment, are subject to the IEC62368-

1 of International Safety Standards. However, this standard requires that the power supply be shut off quickly and securely in the event of an abnormality in the equipment.

Since the TCKE800/805/812 series is scheduled to acquire this standard, and testing of equipment related to safety standards can be partially omitted, it contributes to labor saving of equipment design and shortening of design period.

## INFORMATION 3.7-8

## DIFFERENT TYPES OF FUSES AND ITS APPLICATION




**How does a fuse work?**

The primary job of a fuse is to break the circuit if a current higher than desired is drawn by the circuit, thus preventing damage due to short circuits.

The simplest kind of fuse consists of a resistive element, selected carefully for its melting point. When a current passes through this element, a small voltage drop (small enough so the circuit downstream won't be affected) is created across the element, and some power is dissipated as heat. The temperature of the element thus increases. For normal currents, this temperature increase is not enough to melt the filament. However, if the current draw exceeds the rated current of the fuse, the melting point is quickly reached. The resistive element melts and the circuit is interrupted. The thickness and length of the resistive element determine the rated current.

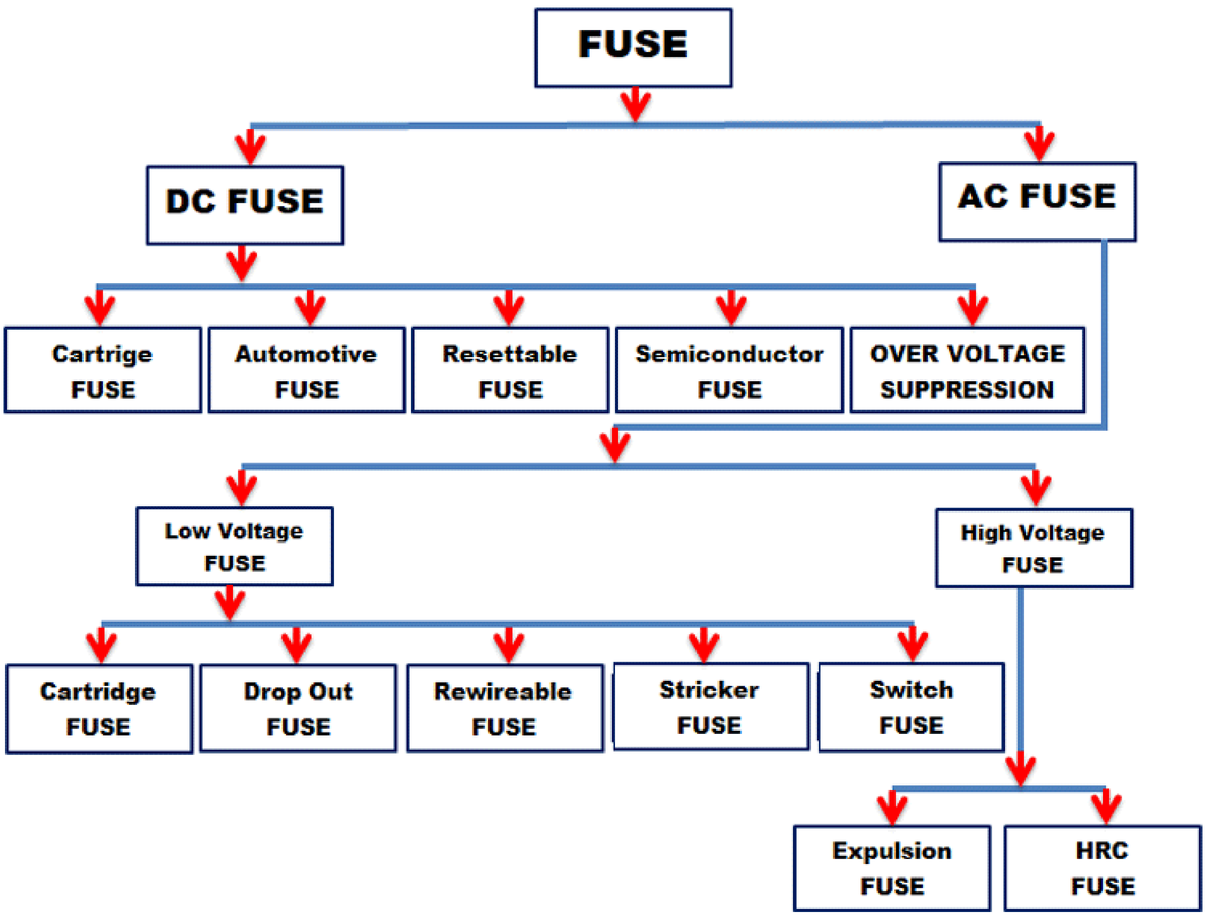
Fuse elements are made of zinc, copper, silver, aluminium or other alloys to provide predictable trip currents. The element must not oxidize or corrode over time.

**SYMBOL OF FUSE**

The standard IEEE/ANSI symbols for the fuse is as follows:

However, the IEC fuse is slightly different:

**TYPE OF FUSES**




1. CARTRIDGE FUSE


This is the most common type of fuse. The fuse element is encased in a glass envelope that is terminated by metal caps. The fuse is placed in an appropriate holder. Since the glass envelope is clear, it is easy to visually determine if the fuse is blown.

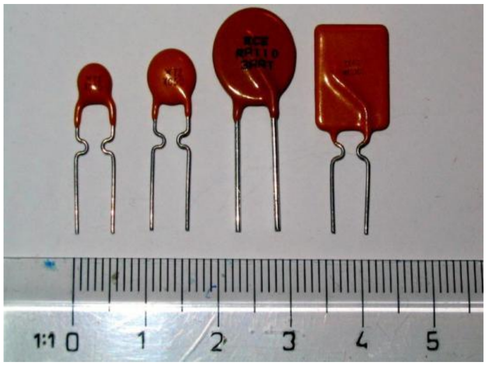
There are many variants of this design, including slow blow fuse and fast blow fuse. Slow blow fuses have a larger element that can handle overcurrent for a relatively short period of time and are unaffected by spikes in the appliance. Fast blow fuses react instantly to current spikes.

Some variants of this fuse are encased in ceramic to withstand high temperatures. Fuses for high voltage applications are filled with sand or oil. This is to prevent arcing between the two ends of the fuse after it has blown. SMD variants of cartridge fuses also exist for direct PCB mounting.

2. AUTOMOTIVE FUSES

These fuses are specifically designed for automotive systems that run up to 32V and occasionally 42V. They come in 'blade' form (a transparent plastic envelope with flat contacts) and are colour coded according to rated current. Some of these types are also used in other high-power circuits.

3. RESETTABLE FUSES




Like their name suggests, these fuses are self-resetting. They contain carbon black particles embedded in organic polymers. Normally, the carbon black makes the mixture conductive. When a large current flows, heat is generated which expands the organic polymer. The carbon black particles are forced apart, and conductivity decreases to the point where no current flows. Conductivity is restored as temperature decreases. Thus, the fuse does not have to be physically replaced. This kind of fuse is also called a PTC, meaning positive temperature coefficient, since resistance increases with temperature. PTC Fuse is ubiquitous in computer

power supplies and phone chargers. They are particularly handy here since replacement is difficult. For the same reason, they are used in aerospace devices.
orange colour and disc (and occasionally rectangular) shape in their through-hole variants. SMD poly fuses usually come in green with white markings or black with gold markings. PTCs are available in virtually every current rating.

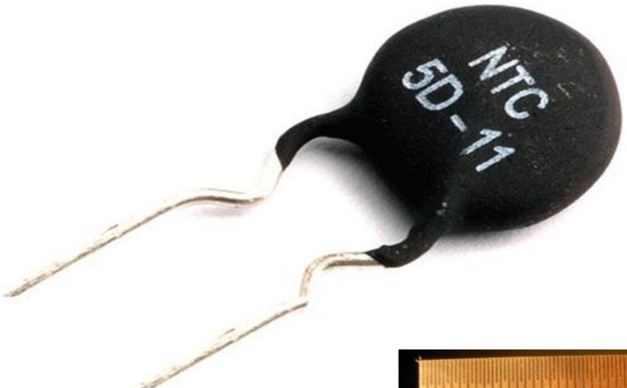
4. SEMICONDUCTOR FUSES

The power dissipated by a semiconductor increases exponentially with current flow, and hence semiconductors are used for ultrafast fuses. These fuses are usually used to protect semiconductor switching devices that are sensitive to even small current spikes.

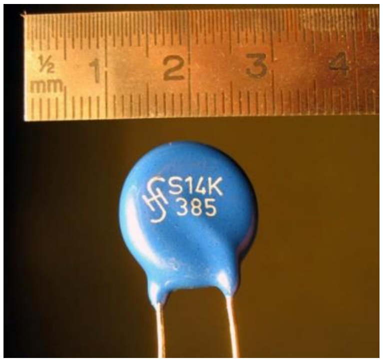
5. OVERVOLTAGE SUPPRESSION

Sometimes voltage spikes can be harmful to circuits too, and often an overvoltage protection device is used with a fuse to protect against both voltage and current spikes.

NTCs (negative temperature coefficient) are placed in parallel with the supply. When the supply voltage spikes, NTC Fuses decrease resistance due to higher current flow and 'absorb' spikes.




Metal oxide varistors (MOVs) are semiconductor like devices that bidirectionally absorb voltage spikes. You can learn more about MOV and its working using the linked article.




SELF CHECK 3.7-8

EFUSE

Enumeration (10pts)

Direction: Enumerate all the things that being asked.

1. Enumerate the advantage of EFuse and explain each.

ESSAY (20pts)

Direction: Explain each item in minimum of 5 sentences.

1. Why efuse is important in electronics devices?
2. Relate EFuse in Real life scenario.

INFORMATION SHEET 4.1-2

INTRODUCTION TO ELECTRONIC CIRCUIT DESIGN

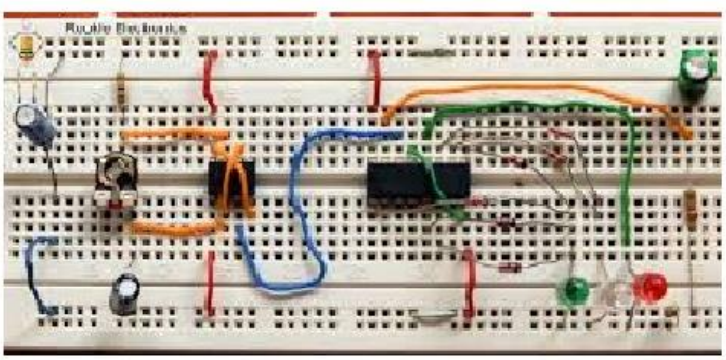
**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to recognize EFuse. (ELC724335)
- Align with AEP,
  - 1.6 Obtain parts and components needed to complete the work in accordance with requirements.( TLE_IAEPAS9-12AEP-IVa-27)

ELECTRONIC CIRCUIT DESIGN

An electronic circuit consists of various electronic components like resistors, capacitor, diodes and transistors connected by a wire, through which current flows in the circuit. The electronic circuit design is generally designed on a breadboard first (prototyping) that helps the designer for modification and enhancement of the circuit. These electronic circuits are used in computations, data transfer and signal amplifications.

Nowadays, instead of connecting the components through a wire, components are soldered to the interconnections which are created on the printed circuit board (PCB) to form a finished circuit.




**Basics of an Electronics Circuit Design Process**

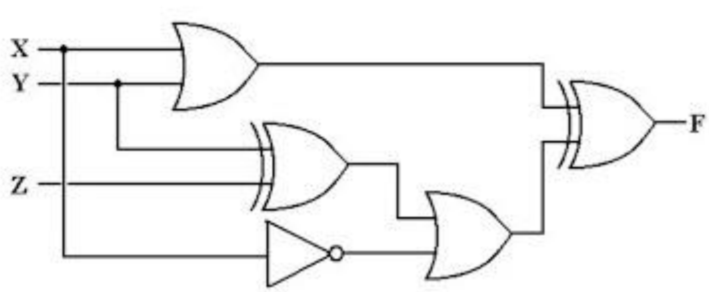
An every elementary electronic device constructed as a single unit. Before the invention of digital circuits (ICs), all individual transistors, diodes, resistors, capacitors, and inductors were discrete in nature. Any circuit or a system can produce the preferred output based on its input. Here we discuss some basic knowledge on electronic circuit design process. Furthermore read about The difference between analogue circuit and digital circuit

**Analog Circuit**

Analogue electronic circuit designs are those in which current or voltage varies with time to correspond to the information being represented. Diodes, capacitors, resistors, transistors and wires are the major components of an analog circuit. In analog circuits, electrical signals take the continuous value, and these circuits are represented in schematic diagrams, where wires are represented by lines and each component is represented by unique symbols. Every analog circuitry has series or parallel or both circuits.

**Digital Circuits**

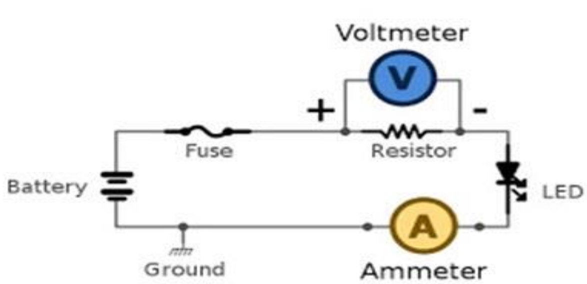
Digital electronic circuit design takes the electrical signals in the form of discrete values. The data are represented in the form of zeros and ones. Digital circuits extensively use transistors, interconnected to give create logic gates that provide the function of Boolean logic. Transistors are interconnected to provide the positive feedback as used in latches and flip-flops. Therefore digital circuits can provide both logic and memory, enabling them to perform computations.

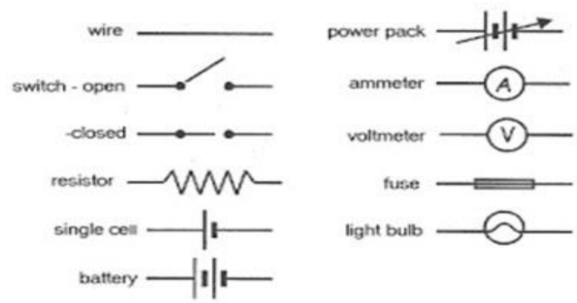



Digital circuit is used to create general purpose computing chips like microprocessors and application specific integrated circuits.

**Schematic Circuit Diagrams**

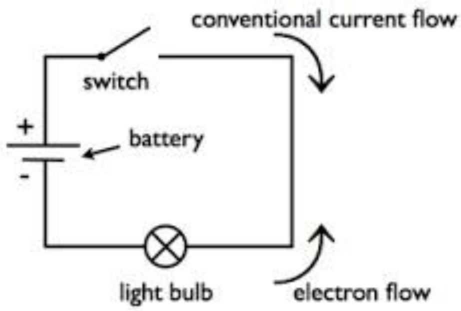
A schematic circuit diagram is the representation of components and interconnections in a circuit using standardised symbols without using the actual image of the component. Circuit diagrams are used for design, construction and maintenance of the electrical and electronic equipment.




Though it is not standardised, the schematic diagrams are organised on a page from left to right and top to bottom. Like, in signalling circuitry the antenna is to the left and speaker to the right. Similarly, positive power supply at the top of the page, with ground and negative supply at the bottom. Relay logic line diagrams also use standardised methods to represent schematic diagrams. A vertical power supply rail at the left and another on the right with the components strung between them representing a ladder. Hence, it is also called as ladder logic diagram.

**Electronic Switch Circuit**



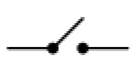

A switch is an electrical device used to interrupt the flow of current in the circuit. These are essentially binary devices which are either completely ON or completely OFF. Besides ON/OFF switches controls the work of a circuit and activates different features of the circuit.

Switches are the mechanical devices with two or more terminals that are connected to the metal contacts. When the contacts are together, the switch is closed. Thus the current flows and switch is ON. When the contact is apart, the switch is open and no current flows.

The above circuitry shows how the switch is used to control the current flow in the bulb. The below are the various switches used in the electronic circuits.

**Toggle Switch**

Toggle switch



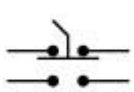
The toggle switch is actuated by a lever angled in one or more positions. The lever flips up or down to close or open the contact. The light switches used in the household are the example of a toggle switch.

**Push Button Switch**

Pushbutton switch

Push button switch is a two-position device actuated with a button to open and close the contacts. Each time you push the button the contact alternates between the open and close.

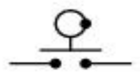
**Selector Switch**



Selector switch

Selector switches are actuated with a rotary knob or a lever to select one or two positions. Selector switch can either rest in any of their positions like the toggle switch.

**Joystick**



Joystick switch

A joystick switch is triggered by a lever free to move in more than one axis of motion. The circle and dot notation on the switch symbol indicate the direction of joystick lever motion that is required to trigger the contact. Joystick hand switches are used to control crane, robot and in games.

**Liquid Level Switch**

Liquid level switch

A floating object is used to activate the switch mechanism when the liquid level rises to a fixed point. When the liquid level reaches a point, the floating object closes the circuit. This closed circuit conducts, making it perform the specific task.

SELFCHECK 4.1-2

ELECTRONIC CIRCUIT DESIGN

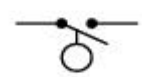
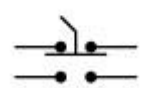
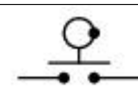
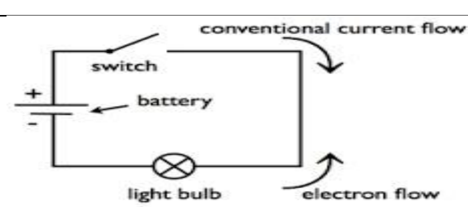
I. FILL IN THE BLANKS

Direction: Write the answer on the blanks provided.

1. An ____________ consists of various electronic components like resistors, capacitor, diodes and transistors connected by a wire, through which current flows in the circuit.
2. Electronic circuits are used in ________, ________ and ______________.
3. _________________ designs are those in which current or voltage varies with time to correspond to the information being represented.
4. ________________ takes the electrical signals in the form of discrete values.
5. ___________________ is the representation of components and interconnections in a circuit using standardized symbols without using the actual image of the component.

II. Matching type

Direction: Match Column A with Column B

| COLUMN A | COLUMN B |
|---|---|
| ELECTRONIC SWITCH CIRCUITS |  |
| JOYSTICK |  |
| SELECTOR SWITCH |  |
| LIQUID LEVEL SWITCH |  |
| PUSH BUTTON SWITCH |  |

INFORMATION SHEET 4.3-5

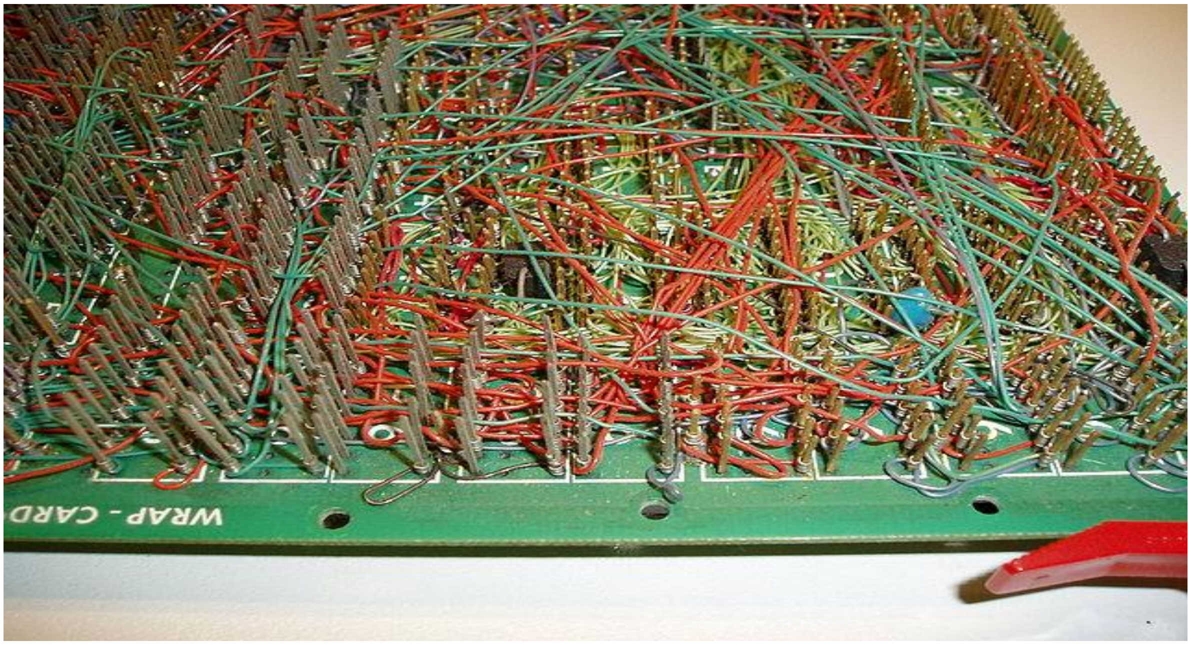
PRINTED CIRCUIT BOARD (PCB)

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to recognize printed circuit board (PCB). (ELC724335)
- Align with AEP,
  - 1.7 Obtain parts and components needed to complete the work in accordance with requirements.( TLE_IAEPAS9-12AEP-Iva-27)
  - LO 3. Mount and solder electronic components
    - 3.1 Apply knowledge on lead and lead-free soldering characteristics and requirements in mounting and soldering process in accordance with OHS standards

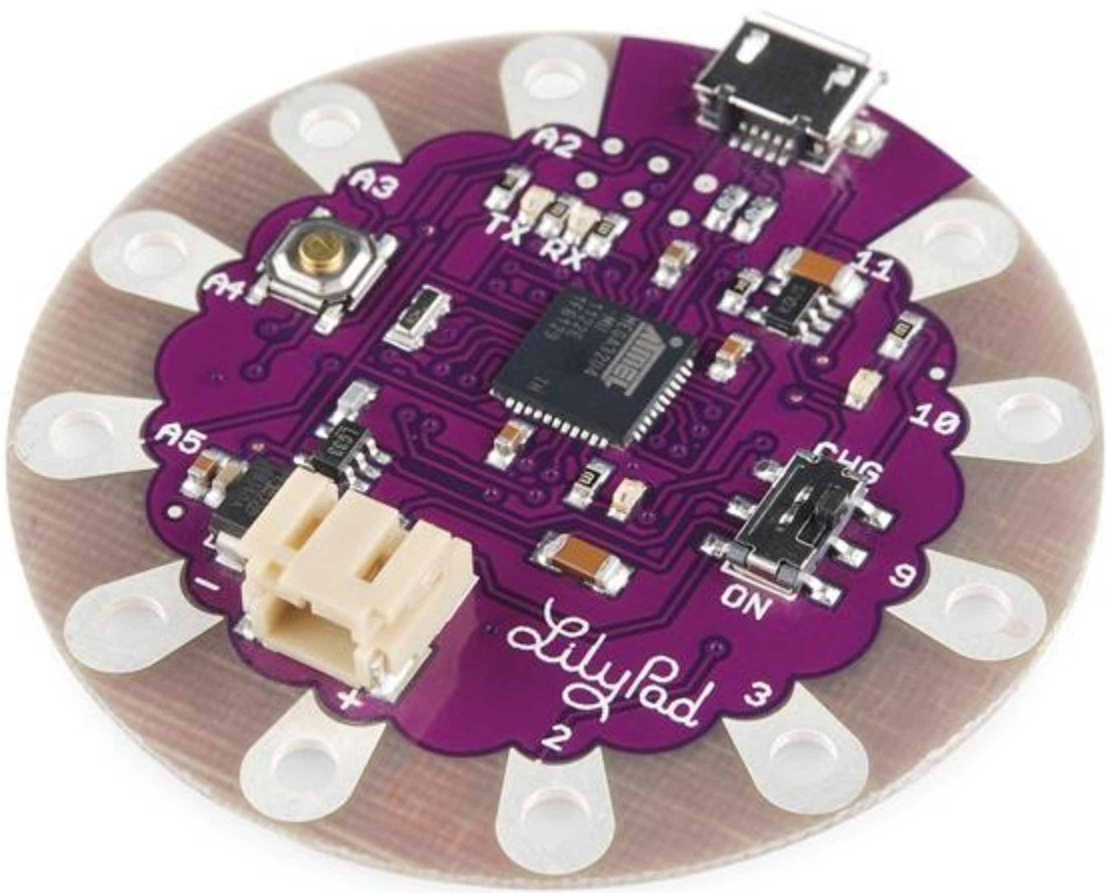
What's a PCB?

Printed circuit board is the most common name but may also be called "printed wiring boards" or "printed wiring cards". Before the advent of the PCB circuits were constructed through a laborious process of point-to-point wiring. This led to frequent failures at wire junctions and short circuits when wire insulation began to age and crack.




A significant advance was the development of wire wrapping, where a small gauge wire is literally wrapped around a post at each connection point, creating a gas-tight connection which is highly durable and easily changeable.

As electronics moved from vacuum tubes and relays to silicon and integrated circuits, the size and cost of electronic components began to decrease. Electronics became more prevalent in consumer goods, and the pressure to reduce the size and manufacturing costs of electronic products drove manufacturers to look for better solutions. Thus was born the PCB.




PCB is an acronym for printed circuit board. It is a board that has lines and pads that connect various points together. In the picture above, there are traces that electrically connect the various connectors and components to each other. A PCB allows signals and power to be routed between physical devices. Solder is the metal that makes the electrical connections between the surface of the PCB and the electronic components. Being metal, solder also serves as a strong mechanical adhesive.

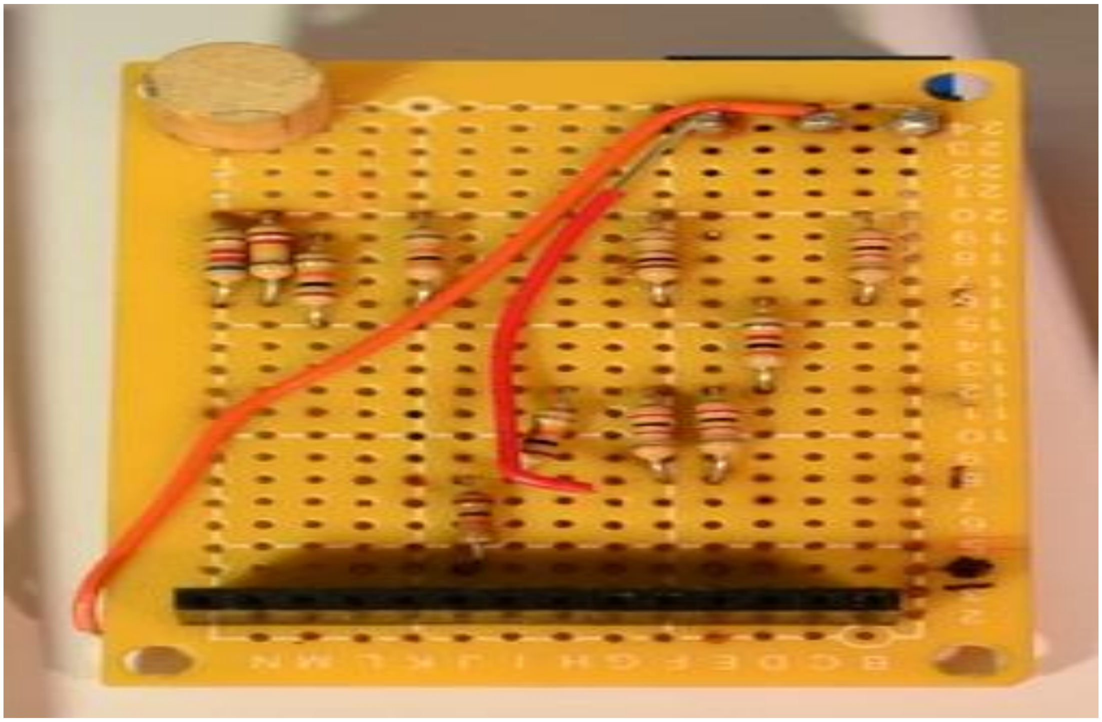
Composition

A PCB is sort of like a layer cake or lasagna- there are alternating layers of different materials which are laminated together with heat and adhesive such that the result is a single object.

**FR4**

The base material, or substrate, is usually fiberglass. Historically, the most common designator for this fiberglass is “FR4”. This solid core gives the PCB its rigidity and thickness. There are also flexible PCBs built on flexible high-temperature plastic (Kapton or the equivalent).

You will find many different thickness PCBs; the most common thickness for SparkFun products is 1.6mm (0.063”). Some of our products- LilyPad boards and Arudino Pro Micro boards- use a 0.8mm thick board.



Cheaper PCBs and perf boards (shown above) will be made with other materials such as epoxies or phenolics which lack the durability of FR4 but are much less expensive. You will know you are working with this type of PCB when you solder to it – they have a very istinctive bad smell. These types of substrates are also typically found in low-end consumer electronics. Phenolics have a low thermal decomposition temperature which causes them to delaminate, smoke and char when the soldering iron is held too long on the board.

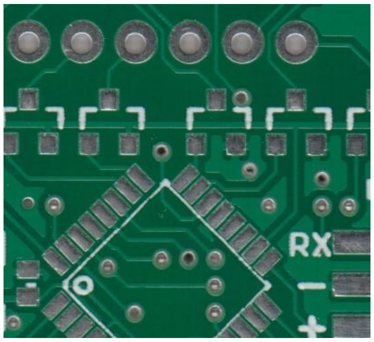
**Copper**

The next layer is a thin copper foil, which is laminated to the board with heat and adhesive. On common, double sided PCBs, copper is applied to both sides of the substrate. In lower cost electronic gadgets the PCB may have copper on only one side. When we refer to a double sided or 2-layer board we are referring to the number of copper layers (2) in our lasagna. This can be as few as 1 layer or as many as 16 layers or more

PCB with copper exposed, no solder mask or silkscreen.

The copper thickness can vary and is specified by weight, in ounces per square foot. The vast majority of PCBs have 1 ounce of copper per square foot but some PCBs that handle very high power may use 2 or 3 ounce copper. Each ounce per square translates to about 35 micrometers or 1.4 thousandths of an inch of thickness of copper.

**Soldermask**

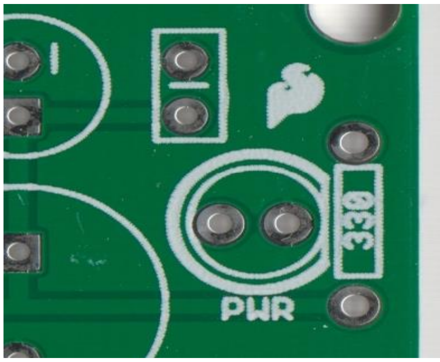



The layer on top of the copper foil is called the soldermask layer. This layer gives the PCB its green (or, at SparkFun, red) color. It is overlaid onto the copper layer to insulate the copper traces from accidental contact with other metal, solder, or conductive bits. This layer helps the user to solder to the correct places and prevent solder jumpers.

In the example below, the green solder mask is applied to the majority of the PCB, covering up the small traces but leaving the silver rings and SMD pads exposed so they can be soldered to.

Soldermask is most commonly green in color but nearly any color is possible. We use red for almost all the SparkFun boards, white for the IOIO board, and purple for the LilyPad boards.

**Silkscreen**



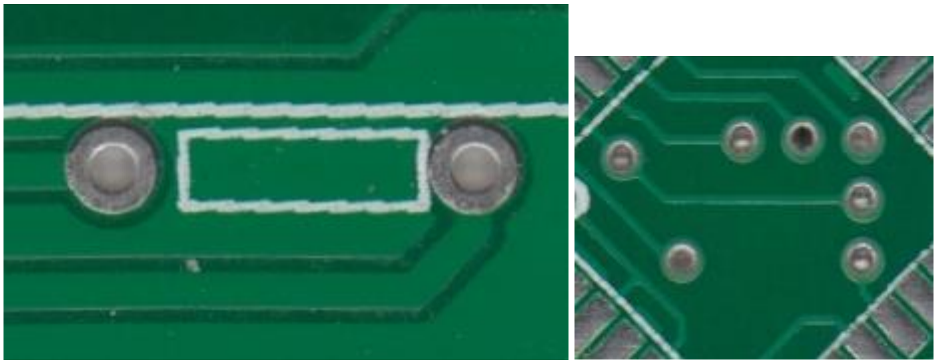

The white silkscreen layer is applied on top of the soldermask layer. The silkscreen adds letters, numbers, and symbols to the PCB that allow for easier assembly and indicators for humans to better understand the board. We often use silkscreen labels to indicate what the function of each pin or LED.

Silkscreen is most commonly white but any ink color can be used. Black, gray, red, and even yellow silkscreen colors are widely available; it is, however, uncommon to see more than one color on a single board.

### Terminology

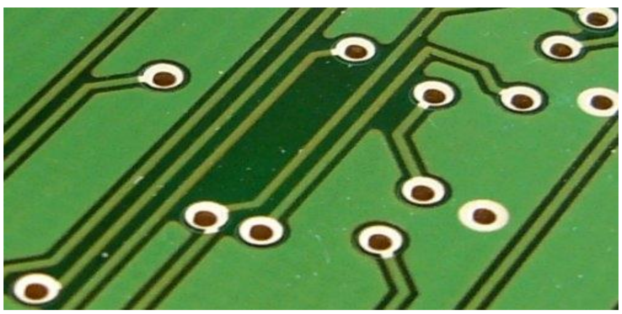
Now that you've got an idea of what a PCB structure is, let's define some terms that you may hear when dealing with PCBs:

- Annular ring – the ring of copper around a plated through hole in a PCB.



*Examples of annular rings.*

DRC – design rule check. A software check of your design to make sure the design does not contain errors such as traces that incorrectly touch, traces too skinny, or drill holes that are too small.



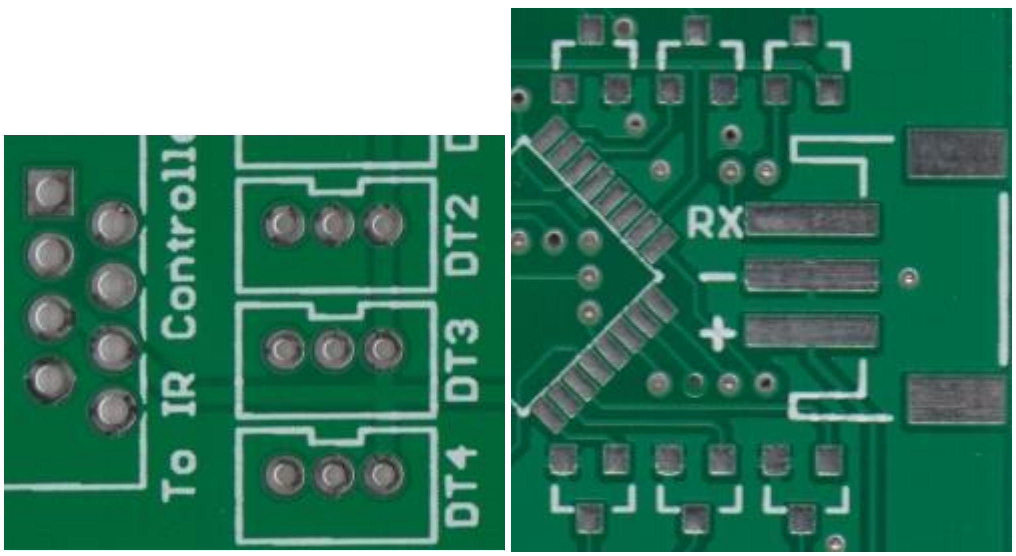
Drill hit – places on a design where a hole should be drilled, or where they actually were drilled on the board. Inaccurate drill hits caused by dull bits are a common manufacturing issue.

Finger – exposed metal pads along the edge of a board, used to create a connection between two circuit boards. Common examples are along the edges of computer expansion or memory boards and older cartridge-based video games.

Mouse bites – an alternative to v-score for separating boards from panels. A number of drill hits are clustered close together, creating a weak spot where the board can be broken easily after the fact. See the SparkFun Protosnap boards for a good example.


*Mouse bites on the [LilyPad ProtoSnap]() allow the PCB to be snapped apart easily.*

Pad – a portion of exposed metal on the surface of a board to which a component is soldered.




*PTH (plated through-hole) pads on the left, SMD (surface mount device) pads on the right.*

Panel – a larger circuit board composed of many smaller boards which will be broken apart before use. Automated circuit board handling equipment frequently has trouble with smaller boards, and by aggregating several boards together at once, the process can be sped up significantly.

Paste stencil – a thin, metal (or sometimes plastic) stencil which lies over the board, allowing solder paste to be deposited in specific areas during assembly.

Pick-and-place – the machine or process by which components are placed on a circuit board.

Plane – a continuous block of copper on a circuit board, define by borders rather than by a path. Also commonly called a “pour”.


*Various portions of the PCB that have no traces but has a ground pour instead.*

Plated through hole – a hole on a board which has an annular ring and which is plated all the way through the board. May be a connection point for a through hole component, a via to pass a signal through, or a mounting hole.


*A PTH resistor inserted into the [FabFM](FabFM) PCB, ready to be soldered. The legs of the resistor go through the holes. The plated holes can have traces connected to them on the front of the PCB and the rear of the PCB*

Pogo pin – spring-loaded contact used to make a temporary connection for test or programming purposes.

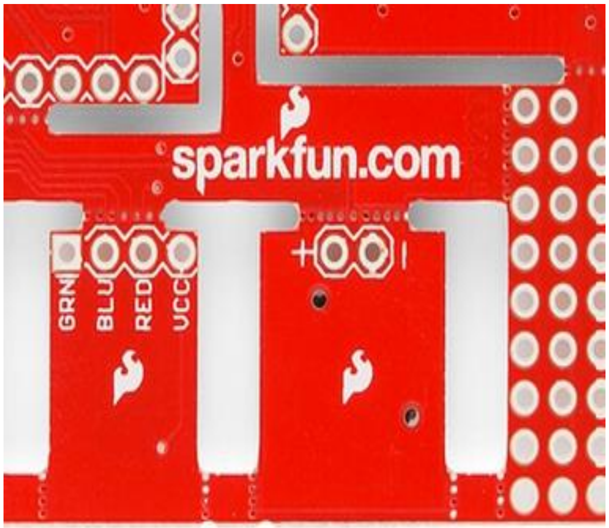

*The popular [pogo pin with pointed tip](). We use tons of these on our test beds.*

Reflow – melting the solder to create joints between pads and component leads.

Silkscreen – the letters, number, symbols, and imagery on a circuit board. Usually only one color is available, and resolution is usually fairly low.

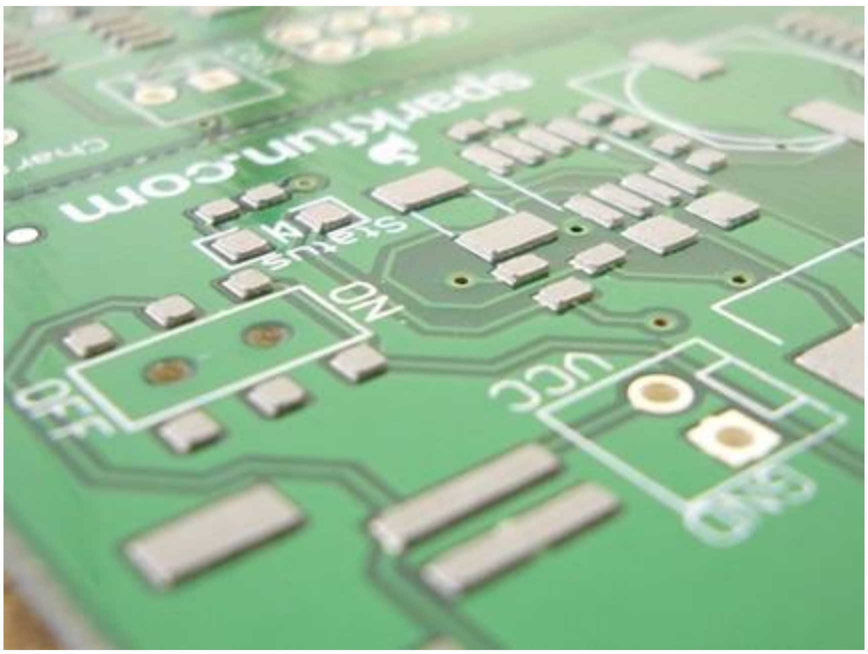

*Silkscreen identifying this LED as the power LED.*

Slot – any hole in a board which is not round. Slots may or may not be plated. Slots sometimes add to add cost to the board because they require extra cut-out time.




*Complex slots cut into the [ProtoSnap – Pro Mini](). There are also many mouse bites shown.* ***Note:*** *the corners of the slots cannot be made completely square because they are cut with a circular routing bit.*

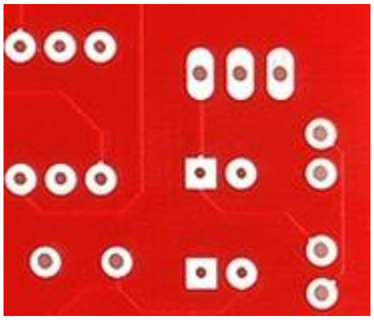
Solder paste – small balls of solder suspended in a gel medium which, with the aid of a paste stencil, are applied to the surface mount pads on a PCB before the components are placed. During reflow, the solder in the paste melts, creating electrical and mechanical joints between the pads and the component.




*Solder paste on a PCB shortly before the components are placed. Be sure to read about *paste stencil* above as well.*

Solder pot – a pot used to quickly hand solder boards with through hole components. Usually contains a small amount of molten solder into which the board is quickly dipped, leaving solder joints on all exposed pads.

Soldermask – a layer of protective material laid over the metal to prevent short circuits, corrosion, and other problems. Frequently green, although other colors (SparkFun red, Arduino blue, or Apple black) are possible. Occasionally referred to as “resist”.

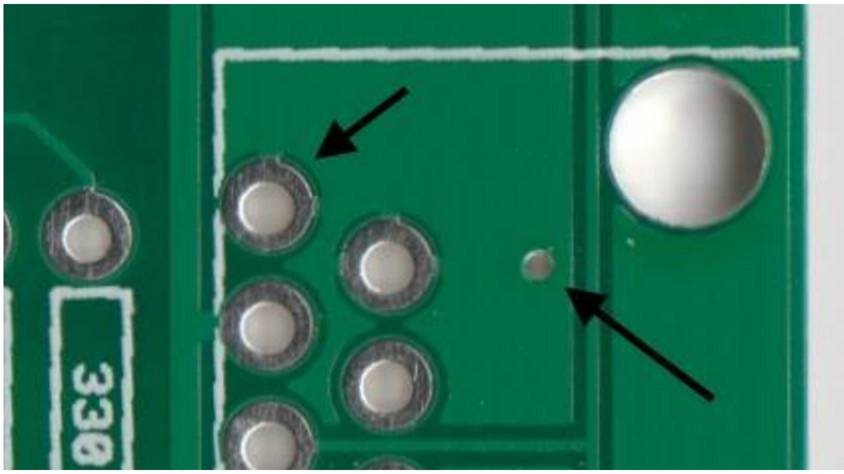


*Solder mask covers up the signal traces but leaves the pads to solder to.*

Solder jumper – a small, blob of solder connecting two adjacent pins on a component on a circuit board. Depending on the design, a solder jumper can be used to connect two pads or pins together. It can also cause unwanted shorts.

Surface mount – construction method which allows components to be simply set on a board, not requiring that leads pass through holes in the board. This is the dominant method of assembly in use today, and allows boards to be populated quickly and easily.

Thermal – a small trace used to connect a pad to a plane. If a pad is not thermally relieved, it becomes difficult to get the pad to a high enough temperature to create a good solder joint. An improperly thermally relieved pad will feel “sticky” when you attempt to solder to it, and will take an abnormally long time to reflow.



*On the left, a solder pad with two small traces (thermals) connecting the pin to the ground plane. On the right, a via with no thermals connecting it completely to the ground plane*

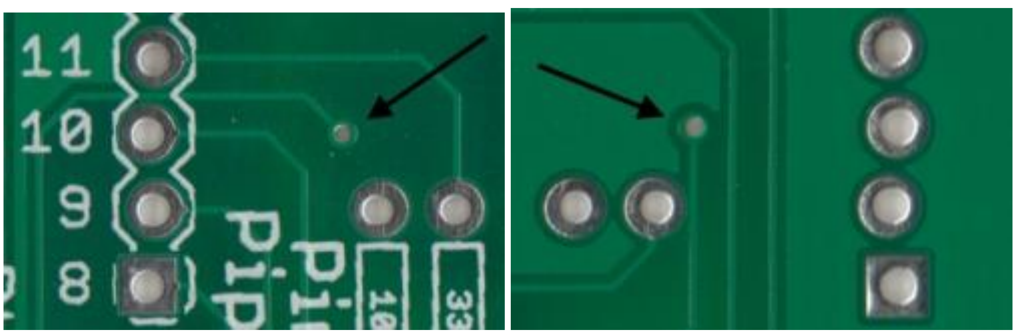
Thieving – hatching, gridlines, or dots of copper left in areas of a board where no plane or traces exist. Reduces difficulty of etching because less time in the bath is required to remove unneeded copper.

Trace – a continuous path of copper on a circuit board.


*-> A small trace connecting the **Reset** pad to elsewhere on the board. A larger, thicker trace connects to the **5V** power pin. <-*

V-score- a partial cut through a board, allowing the board to be easily snapped along a line.

Via – a hole in a board used to pass a signal from one layer to another. Tented vias are covered by soldermask to protect them from being soldered to. Vias where connectors and components are to be attached are often untented (uncovered) so that they can be easily soldered.




*Front and back of the same PCB showing a tented via. This via brings the signal from the front side of the PCB, through the middle of the board, to the back side.*

Wave solder – a method of soldering used on boards with through-hole components where the board is passed over a standing wave of molten solder, which adheres to exposed pads and component leads.

**Designing Your Own!**

How do you go about designing your own PCB? The ins and outs of PCB design are way too in depth to get into here, but if you really want to get started, here are some pointers:

Find a CAD package: there are a lot of low-cost or free options out there on the market for PCB design. Things to consider when choosing a package:

Community support: are there a lot of people using the package? The more people using it, the more likely you are to find ready-made libraries with the parts you need.

Ease-of-use: if it's painful to use it, you won't.

Capability: some programs place limitations on your design- number of layers, number of components, size of board, etc. Most of them allow you to pay for a license to upgrade their capability.

Portability: some free programs do not allow you to export or convert your designs, locking you in to one supplier only. Maybe that's a fair price to pay for convenience and price, maybe not.

Look at other people's layouts to see what they have done. Open Source Hardware makes this easier than ever.

Practice, practice, practice.

Maintain low expectations. Your first board design will have lots of problems. Your 20$^{th}$ board design will have fewer, but will still have some. You'll never get rid of them all.

Schematics are important. Trying to design a board without a good schematic in place first is an exercise in futility.

Finally, a few words on the utility of designing your own circuit boards. If you plan on making more than one or two of a given project, the payback on designing a board is pretty good- point-to-point wiring circuits on a protoboard is a hassle, and they tend to be less robust than purpose-designed boards. It also allows you to sell your design if it turns out to be popular.

SELF CHECK 4.3-5

PRINTED CIRCUIT BOARD (PCB)

ANSWER BOX

Direction: Read each question carefully and find your answer in the box.

| | | |
|---|---|---|
| Solder | Solder Mask | Silkscreen |

| | | |
|---|---|---|
| FR4 | Solder Paste | Printed Circuit Board (PCB) |

1. The base material, or substrate, is usually fiberglass. Historically, the most common designator for this fiberglass is________?

2. It is a board that has lines and pads that connect various points together.

3. The layer on top of the copper foil is called the_____________?

4. A metal that makes the electrical connections between the surface of the PCB and the electronic components

5. A small balls of solder suspended in a gel medium which, with the aid of a paste stencil, are applied to the surface mount pads on a PCB before the components are placed

Fill the Box

Direction: The fill out the table with terminology or definition.

| Terminology | Definition |
|---|---|
| **Slot** | |
| | melting the solder to create joints between pads and component leads. |
| | a pot used to quickly hand solder boards with through hole components. Usually contains a small amount of molten solder into which the board is quickly dipped, leaving solder joints on all exposed pads. |
| **Solder jumper** | |
| **Thermal** | |
| | hatching, gridlines, or dots of copper left in areas of a board where no plane or traces exist. Reduces difficulty of etching because less time in the bath is required to remove unneeded copper. |
| **Trace** | |
| | the letters, number, symbols, and imagery on a circuit board. Usually only one color is available, and resolution is usually fairly low. |

| | |
|---|---|
| | a hole on a board which has an annular ring and which is plated all the way through the board. May be a connection point for a through hole component, a via to pass a signal through, or a mounting hole. |
| **Plane** | |
| **Plated through hole** | |

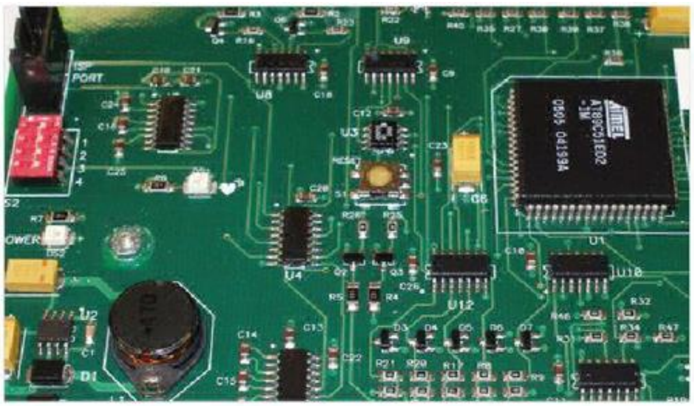
INFORMATIONSHEET 4.6.1

PCB DESIGNING

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to recognize printed circuit board (PCB). (ELC724335)
- Align with AEP,
    1.8 Obtain parts and components needed to complete the work in accordance with requirements.( TLE_IAEPAS9-12AEP-Iva-27)

PCB DESIGN GUIDELINES



It's easy to leave the PCB design guidelines as an afterthought, spending most of your time focusing on circuit design, functionality, and component selection. However, not providing attention to PCB layout basics can lead to a design that translates poorly from the digital domain to physical reality. Thereby making it more difficult to fabricate.

The top 5 PCB design guidelines we can suggest to improve manufacturability, functionality, and reliability are discussed below.

**1. Fine-Tune Component Placement**

The component placement requires strategic consideration of the available PCB real estate available on your board. This process can be challenging. However, placement of electronic components will determine how easy the board is to manufacture, as well as how well it meets your design requirements.

There are many PCB layout rules to consider during component placement. While general board layout guidelines tell you to place components in order of connectors, power circuits, precision circuits, critical circuits, etc, there are also several specific board layout guidelines to consider.

Orientation: Be sure to orient similar components in the same direction as this will help with effective routing in PCB design. It also helps ensure an efficient and error-free soldering process during assembly.

Placement: Avoid placing components on the solder side of a board that would rest behind plated through-hole components.

Organization: It’s recommended to place all your surface mount devices (SMD) components on the same side of your board according to SMD PCB design rules. All through-hole (TH) components should be placed on the top side of your board to minimize the number of assembly steps.

When using mixed-technology components (through-hole and surface mount components), manufacturers might require an extra process to assemble your board, which will add to your overall printed circuit board costs.

**2. Power, Ground & Signal Traces**
After component placement, route your power, ground, and signal traces to ensure your signals have a clean and trouble-free path of travel. Here are some guidelines to keep in mind for this stage of your layout process:

Place your power and ground planes internal to your printed circuit board keeping them symmetrical and centered. This will help to prevent your board from bending, which will also affect whether your components are properly positioned. Note that this is not possible on a two-layer board as you will not have any room for components. To power your ICs, it’s recommended to use common rails for each supply, ensure you have solid and wide traces, and also avoid daisy-chaining power lines from part to part.

Next connect the signal traces to match your schematic guidelines. PCB layout best practices recommend that you always keep traces as shortand directas possible between components. If your component placement forces horizontal trace routing on one side of the board, then always route traces vertically on the opposite side.

Printed circuit board design rules and PCB layout guidelines become more complex as the number of layers in your stack-up increases. Your routing strategy will require alternating horizontal and vertical traces in alternating layers unless you separate each signal layer with a reference plane.

Your printed circuit board design will likely require different nets that will carry a wide range of currents, which will dictate the required net width. It’s recommended to provide a 0.010” width for low current analog and digital signals. Printed circuit board traces that carry more than 0.3 A should be wider.

**3. Keep Things Separate**
Large voltage in power circuits and current spikes can interfere with low voltage and current control circuits. To minimize this interference issue, it’s recommended to:

Separate power ground and control ground for each power supply stage. If you do have to tie them together in your PCBs, make sure it’s toward the end of your supply path.

If you have placed your ground plane in the middle layer be sure to place a small impedance path to reduce the risk of any power circuit interference and to help protect your control signals. The same guideline can be followed to keep your digital and analog ground separate.

To reduce capacitive coupling due to the placement of a large ground plane and the lines routed above and under it, try to have your analog ground crossed only by analog lines.

**4. Minimize Heating Issues**

Heat dissipation can degrade performance. Some guidelines to minimize include:

Identify Problem Parts -considerwhich components will dissipate the most heat on your board. This can be accomplished by first finding the “Thermal Resistance” ratings in the component’s datasheet, and then following the recommended guidelines to divert the heat being produced. Of course, heatsinks and cooling fans can be added to keep component temperatures down. Keep critical components away from any high heat sources.

If you have more than one component that generates a large amount of heat, it may be best to distribute these components throughout the board, rather than clustering them in one location. This prevents hot spots from forming in the board. You may have to carefully balance the placement of these components against keeping trace lengths short as you devise a routing strategy, which can be challenging.

Thermal reliefs can be useful to produce a manufacturable board and they are critical for wave soldering application on assemblies and multilayer boards with high copper content. Because it can be difficult to maintain process temperatures, it’s always recommended to utilize thermal reliefs on through-hole components to make the soldering process as easy as possible by slowing the rate of heat sinking through the component plates.

Some designers advise using a thermal relief pattern for any via or hole that is connected to a ground or power plane. This is not always the best advice. Note that a power/ground via can appear near an IC with a fast switching speed, which generates a lot of heat. Moving heat away from the IC helps regulate the temperature of the IC.

The ground plane can act as a large heat sink that then transports heat evenly throughout the board. Therefore, if a particular via is connected to a ground plane, omitting the thermal relief pads on that via will allow heat to conduct to the ground plane. This is preferable to keeping heat trapped near the surface. However, this can create a problem if your board is assembled using wave soldering, as you need to keep heat trapped near the surface.

In addition to thermal reliefs, you can also add teardrops where traces join pads to provide additional copper foil /metal support. This will help to reduce mechanical stress and thermal stress.

**5. Verify Your Layout Against Your PCB Design Rules**
It's easy to get overwhelmed as you scramble to fit your remaining pieces together for manufacturing. Double and triple-checking your work for any errors at this stage can mean the difference between a manufacturing success or failure.

To help with this quality control process, it's always recommended to start with your Electrical Rules Check (ERC) and Design Rules Check (DRC) to verify you've met all of your established constraints. With these two systems, you can easily define gap widths, trace widths, common manufacturing requirements, high-speed electrical requirements, and other physical requirements for your particular application. This automates PCB layout review guidelines for validating your layout.

Note that many design processes state that you should run design rule checks at the end of the design phase while preparing for manufacturing. If you use the right design software, you can run checks throughout the design process, which allows you to identify design potential problems early and correct them quickly.

When your final ERC and DRC have produced error-free results, it's then recommended to check the routing of every signal and confirm that you haven't missed anything by running through your schematic one wire at a time. And of course, ensure that your PCB layout matches your schematic with the use of your design tool's probing and masking feature.

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## Ten golden rules of PCB design

Although the current level of semiconductor integration is getting higher and higher, many applications also have system-on-chips available at any time, and many powerful and out-of-the-box development boards are also more and more easily available, but many use cases in electronic products The application still needs to use a custom PCB. In one-time development, even an ordinary PCB can play a very important role. PCB is the physical platform for design and the most flexible part for electronic system design of original components.

**Rule 1: Choose the right grid-set and always use the grid spacing that matches the most components.**

Although the multi-grid seems to be effective, if engineers can think more in the early stage of PCB layout design, they can avoid the problems encountered in the interval setting and maximize the application of the circuit board. Because many devices use multiple package sizes, engineers should use the product that is most conducive to their own design. In addition, polygon is very important for circuit board copper. Multi-grid circuit boards generally produce polygonal filling deviation when polygonal copper is applied. Although it is not as standard as based on a single grid, it can provide more than the required circuit board life.

**Rule 2: Keep the path shortest and most direct.**

This sounds simple and common, but it should be kept in mind at every stage, even if it means to change the circuit board layout to optimize the wiring length.

**Rule 3: Use the power layer as much as possible to manage the distribution of power lines and ground lines.**

The power layer copper is a faster and simpler choice for most PCB design software. By connecting a large number of wires in common, it is possible to ensure that the current with the highest efficiency and minimum impedance or voltage drop is provided, while providing sufficient ground return paths.

**Rule 4: Group related components together with the required test points.**

**Rule 5: Copy the required circuit board on another larger circuit board multiple times for PCB imposition.**

Choosing the size that is most suitable for the equipment used by the manufacturer will help reduce the cost of prototyping and manufacturing. First carry out the circuit board layout on the panel, contact the circuit board manufacturer to obtain their preferred size specifications for each panel, then modify your design specifications, and try to repeat your design multiple times within these panel sizes.

**Rule 6: Integrate component values.**

As a designer, you will choose discrete components with higher or lower component values ??but the same performance. By integrating within a smaller standard value range, the bill of materials can be simplified and costs can be reduced. If you have a series of PCB products based on the value of the preferred component, it will be more conducive to you to make the correct inventory management decision from a longer-term perspective.

**Rule 7: Perform design rule checks (DRC) as much as possible.**

Although it only takes a short time to run the DRC function on the PCB software, in a more complex design environment, as long as you always perform checks during the design process, you can save a lot of time. This is a good habit worth keeping.

**Rule 8: Use screen printing flexibly.**

Screen printing can be used to mark various useful information for future use by circuit board manufacturers, service or test engineers, installers, or equipment debuggers. Not only mark clear function and test point labels, but also mark the direction of components and connectors as much as possible, even if these comments are printed on the lower surface of the components used on the circuit board (after the circuit board is assembled). The full application of screen printing technology on the upper and lower surfaces of the circuit board can reduce repetitive work and streamline the production process.

**Rule 9: Decoupling capacitors must be selected.**

Don't try to optimize your design by avoiding decoupling the power lines and based on the limit values ??in the component data sheet. Capacitors are inexpensive and durable. You can spend as much time as possible to assemble the capacitors. At the same time, follow Rule 6 and use the standard value range to keep your inventory tidy.

**Rule 10: Generate PCB manufacturing parameters and verify them before submitting for production.**

Although most circuit board manufacturers are happy to download it directly and verify it for you, you'd better output the Gerber file yourself and check whether it is the same as expected with a free viewer to avoid misunderstandings. Through personal verification, you may even find some negligent errors, and therefore avoid losses caused by completing production according to the wrong parameters.

SELF CHECK 4.6.1

PCB DESIGNING

Direction: Enumerate what is being asked.

1. Enumerate the 5 guidelines in making PCB.
2. Enumerate the 10 golden rules in making PCB.

INFORMATION SHEET 4.7-8

DESIGNING MOTHERBOARD FOR ELECTRONIC PROJECTS

**Learning Objective:**

- After reading this INFORMATION SHEET, YOU MUST be able to create a motherboard for electronics project (PCB). (ELC724335)
- Align with AEP,

  1.9 Obtain parts and components needed to complete the work in accordance with requirements.( TLE_IAEPAS9-12AEP-Iva-27)

  LO 3. Mount and solder electronic components

  3.1 Apply knowledge on lead and lead-free soldering characteristics and requirements in mounting and soldering process in accordance with OHS standards

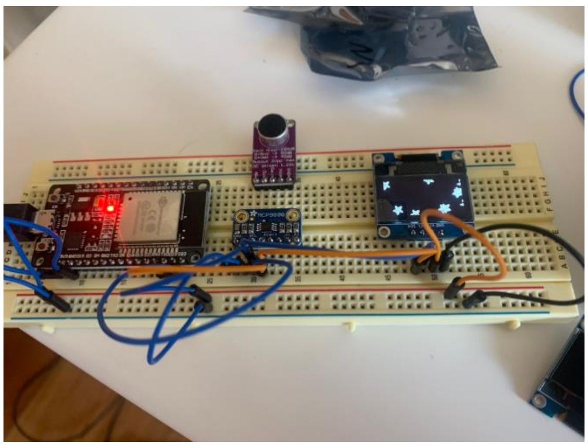
**How to design a motherboard for your electronics project**

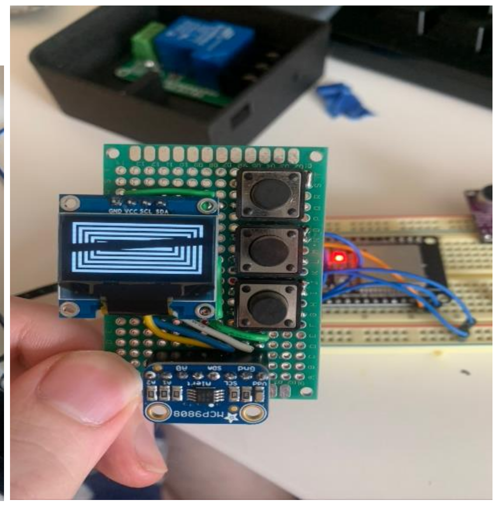

**Overview**

After the prototyping phase of any electronics project, I like to make a "Motherboard" PCB. For this phase I will continue to use breakout boards for all of the individual components, but link them together using a PCB. This allows the PCB design to stay simple and flexible, and makes them easy to hand manufacture them in my workshop. This is a great setup if you want to do a small (10ish) beta run of your project before designing a full product. I have shipped many hardware products using this stage, it's a great way to validate your MVP before putting money into tooling and CM bring up.

**Before you build a PCB**

Before you build a PCB, you should already have all of the breakout boards & devkits you want to use for the project. When designing the motherboard, you should already have a good understanding of how the electronics components are wired together, if you don't it's easy to make costly mistakes.





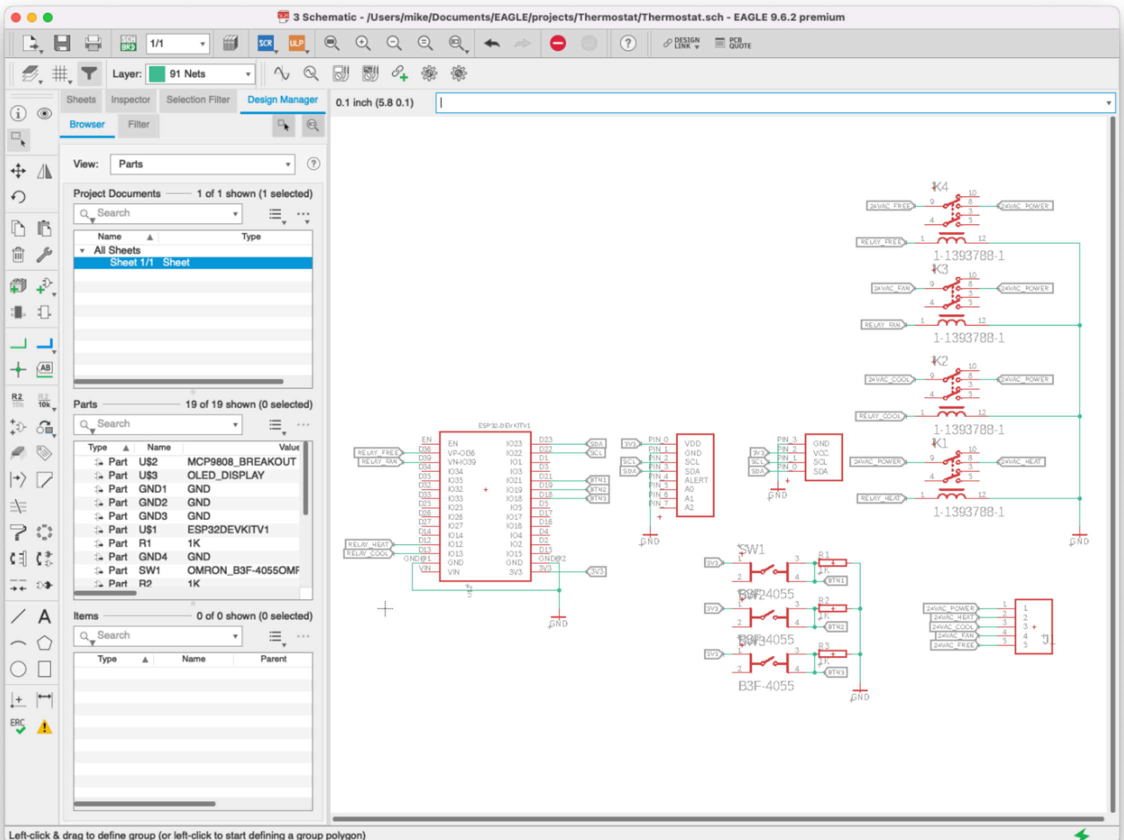
This project contains 3 different breakout boards and a few through hole components. The brains of the operation are an ESP32 Devkit, there are breakouts for the Thermostat and Screen, and through hold components for the buttons, resistors, and relays.

1 Installing Eagle

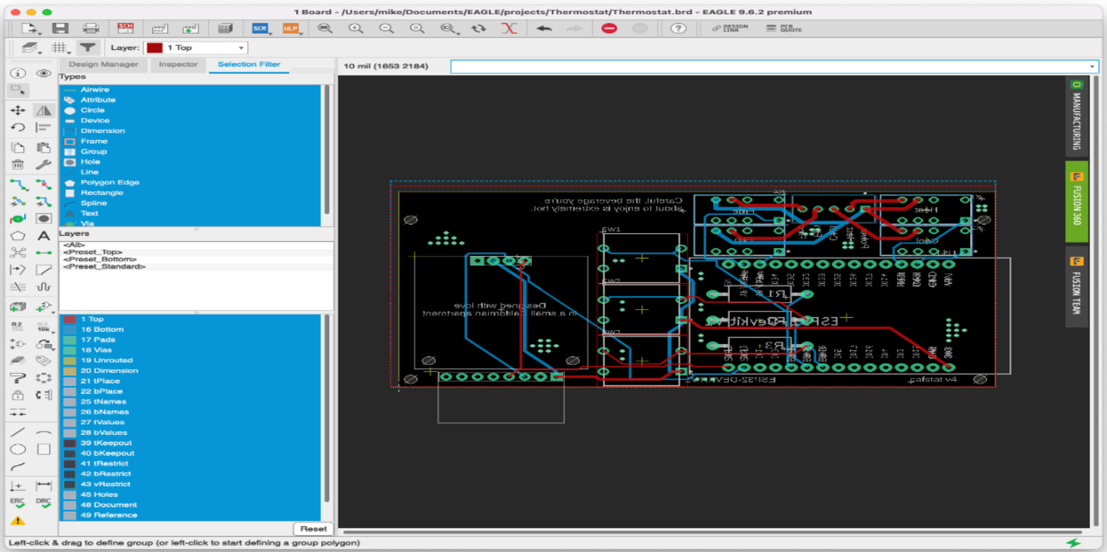
We will we be using Eagle. It's got a free tier tool that, and it integrates well into the Autodesk suite. Eagle is free for up to two layer boards, which should be all you need for most electronics projects. The information here will be pretty generally applicable to any tool, although the screenshots will be of eagle specifically.

1. Anatomy of a PCB Design

A PCB Design contains two main parts, the schematic and the layout. The schematic is an abstract diagram of the connections between components in your project, and the layout is the actual physical layout of those components, and the electrical traces that connect them. The great thing about PCB design software, is that the schematic will be enforced when you are creating the layout, this makes it very straight forward to create the layout after you've created the schematic.



This is the completed schematic for the caffstat project. You can see all of the breakout boards as individual components (red). The connections between them are mostly being managed by net labels to simplify the schematic (more on this later).




Here is an image of the completed layout. Every component has found a space on the board, and all of the electrical traces have been drawn. Don't worry if it looks complicated/messy now, when we go step by step it will be very easy to create.

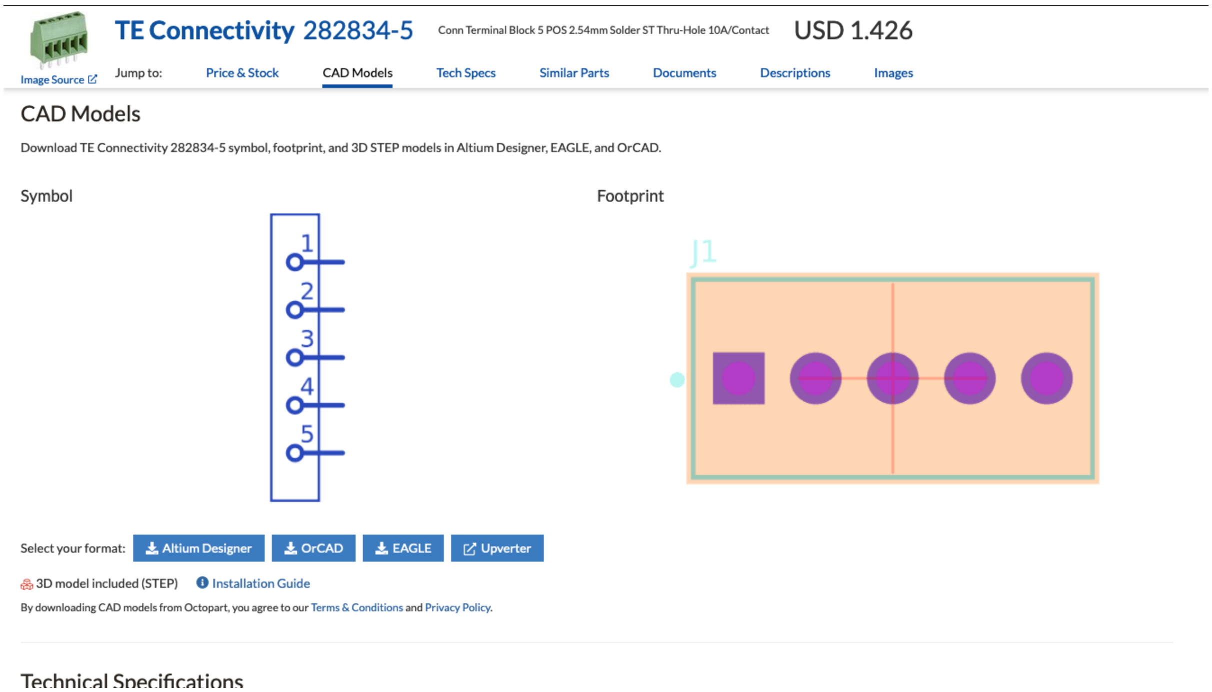
### 2. Finding or Creating Component Models

Before you can begin drawing a schematic and layout, you need to find or create models for each and every one of your components. A device model contains both a symbol for part (goes in the schematic) and a footprint of the part (for the layout). I will list out some great resources for finding or creating these here.

### 2.1. Octopart

The best tool I have found for looking up components and downloading models is Octopart. Their mission is to provide the best search engine for electronics components. Almost every part can be found in the search engine, I always check here first.

If octopart has the CAD Model for your part, it will appear like this, you want to download the Eagle format, this will download the library that you can install later.

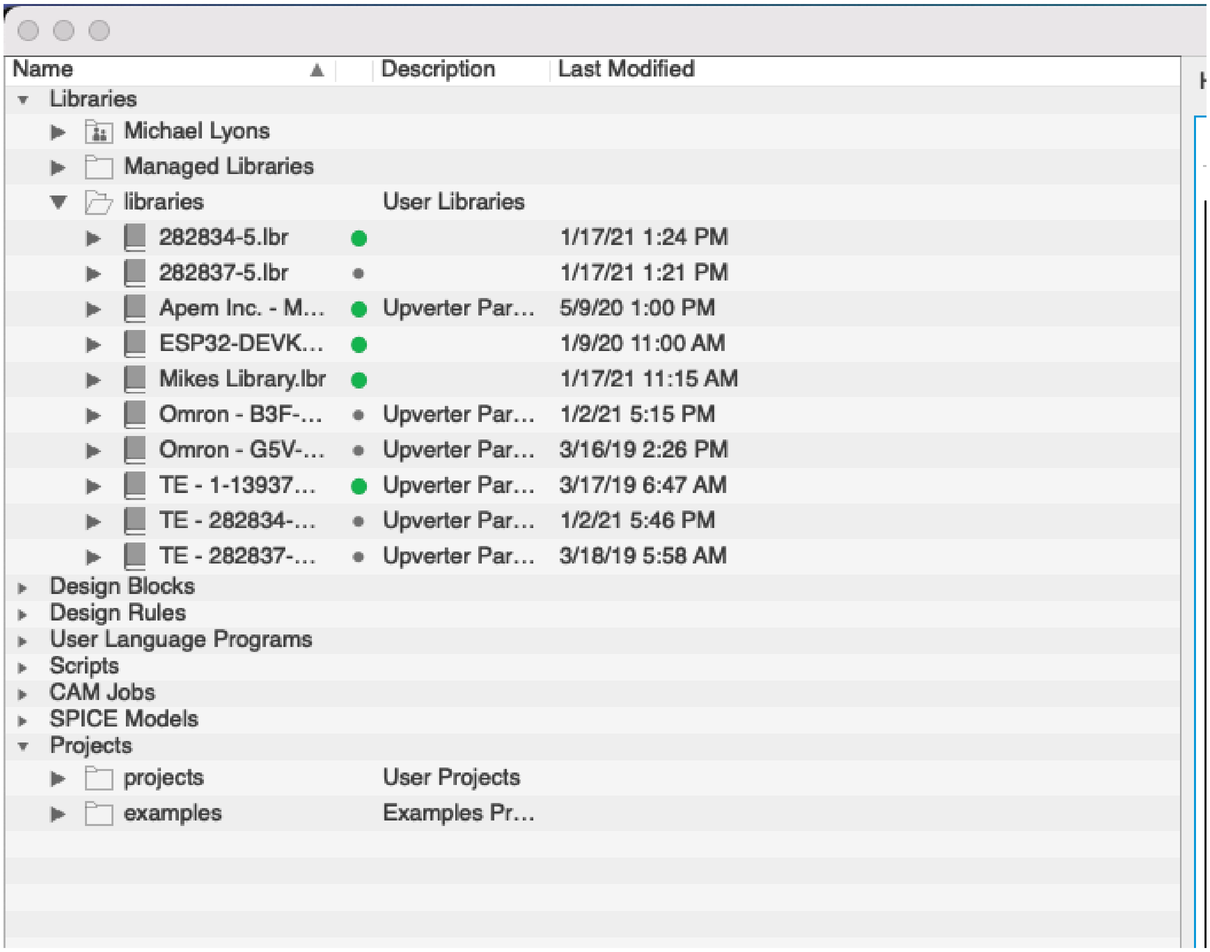



2.2. Desperate Googling

I have also found quite a few schematics by just googling the part. It can often be helpful to try different variations on the name, and include the term “Eagle” or “.lbr” (Eagle library file extension) in your query. If you do find a schematic, make sure you do some measurements (you can do this on the layout of your design) to ensure it matches well with your part (sometimes people upload bad designs, or are modeling something slightly different than yours, you don’t want to order a PCB with bad footprints)

## 2.3. Installing a library

Once you have a library it’s easy to install, drag the Library (.lbr) file into the libraries section of the Eagle Control Panel. Important: after dragging the lbr file, make sure you right click and hit “Use” otherwise you won’t actually be able to add it to your project. Libraries in use will have a green dot next to them.




### 2.4. Creating your own Library

If you fail to find any schematics online (often the case with cheap breakout boards, or with chinese knockoffs) you might have to make your own. It's not too hard to make your own models, mostly just a little bit tedious. Creating your own models & libraries is a full tutorial in itself, if I get interest I can put that together, for now I will refer you to the resources I used to learn the process.

## 3. Creating your Schematic

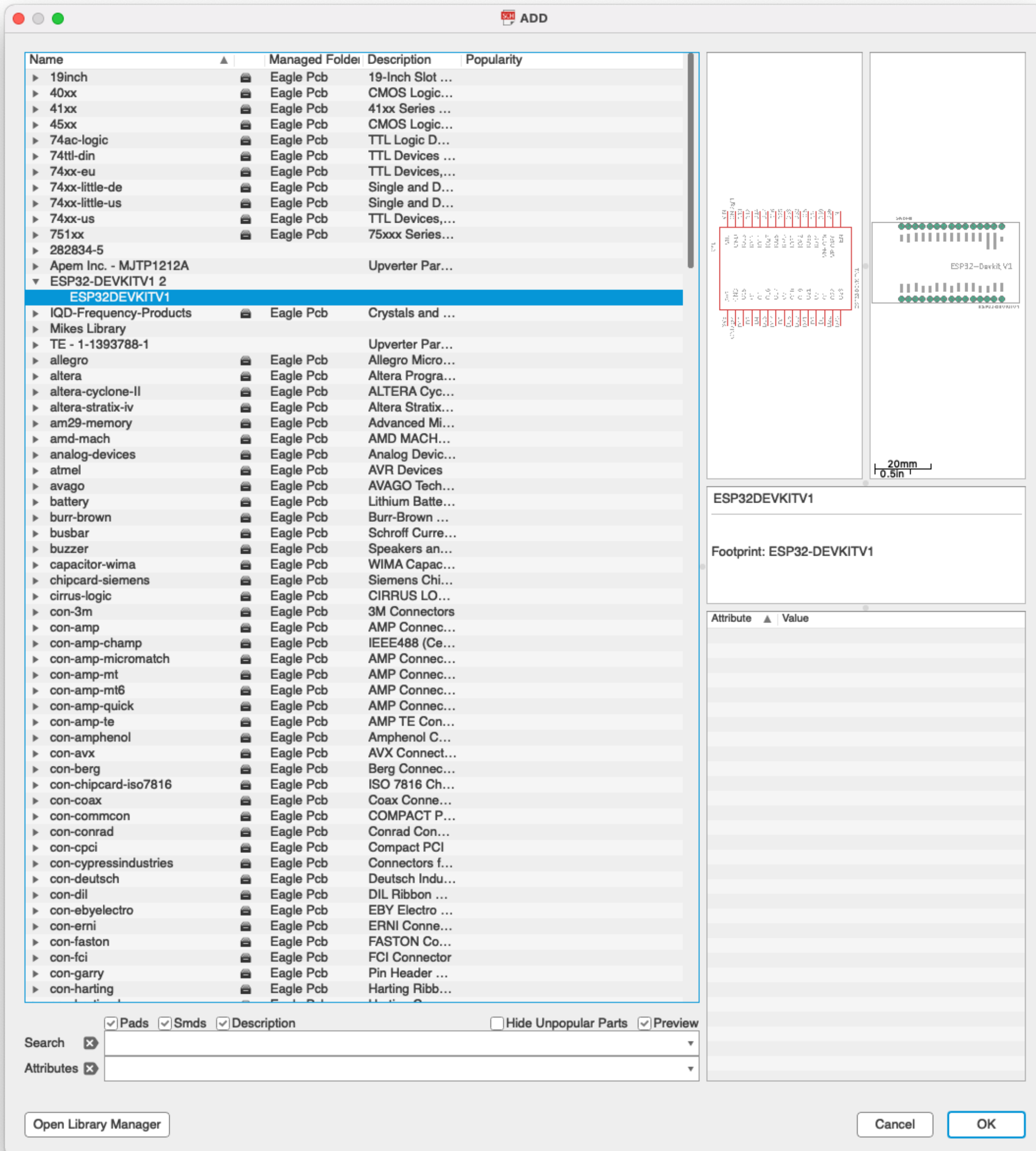
Once you have your components, you can start creating your schematic.

### 3.1. Basic Project Setup

First thing is to make a new Project and new Schematic in eagle. Go into the projects section, right click and hit "New Project". Then right click and hit "New Schematic". Once the schematic opens, you also want to create a layout (We'll use this in Step 4). Do this by hitting the "Generate/Switch to Board" button on the top bar.

### 3.2. Place your components

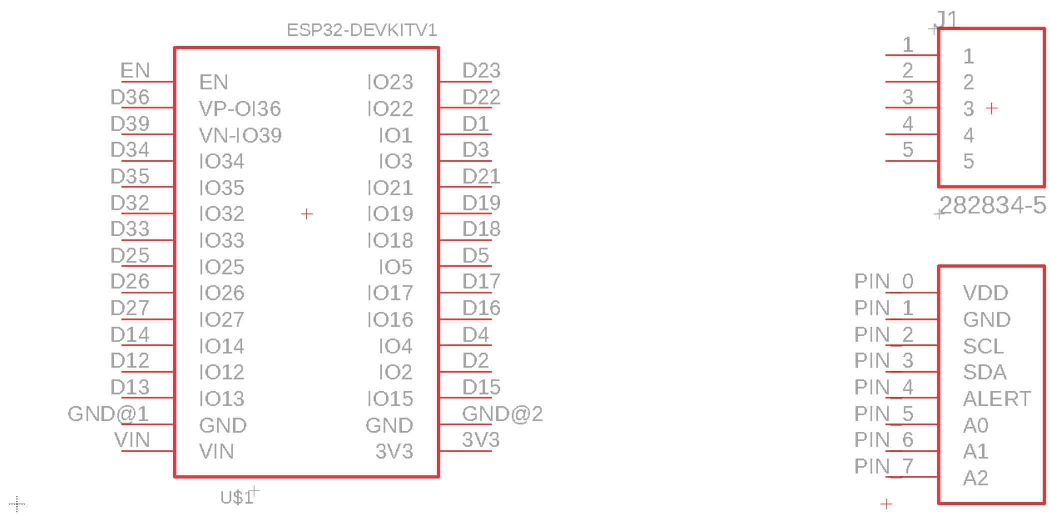
Once you have a schematic you need to put all of your part symbols on. The add part button is on the left bar, clicking this will bring up a dialogue that lets you choose a component. If you don't see a component you installed here, go back to the control panel and make sure you selected "Use" on the right click menu.




Add all of your components to your schematic. Make sure you give yourself a bunch of room around components to create connections. You should also try to sort the parts in logical groupings, the simpler your schematic, the less likely-hood of bugs.

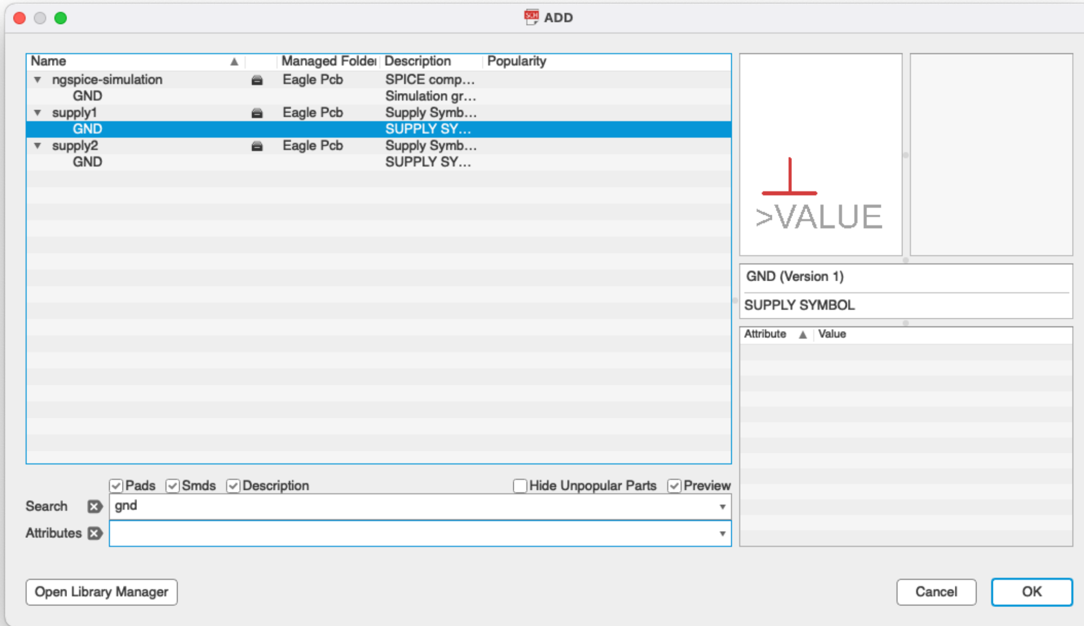
While placing components there are a few useful tools at your disposal. The Move, Rotate and Copy tools at the top of the left panel are all useful for organizing your schematic. When you want to select an object, the easiest thing to do is to click the + symbol (probably either at the center, or the origin of the part).

Here is what my schematic looks like after I have placed all of my parts.

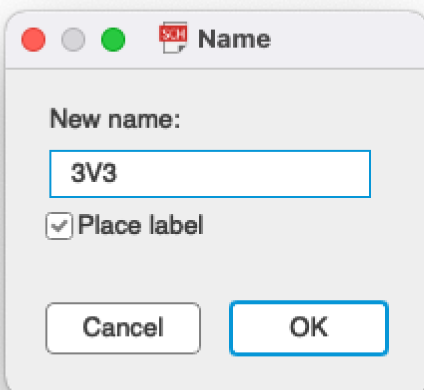



### 3.3. Placing the Ground Label

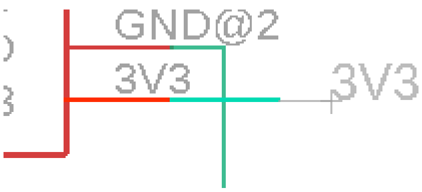
The standard for schematics is to use a specialty component to label the shared ground. You can find this by searching “gnd” in the Add Part menu.



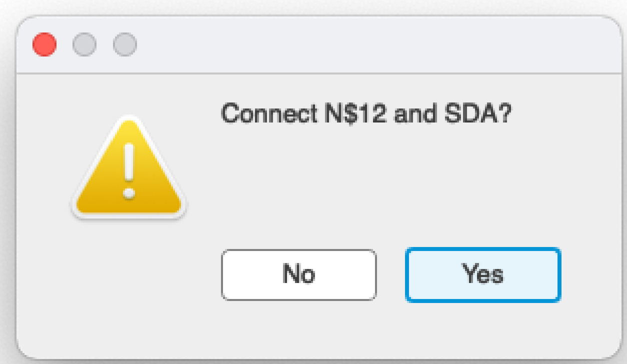

Then using the “Name” tool I will name all of the new nets something that makes them easier to keep track of. To name a net, select the tool, then select the green line for the net, a text dialogue should pop up asking you for a name, you can then give the net a unique name, make sure that “Place Label” is checked, and click OK.




The first label you make probably won’t have the “Xref On” option selected (looks like a little tag symbol on the toolbar). Selecting this will clean up your diagram a bit. I also prefer to set my size to 0.05 so that tags can be neatly stacked on top of each other. You can also use the mirror options to make a left or right side label.



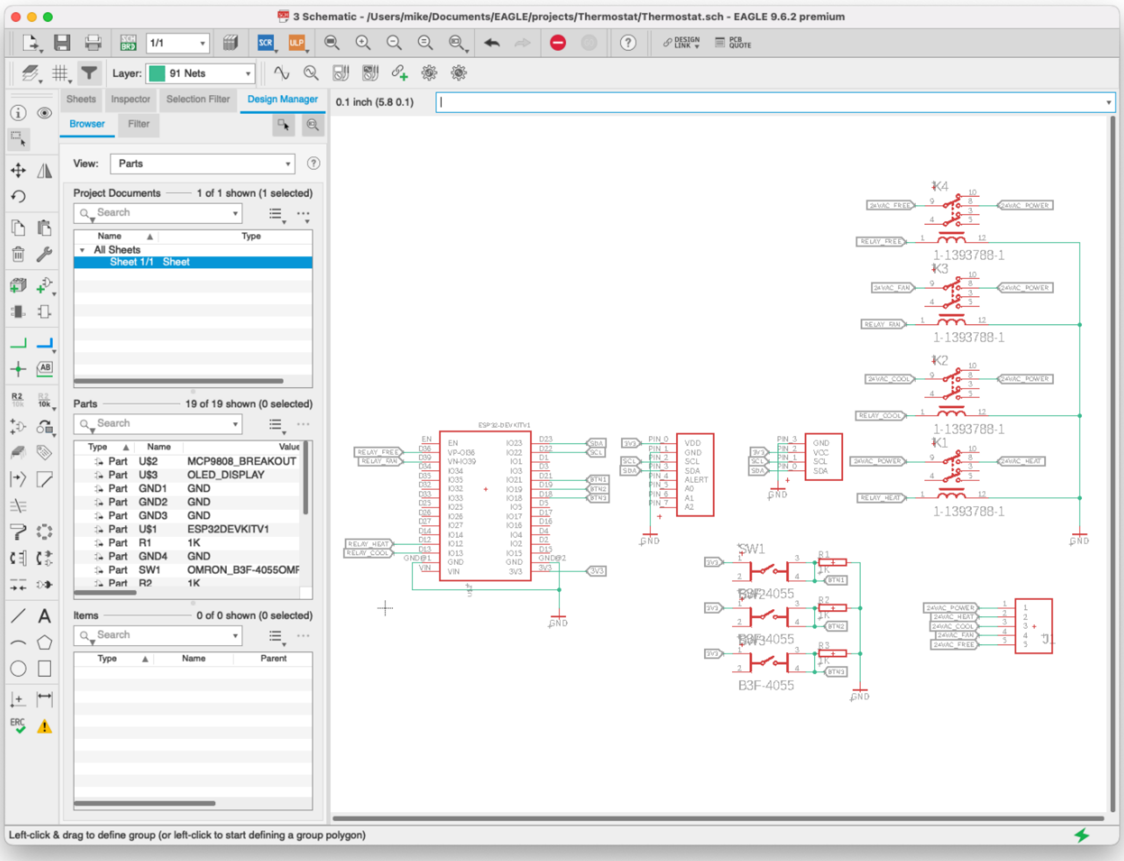

If you want to connect two different nodes together then you should label them the same thing. When you do this Eagle will pop up and ask you if you want to connect the two nets together. Click yes and Eagle will now know that you want those two pins to be on the same net (they will be electrically connected on your layout) .




Once you have all of your components connected properly on the schematic, it's time to do a final review before moving on to

3.5. Reviewing your Schematic

After wiring all of the components together, I will take a moment to review. Here is the completed schematic diagram for my thermostat motherboard. Before moving on to layout I like to rubber-duck (literally say out loud) the different connections to make sure I didn't make any stupid mistakes.




TASK SHEET 4.7-8

DESIGNING MOTHERBOARD FOR ELECTRONIC PROJECTS

Direction:

Divide the students into 4 groups

Make a Flow chart in how to design motherboard for Electronic Projects and discuss with the class after.

JOBSHEET 4.3-8

PRINTED CIRCUIT BOARD (PCB)

Direction: Make your own PCB design and follow the guidelines and 10 golden rules.