Ethiopian TVET-System

BASIC ELECTRICAL/ELECTRONIC EQUIPMENT SERVICING Level I

Based on May 2011 Occupational standards

October, 2019

Module Title: Designing and constructing simple printed circuit board

TTLM Code: EEL BEE1TTLM 0919 v1

This module includes the following Learning Guides

LG39:- Plan and prepare to construct/ electrical/electronic circuits

LG Code: EEL BEE1 M11 LO1-LG-39

LG40:- Plan and prepare to construct/ electrical/electronic circuits

LG Code: EEL BEE1 M11 LO2-LG-40

LG41:- Test the construction of electrical/ electronic circuits

LG Code: EEL BEE1 M11 LO3-LG-41

Instruction Sheet	LG39:Plan and prepare to construct/ electrical/ electronic circuits

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics

- Checking Materials
- Selecting appropriate tools and equipment's
- Planning task to ensure occupational health and safety
- Preparing Electrical/electronic circuits correctly for connecting and soldering

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, **upon completion of this Learning Guide, you will be able to**:

- Check materials according to specifications and tasks
- Select appropriate tools and equipments according to task requirements
- Plan task to ensure occupational health and safety (OHS) guidelines and follow procedures
- Prepare electrical/electronic circuits correctly for connecting and soldering in accordance with instructions and work site procedures

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information "Sheet 1, Sheet 2, Sheet 3 and Sheet 4".
4. Accomplish the "Self-check 1, Self-check t 2, Self-check 3 and Self-check 4" **in page - 13, 35, 40 and 45** respectively.
5. If you earned a satisfactory evaluation from the "Self-check" proceed to "Operation Sheet 1" **in page - 46.**
6. Do the "LAP test" **in page – 47** (if you are ready).

Information Sheet-1	Checking Materials

1.1. Materials

Materials that are used in constructing electrical/electronic circuits are:

Soldering lead

Solder is a metallic compound that has a low melting point, usually around 200°C. The composition of solder varies depending on the type, but usually contains lead or tin or both. The most common types are given below. It is available in wire, stick or pellet form. Sticks and pellets are for solder-pots; for normal soldering, you will need solder wire.

Solder wire is available in widths given in "standard wire gauge" (SWG). The larger the SWG number, the thinner the wire. Common gauges are 18 and 22, although others are available. 18-gauge solder is suitable for soldering large components and thick wire, as a large quantity of solder can be delivered quickly. 22 gauge solder is thinner than 18 gauge, and should be used for most electronics work, as it allows much greater control over the quantity of solder delivered, and the chances of accidentally bridging a gap due to over-application or the wire's width are greatly reduced. Finer gauges such as 26 are available for very fine work with SMT (surface-mount) components.

Fig 1.1.soldering lead (solder)

60/40 solder is made of 60% tin and 40% lead. It has a melting point of around 190°C, depending on the exact composition. Iron tip temperatures of at least 300°C are recommended. It is also very soft, meaning that cracks do not form so readily if the joint moves during cooling.

63/37 solder is made of 63% tin and 37% lead. It has a melting point of 183°C, slightly lower than the more common 60/40 blend. The primary advantage of this solder is not the lower melting point, but its eutectic property.

50/50 is made of a half and half mix of tin and lead. Never use 50/50 solder for electronics — it is meant for plumbing. Otherwise, you may end up with failed joints.

Flux

Flux is a compound that is used to improve the quality of the soldered joint. It does this in three ways:

- It chemically removes oxidation from the surfaces being soldered.
- It prevents air from oxidising the surfaces once they have been cleaned.
- It increases the "wetting" of the surfaces when the solder is applied

Wetting is the degree to which the solder flows across the surfaces being joined. Without flux, a **dry joint** may be formed, making a poor connection.

Fig 1.2. flux

Jumper wire

In order to make quick, temporary connections between some electronic components, you need *jumper wires* with small "alligator-jaw" clips at each end. These may be purchased complete, or assembled from clips and wires.

Fig 1.3. Jumper wire

Ferric chloride

Usually to etch the copper from the PCB, an aqueous solution of ferric chloride (also called iron(III) chloride, $FeCl3$) is used. It works quite well but it's terribly slow: a fresh solution will probably etch a PCB in about 30 minutes. But as copper is consumed from the boards, the etchant becomes saturated and less effective: the time required can easily double after a few PCBs. Furthermore, the speed of this reaction is also dependent on temperature, the colder the slower.

Fig 1.4. Ferric chloride

Permanent marker (ink)

To transfer your design to the copper or for correction, use a permanent marker (solvent-based permanent-marker pen) and draw your traces directly on the copper which is capable of resist the etchant Ferric Chloride solution. One layer of ink is not enough, let it dry for 10 minutes and redraw it again on top to make the layer thicker.

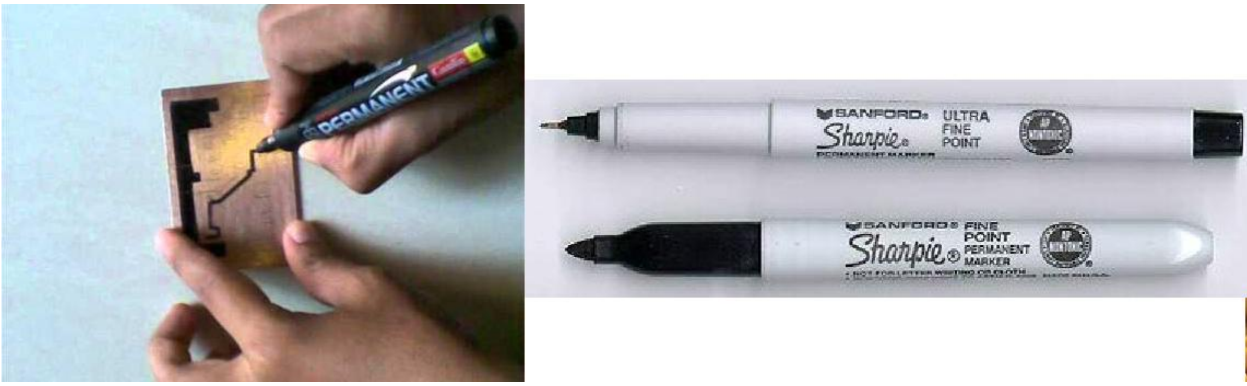


Fig 1.5. Permanent marker (ink)

Printed circuit board (PCB)

A printed circuit board (PCB) made from glass reinforced plastic with copper track in the place of wires. They mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate.

A printed circuit board has pre-designed copper tracks on a conducting sheet. The pre-defined tracks reduce the wiring thereby reducing the faults arising due to lose connections. One needs to simply place the components on the PCB and solder them.

Fig 1.6. PCB

Different method to make PCB

There are in all three basic methods to make PCB

1. Iron on Glossy paper method
2. Circuit by hand on PCB
3. Laser cutting edge etching.

Since laser method is industrial method to make PCB we will get in detail of first two methods to make PCB at home.

To Creating PCB layout of your circuit, we usually did by converting your circuit's schematic diagram into a PCB layout using PCB layout software. There are many open source software packages for PCB layout creation and design.

Bread board or Solder less breadboard

A few tools are required for basic electronics work. Most of these tools are inexpensive and easy to obtain.

Also essential is a *solder less breadboard*, sometimes called a *prototyping board*, or *proto-board*. This device allows you to quickly join electronic components to one another without having to solder component terminals and wires together. They have different size and physical characteristics

1. Insulated bread board
2. Un insulated breadboard

Stripboard (uninsulated breadboard)

Stripboard is one of the commonly-used types of prototyping board. These boards are intended for permanently assembling one-off circuits, especially prototypes. The board is made from insulating material, usually a resin-bonded plastic or fibreglass. One side has parallel copper strips on it, spaced 2.54 mm apart. There are holes bored in these strips, also 2.54 mm apart. Components are placed on the other side of the board with their wires bent to pass through the holes. The wires are soldered to the copper strips, the projecting ends being cut off to make the assembly neater.

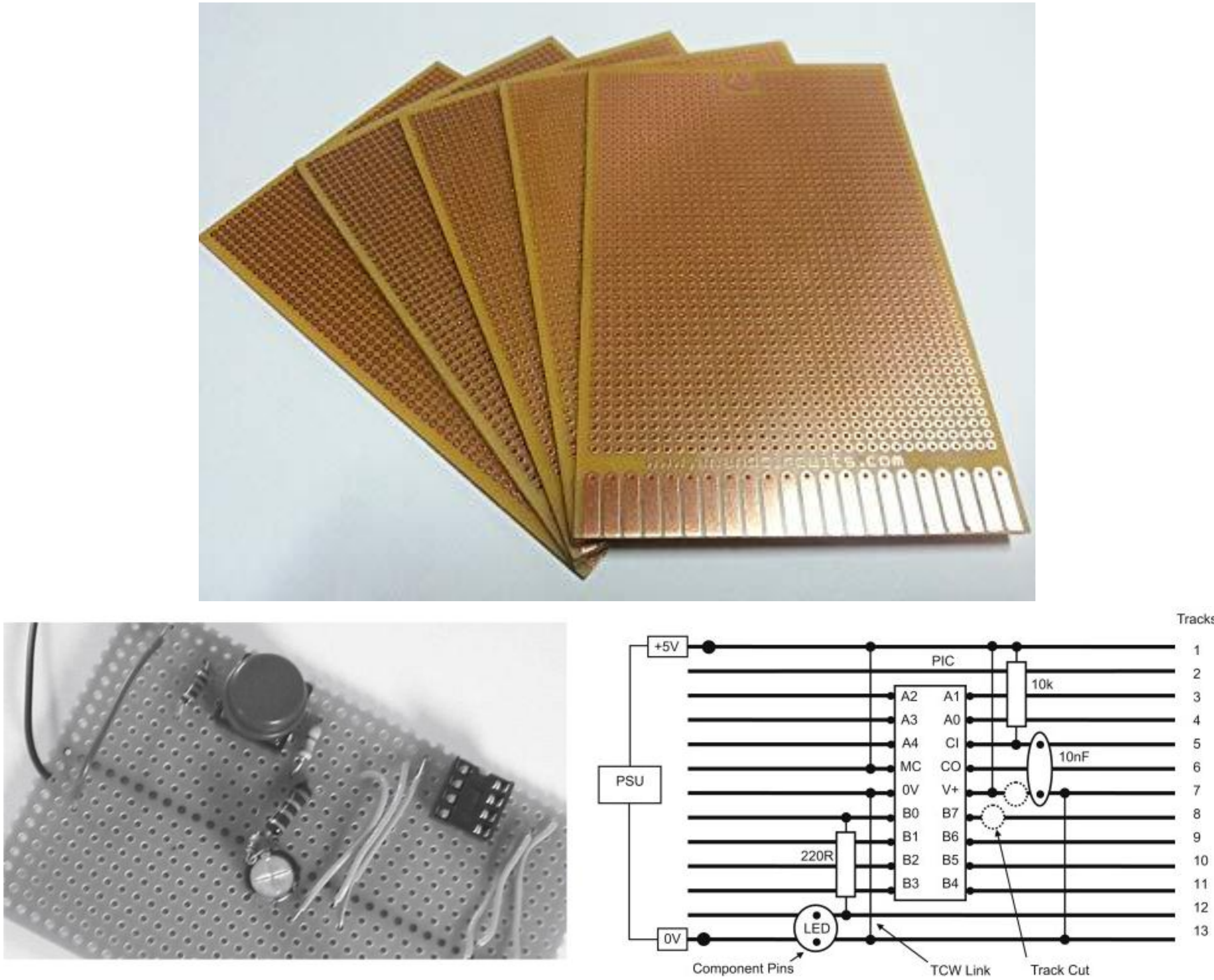
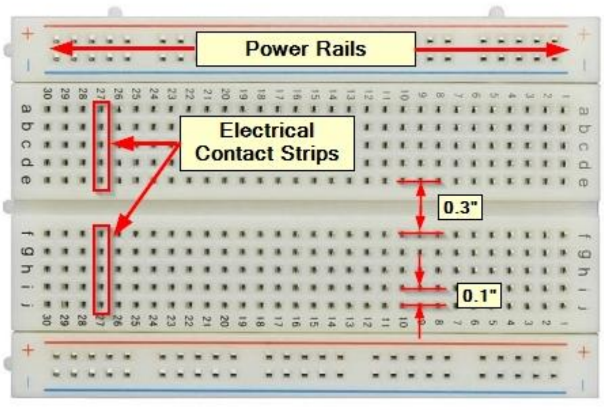


Fig 1.7. Stripboard (uninsulated breadboard)

Breadboard (insulated breadboard)

The breadboard consists of a plastic housing usually made of ABS plastic that has a series of holes arranged in rows of 5. These holes are sized to allow wire of up to 20 AWG to be inserted. Each of the rows of 5 holes has internal spring contacts that connect the 5 holes electrically. These contacts are inserted into the plastic housing from the back side. When a component lead or wire is inserted into one of these holes, the spring contacts electrically connect it to anything else that is inserted into one of the other 4 remaining holes in the same row of contacts. This forms a circuit node.

These rows of contacts are then arranged into two columns. These two columns of contacts are separated by a 0.3" space to form a breadboard. This spacing is chosen because the typical DIP style IC has leads on a 0.3" spacing from one side of the IC to the other. By placing the IC across this space in the middle of the breadboard, each of the pins of the IC is connected to its own separate row of 5 contacts.



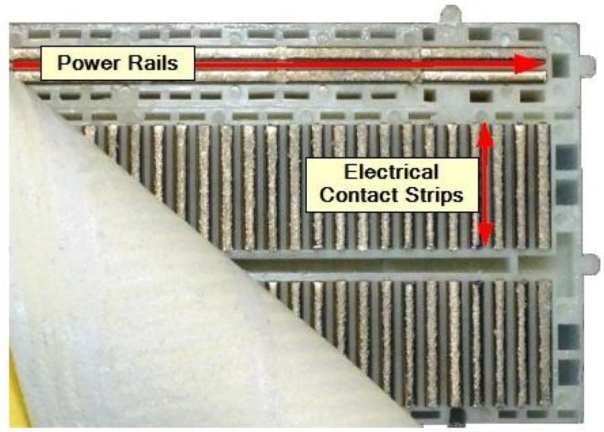


Fig 1.8. Breadboard (insulated breadboard)

Electrical/Electronics component and elements

Electrical/Electronics component

An electronic component is any basic discrete device or physical entity in an electronic system used to affect electrons or their associated fields. Electronic components have two or more electrical terminals (or *leads*). These leads connect, usually soldered to a printed circuit board, to create an electronic circuit (a discrete circuit) with a particular function (for example an amplifier, radio receiver, or oscillator).

Components are categorized as:

1. **Active components** rely on a source of energy (usually from the DC circuit, which we have chosen to ignore) and usually can inject power into a circuit, though this is not part of the definition. Active components include amplifying components such as transistors, triode vacuum tubes (valves), and tunnel diodes.

2. **Passive components** cannot introduce net energy into the circuit. They also can't rely on a source of power, except for what is available from the (AC) circuit they are connected to. As a consequence they can't amplify (increase the power of a signal), although they may increase a voltage or current (such as is done by a transformer or resonant circuit). Passive components include two-terminal components such as resistors, capacitors, inductors, and transformers.

3. **Electromechanical components** can carry out electrical operations by using moving parts or by using electrical connections

Active components includes:

Diodes (All) ▪ Rectifier Diode ▪ Schottky Diode ▪ Zener Diode ▪ Unipolar / Bipolar Diode ▪ Varicap ▪ Varactor ▪ Light-Emitting Diode (LED) ▪ Solar PV Cell, PV Panel	Transistors (All) ▪ Photo Transistor ▪ Darlington Transistor ▪ Compound Transistor ▪ Field-Effect Transistor (FET) ▪ JFET (Junction Field-Effect Transistor) ▪ MOSFET (Metal Oxide Semiconductor FET) ▪ Thyristors ▪ Composite Transistors
Integrated Circuits (All) ▪ Digital Circuit ▪ Analog Circuit ▪ Hall Effect Sensor ▪ Current Sensor ▪ BGA Packages ▪ Processor ▪ Power ICs ▪ Optoelectronic Components	▪ CRT / LCD / VFD / TFT / LED ▪ Vacuum Tubes ▪ Rectifier Tubes ▪ Emitters ▪ Gas discharge tube ▪ Ignitron ▪ Thyratron ▪ Battery / Power Supply ▪ Electric Generator

Passive components includes:

▪ Resistors (All Types) ▪ Capacitors (All Types) ▪ Inductors / Coil ▪ Memristor / Network ▪ Sensors	▪ Detectors ▪ Transducers ▪ Antennas ▪ Assembly Modules

Electromechanical components

▪ Piezoelectric devices ▪ Crystals ▪ Resonators ▪ Terminals and Connectors ▪ Cables	▪ Switches ▪ Circuit Protection Devices ▪ PCB ▪ Mechanical Devices such as a Fan, Lamp

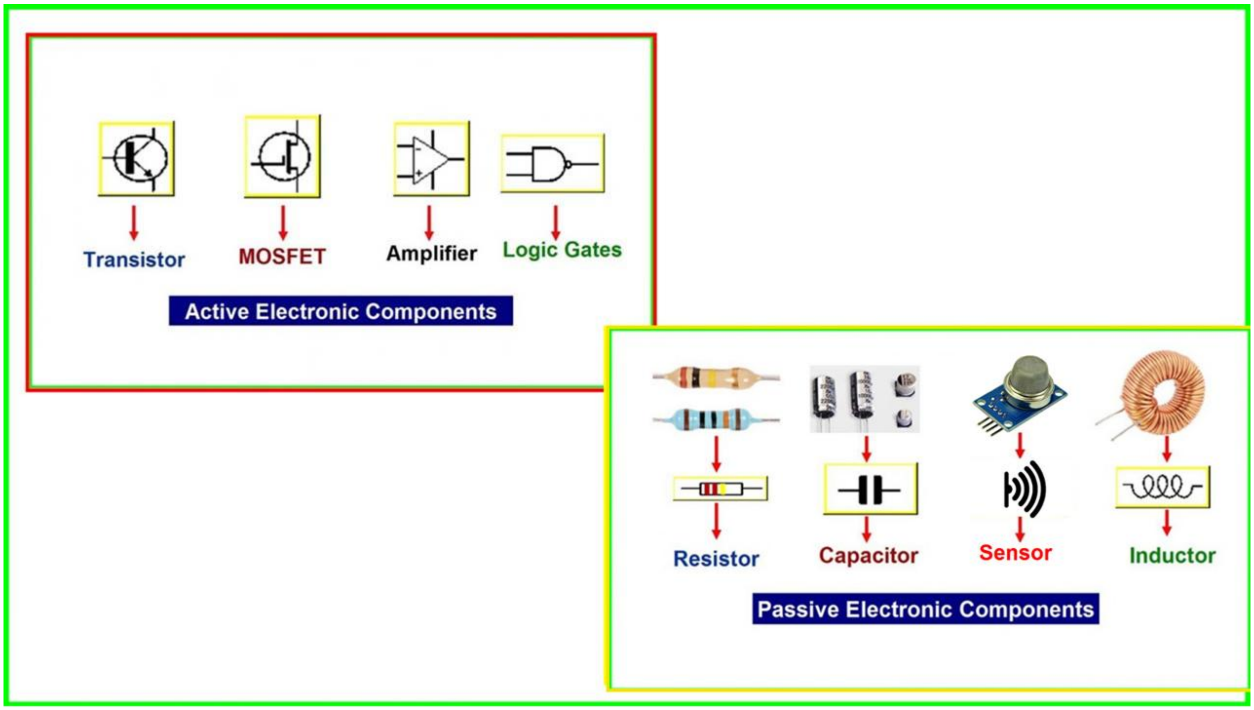


Fig 1.9. Passive and active Electronic component

The Basic elements of an Electric Circuit

Every electric circuit, regardless of where it is or how large or small it is, has four basic parts: an energy source (AC or DC), a conductor (wire), an electrical load (device), and at least one controller (switch).

1. The Energy Source

In an electrical circuit, the power source provides the voltage (the force that pushes electrons through a conductor -- measured in volts) and current (the rate of flow of electrons -- measured in amperes) to energize a device attached to the circuit.

2. The Conductor

In a typical electrically powered environment that uses common electrical devices, the conductor is the wiring in a home or device that provides the path of the circuit, on which the energy flows. The conductor (conduction) system interconnects all of the other parts of the circuit.

3. The controller (switch)

The controller (switch) provides the control that closes (continues) or opens (breaks) the electrical energy flow on the circuit. A variety of circuit switches exist, including wall switches, push buttons, key toggles, and many biometric devices.

4. The Load

Any device attached to an electrical circuit that is activated or energized by the flow of electricity to it, provides the electrical load on the circuit. The load is the amount of electrical energy the device uses to complete its task. This electrical consumption is measured in watts, which equals the current (amps) multiplied by the volts on the circuit. Lights, TVs, motors, heaters and appliances are load devices that consume power.

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. List out same the materials used to construct electrical electronics circuits. (5 points)

2. Identify the listed components below as active and passive components. (10 points)

- Schottky Diode
- Resistors
- Memristor / Network
- Capacitors
- Transducers

Zener Diode
MOSFET (Metal Oxide Semiconductor
Inductors / Coil
Vacuum Tubes
JFET (Junction Field-Effect Transistor)

Active components	Passive components
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.

Note: - Satisfactory rating: 7.5 and above - Unsatisfactory Rating: below 7.5

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating: _____________

Name: ____________________________ Date: _________________

Information Sheet - 2	Selecting appropriate tools and equipment's

2.1. Introduction on electrical/electronics tools, equipments and test instrument

Electrical tools normally refer to electrical hand tools - typically tools used in construction activities such as electrical drills, wire strippers, and can also include electrician tools such as electrical meters (voltmeters, multimeters, etc.). Electrical tools are plentiful and you can find them for tool shops.

Electrical equipment refers to manufactured systems that distribute, transform, protect, or convert electrical energy. Electrical equipment includes motors, generators, transformers, switches and switchgear, and more, and ranges from low voltage (up to 600V), medium voltage (1kV to 38kV) or high voltage.

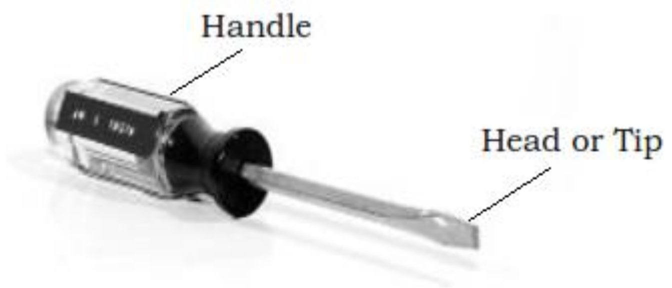
Testing equipment used to detect faults in the operation of electronic devices by creating stimulus signals and capture responses from electronic devices under test is known as electronic test equipment. They include voltmeter, ammeter, ohmmeter, multimeter, power supply, signal generator, If any faults are detected, then identified faults can be traced and rectified using electronic testing equipment. Most often all electrical and electronic circuits are tested and troubleshooted to detect faults or abnormal functioning if any. Therefore, testing equipment is necessary to find and analyze the circuit conditions, for checking electronic test equipment and maintenance in various industries. Many industries utilize different types of electronic test equipment ranging from the very simple and inexpensive to complex and sophisticated ones.

2.2. Selecting appropriate tools and equipments

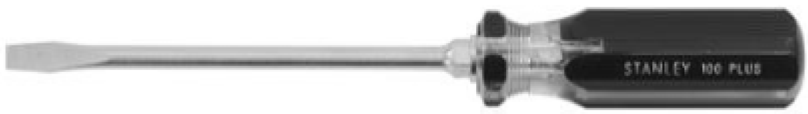
It is hard to do a good job of electronics construction unless proper electronic tools and knowledge of using them are adequate.

2.2.1. Driving of Tools

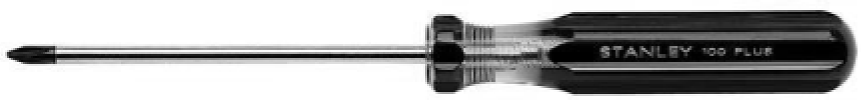
Screwdriver. It is a device specifically designed to insert and tighten or to loosen and remove screws. A screwdriver comprises a head or tip which engages with a screw, a mechanism to apply torque by rotating the tip and some way to position and support the screwdriver. A typical hand screwdriver comprises an approximately cylindrical handle of a size and shape to be held by a human hand and an axial shaft fixed to the handle, the tip of which is shaped to fit a particular type of screw. The handle and shaft allow the screwdriver to be positioned and supported when rotated to apply torque.



- **Flat Screwdriver**. It is used to drive or fasten negative slotted screws.



- **Phillips Screwdriver**. It is used to drive or fasten positive slotted screws. It is a screwdriver that could take greater torque and can provide tighter fastenings.



Hex (Allen Wrench). It is used to drive or fasten hexagonal screws. The head has a hexagonal hole turned by an allen key. An Allen key is a hexagonal shaped wrench bent in letter-L. The Allen key was invented by an American, Gilbert F. Heublein.

Fig 2.1. hex (Allen wrench)

Precision Screwdriver Set. It is a set of small screw drivers composed of slotted and Philips screwdrivers.

Fig 2.2. Screwdriver set

2.2.2. Soldering Tools

Soldering Iron. It is a device used for applying heat to melt solder in attaching two metal parts. A soldering iron is composed of a heated metal tip and an insulated handle.

Heating is often achieved electrically, by passing a current, supplied through an electrical cord, through a heating element.

For electrical work, wires are usually soldered to printed circuit boards, other wires, or small terminals. A low-power iron (1530 Watts) is suitable for this work.

Fig 2.3. soldering iron

Some soldering irons have interchangeable tips for different types of work. Fine round or chisel tips are typically used for electronics work. A new tip needs to be coated, heated, and then covered with solder before its first use. This procedure is called "tinning". The tinning forms a liquid layer, which facilitates the transfer of heat to the work piece. A dirty tip does not transfer heat well. The tip needs to be kept coated with a shiny layer of solder by occasional wiping and applying solder directly to the tip.

Soldering station

Working with surface-mount parts requires soldering tools that are capable of working with small parts and closely spaced leads. Soldering stations for surface-mount work can be rather pricey, particularly for the stations that also include a hot-air attachment. The good news is that a soldering station like the one shown in Figure below will handle a lot of SMT tasks if used with a fine tip and the appropriate temperature.

Figure below shows a soldering station specifically designed for working with surface-mount parts. In addition to the soldering iron with a fine-point tip, it also has a hot-air blower with a selection of nozzles. The hot air is used to disorder or rework a surface-mount part. The kit comes with the magnifying light shown.

Fig 2.4. soldering station

Soldering Tool Stand. It is a place of the soldering iron to keep them away from flammable materials. The stand often also comes with a sponge and flux pot for cleaning the tip.

Fig 2.5. Soldering iron stand

Brass Sponge - As you solder, your tip will tend to **oxidize**, which means it will turn black and not want to accept solder. Especially with lead-free solder, there are impurities in the solder that tend to build up on the tip of your iron, which causes this oxidization. This is where the sponge comes in. Every so often you should give your tip a good cleaning by wiping off this build-up. Traditionally, an actual wet sponge was used to accomplish this. However, using a wet sponge can drastically reduce the lifespan of your tip. By wiping your tip on a cool, wet sponge, the tip tends to expand and contract from the change in temperature. This expansion and contraction will wear out your tip and can sometime cause a hole to develop in the side of the tip. Once a tip has a hole, it is no good for soldering. Thus, brass sponges have become the standard for tip cleaning. Brass sponges pull the excess solder from your tip while allowing the tip to maintain its current heat level. If you do not have a brass sponge, a regular sponge is better than nothing.

Fig 2.6. Brass sponge

Disordering tool. It is used for the removal of solder and components from a circuit when troubleshooting, repair purposes and to save components. Electronic components are often mounted on a circuit board and it is usually desirable to avoid damaging the circuit board, surrounding components, and the component being removed.

Fig 2.7. sucker

2.2.3. Splicing Tools

Long Nose. It is used for holding, bending and stretching the lead of electronic component or connecting wire.

Fig 2.8. Long nose

Side Cutter. It is a wire-cutting plier, though they are not used to grab or turn anything, but are used to cut wire.

Fig 2.9. Side cutter

Wire Stripper. It is a pair of opposing blades much like scissors or wire cutters. The addition of a center notch makes it easier to cut the insulation without cutting the wire. This type of wire stripper is used by rotating it around the insulation while applying pressure in order to make a cut around the insulation. Since the insulation is not bonded with the wire, it will be pulled easily at the end.

Fig 2.10. Wire striper (a) manual (b) automatic

2.2.4. **Boring Tools**

12 Volt Mini-Drill. It is used to bore or drill holes in the printed circuit board (PCB).

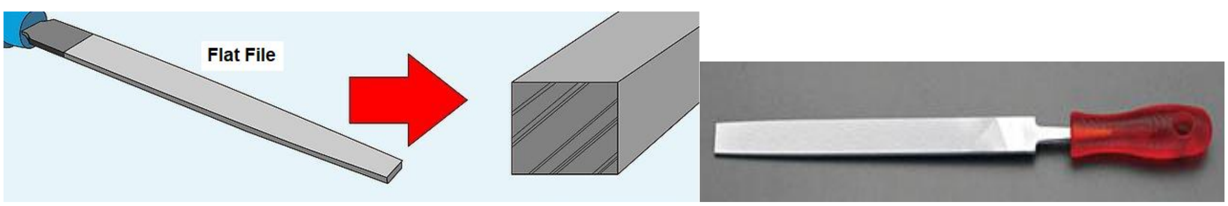
Fig 2.11. 12 volt mini drill

Portable Electric Drill. It is used for boring hole/s in the plastic chassis or metal chassis with the used of drill bits.

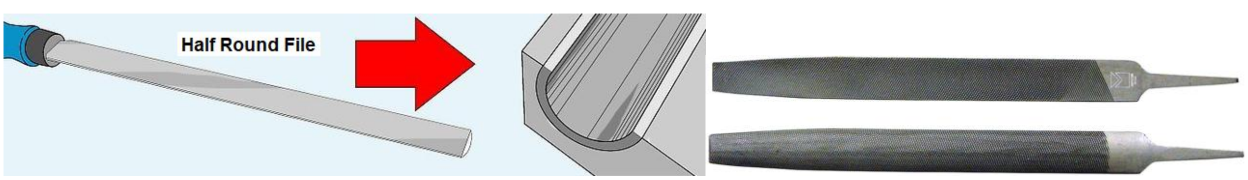
Fig 2.12. Portable electric drill

Metal File. It is a hand tool used to shape metals by grinding. A file series of sharp, parallel ridges or teeth. Most files have a narrow, pointed tang at one end to which a handle can be fitted.

- **Flat Files**. They are parallel in width and tapered in thickness. They are used for flat surfaces and edges.



- **Half Round Files**. They are tapers in width and thickness, coming to a point, and are narrower than a standard half round which are used for filing inside of rings.



- **Round Files**. They are also called rat-tail files gradually tapered and are used for many tasks that require a round tool, such as enlarging round holes or cutting a scalloped edge.

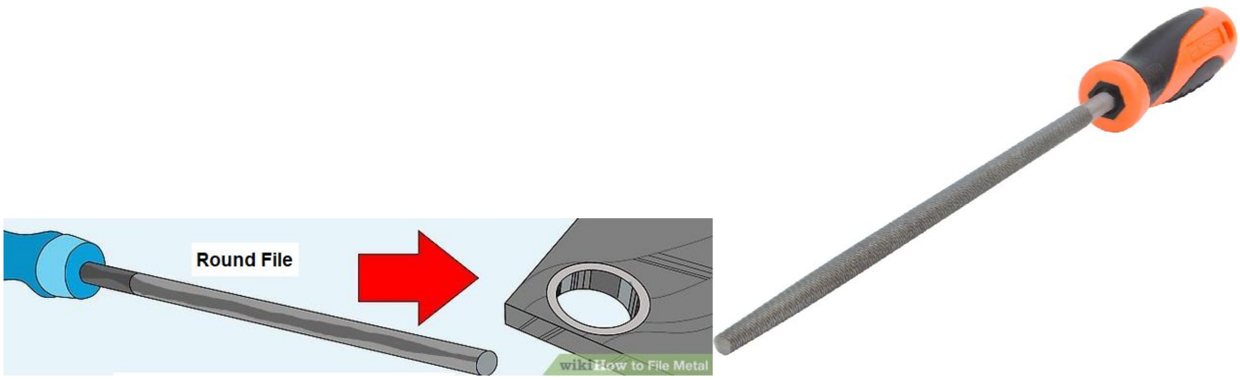


Fig 2.13. Files (flat, half round and round)

2.2.5. Cutting Tools

Utility Knife. It is a common tool used in cutting various trades and crafts for a variety of purposes.

Fig 2.14. Utility knife

Hacksaws. They are saws for cutting metal. Some of them have pistol grips which keep the hacksaw firm and easy to grip. The small hand-held hacksaws are consist of a metal arch with a handle that fits around a narrow, rigid blade. The blade has many small saw teeth along one side. It can either be attached such that the teeth face away from the handle, resulting in sawing action by pushing, or be attached such that the teeth face toward the handle, resulting in sawing action by pulling. On the push stroke, the arch will bend a little, releasing the tension on the blade. The blade is normally quite brittle; so extra care is needed to be taken to prevent brittle fracture of the blade.

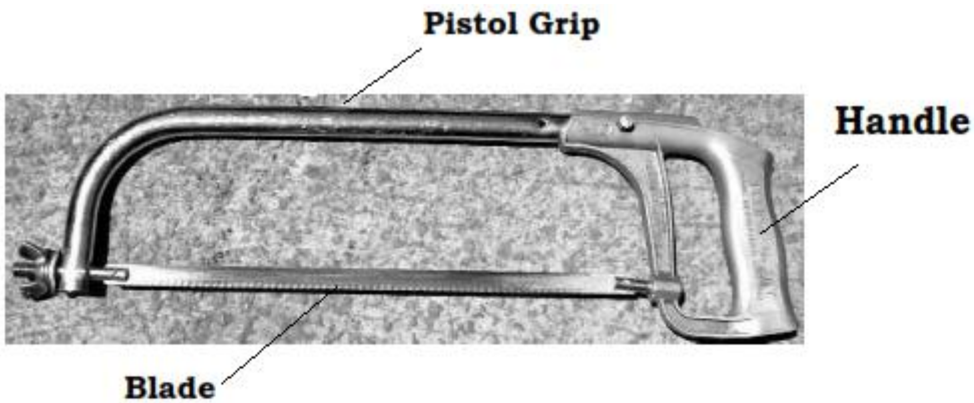


Fig 2.15. Hacksaw

2.2.6. Designing tools

Electronic circuit design and simulation software: uses mathematical models to replicate the behavior of an actual electronic device or circuit. Simulation software allows for modeling of circuit operation and is an invaluable analysis tool. Due to its highly accurate modeling capability, many colleges and universities use this type of software for the teaching of electronics technician and electronics engineering programs. Electronics simulation software engages its users by integrating them into the learning experience. These kinds of interactions actively engage learners to analyze, synthesize, organize, and evaluate content and result in learners constructing their own knowledge.

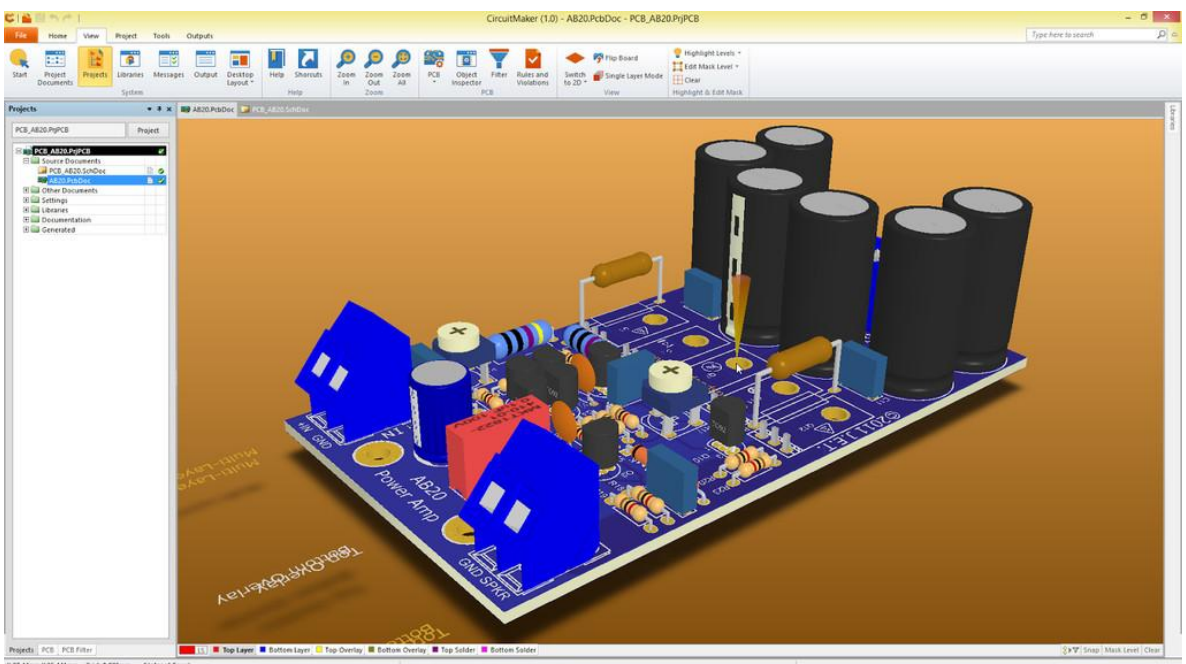


Fig 2.16. circuit simulation on circuit-maker CAD software

Simulating a circuit's behavior before actually building it can greatly improve design efficiency by making faulty designs known as such, and providing insight into the behavior of electronics circuit designs.

Examples of Electronic circuit design and simulation software:

- CircuitMaker
- Open Circuit Design Software
- KiCad EDA
- ADS Circuit Design Software
- SuperSim Circuit Design Software
- Portus

Computer: is a device that accepts information (in the form of digitalized data) and manipulates it for some result based on a program, software, or sequence of instructions on how the data is to be processed.

By installing Electronic circuit design and simulation software, we can use them to design and construct electrical/electronics circuit.

Fig 2.17. Computer (desktop and laptop)

2.2.7. Auxiliary Tools

Ball-peen Hammer It is a type of hammer used in metalworking. The ball-peen hammer remains useful for many tasks such as tapping punches and chisels. The original function of the hammer was to "peen" riveted or welded material so that it will exhibit the same elastic behavior as the surrounding material. Specifically, striking the metal imparts a stress at the point of impact which results in strain-hardening of that area. Strain hardening raises the elastic limit of a material into the plastic range without affecting its ultimate strength. A strain-hardened material will not deform under the same low stresses as a non-hardened material. Most metals can be "worked" by such methods until they lose all of their ductile characteristics and become strong but brittle.

Fig 2.18. Ballpin hammer

Magnifying Glass It is a convex lens which is used to produce a magnified image of an object. The lens is usually mounted in a frame with a handle (see image). Roger Bacon is the original inventor of the magnifying glass. A magnifying glass works by creating a magnified virtual image of an object behind the lens.

The distance between the lens and the object must be shorter than the focal length of the lens for this to occur. Otherwise, the image appears smaller and inverted, and can be used to project images onto surfaces. The framed lens may be mounted on a stand, keeping the lens at the right distance from the table, and therefore at the right distance from the object on the table. The latter applies if the object is small and also if the height is adjustable. Some magnifying glasses are foldable with built-in light

Fig 2.19. magnifying glass

Anti-Static Brush. It is made of bristles set in handle used for cleaning dirty parts of a circuit or an object.

Fig 2.20. Anti-static brush

Tweezers

Small tweezer is used to hold small components especially when doing soldering and de-soldering of surface mount components.

Fig 2.21. Tweezer

2.3. Selecting testing instrument

Below are the list of measuring instruments used in electrical and electronic work.

Types of test equipment

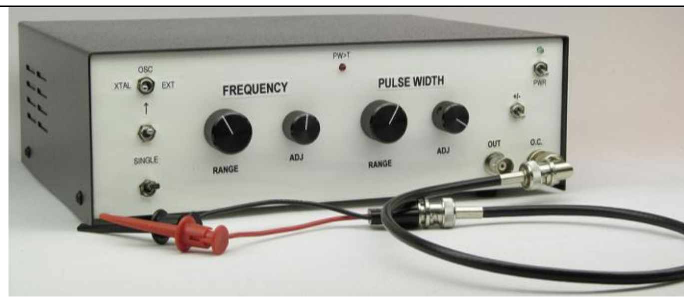
1. The following items are used for basic measurement of voltages, currents, and components in the circuit under test.

1. Voltmeter (Measures voltage)	
2. Ohmmeter (Measures resistance)	

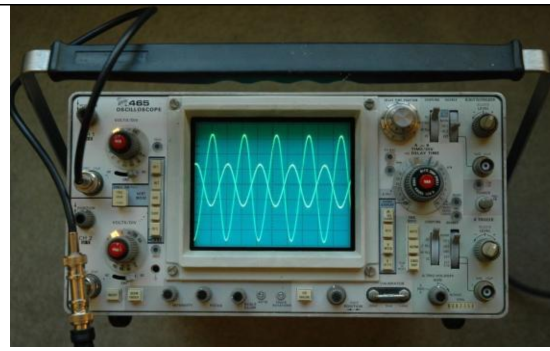
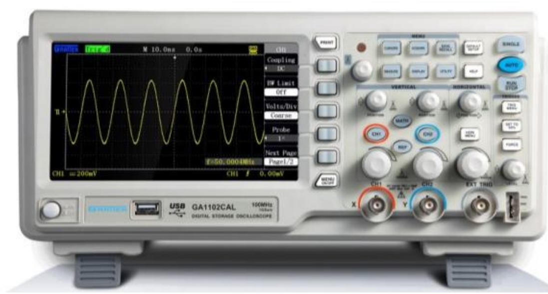
3. Ammeter, e.g. Galvanometer or Milli Ammeter (Measures current)	
4. Multimeter e.g., VOM (Volt-Ohm-Millimeter) or DMM (Digital Multimeter) (Measures all of the above)	
5. LCR Meter e.g., LCR meter or Resistance, Inductance and capacitance meter (measure LCR values)	

2. The following are used for stimulus of the circuit under test

1. Power supplies	

	
2. Signal generator	
3. Digital pattern generator	
4. Pulse generator	

3. The following analyze the response of the circuit under test:

1. Oscilloscope (Displays voltage as it changes over time)	 
2. Frequency counter (Measures frequency) and connecting it all together	
3. Test probes	

4. Advanced or less commonly used equipment Meters

Solenoid voltmeter (Wiggly)	
Clamp meter (current transducer)	
Wheatstone bridge (Precisely measures resistance)	

Capacitance meter (Measures capacitance)	
EMF Meter (Measures Electric and Magnetic Fields)	
Electrometer (Measures charge)	

Self-Check - 2	Written Test

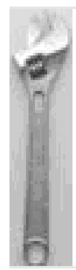
Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Match the different hand tools with their actual pictures. Write the letter on a separate provided.

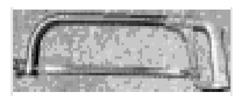
_____1. Desoldering Sucker	______6. For soldering
_____2. Soldering Stand	______7. Long Nose Pliers
_____3. For drilling small hole	______8. Portable Electric Drill
_____4. For cutting metal	______9. For cutting wires
_____5. Wire Splicer	______10. Magnifying Glass

a

b



g



h

c

d

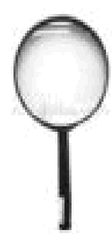
i

j

e

f

k



l

2. Write two measuring instruments used to measure voltage. (2 points)

a. ___________________________________

b. ___________________________________

3. Write two instruments that are used for stimulus of the circuit under test. (2 points)

a. ___________________________________

b. ___________________________________

4. What is the instrument used to measure LCR values? (2 points)

____

Note: - Satisfactory rating: 4.5 and above - Unsatisfactory Rating: below 4.5

You can ask your teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating: _____________

Name: ___________________________ Date: ________________

Information Sheet - 3	Planning task to ensure occupational health and safety

3.1. Introduction to occupational health and safety

Occupational safety and health (OSH), also commonly referred to as occupational health and safety (OHS), occupational health, or workplace health and safety (WHS), is a multidisciplinary field concerned with the safety, health, and welfare of people at work.

OSH may also protect co-workers, family members, employers, customers, and many others who might be affected by the workplace environment. In the United States, the term occupational health and safety is referred to as occupational health and occupational and non-occupational safety and includes safety for activities outside of work.

In common-law jurisdictions, employers have a common law duty to take reasonable care of the safety of their employees. Statute law may in addition impose other general duties, introduce specific duties, and create government bodies with powers to regulate workplace safety issues: details of this vary from jurisdiction to jurisdiction.

All organizations have the duty to ensure that employees and any other person who may be affected by the organization's activities remain safe at all times.

As defined by the World Health Organization (WHO) "occupational health deals with all aspects of health and safety in the workplace and has a strong focus on primary prevention of hazards."

"The main focus in occupational health is on three different objectives:

(i) the maintenance and promotion of workers' health and working capacity;
(ii) the improvement of working environment and work to become conducive to safety and health and
(iii) Development of work organizations and working cultures in a direction which supports health and safety at work and in doing so also promotes a positive social climate and smooth operation and may enhance productivity of the undertakings.

The concept of working culture is intended in this context to mean a reflection of the essential value systems adopted by the undertaking concerned. Such a culture is reflected in practice in the managerial systems, personnel policy, principles for participation, training policies and quality management of the undertaking."

"Occupational health should aim at:

- the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations;
- the prevention amongst workers of departures from health caused by their working conditions;
- the protection of workers in their employment from risks resulting from factors adverse to health;
- the placing and maintenance of the worker in an occupational environment adapted to his physiological and psychological capabilities; and, to summarize,
- the adaptation of work to man and of each man to his job

3.2. Identifying safety and health hazards

3.2.1. Hazards, risks, outcomes

The terminology used in OSH varies between countries, but generally speaking:

- A hazard is something that can cause harm if not controlled.
- The outcome is the harm that results from an uncontrolled hazard.
- A risk is a combination of the probability that a particular outcome will occur and the severity of the harm involved.

"Hazard", "risk", and "outcome" are used in other fields to describe e.g. environmental damage, or damage to equipment. However, in the context of OSH, "harm" generally describes the direct or indirect degradation, temporary or permanent, of the physical, mental, or social well-being of workers. For example, repetitively carrying out manual handling of heavy objects is a hazard.

3.2.2. Hazard identification

Hazard identification or assessment is an important step in the overall risk assessment and risk management process. It is where individual work hazards are identified, assessed and controlled/eliminated as close to source (location of the hazard) as reasonably as possible. As technology, resources, social expectation or regulatory requirements change, hazard analysis focuses controls more closely toward the source of the hazard. Thus hazard control is a dynamic program of prevention. Hazard-based programs also have the advantage of not assigning or implying there are "acceptable risks" in the workplace. A hazard-based program may not be able to eliminate all risks, but neither does it accept "satisfactory" – but still risky – outcomes. And as those who calculate and manage the risk are usually managers while those exposed to the risks are a different group, workers, a hazard-based approach can by-pass conflict inherent in a risk-based approach.

3.2.3. Risk assessment

Modern occupational safety and health legislation usually demands that a risk assessment be carried out prior to making an intervention. It should be kept in mind that risk management requires risk to be managed to a level which is as low as is reasonably practical.

This assessment should:

- Identify the hazards
- Identify all affected by the hazard and how
- Evaluate the risk
- Identify and prioritize appropriate control measures

The calculation of risk is based on the likelihood or probability of the harm being realized and the severity of the consequences. This can be expressed mathematically as a quantitative assessment (by assigning low, medium and high likelihood and severity with integers and multiplying them to obtain a risk factor), or qualitatively as a description of the circumstances by which the harm could arise.

Self-Check - 3	Written Test

Directions: Fill in the blank for questions listed below. Use the Answer sheet provided in the next page:

1. The main focus in occupational health is on three different objectives, those are: (6 points)
   a. ____
   ____
   b. ____
   ____
   c. ____
   ____
2. **What is meant by risk assessment? (4 points)**
   ____
   ____
   ____
   ____

Note: - Satisfactory rating: 5 and above - Unsatisfactory Rating: below 5

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________
Rating: ____________

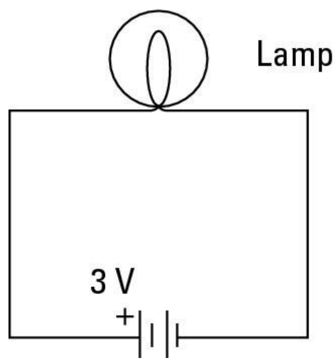
Name: ______________________________ Date: ________________

Information Sheet – 4	Preparing Electrical/electronic circuits correctly for connecting and soldering

4.1. Definition of circuit

An electronic *circuit* is a complete course of conductors through which current can travel. Circuits provide a path for current to flow. To be a circuit, this path must start and end at the same point. In other words, a circuit must form a loop. An electronic circuit and an electrical circuit has the same definition, but electronic circuits tend to be low voltage circuits.

For example, a simple circuit may include two components: a battery and a lamp. The circuit allows current to flow from the battery to the lamp, through the lamp, then back to the battery. Thus, the circuit forms a complete loop.



Of course, circuits can be more complex. However, all circuits can be distilled down to three basic elements:

- **Voltage source:** A voltage source causes current to flow like a battery, for instance.
- **Load:** The load consumes power; it represents the actual work done by the circuit. Without the load, there is not much point in having a circuit. The load can be as simple as a single light bulb. In complex circuits, the load is a combination of components, such as resistors, capacitors, transistors, and so on.
- **Conductive path:** The conductive path provides a route through which current flows. This route begins at the voltage source, travels through the load, and then returns to the voltage source. This path must form a loop from the negative side of the voltage source to the positive side of the voltage source.

4.2. Connecting and soldering Electrical/electronic circuits correctly

Circuits should be designed in such a way that it is easy to make connection and soldering. All the materials, components of the circuit have to be available in the working area in order for the connection to be made. The steps of preparing circuits for connection and soldering are:

- Material and equipment selection
- Placing the components in the project board according to the design of the circuit
- Removing the insulation of wires.

Materials and Equipment

- A soldering iron
    - A soldering iron is used to heat the connections to be soldered.
    - For electronic circuits, you should use a 25- to 40-watt (W) soldering iron.
    - Higher wattage soldering irons are not necessarily hotter; they are just able to heat larger components. A 40-W soldering iron makes joints faster than a 25-W soldering iron does.

- Rosin core solder or lead
    - Solder has a lower melting point than the metals that are being connected do. The solder melts when it is heated by the soldering iron, but the metals being joined will not melt.
    - The rosin core acts as a *flux.* It prevents oxidation of the metals that are being connected, and enhances the ability of the solder to "wet" the surfaces that are being joined.
    - Solder that is used to join copper pipes has an acid core, which is appropriate for pipes, but will corrode electronic connections. Use solder that has a rosin core.
    - For most electronics work, a solder with a diameter of 0.75 millimeters (mm) to 1.0 mm is best. Thicker solder might make soldering small joints difficult and also increases the chances of creating *solder bridges* between copper pads that are not meant to be connected.
    - An alloy of 60/40 (60% tin, 40% lead) is used for most electronics work, but lead-free solders are available as well.

- Stand on which to hold the hot soldering iron
    - There are a variety of stands available. It is important to always keep the hot iron in its stand when not in use.

- Sponge
    - The damp sponge is used to clean the tip of the iron.

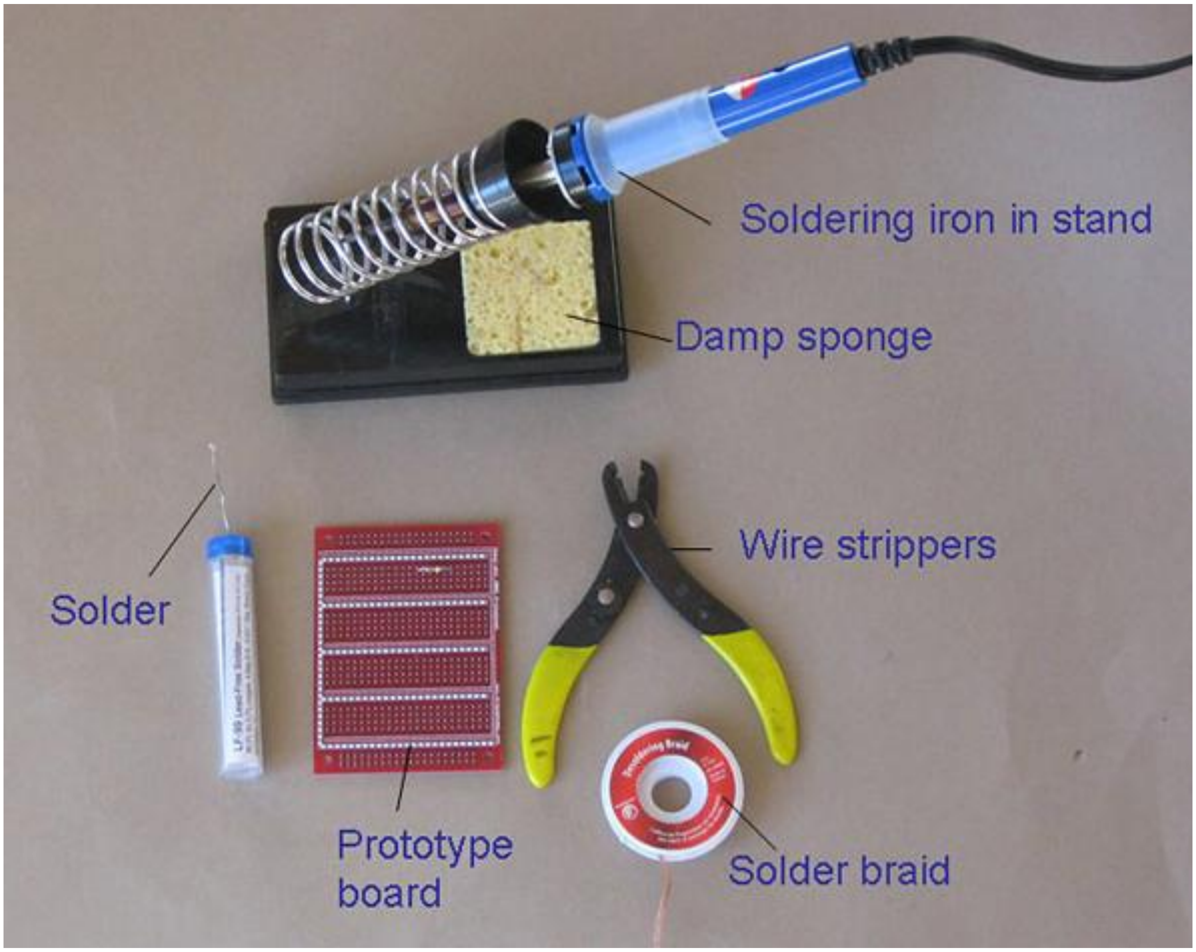


Figure 4.1. Soldering equipment and materials.

The *solder* in this picture is coiled inside a plastic tube; it is pulled through the top as needed. The spring on the stand holds the hot soldering iron. The *damp sponge* is used to clean the tip of the iron. *Solder braid* is used to remove solder; solder is "soaked up" into the braid when it is heated by the soldering iron. The *wire strippers* can be adjusted to strip the plastic covering off of various thicknesses of wire. The *prototype board* is used to connect electronic components in a circuit.

- Solder braid
    - This is used to remove solder.
    - To use the braid, place it over the solder to be removed and heat it from above with the iron. The solder will flow into the braid.

- Solder braid is used to extract an electronic component that is soldered onto a board.
- It is also used to reduce the amount of solder on a connection.

- Prototype board
    - A prototype board is used to assemble the circuit.
    - Prototype boards have copper tracks or pads for connecting components.

- Steel wool or fine sandpaper
    - This is used to clean connections prior to soldering.
    - Solder will *not* flow over a dirty connection.

- Crocodile clips
    - These can be used as heat sinks, if needed

Self-Check – 4	Written Test

Directions: Fill in the blank for questions listed below. Use the Answer sheet provided in the next page:

1. Name five of the soldering equipment and materials used when connecting and soldering Electrical/electronic circuits. (2 points each)

   a. ________________________________

   b. ________________________________

   c. ________________________________

   d. ________________________________

   e. ________________________________

Note: - Satisfactory rating: 5 and above   - Unsatisfactory Rating: below 5

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating: _____________

Name: ___________________________   Date: ________________

Operation Sheet 1	Techniques of Selecting appropriate *tools and equipments*

	according to task requirements

Techniques to Select appropriate *tools and equipments* according to task requirements

Step 1: prepare clean and safe work station

Step 2: analyze and understand the given task

Step 3: list out tools, materials and equipments necessary for the specific task

Step 4: calibrate/adjust the equipments to be used for the task if necessary

Step 5: make the workstation ready for the task to be start

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: _________________________ Time finished: ________________

Instructions: Given necessary templates, tools, materials and equipments you are required to perform the following tasks within 5 hour.

Task 1: Check materials with specifications and tasks given

Task 2: Select appropriate tools and equipments for task required

Task 3: Plan and follow procedures to ensure occupational health and safety (OHS) guidelines

Task 4: Prepare electrical/electronic circuits for connecting and soldering correctly with instructions and work site procedures

Instruction Sheet	LG40:- Plan and prepare to construct/ electrical/ electronic circuits

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics

- Observing safety procedures in using hand tools/equipment's and PPE
- Undertaking work safely
- Identifying important Electrical/Electronic Components
- Using appropriate range of methods in constructing electrical/electronics circuit
- Following correct sequence of operation.
- Adjusting Accessories used , if necessary
- Undertaking confirmation of construction successfully

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, **upon completion of this Learning Guide, you will be able to**:

- Observe safety procedures in using hand tools/equipment's at all times and using appropriate personal protective equipment
- Undertake work safely in accordance with the workplace and standard procedures
- Identify important Electrical/Electronic Components
- Use appropriate range of methods in constructing electrical /electronic circuits (Amplifiers, oscillators, power supply, digital circuits, air conditioner control circuit) according to specifications, manufacturer's requirements and safety
- Follow correct sequence of operation according to job specifications (for example Transformer → Rectifier→ Filter → Regulator → Output to construct linear power supply circuit)
- Adjust accessories used, if necessary
- Confirm the construction undertaken successfully in accordance with job specification

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information "Sheet 1, Sheet 2, Sheet 3, Sheet 4, Sheet 5, Sheet 6, and Sheet 7".
4. Accomplish the "Self-check 1, Self-check t 2, Self-check 3, Self-check 4, Self-check 5, Self-check 6, and Self-check 7" **in page 58, 65, 78, 135, 196, 199, and 201** respectively.
5. If you earned a satisfactory evaluation from the "Self-check" proceed to "Operation Sheet 1, Operation Sheet 2, Operation Sheet 3, Operation Sheet 4 and Operation Sheet 5" **in page - 202.**
6. Do the "LAP test" **in page – 209**(if you are ready).

Information Sheet-1	Observing safety procedures in using hand tools/equipment's and PPE

1.1 Safety

Safety: Relative freedom from danger, risk, or threat of harm, injury, or loss to personnel and/or property, whether caused deliberately or by accident.

Hazards may occur due to improper handling of tools and equipments, unsafe work areas, operating machines without knowing how to operate and using materials out of their intended purpose etc…

1.2. SAFE WORK PRACTICES

A safe work environment is not enough to control all electric hazards. You must also work safely. Safe work practices help you control your risk of death from workplace hazards. If you are working on electrical circuits or with electrical tools and equipment, you need to use safe work practices.

Before you begin a task, ask yourself:

- What could go wrong?
- Do I have the knowledge, tools, and experience to do this work safely?

All workers should be very familiar with the safety procedures for their jobs. You must know how to use specific controls that help keep you safe. You must also use good judgment and common sense.

1.3. Safety Procedures in Using Hand Tools and Equipment

We are already familiar with the different hand tools and their proper use. Know we need to know how to be safe in using these. What are the safety precautions in using hand tools and equipment? What are it's do's and don't's?

Safety Precautions in Using Hand Tools and Equipment

1. All tools must be kept in good condition with regular maintenance.
2. Right tool must be used for job.

3. Each tool must be examined before use and damaged or defective tools not to be used.

4. Tools must be operated according to manufacturer's instruction.

5. The right protective equipment for the tool and activity must be used.

Procedures in Cleaning, Tightening and Simple Repair for Hand tools and Equipment

1. Cleaning the tools after use is highly recommended.

2. All tools and equipment must be placed in a clean and dry place.

3. The work area must always be kept neat and tidy.

4. Lubricants must also be applied after tightening to reduce the friction.

5. Before cleaning any tool, be sure to wear the proper personal protective equipment (PPE). Gloves, masks and goggles are usually worn when cleaning tools since most cleaning agents and solutions are harmful to the human body.

6. Only use cleaning agents as prescribed by the tool or equipment's manufacturer. Follow the cleaning procedures as well to make sure that no damage will be inflicted on the tools.

1.4. Personal Protective Equipment

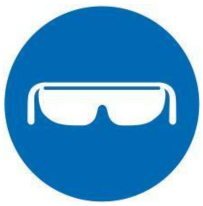
1.4.1. What is Personal Protective Equipment?

Personal Protective Equipment (PPE) is anything used or worn by a person to minimize risk to the person's health or safety and includes a wide range of clothing and safety equipment. PPE includes boots (safety shoes, face masks, hard hats (helmet), ear plugs, respirators, gloves, safety harnesses and high visibility clothing.

1. SAFETY FOR THE HEAD

Wearing a **helmet** offers protection and can prevent head injuries. Select a sturdy helmet that is adapted to the working conditions. These days you can find many elegant designs and you can choose extra options such as an adjustable interior harness and comfortable sweatbands.

2. PROTECT YOUR EYES



The eyes are the most complex and fragile parts of our body. Each day, more than 600 people worldwide sustain eye injuries during their work. Thanks to a good pair of **safety glasses**, these injuries could be prevented. Do you come into contact with bright light or infrared radiation? Then **welding goggles or a shield** offer the ideal protection!

3. HEARING PROTECTION

Do you work in an environment with high sound levels? In that case it is very important to consider hearing protection. **Earplugs** are very comfortable, but earmuffs are convenient on the work floor as you can quickly put these on or take them off.

4. MAINTAIN A GOOD RESPIRATION

Wearing a **mask** at work is no luxury, definitely not when coming into contact with hazardous materials. 15% of the employees within the EU inhale vapours, smoke, powder or dusk while performing their job. **Dust masks** offer protection against fine dust and other dangerous particles. If the materials are truly toxic, use a **full-face mask**. This adheres tightly to the face, to protect the nose and mouth against harmful pollution.

5. PROTECT YOUR HANDS WITH THE RIGHT GLOVES

Hands and fingers are often injured, so it is vital to protect them properly. Depending on the sector you work in, you can choose from gloves for **different applications**:

- protection against vibrations
- protection against cuts by sharp materials
- protection against cold or heat
- protection against bacteriological risks
- protection against splashes from diluted chemicals.

6. PROTECTION FOR THE FEET

Even your feet need solid protection. **Safety shoes** (type Sb, S1, S2 or S3) **and boots** (type S4 or S5) are the ideal solution to protect the feet against heavy weights. An **antiskid sole** is useful when working in a damp environment, definitely if you know that 16,2% of all industrial accidents are caused by tripping or sliding. On slippery surfaces, such as snow and ice, **shoe claws**are recommended. Special socks can provide extra comfort.

7. WEAR THE CORRECT WORK CLOTHING

Preventing accidents is crucial in a crowded workshop. That is why a good visibility at work is a must: a **high-visibility jacket and pants made of a strong fabric** can help prevent accidents. Just like the hand protection, there are versions for different applications.

1.4.2. When does PPE used?

PPE is one of the least effective ways of controlling risks to work health and safety and should only be used:

- when there are no other practical control measures available (as a last resort)
- As an interim measure until a more effective way of controlling the risk can be used, or
- To supplement higher level control measures (as a back-up).

1.4.3. What standard of PPE is required?

PPE used at a workplace must be:

- selected to minimize risk to work health and safety
- suitable for the nature of the work and any hazard associated with the work
- a suitable size and fit and reasonably comfortable for the person wearing it
- maintained, repaired or replaced so it continues to minimize the worker's health and safety risk, and
- Used or worn by the worker, so far as is reasonably practicable.

1.4.4. How do I choose the right PPE for the job?

Selection processes for choosing the right PPE must involve consultation with workers and their representatives and should include:

- a detailed evaluation of the risk and performance requirements for the PPE
- compatibility of PPE items where more than one type of PPE is required (for example ear muffs with a hard hat)
- Consultation with the supplier to ensure PPE is suitable for the work and workplace conditions, and
- Preference for PPE that complies with the relevant Australian Standard or equivalent standard.

Always remember to use PPE and apply safety rules while working any electrical works. For further information about PPE, read Learning Guide 1.

Self-Check 1	Written Test

Directions: Answer the questions listed below. Use the Answer sheet provided in the next page.

1. Before we begin our tasks in our workplace, what do we ask ourselves for safety? (2 points)
2. What is Personal Protective Equipment? (3 points)
3. When does PPE used? (3 points)
4. Match the different PPEs with their uses. Write the letter on a separate provided. (5 points)

Answer	"A"	"B"
	1. Helmet	A. Protect the feet against heavy weights
	2. Safety glasses	B. Protect Hands and fingers against cuts by sharp materials
	3. Mask	C. Protect eyes from eye injuries
	4. Gloves	D. Protect head from head injuries
	5. Safety shoes	E. Protect workers from inhale vapors, smoke, powder or dusk

Note: - Satisfactory rating: 6.5 and above - Unsatisfactory Rating: below 6.5

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet - 2	Undertaking work safely

2.1. Introduction to undertaking work

The electrical and electronics industry includes a range of work activities such as using measuring instruments, soldering, using hand, power and specialist tools and constructing circuits.

2.2. Carrying out electrical work

An electrical risk is a risk to a person of death, shock or other injury caused directly or indirectly by electricity.

The main hazards associated with these risks are:

- contact with exposed live parts causing electric shock and burns (for example exposed leads or other electrical equipment coming into contact with metal surfaces such as metal flooring or roofs);
- the use of outdated, poorly maintained equipment or unsafe use of equipment;
- faults which could cause fires; and,
- Fire or explosion where electricity could be the source of ignition in a potentially flammable or explosive atmosphere.

Electrocution incidents can be fatal. Non-fatal shocks can result in serious and permanent burn injuries to skin, internal tissues and damage to the heart. Other injuries or illnesses may include muscle spasms, palpitations, nausea, vomiting, collapse and unconsciousness. Electric shocks may also contribute to related incidents including falls from ladders, scaffolding or other elevated work platforms.

Those working with electricity may not be the only ones at risk. Poor electrical installation and faulty electrical appliances can lead to electric shock to others at or near the workplace.

The risk of injury from electricity is strongly linked to where and how it is used. The risk of injury is greatest in harsh conditions such as:

- Outdoors or in wet surroundings - equipment may become wet and may be at greater risk of damage; and,
- In cramped spaces with earthed metalwork, such as inside a tank or bin - it may be difficult to avoid electrical shock if an electrical fault develops.

Some items of equipment also involve greater risk of electrical injury than others. Portable electrical equipment is particularly liable to damage. Plugs, sockets, connections and cables on portable electrical equipment and extension leads connected to frequently moved equipment are all particularly susceptible to damage and therefore may pose a greater electrical risk.

2.2.1. Duty to manage risks

A person conducting a business or undertaking must manage electrical risks at the workplace. If elimination is not reasonably practicable, the risks must be minimised so far as is reasonably practicable. Any person conducting a business or undertaking with management or control over electrical equipment (including an electrical installation) must ensure, so far as is reasonably practicable, that the equipment is safe to use. This duty applies regardless of whether the person conducting a business or undertaking owns or supplied the electrical equipment.

2.2.2. Reducing the risk

Inspecting and testing electrical equipment will help determine whether it is electrically safe. Regular visual inspection can identify obvious damage, wear or other conditions which might make electrical equipment unsafe. Many electrical defects such as damaged cords are detectable by visual inspection.

Regular testing can detect electrical faults and deterioration that cannot be detected by visual inspection. The nature and frequency of inspection and testing depends on factors such as the nature of the electrical equipment, how it is used and its operating environment.

The *Work Health and Safety Regulation 2011* prescribes mandatory testing and tagging for electrical power equipment used in 'a hostile operating environment'. This term is used to describe an environment in which the normal use of electrical equipment exposes it to operating conditions that are likely to result in damage or a reduction in its expected life span. This includes conditions that involve exposing the electrical equipment to moisture, heat, vibration, mechanical damage, corrosive chemicals or dust such as in outdoor workplaces, commercial kitchens and workshops.

Electrical equipment that is connected by a plug and socket used in a hostile operating environment must be regularly inspected and tested by a competent person. If this equipment has not been regularly tested then it must not be used until it is tested.

Brand new equipment that is 'out of the box' does not need to be tested before being put into service unless there are reasonable grounds to believe it is electrically unsafe.

As a general rule, electrical equipment used in a hostile operating environment should be inspected and tested at least once every 12 months. More frequent testing will be required where plug in equipment is exposed to increased risk of mechanical damage or electrical deterioration such as when it is used in the manufacturing or hire environment. Also as a general rule, electrical equipment connected by a plug and socket that is used on construction and demolition sites should be inspected and tested at least once every three months. More frequent testing may be required as indicated by a site-specific risk assessment.

In addition to regular inspection and testing, plug in equipment should also be tested:

- after a repair or servicing that could affect the electrical safety of the equipment in essence undertaken by the person carrying out the repair or servicing before return to use;
- before first use if bought second-hand; and,
- If there is no record of it being tested previously.

A record of testing of electrical equipment used in a hostile environment must be kept until the electrical equipment is next tested, permanently removed from the workplace or disposed of.

2.2.3. Unsafe electrical equipment

A person conducting a business or undertaking must ensure that any unsafe electrical equipment within their management or control is disconnected or isolated from its electricity supply and once disconnected is not reconnected until it is repaired or tested and found to be safe or is replaced or permanently removed from use.

Isolation, tagging and lock out procedures are all designed to protect people and property in a workplace from hazards related to electrical power, damaged equipment or machinery or when repairs, maintenance or inspections are carried out.

Yellow and black 'OUT OF SERVICE' tags are used to warn people that machinery, appliances or equipment is damaged, unsafe or out of service for repairs. While an 'OUT OF SERVICE' tag is attached the machinery, appliance or equipment must not be operated.

To attach an 'OUT OF SERVICE' tag a worker must:

- be authorized to fix and remove them;
- write their name and the fault on the tag;
- place the tag in a prominent position;
- place tags at common isolation points; and,
- Leave tags on until the machinery or equipment is repaired and is safe to use.

Before any repair or alteration work is started the electrical circuits or equipment to be worked on must be disconnected from the electricity supply, unless other adequate precautions are taken to prevent electric shock.

Personal 'DANGER' tags are colour-coded red, black and white, and are used to warn all persons that the equipment or machinery is being repaired or serviced. A circuit must not be energised while a 'DANGER' tag is attached.

'DANGER' tags must be placed at common isolation points, signed and dated and removed when the work is complete.

Lock out is the best way of preventing machinery or electrical current becoming operational during maintenance. A lock is attached to the machine switch so that it cannot be turned on.

The worker working with the machine should hold the only key to the lock. A lock must only be removed from equipment or machinery by the person who attached it. Procedures must be put in place for the removal of the lock in case this person is not available, for example if there has been a change of shift workers.

2.2.4. Minimizing risks

Common measures to control electrical risks at a workplace include:

- safe and suitable electrical equipment is used;
- only appropriately licensed or registered electricians carry out electrical work;
- procedures for pre checks, testing, tagging and preventative maintenance of electrical equipment, residual current devices and personal protective equipment are in place and used;
- inspection, testing and maintenance is undertaken by a suitably trained and competent person;
- procedures for tag out, isolation, labelling and reporting of faulty equipment are in place and used;
- procedures for the reinstatement of items tested as being safe are in place and used;

- sufficient socket outlets are provided-overloading socket outlets by using adaptors can cause fires;
- first aid equipment and facilities are available;
- correct fire extinguishers are available and operators know how to use them;
- procedures for reporting and responding to electrical accidents are in place and used;
- work is planned and discussed;
- all bracelets, rings, neck chains, exposed metal zips and watches are removed;
- work is not carried out on energised equipment or cables whenever possible;
- procedures to prevent inadvertent re-energising while work is being undertaken are in place and used;
- not increasing the fuse rating if the circuit keeps overloading as this creates a fire risk due to overheating;
- using tools, instruments, equipment and personal protective equipment suitable for the purpose and conditions (insulated ladders and non-conducting tape measures);
- regularly checking and cleaning tools;
- using battery powered tools instead of mains operated where possible;
- using lead stands, insulated cable hangers, cable protection ramps etc to protect cables and keep them off the ground;
- keeping the workplace clean and orderly;
- using residual current devices to protect workers using portable equipment as required by the *Work Health and Safety Regulation 2011*;
- determining the reason why an residual current devices, circuit breaker or other over current protective device disconnected the electricity before it is switched back on;
- ensuring unsafe equipment is not reconnected until it is repaired and tested as being safe;
- erecting safety barriers when required; and,
- meeting electrical safety standards.

On completion of electrical work, workers should:

- check that no tools are left on or in the job;
- remove their own earthing equipment;
- check that the work is complete and the equipment can be energised;
- notify all personnel involved that the equipment will be energised;
- remove 'DANGER - DO NOT OPERATE' tags;
- energise power supply; and,
- remove and store all safety barriers.

Self-Check - 2	Written Test

Directions: Answer the questions listed below. Use the Answer sheet provided in the next page.

1. To attach an 'OUT OF SERVICE' tag a worker must: (5 points)

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

2. Write three that are included under common measures to control electrical risks at a workplace. (4 points)

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

3. On completion of electrical work, workers should: (3 points)

   a. ______________________________

   b. ______________________________

   c. ______________________________

Note: - Satisfactory rating: 6 and above - Unsatisfactory Rating: below 6

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating: _____________

Name: ___________________________ Date: ________________

3.1. Introduction to Electrical/Electronics components

There are various basic electrical and electronic components which are commonly found in different circuits of peripherals. In many circuits, these components are used to build the circuit, which are classified into two categories such as active components and passive components. . Active components are nothing but the components that supply and control energy. Passive components can be defined as the components that respond to the flow of electrical energy and can dissipates or store energy. These components can be found in numerous peripherals like hard disks, mother boards, etc. Many circuits are designed with various components like resistors, capacitors, inductors, transistors, transformers, switches, fuses, etc.

3.2. Active Component

Definition - What does Active Component mean?

An active component is a device that has an analog electronic filter with the ability to amplify a signal or produce a power gain. There are two types of active components: electron tubes and semiconductors or solid-state devices. A typical active component would be an oscillator, transistor or integrated circuit.

An active component works as an alternating-current circuit in a device, which works to increase the active power, voltage or current. An active component is able to do this because it is powered by a source of electricity that is separate from the electrical signal.

The majority of electronic devices are semiconductors, the most common of which is a transistor. A basic transistor is generally used in an amplifier, which increases the active current I/O signal using a direct current (DC) power supply to provide the necessary power.

An active device has the ability to control electron flow and either allows voltage to control the current or allows another current to take control. Voltage-controlled devices, such as vacuum tubes, control their own signal, while current-controlled devices, such as bipolar junction transistors, allow one current to control another.

All active components require a source of energy, which generally comes from a DC circuit. In addition, an active device can generally infuse power into a circuit such as a transistor, triode vacuum tube or tunnel diode.

A component that is not active is called a passive component. It consumes energy and does not have the ability to boost power. Basic passive components include capacitors, resistors and inductors.

3.3. Passive Component

Definition - What does Passive Component mean?

A passive component is a module that does not require energy to operate, except for the available alternating current (AC) circuit that it is connected to. A passive module is not capable of power gain and is not a source of energy. A typical passive component would be a chassis, inductor, resistor, transformer, or capacitor.

Generally, passive components are not able to increase the power of a signal nor are they able to amplify it. However, they can increase current or voltage by an LC circuit that stores electrical energy from resonant frequencies or by a transformer that acts like an electrical isolator.

In the context of electronic technology, there are stricter guidelines for the term passive component. Electronic engineers view this term usually in correlation with circuit analysis, which involves methods of finding the currents through and the voltages across every component in the network

An electronic circuit that is composed of just passive components is called a passive circuit. A module that is not passive is called an active component.

Passive components can be divided into two types:

- Lossy or dissipative: Does not have the capacity to absorb power from an external circuit over a period of time. A classic example would be a resistor.
- Lossless: Does not have an input or output net power flow. This type includes components such as inductors, capacitors, transformers, and gyrators.

The majority of passive components that have two terminals are usually defined as a two-port parameter, which is an electric circuit or module that has two pairs of terminals linked together by an electric network. Two-port parameters comply with the standards of reciprocity. A two-port network would be a transistor, electronic filters, or impedance matching networks. A transducer or switch would not be a two-port parameter because it is a closed system. Although active components typically have more than two terminals, they are not classified as a two-port parameter because they lack the properties.

Passive components that use circuit architecture would include inductors, resistors, voltage and current sources, capacitors, and transformers. Likewise, passive filter are comprised of four elementary linear elements that include an inductor, capacitor, resistor, and transformer. Some high-tech passive filters can have non-linear elements like a transmission line.

3.4. Difference between Active and Passive Components

The active and passive components are differentiated on various factors like nature of the source, its functions, power gain, controlling the flow of current. Various examples of the component, nature of the energy, requirement of the external resistance. The **Difference between Active** and **Passive Components** is given below in the tabulated form.

Table 3.1. Comparison Chart b/n active and passive

BASIS	ACTIVE COMPONENTS	PASSIVE COMPONENT
Nature of source	Active components deliver power or energy to the circuit.	Passive elements utilizes power or energy in the circuit.
Examples	Diodes, Transistors, SCR, Integrated circuits etc.	Resistor, Capacitor, Inductor etc.
Function of the component	Devices, which produce energy in the form of voltage or current.	Devices, which stores energy in the form of voltage or current.
Power Gain	They are capable of providing power gain.	They are incapable of providing power gain.
Flow of current	Active components can control the flow of current.	Passive components cannot control the flow of the current.
Requirement of external source	They require an external source for the operations.	They do not require any external source for the

BASIS	ACTIVE COMPONENTS	PASSIVE COMPONENT
		operations.
Nature of energy	Active components are energy donor.	Passive components are energy acceptor.

In this article difference between Active and Passive components are explained considering various points. **Active components** are the elements or devices which are capable of providing or delivers energy to the circuit. **Passive components** are the devices which do not require any external source for the operation and are capable of storing energy in the form of voltage or current in the circuit.

The Difference between Active and Passive Components are as follows:-

- Active components are those who delivers or **produce energy** or power in the form of a voltage or current. Passive components are those who **utilises or store energy** in the form of voltage or current.
- Examples of the active components are Diodes, transistors, SCR, integrated circuits, etc. similarly examples of the passive components are resistor, capacitor and inductor.
- Active components are capable of providing the **power gain**, whereas the passive components are not capable of providing the power gain.
- Active components can control the **flow of current**, but the passive components cannot control the flow of the current.
- Active components are energy donor, whereas the passive components are energy acceptor.
- The active component requires an external source for the operation, whereas the passive components do not require any external source for the operations.

3.5. Logic gates

Logic gates perform basic logical functions and are the fundamental building blocks of digital integrated circuits. Most logic gates take an input of two binary values, and output a single value of a 1 or 0. Some circuits may have only a few logic gates, while others, such as microprocessors, may have millions of them. There are seven different types of logic gates, which are outlined below.

In the following examples, each logic gate except the NOT gate has two inputs, A and B, which can either be 1 (True) or 0 (False). The resulting output is a single value of 1 if the result is true, or 0 if the result is false.

3.5.1. Basic logic gates

There are seven basic logic gates: AND, OR, XOR, NOT, NAND, NOR, and XNOR.

1. **AND** - True if A and B are both True
2. **OR** - True if either A or B are True
3. **NOT** - Inverts value: True if input is False; False if input is True
4. **XOR** - True if either A or B are True, but False if both are True
5. **NAND** - AND followed by NOT: False only if A and B are both True
6. **NOR** - OR followed by NOT: True only if A and B are both False
7. **XNOR** - XOR followed by NOT: True if A and B are both True or both False

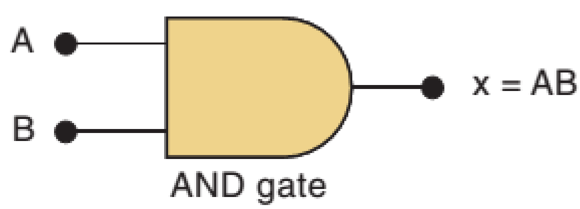
1. AND gate

The *AND gate* is so named because, if 0 is called "false" and 1 is called "true," the gate acts in the same way as the logical "and" operator. The following illustration and table show the circuit symbol and logic combinations for an AND gate. (In the symbol, the input terminals are at left and the output terminal is at right.) The output is "true" when both inputs are "true." Otherwise, the output is "false." In other words, the output is 1 only when both inputs one AND two are 1.

AND

A	B	$x = A \cdot B$
0	0	0
0	1	0
1	0	0
1	1	1

(a)



(b)

Fig 3.1. AND gate (a) truth table (b) symbol

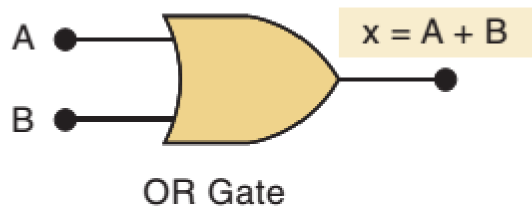
2. OR gate

The *OR gate* gets its name from the fact that it behaves after the fashion of the logical inclusive "or." The output is "true" if either or both of the inputs are "true." If both inputs are "false," then the output is "false." In other words, for the output to be 1, at least input one OR two must be 1.

OR

A	B	x = A + B
0	0	0
0	1	1
1	0	1
1	1	1

(a)

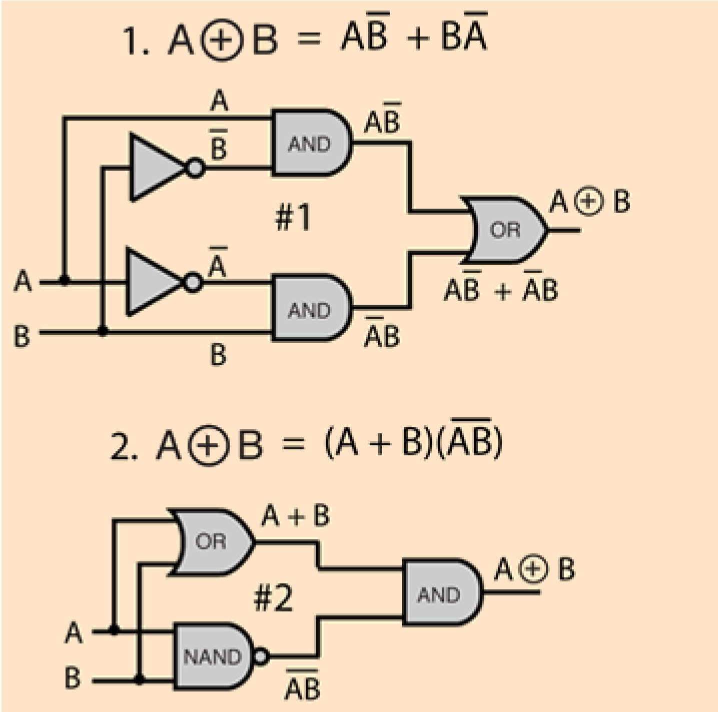


(b)

Fig 3.2. OR gate (a) truth table (b) symbol

3. XOR gate

The *XOR* (exclusive-*OR*) *gate* acts in the same way as the logical "either/or." The output is "true" if either, but not both, of the inputs are "true." The output is "false" if both inputs are "false" or if both inputs are "true." Another way of looking at this circuit is to observe that the output is 1 if the inputs are different, but 0 if the inputs are the same.



A	B	Out
0	0	0
0	1	1
1	0	1
1	1	0

Fig 3.3. XOR gate (a) truth table (b) symbol

4. Inverter or NOT gate

A logical *inverter*, sometimes called a *NOT gate* to differentiate it from other types of electronic inverter devices, has only one input. It reverses the logic state. If the input is 1, then the output is 0. If the input is 0, then the output is 1.

NOT

A	$x = \overline{A}$
0	1
1	0

(a)

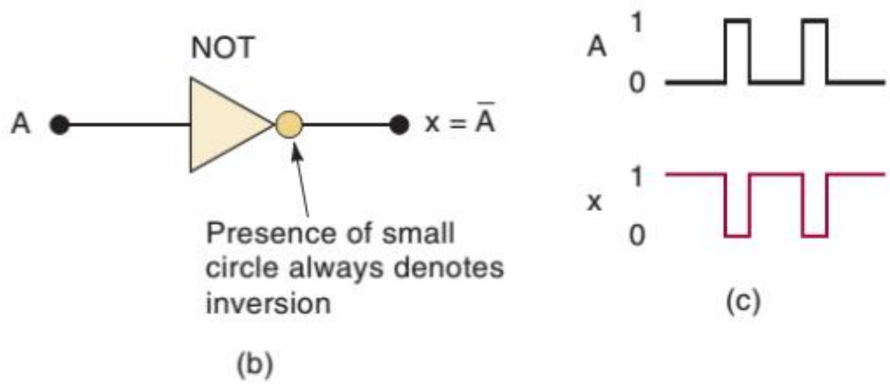
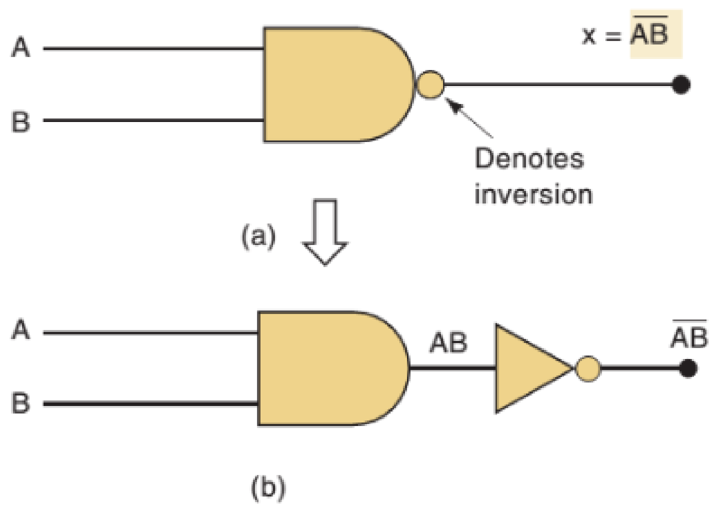


Fig 3.4. NOT gate (a) truth table (b) symbol (c) output signal

5. **NAND gate**

The *NAND gate* operates as an AND gate followed by a NOT gate. It acts in the manner of the logical operation "and" followed by negation. The output is "false" if both inputs are "true." Otherwise, the output is "true."



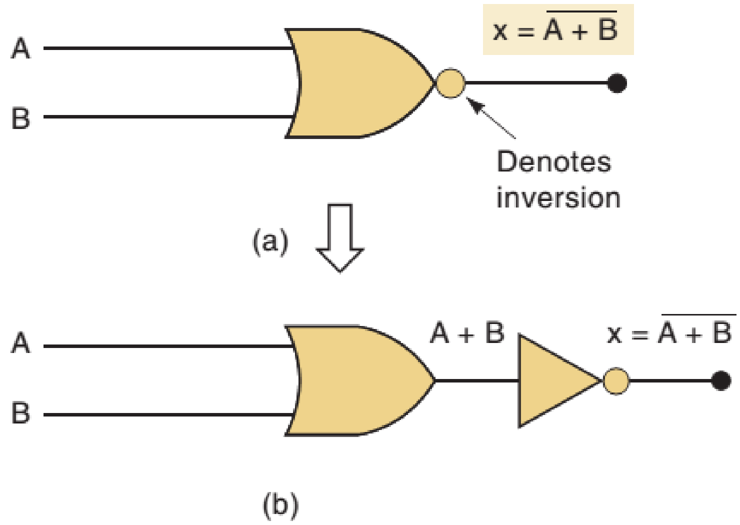
		AND	NAND
A	B	AB	$\overline{AB}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

(c)

Fig 3.5. NAND gate (a&b) symbol (c) truth table

6. **NOR gate**

The *NOR gate* is a combination OR gate followed by an inverter. Its output is "true" if both inputs are "false." Otherwise, the output is "false."



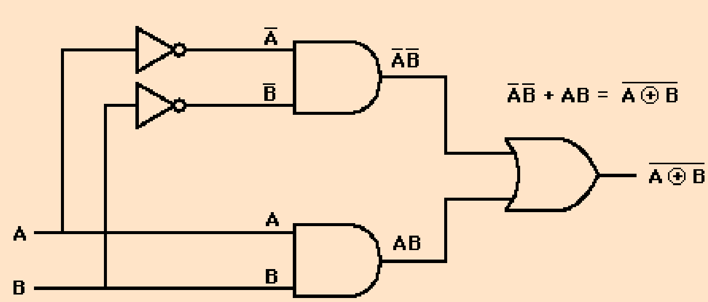
A	B	A + B (OR)	$\overline{A + B}$ (NOR)
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

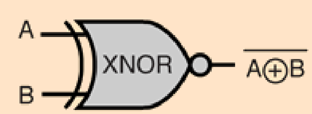
(c)

Fig 3.6. NOR gate (a) & (b) symbol (c) truth table

7. XNOR gate

The *XNOR (exclusive-NOR) gate* is a combination XOR gate followed by an inverter. Its output is "true" if the inputs are the same, and"false" if the inputs are different.





A	B	Out
0	0	1
0	1	0
1	0	0
1	1	1

Fig 3.7. XNOR gate (a) truth table (b) symbol

3.5.2. Composition of logic gates

High or low binary conditions are represented by different voltage levels. The logic state of a terminal can, and generally does, change often as the circuit processes data. In most logic gates, the low state is approximately zero volts (0 V), while the high state is approximately five volts positive (+5 V).

Logic gates can be made of resistors and transistors, or diodes. A resistor can commonly be used as a pull-up or pull-down resistor. Pull-up or pull-down resistors are used when there are any unused logic gate inputs to connect to either a logic level 1 or 0 respectively. This prevents any false switching of the gate. Pull-up resistors are connected to Vcc (+5V), and pull-down resistors are connected to ground (0 V).

Commonly used logic gates are TTL and CMOS. TTL, or Transistor-Transistor Logic, ICs will use NPN and PNP type Bipolar Junction Transistors. CMOS, or Complementary Metal-Oxide-Silicon, ICs are constructed from MOSFET or JFET type Field Effect Transistors. TTL IC's may commonly be labeled as the 7400 series of chips, while CMOS ICs may often be marked as a 4000 series of chips.

Refer https://youtu.be/95kv5BF2Z9E?t=27

https://www.youtube.com/watch?v=RhS-AL2ZcyE

https://www.youtube.com/watch?v=q2OBYz3K6PM

3.6. Integrated circuits (IC's)

An integrated circuit (IC), sometimes called a *chip* or microchip, is a semiconductor wafer on which thousands or millions of tiny resistors, capacitors, and transistors are fabricated. An IC can function as an amplifier, oscillator, timer, counter, computer memory, or microprocessor. A particular IC is categorized as either linear (analog) or digital, depending on its intended application.

Linear ICs have continuously variable output (theoretically capable of attaining an infinite number of states) that depends on the input signal level. As the term implies, the output signal level is a linear function of the input signal level. Ideally, when the instantaneous output is graphed against the instantaneous input, the plot appears as a straight line. Linear ICs are used as audio-frequency (AF) and radio-frequency (RF) amplifiers. The *operational amplifier*(op amp) is a common device in these applications.

Digital ICs operate at only a few defined levels or states, rather than over a continuous range of signal amplitudes. These devices are used in computers, computer networks, modems, and frequency counters. The fundamental building blocks of digital ICs are logic gates, which work with binary data, that is, signals that have only two different states, called low (logic 0) and high (logic 1).

3.6.1. Polarity Marking and Pin Numbering

All ICs are polarized, and every pin is unique in terms of both location and function. This means the package has to have some way to convey which pin is which. Most ICs will use either a **notch** or a **dot** to indicate which pin is the first pin. (Sometimes both, sometimes one or the other.)

Fig 3.8. Polarity and pin numbering of ICs

Once you know where the first pin is, the remaining pin numbers increase sequentially as you move counter-clockwise around the chip.

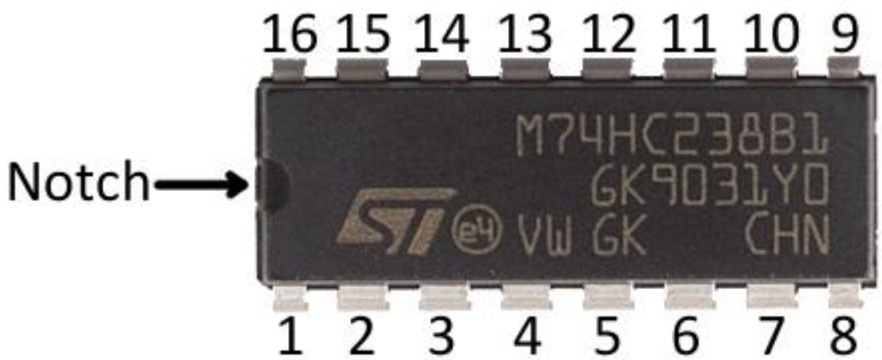


Fig 3.9. Polarity and pin numbering of ICs

3.6.2. Mounting Style

One of the main distinguishing package type characteristics is the way they mount to a circuit board. All packages fall into one of two mounting types: through-hole (PTH) or surface-mount (SMD or SMT).

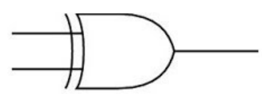
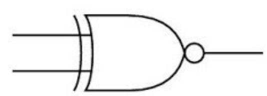
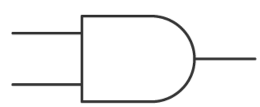
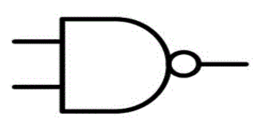
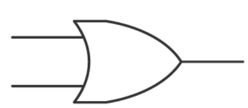
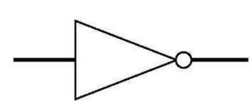
Through-hole packages are generally bigger, and much easier to work with. They are designed to be stuck through one side of a board and soldered to the other side.

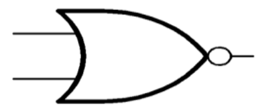
Surface-mount packages range in size from small to minuscule. They are all designed to sit on one side of a circuit board and be soldered to the surface. The pins of a SMD package either extrude out the side, perpendicular to the chip, or are sometimes arranged in a matrix on the bottom of the chip. ICs in this form factor are not very "hand-assembly-friendly." They usually require special tools to aid in the process. Refer https://youtu.be/drtUkvtxp6s , https://youtu.be/sTwRQDVHNiw

Self-Check - 3	Written Test

Directions: Answer the questions listed below. Use the Answer sheet provided in the next page.

1. What is active and passive components mean? (4 points)
2. Write the difference between active and passive components and give an example for both. (4 points)
3. ____________________ is a semiconductor wafer on which thousands or millions of tiny resistors, capacitors, and transistors are fabricated. (1 points)
4. Match the different PPEs with their uses. Write the letter on a separate provided. (7 points)

Answer	"A"	"B"
	1. OR gate	A. 
	2. AND gate	B. 
	3. NOT gate	C. 
	4. NOR gate	D. 
	5. NAND gate	E. 
	6. XOR gate	F. 

	7. XNOR gate	G. 

Note: - Satisfactory rating: 8 and above - Unsatisfactory Rating: below 8

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Information Sheet - 4	Using appropriate range of methods in constructing electrical/electronics circuit

4.1. Electrical /electronic circuits

4.1.1. Amplifier

Amplifier is the generic term used to describe a circuit which produces and increased version of its input signal. However, not all amplifier circuits are the same as they are classified according to their circuit configurations and modes of operation.

In "Electronics", small signal amplifiers are commonly used devices as they have the ability to amplify a relatively small input signal, for example from a *Sensor* such as a photo-device, into a much larger output signal to drive a relay, lamp or loudspeaker for example.

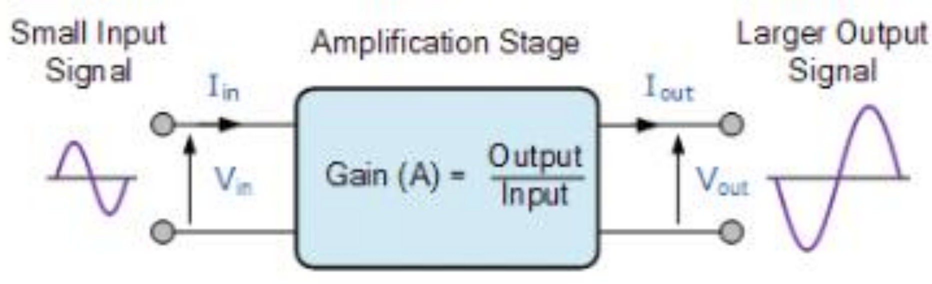


Fig 4.1. amplifier block diagram

There are many forms of electronic circuits classed as amplifiers, from Operational Amplifiers and Small Signal Amplifiers up to Large Signal and Power Amplifiers. The classification of an amplifier depends upon the size of the signal, large or small, its physical configuration and how it processes the input signal, that is the relationship between input signal and current flowing in the load.

The type or classification of an Amplifier is given in the following table.

Table 4.1. Classification of Signal Amplifier

Type of Signal	Type of Configuration	Classification	Frequency of Operation
Small Signal	Common Emitter	Class A Amplifier	Direct Current (DC)

Large Signal	Common Base	Class B Amplifier	Audio Frequencies (AF)
	Common Collector	Class AB Amplifier	Radio Frequencies (RF)
		Class C Amplifier	VHF, UHF and SHF Frequencies

Amplifiers can be thought of as a simple box or block containing the amplifying device, such as a Bipolar Transistor, Field Effect Transistor or Operational Amplifier, which has two input terminals and two output terminals (ground being common) with the output signal being much greater than that of the input signal as it has been “Amplified”.

An ideal signal amplifier will have three main properties: Input Resistance or (R_{IN}), Output Resistance or (R_{OUT}) and of course amplification known commonly as Gain or (A). No matter how complicated an amplifier circuit is, a general amplifier model can still be used to show the relationship of these three properties.

Ideal Amplifier Model

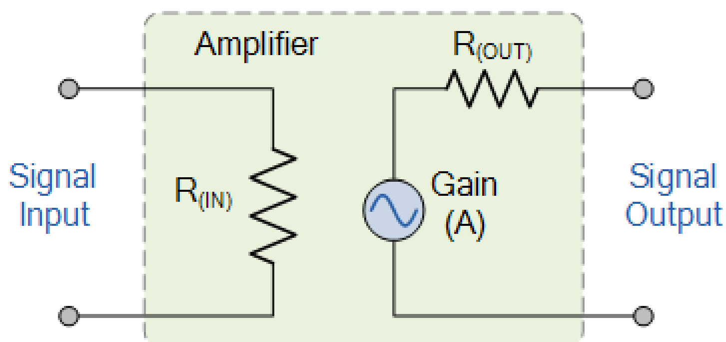


Fig 4.2. Simple representation of ideal amplifier

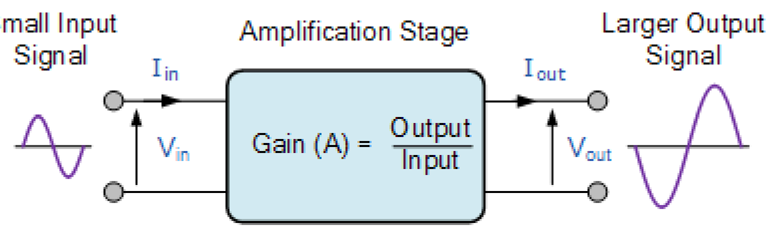
The amplified difference between the input and output signals is known as the Gain of the amplifier. Gain is basically a measure of how much an amplifier “amplifies” the input signal. For example, if we have an input signal of 1 volt and an output of 50 volts, then the gain of the amplifier would be “50”. In other words, the input signal has been increased by a factor of 50. This increase is called **Gain**.

Amplifier gain is simply the ratio of the output divided-by the input. Gain has no units as its a ratio, but in Electronics it is commonly given the symbol “A”, for Amplification. Then the gain of an amplifier is simply calculated as the “output signal divided by the input signal”.

Amplifier Gain

The introduction to the amplifier gain can be said to be the relationship that exists between the signal measured at the output with the signal measured at the input. There are three different kinds of amplifier gain which can be measured and these are: *Voltage Gain* (Av), *Current Gain* (Ai) and *Power Gain* (Ap) depending upon the quantity being measured with examples of these different types of gains are given below.

Amplifier Gain of the Input Signal



Voltage Amplifier Gain

$$Voltage\,Gain\,(A_v) = \frac{Output\ Voltage}{Input\ Voltage} = \frac{Vout}{Vin}$$

Current Amplifier Gain

$$Current\,Gain\,(A_i) = \frac{Output\ Current}{Input\ Current} = \frac{Iout}{Iin}$$

Power Amplifier Gain

$$Power\,Gain\,(A_p) = A_v\ x\ A_i$$

Note that for the Power Gain you can also divide the power obtained at the output with the power obtained at the input. Also when calculating the gain of an amplifier, the subscripts v, i and p are used to denote the type of signal gain being used.

Ideal Amplifier

We can know specify the characteristics for an ideal amplifier from our discussion above with regards to its **Gain**, meaning voltage gain:

- The amplifiers gain, (A) should remain constant for varying values of input signal.
- Gain is not be affected by frequency. Signals of all frequencies must be amplified by exactly the same amount.
- The amplifiers gain must not add noise to the output signal. It should remove any noise that is already exists in the input signal.
- The amplifiers gain should not be affected by changes in temperature giving good temperature stability.
- The gain of the amplifier must remain stable over long periods of time.

Electronic Amplifier Classes

The classification of an amplifier as either a voltage or a power amplifier is made by comparing the characteristics of the input and output signals by measuring the amount of time in relation to the input signal that the current flows in the output circuit.

- **Class A Amplifier** – has low efficiency of less than 40% but good signal reproduction and linearity.
- **Class B Amplifier** – is twice as efficient as class A amplifiers with a maximum theoretical efficiency of about 70% because the amplifying device only conducts (and uses power) for half of the input signal.
- **Class AB Amplifier** – has an efficiency rating between that of Class A and Class B but poorer signal reproduction than Class A amplifiers.
- **Class C Amplifier** – is the most efficient amplifier class but distortion is very high as only a small portion of the input signal is amplified therefore the output signal bears very little resemblance to the input signal. Class C amplifiers have the worst signal reproduction.

Voltage amplifier

A voltage amplifier in simplest form is any circuit that puts out a higher voltage than the input voltage. When you are forced to work with a set amount of voltage, these amplifiers are commonly used to increase the voltage and thus the amount of power coming out of a circuit. This is useful for reading and adapting small signals such as boosting an audio signal before sending it on its way to speakers. The voltage amplifier is a form of the common emitter amplifier, which relies on the transistor; the amplification of voltage is dependent on the ratio of resistors on the collector and emitter of this transistor.

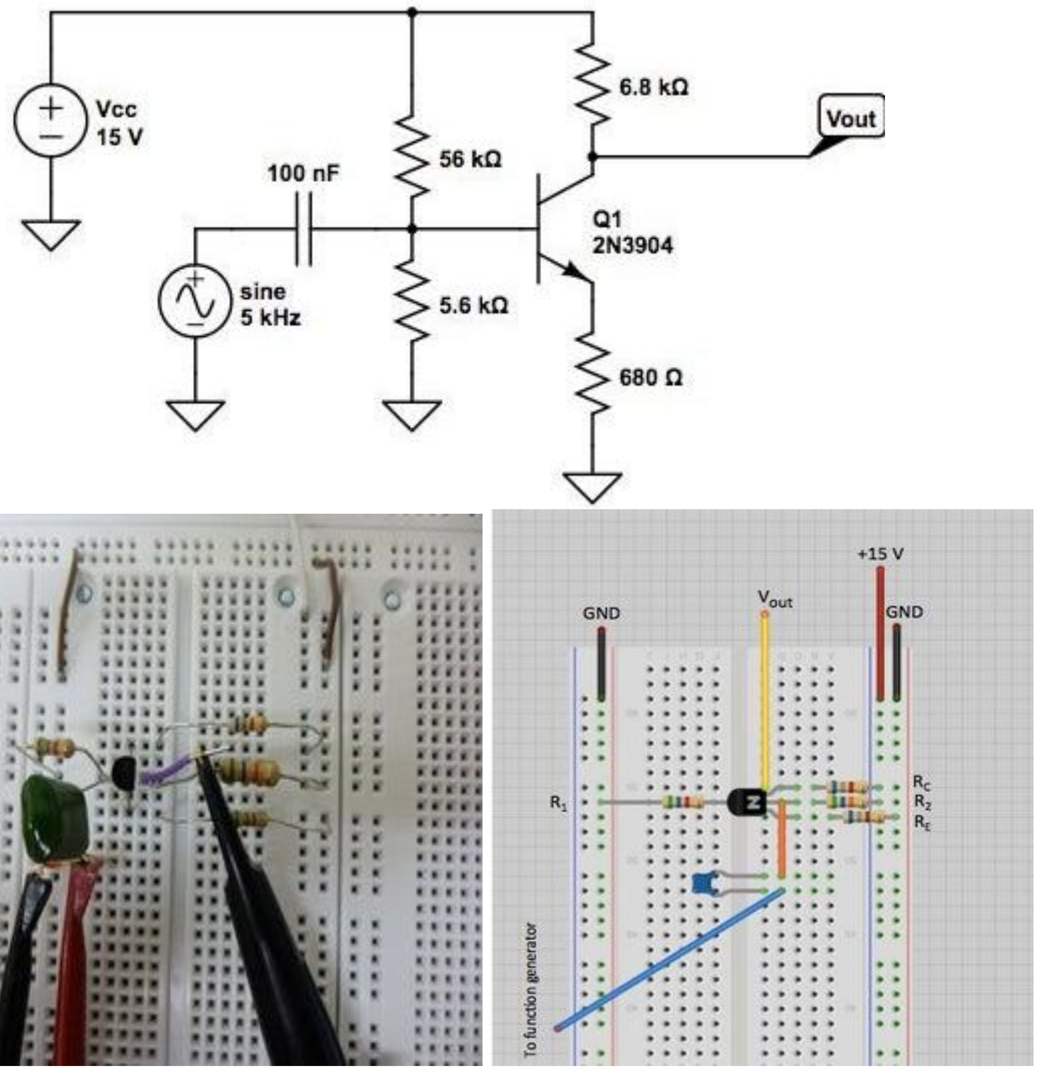


Fig 4.3. Voltage amplifier circuit schematic diagram and component arrangement on breadboard

Current Amplifiers and Buffers

A Current amplifier is an electronic circuit that increases the magnitude of current of an input signal by a fixed multiple, and feeds it to the succeeding circuit/device. This process is termed as current amplification of an input signal.

The input can either be a constant signal or a time varying waveform. Ideally, during this process of current amplification, the current amplifier will keep the voltage component of the input signal unchanged.

Below is the circuit diagram of a simple 2-stage current amplifier circuit that uses npn and pnp transistors as the amplifying element.

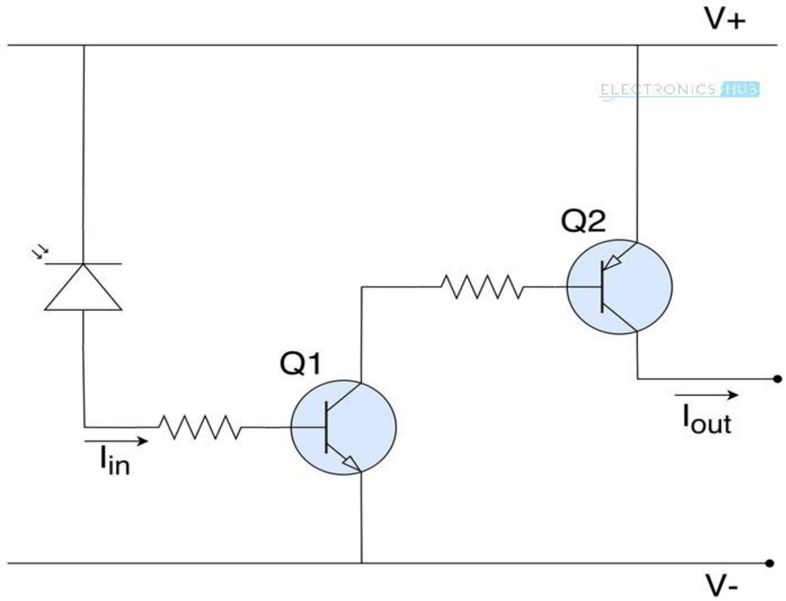


Fig 4.4. current amplifier circuit

The photodiode absorbs energy from light and releases electrons, thereby acting as an input current source. This current from the photodiode is first amplified by the transistor Q1 and is further amplified by the transistor Q2. The resistors at the bases of both the transistors are used to adjust the gain. The number of times a signal is amplified is same as stages in an amplifier. Here the current is amplified twice, so this is a 2-stage current amplifier.

Applications of Current Amplifiers

Following are some of the practical applications of current amplifiers:

- In amplifier systems, current amplifiers are used to obtain a better bass output, by increasing the intensity with which the speakers are driven.
- Current amplifiers with variable gain are used in many industrial manufacturing systems like laser and water jet cutting machines to control the intensity with which the fabrication is done

- In sensor systems, current amplifiers are used to strengthen weak input signals, for use in subsequent circuits

Current Buffer

Current buffer is an electronic circuit that is used to transfer electric current from input source having very less impedance (effective resistance) to output loads with high impedance. It is designed to prevent signal sources from getting affected because of any differences in the amount of current drawn by output loads.

In most scenarios it acts as a bridge between weak input signals (like signals from sensors) and output loads that might draw larger currents. Below is the diagram of an ideal current buffer.

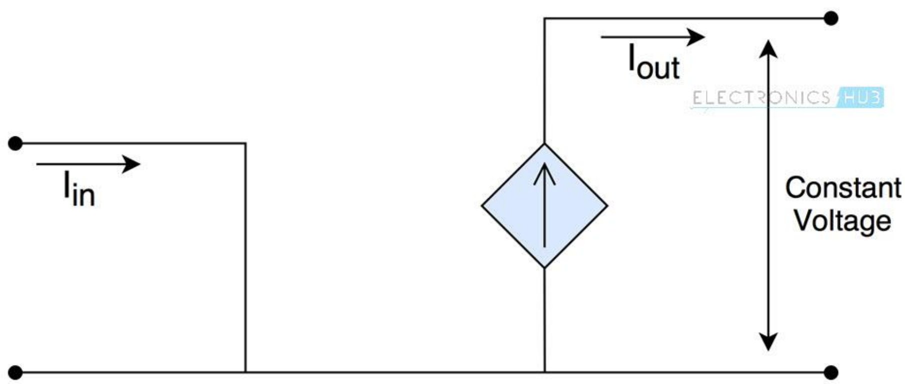


Fig 4.5. Ideal current buffer

It is primarily designed to remove the influence of output load on the input source. So you can think of current buffer as a circuit that isolates input and output circuitries while allowing the required flow of current to the output load in order to maintain a constant voltage across it.

Practical Use of a Current Buffer

Consider a circuit that uses an LDR sensor to drive a robot. The current consumed by the motors of robot is not constant and depends on the surface inclination or roughness i.e. load on the motors.

Therefore, if the motors are directly coupled with the temperature sensor using a current amplifier or other similar drivers, the motors might sometimes draw more current, which affects the accuracy of the sensor. The voltage across the motors will change as well, which in turn changes speed of the robot.

In order to prevent that from happening, current buffers are used. They can provide desired current to the motors without affecting accuracy of the sensor, while maintaining a constant voltage across the terminals of motors i.e. output loads.

Current Follower

A current buffer circuit with a Gain of 1 (i.e. the input and output currents are the same) is named as a current follower. It means that a current follower circuit does not provide any amplification of current to the input signal.

You might be wondering why a current follower circuit is used as the input and output currents from the current follower are the same. The reason is that a current follower not used to increase the output current.

But it is used to isolate input and output terminals while allowing the same amount of current flow into the input, and from the output. This is the reason why current follower circuits are also called as isolation buffers.

Below is the circuit diagram of a simple MOSFET current buffer.

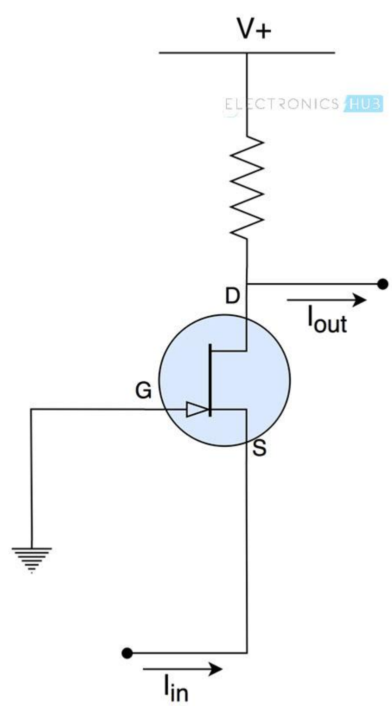


Fig 4.6. A simple MOSFET current buffer circuit

This arrangement provides very less impedance to the input signal and high impedance at the output terminal, making it a near ideal current buffer.

Applications of Current Buffers

Following are some of the practical applications of current buffers:

- In digital logic gates, current buffers are used to isolate input signals from the succeeding circuits
- Current buffers are used in high precise sensor systems in order to reduce the influence of voltage/current fluctuations because of varying output impedances
- In motor drivers and other electrical actuator systems

Power Amplifier

A power amplifier is an electronic amplifier designed to increase the magnitude of power of a given input signal. The power of the input signal is increased to a level high enough to drive loads of output devices like speakers, headphones, RF transmitters etc. Unlike voltage/current amplifiers, a power amplifier is designed to drive loads directly and is used as a final block in an amplifier chain.

The input signal to a power amplifier needs to be above a certain threshold. So instead of directly passing the raw audio/RF signal to the power amplifier, it is first pre-amplified using current/voltage amplifiers and is sent as input to the power amp after making necessary modifications. You can observe the block diagram of an audio amplifier and the usage of power amplifier below.

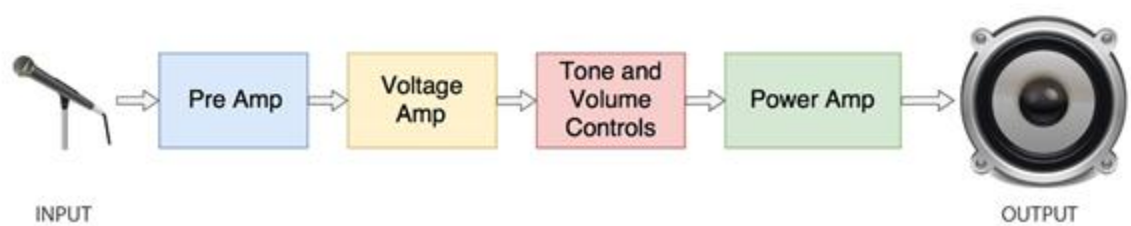


Fig 4.7. Block diagram of an audio amplifier

In this case a microphone is used as an input source. The magnitude of signal from the microphone is not enough for the power amplifier. So first it is pre-amplified where its voltage and current are increased slightly. Then the signal is passed through tone and volume controls circuit which makes aesthetic adjustments to the audio waveform. Finally the signal is passed through a power amplifier and the output from power amp is fed to a speaker.

Types of Power Amplifiers

Depending on the type of output device that is connected, power amplifiers are divided into the following three types.

Audio Power Amplifiers

This type of power amplifiers are used for increasing the magnitude of power of a weaker audio Signal. The amplifiers used in speaker driving circuitries of televisions, mobile phones etc. come under this category.

The output of an audio power amplifier ranges from a few milliwatts (like in headphone amplifiers) to thousands of watts (like power amplifiers in Hi-Fi/Home theatre systems).

Radio Frequency Power Amplifiers

Wireless transmissions require modulated waves to be sent over long distances via air. The signals are transmitted using antennas and the range of transmission depends on the magnitude of power of signals fed to the antenna.

For wireless transmissions like FM broadcasting, antennas require input signals at thousands of kilowatts of power. Here, Radio Frequency Power amplifiers are employed to increase the magnitude of power of modulated waves to a level high enough for reaching required transmission distance.

DC Power Amplifiers

DC power amplifiers are used to amplify the power of a PWM(Pulse Width Modulated) signals. They are used in electronic control systems which need high power signals to drive motors or actuators. They take input from microcontroller systems, increase its power and feed the amplified signal to DC motors or Actuators.

Power Amplifier Classes

There are multiple ways of designing a power amplifier circuit. The operation and output characteristics of each of the circuit configurations differs from each other.

To differentiate the characteristics and behaviour of different power amplifier circuits, Power Amplifier Classes are used in which letter symbols are assigned to identify the method of operation.

They are broadly classified into two categories. Power amplifiers designed to amplify analog signals come under A, B, AB or C category. Power amplifiers designed to amplify Pulse Width Modulated(PWM) digital signals come under D, E, F etc.

The most commonly used power amplifiers are the ones that are used in audio amplifier circuits and they come under classes A, B, AB or C. So let's take a look at them in detail.

Class A Power Amplifier

Analog waveforms are made up of positive highs and negative lows. In this class of amplifiers, the entire input waveform is used in the amplification process.

A single transistor is used to amplify both the positive and negative halves of the waveform. This makes their design simple and makes class A amplifiers the most commonly used type of power amplifiers. Although this class of power amplifiers are superseded by better designs, they are still popular among hobbyists.

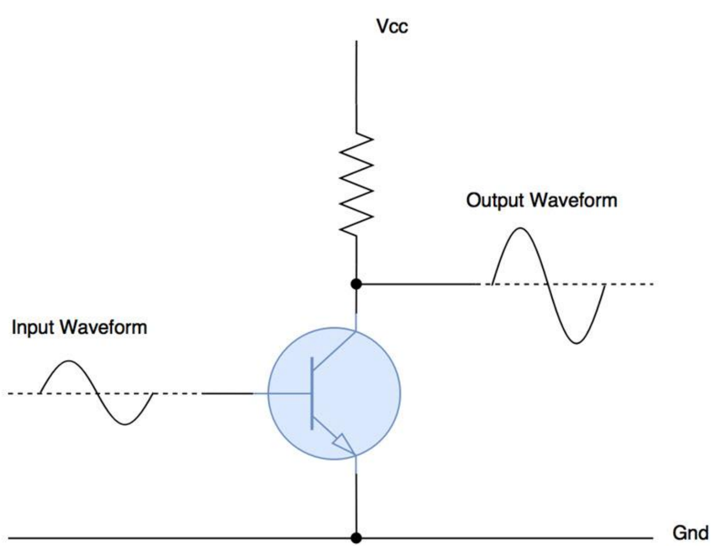


Fig 4.8. Class a Power Amplifier

In this class of amplifiers, the active element (the electronic component used for amplifying, which is transistor in this case) is in use all the time even if there is no input signal. This generates lot of heat and reduces the efficiency of class A amplifiers to 25% in normal configuration and 50% in a transformer coupled configuration.

The conduction angle (the portion of waveform used for amplification, out of 360°) for class A amplifiers is 360°. So the signal distortion levels are very less allowing better high frequency performance.

Class B Power Amplifier

Class B power amplifiers are designed to reduce the efficiency and heating problems present in the class A amplifiers. Instead of a single transistor to amplify the entire waveform, this class of amplifiers use two complementary transistors.

One transistor amplifies positive half of the waveform and the other amplifies negative half of the waveform. So each active device conducts for one half (180°) of the waveform and two of them when combined amplify the entire signal.

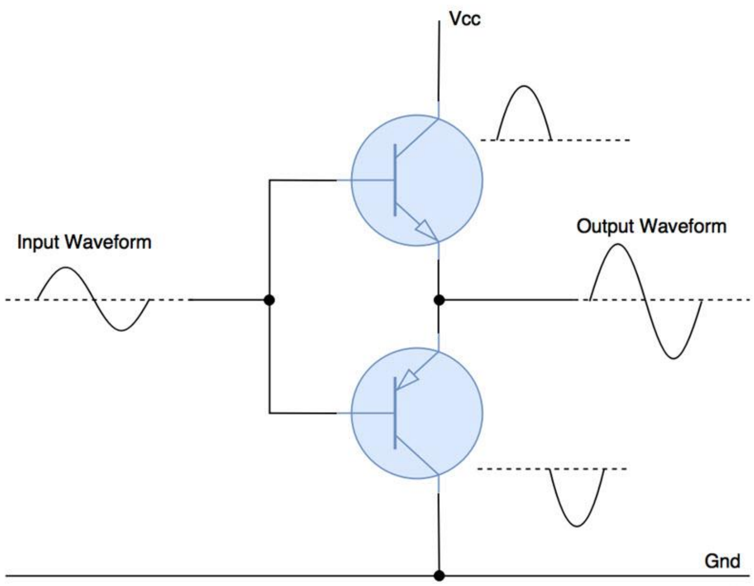


Fig 4.9. Class B Power Amplifier

The efficiency of class B amplifiers is improved a lot over class A amplifiers because of two transistor design. They can reach a theoretical efficiency of about 75%. Power amplifiers of this class are used in battery operated devices like FM radios and transistor radios.

Because of superposition of two halves of the waveform, there exists a small distortion at the crossover region. To reduce this signal distortion, class AB amplifiers are designed.

Class AB Power Amplifier

Class AB amplifiers are a combination of class A and class B amplifiers. This class of amplifiers are designed to reduce the less efficiency problem of class A amplifiers and distortion of signal at crossover region in class B amplifiers.

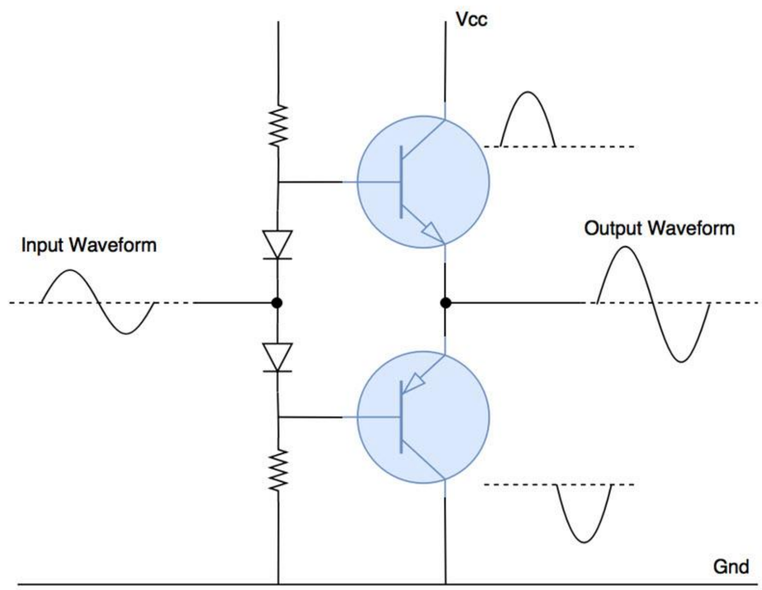


Fig 4.10. Class AB Power Amplifier

It maintains high frequency response like in class A amplifiers and good efficiency as in class B amplifiers. A combination of diodes and resistors are used to provide little bias voltage which reduces the distortion of waveform near the crossover region. There is a little drop in efficiency (60%) because of this.

Class C Power Amplifier

The design of class C power amplifiers allows greater efficiencies but reduces the linearity/conduction angle, which is under 90°. In other words, it sacrifices quality of amplification for increase in efficiency.

Lesser conduction angle implies greater distortion and so this class of amplifiers are not suited for audio amplification. They are used in high frequency oscillators and amplification of Radio Frequency signals.

Class C amplifiers generally contain a tuned load which filters and amplifies input signals of certain frequency, and the waveforms of other frequencies are supressed.

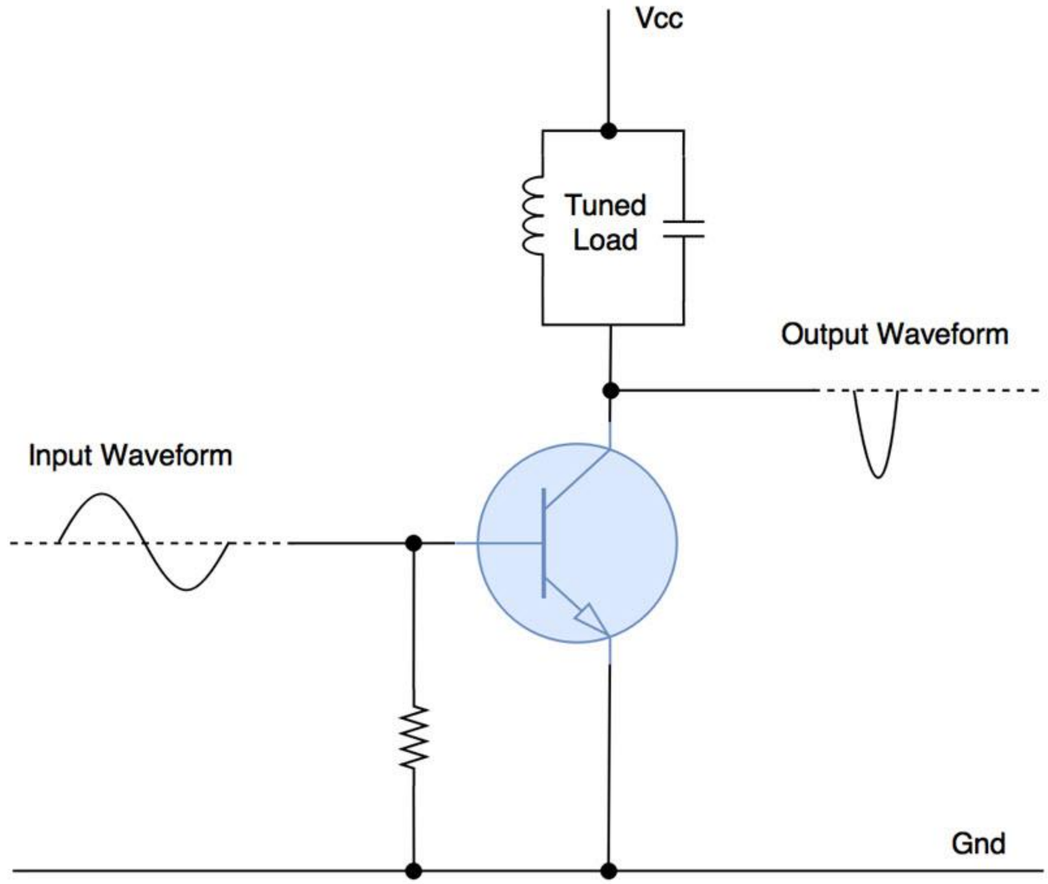


Fig 4.11. Class C Power Amplifier

In this type of power amplifier, the active element conducts only when the input voltage is above a certain threshold, which reduces power dissipation and increases efficiency.

Other Power Amplifier Classes

Power amplifier classes D, E, F, G etc. are used to amplify PWM modulated digital signals. They come under the category of switching power amplifiers and turn the output either constantly ON or constantly OFF without any other levels in between.

Because of this simplicity, power amplifiers falling under the above mentioned classes can reach theoretical efficiencies of upto (90-100)%.

Applications

Below are the applications of power amplifiers across different sectors:

- **Consumer Electronics:** Audio power amplifiers are used in almost all consumer electronic devices ranging from microwave ovens, headphone drivers, televisions, mobile phones and Home theatre systems to theatrical and concert reinforcement systems.
- **Industrial:** Switching type power amplifiers are used for controlling most of the industrial actuator systems like servos and DC motors.
- **Wireless Communication:** High power amplifiers are important in transmission of cellular or FM broadcasting signals to users. Higher power levels made possible because of power amplifiers increases data transfer rates and usability. They are also used in satellite communication equipment.

4.1.2. **Oscillator**

An **oscillator** is a circuit which produces a continuous, repeated, alternating waveform without any input. Oscillators basically convert unidirectional current flow from a DC source into an alternating waveform which is of the desired frequency, as decided by its circuit components.

The basic principle behind the working of oscillators can be understood by analyzing the behavior of an LC tank circuit shown in Figure 1 below, which employs an inductor L and a completely pre-charged capacitor C as its components. Here, at first, the capacitor starts to discharge via the inductor, which results in the conversion of its electrical energy into the electromagnetic field, which can be stored in the inductor. Once the capacitor discharges completely, there will be no current flow in the circuit.

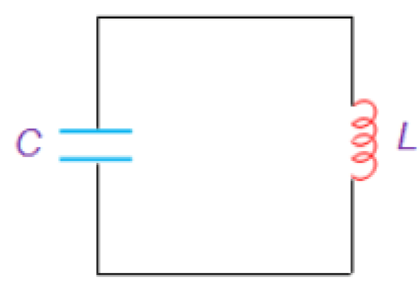


Fig 4.12. LC tank circuit

However, by then, the stored electromagnetic field would have generated a back-emf which results in the flow of current through the circuit in the same direction as that of before. This current flow through the circuit continues until the electromagnetic field collapses which result in the back-conversion of electromagnetic energy into electrical form, causing the cycle to repeat. However, now the capacitor would have charged with the opposite polarity, due to which one gets an oscillating waveform as the output.

However, the oscillations which arise due to the inter-conversion between the two energy-forms cannot continue forever as they would be subjected to the effect of energy loss due to the resistance of the circuit. As a result, the amplitude of these oscillations decreases steadily to become zero, which makes them damped in nature.

This indicates that in order to obtain the oscillations which are continuous and of constant amplitude, one needs to compensate for the energy loss. Nevertheless, it is to be noted that the energy supplied should be precisely controlled and must be equal to that of the energy lost in order to obtain the oscillations with constant amplitude.

This is because, if the energy supplied is more than the energy lost, then the amplitude of the oscillations will increase (Figure 2a) leading to a distorted output; while if the energy supplied is less than the energy lost, then the amplitude of the oscillations will decrease (Figure 2b) leading to unsustainable oscillations.

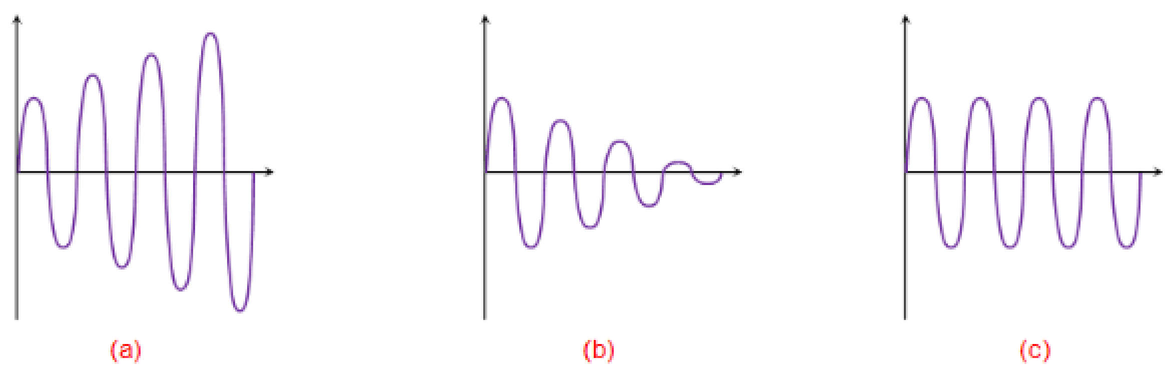


Fig 4.13. *(a)Increasing oscillations (b)Decaying oscillations (c)Constant-Amplitude oscillation*

Practically, the **oscillators** are nothing but the amplifier circuits which are provided with a positive or regenerative feedback wherein a part of the output signal is fed back to the input (Figure 3). Here the amplifier consists of an amplifying active element which can be a transistor or an Op-Amp and the back-fed in-phase signal is held responsible to keep-up (sustain) the oscillations by making-up for the losses in the circuit.

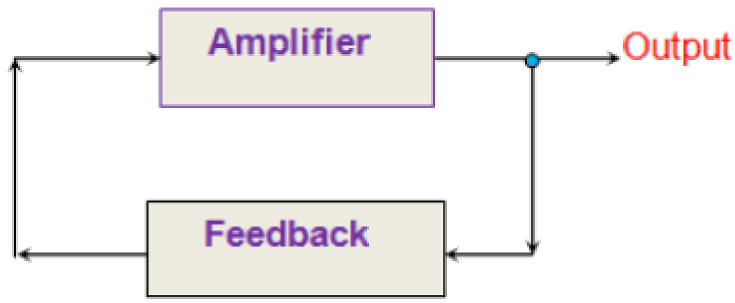


Fig 4.14. typical oscillator

Once the power supply is switched ON, the oscillations will be initiated in the system due to the electronic noise present in it. This noise signal travels around the loop, gets amplified and converges to a single frequency sine wave very quickly. The expression for the closed-loop gain of the oscillator shown in Figure 3 is given as:

$$G = \frac{A}{1 + A\beta}$$

Where A is the voltage gain of the amplifier and β is the gain of the feedback network. Here, if $A\beta > 1$, then the oscillations will increase in amplitude (Figure 2a); while if $A\beta < 1$, then the oscillations will be damped (Figure 2b). On the other hand, $A\beta = 1$ leads to the oscillations which are of constant amplitude (Figure 2c). In other words, this indicates that if the feedback loop gain is small, then the oscillation dies-out, while if the gain of the feedback loop is large, then the output will be distorted; and only if the gain of feedback is unity, then the oscillations will be of constant amplitude leading to self-sustained oscillatory circuit.

Type of Oscillator

There are many types of oscillators, but can broadly be classified into two main categories – Harmonic Oscillators (also known as Linear Oscillators) and Relaxation Oscillators.

In a harmonic oscillator, the energy flow is always from the active components to the passive components and the frequency of oscillations is decided by the feedback path.

Whereas in a relaxation oscillator, the energy is exchanged between the active and the passive components and the frequency of oscillations is determined by the charging and discharging time-constants involved in the process. Further, harmonic oscillators produce low-distorted sine-wave outputs while the relaxation oscillators generate non-sinusoidal (saw-tooth, triangular or square) wave-forms.

The types of Oscillators include:

Wien Bridge Oscillator	Armstrong Oscillator	Opto-Electronic Oscillators
RC Phase Shift Oscillator	Tuned Collector Oscillator	Pierce Oscillators
Hartley Oscillator	Gunn Oscillator	Robinson Oscillators
Voltage Controlled Oscillator	Cross-Coupled Oscillators	Tri-tet Oscillators
Colpitts Oscillator	Ring Oscillators	Pearson-Anson Oscillators
Clapp Oscillators	Dynatron Oscillators	Delay-Line Oscillators
Crystal Oscillators	Meissner Oscillators	Royer Oscillators
Multi-Wave Oscillators	Electron Coupled Oscillators	

Oscillators can be also be classified into various types depending on the parameter considered i.e. based on the feedback mechanism, the shape of the output waveform, etc.. These classifications types have been given below:

1. Classification Based on the Feedback Mechanism: Positive Feedback Oscillators and Negative Feedback Oscillators.

2. Classification Based on the Shape of the Output Waveform: Sine Wave Oscillators, Square or Rectangular Wave oscillators, Sweep Oscillators (which produce saw-tooth output waveform), etc.

3. Classification Based on the Frequency of the Output Signal: Low-Frequency Oscillators, Audio Oscillators (whose output frequency is of audio range), Radio Frequency Oscillators, High-Frequency Oscillators, Very High-Frequency Oscillators, Ultra High-Frequency Oscillators, etc.

4. Classification Based on the type of the Frequency Control Used: RC Oscillators, LC Oscillators, Crystal Oscillators (which use a quartz crystal to result in a frequency stabilized output waveform), etc.

5. Classification Based on the Nature of the Frequency of Output Waveform: Fixed Frequency Oscillators and Variable or Tunable Frequency Oscillators.

Oscillator Applications

Oscillators are a cheap and easy way to generate specific Frequency of a signal. For example, an RC oscillator is used to generate a Low Frequency signal, an LC oscillator is used to generate a High Frequency signal, and an Op-Amp based oscillator is used to generate a stable frequency.

The frequency of oscillation can be varied by varying the component value with potentiometer arrangements.

Some common applications of oscillators include:

- Quartz watches (which uses a crystal oscillator)
- Used in various audio systems and video systems
- Used in various radio, TV, and other communication devices
- Used in computers, metal detectors, stun guns, inverters, ultrasonic and radio frequency applications.
- Used to generate clock pulses for microprocessors and micro-controllers
- Used in alarms and buzzes
- Used in metal detectors, stun guns, inverters, and ultrasonic
- Used to operate decorative lights (e.g. dancing lights)

4.1.3. Power Supply

A power supply is an electronic circuit or a device that converts the primary electric power in to ac or dc needed by different types of electronic circuit. A power supply may be implemented as a discrete, stand-alone device or as integral device that is hard wired to its load and designed to provide various ac and dc voltages. Therefore, all electronic equipments require a source of power for normal operation; but most electronic equipment needs source of dc power to operate properly.

AC Power supply: - An AC power supply typically takes the voltage from the mains supply and lowers it to the desired voltage. It is also known as **unregulated power supply;** this is because its output voltage varies depending on the load and on variation on the AC supply voltage.

DC power Supply: - The function of the DC power supply is to provide the necessary DC voltage and current, with low levels of AC ripple and with a good stability and regulation. A regulated power supply is one that controls the output voltage or current to a specific value; the controlled value is held nearly constant despite variations in either load current or the voltage supplied by the power supply's energy source.

That is, nearly all Electronic circuits require a source of well regulated dc, at voltages of typically between 5 V and 30 V.

Thus a power supply system can be defined as an electronic circuit which converts the ac input of 50/60Hz power line to a dc output voltage.

Generally DC Power supplies for electronic devices can be divided in to **Conventional (linear)** and **switching mode** power supplies.

The conventional power supply is usually a relatively simple design, but it becomes increasingly bulky and heavy for high-current equipment due to the need for large transformers and heat sinked electronic regulation circuitry. Switched mode power supply of the same rating as a linear power supply will be smaller, is usually more efficient, but will be more complex.

Conventional or linear power supply

The block diagram of a linear dc power supply is shown in Fig.1 below. Since the mains input is at a relatively high voltage, a step-down transformer of appropriate turn's ratio is used to convert this to a low voltage. The ac output from the transformer secondary is then rectified using rectifier diodes to produce an unsmoothed (sometimes referred to as **pulsating dc**) output. This is then smoothed and filtered before being applied to a circuit which will **regulate** (or **stabilize**) the output voltage so that it remains relatively constant in spite of variations in both load current and incoming mains voltage. Figure 2 shows how some of the electronic

Components that we have already met can be used in the realization of the block diagram in Fig. 1The iron-cored step-down transformer feeds a rectifier arrangement.

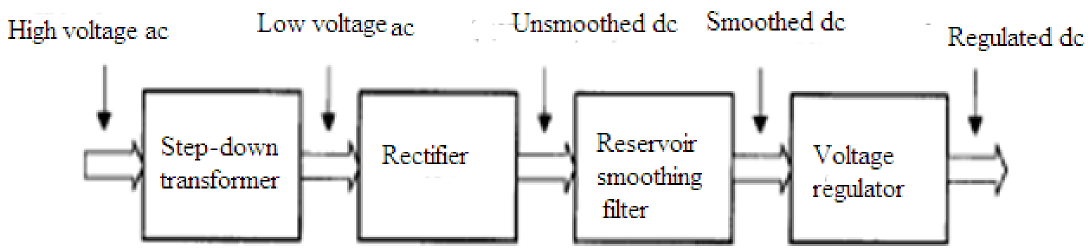


Fig.4.15. block diagram of dc power supply

Main Parts of power supply

The power supply unit used to convert alternating current to direct current consists of four main parts.

a) Transformer b) Rectifier c) Filter d) Voltage regulator

As you know electronic systems are designed to manage the flow of information. In order to achieve this function all of the electronic circuit with its system requires certain constant dc supply voltage. If a small amount of power is needed batteries can be used to deliver a dc supply, as to supply this type of equipment such as Calculators, watches and multi meters etc

With large electronic system such as computers, TV sets, video systems. The dc supply voltage is obtained from a dc power supply, which is generally a sub system within the main system.

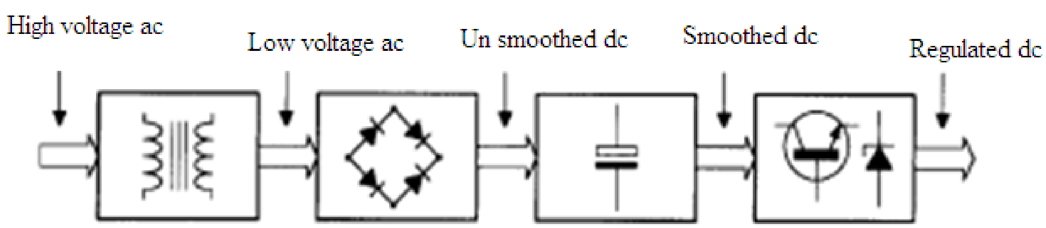


Fig 4.16. Block diagram of dc power supply showing main components

The function of each block diagram is as follows.

1. Transformer: Since the final voltage desired is generally not 220V so a transformer is usually include stepping the ac line voltage up or down depending on the exact needs of the electronic circuits. Generally electronic circuits require low voltage supply; therefore mostly the purpose of the transformer is to step down the line voltage.

2. Rectifiers: It is used to convert alternating current (ac) to direct current (pulsating dc), which is unidirectional current that supplied to the filter circuit as an input. Basically there are two types of rectifiers, such as half wave and full wave (center tap and bridge).

a) **Half wave Rectifier**-The simplest form of rectifier circuit makes use of a single diode to “chop off” half of the ac input cycle.

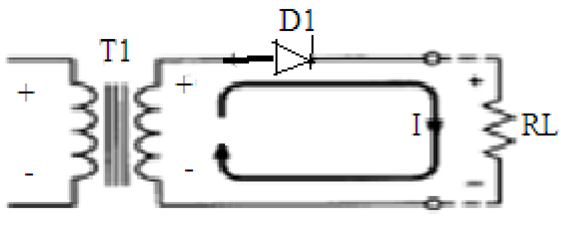


Fig 4.17. Schematic diagram of a Half wave rectifier

b) **Full wave Rectifier: -** the half wave rectifier output is difficult to filter to a smooth dc level because an output voltage and current are only half of each input cycle to the load. Unfortunately, the half-wave rectifier circuit is relatively inefficient as conduction takes place only on alternate half-cycles. A better rectifier arrangement would make use of both positive *and* negative half-cycles. These **full-wave rectifier** circuits offer a considerable improvement over their half wave counterparts. There are two types of full wave rectifiers, these are center tap and bridge rectifier.

1. **Full-wave, Center-Tap Rectifier**: It requires two diodes and a center tapped transformer.

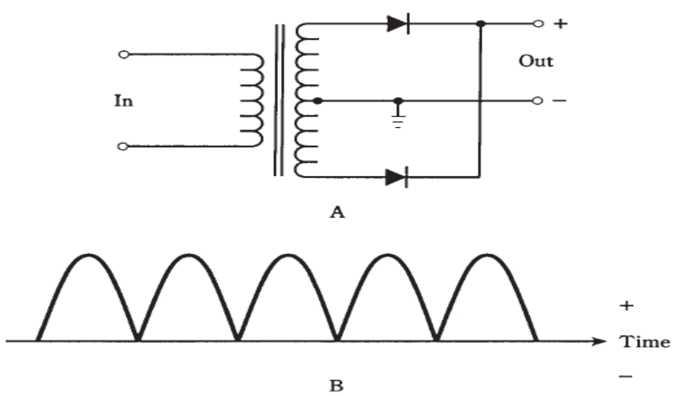


Fig 4.18. Schematic diagram of a full-wave, Center-tap rectifier and its out put

2. **Full-wave Bridge Rectifier:** Another way to get full-wave rectification is the **bridge rectifier***.* The output waveform is just like that of the full-wave, center-tap circuit. The bridge circuit does not need a center-tapped

transformer secondary and it needs four diodes rather than two. This is its main practical advantage.

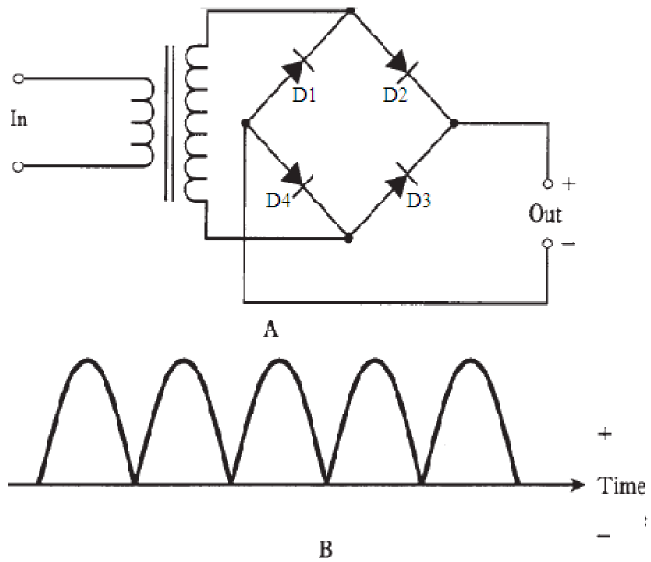


Fig 4.19. Schematic diagram of a full-wave bridge rectifier and its out put

3. Filter or smoothing circuits: used to convert the pulsating dc output coming from the rectifier in to a constant or smooth dc voltage. The simplest filter is one or more large-value capacitors, connected in parallel with the rectifier output.

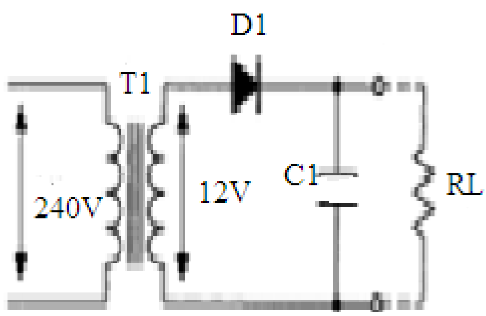


Fig 4.20. A half wave rectifier circuit with filter capacitor

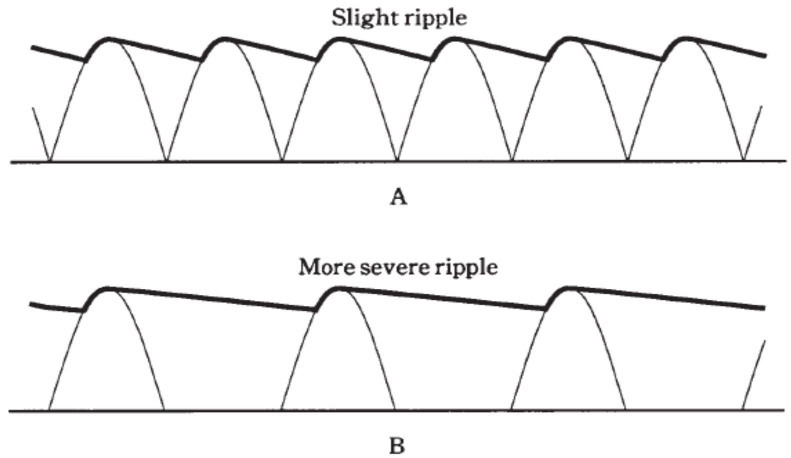


Fig 4.21. Filtered output for full-wave rectification (A) and half-wave rectification (B)

4. Voltage Regulators: All source of power supply have internal resistance due to this resistance there will be an IR drop within the power source and the terminal voltage (output voltage across the load) will decrease as the load is applied. The higher the load the higher the IR drop therefore the term regulation is used as an indication of a power source to maintain a constant output voltage. This is done if reverse-biased Zener diode is connected across the output of a power supply; the diode will limit the output voltage of the supply as long as it has a high enough power rating.

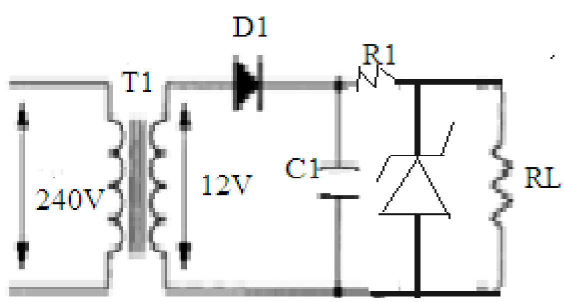


Fig 4.22. Voltage regulator

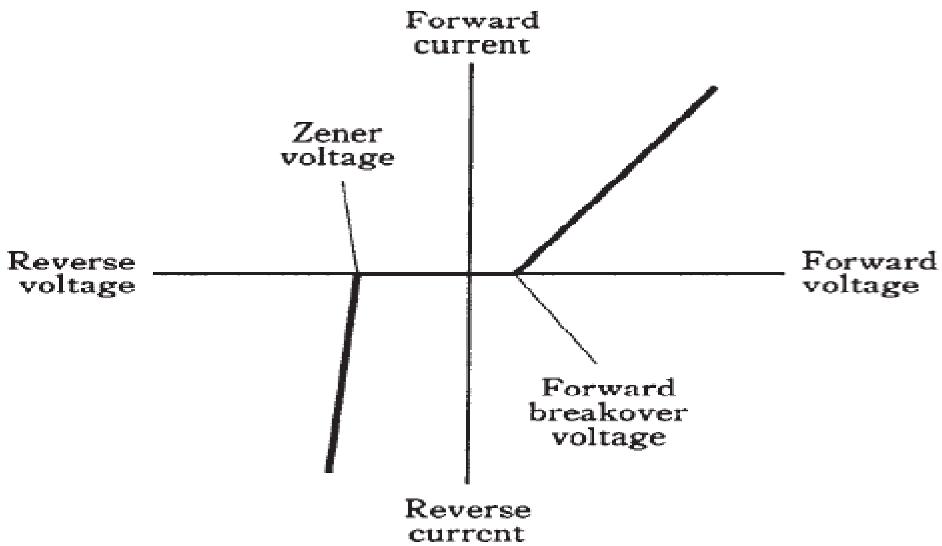


Fig 4.23. Current through a Zener diode, as a function of the bias voltage

Switch Mode Power Supply

It is a power supply that provides the power supply function through low loss components such as capacitors, inductors and transformers and the use of switches that are in one of two states, on or off. The advantage is that the switch dissipates very little power in either of these two states and power conversion can be accomplished with minimal power loss, which equates to high frequency.

SMPS have been used for many years in industrial applications where good efficiency, light weight and small size were of prime concern. Today SMPS often called (often called “chopper” “switchers”) are used extensively in AC powered electronic devices such as computers, monitors, television receivers and VCRs.

In SMPS, the AC mains input is directly rectified and then filtered to obtain a DC voltage. The resulting DC voltage is then switched on and off at a high frequency by electronic switching circuitry, thus producing an ac current that will pass through a high frequency transformer or inductor. Switching occurs at a very high frequency there by enabling the use of transformers and filter capacitors that are much smaller, lighter, and less expensive than those found in linear power supplies operating at mains frequency. After the inductor or transformer secondary, the high frequency AC is rectified and filtered to produce DC output voltage.

SMPS are always regulated to keep the output voltage constant; the power supply employs a feedback controller that monitors current drawn by the load. The switching duty cycle increases as power output requirements increase.

SMPS often include safety features such as current limiting circuit to protect the device and the user from harm. In the event that an abnormal high current power draw is detected, the SMPS can assume this is a direct short and will shut itself down before damage is done.

SMPS have an absolute limit on their minimum current output. They are only able to output above a certain power level and cannot function below that point. SMPS with protection circuits may briefly turn on but then shut down when no load has been detected.

Some SMPS use filters or additional switching stages in the incoming rectifier circuit to improve the wave form of the current taken from the AC line. This adds to the circuit complexity. A SMPS offers three main advantages over a conventional linear power supply.

1. High efficiency & less heat generation
2. Better regulation
3. Smaller size and weight.

Of these, greater efficiency is the biggest advantage. Conventional linear power supplies are inefficient because they regulate by damping the excess power in to heat. That is to maintain regulation for all load conditions; more power is applied to regulator than is needed by the load. This unused power is dissipated as heat. The AC power transformer, operating at 60 Hz, also contributes to the efficiency of some power supplies. When all the efficiencies are added, conventional, linear power supplies are typically 40-50 % efficient, while SMPS have efficiencies from 60-90%. This is very important when the designer wants to reduce generated heat, reduce power costs, or increase battery life. Switchers are very efficient regulators because they only produce as much power as is needed by the load. Another key benefit of SMPS is their ability to closely regulate the output voltage. Switchers adjust for changes in continuously, and follow load changes almost immediately. In addition, switchers have the unique ability to maintain the correct output under low input voltage conditions. In fact switchers can actually produce an output voltage that is higher than the DC voltage applied to the input. A final advantage of switchers is their relatively small size and weight. Because switchers at high frequencies, the parts are physically smaller than those needed for a conventional, 60 Hz power supply of the same power rating. The transformers, capacitors and coils are both physically smaller and lighter. This makes them ideal for use in portable equipment.

Basic Switcher operation

The heart of all SMPS is the switching transistor and switching transformer. Unregulated power is supplied to the switching transistor through the primary winding of the transformer. The switching transistor is a switch, and when the switch is closed (the transistor is turned on) it provides a path for current to flow through the transformer primary to ground. Changing how fast or how long the switch remains closed regulates the output voltages. As the transistor is switched on and off the magnetic field alternately expands and collapses in all of the transformer windings. The output of the transformer is applied to high speed switching diodes and filters which produce the DC output voltages of the SMPS. In SMPs voltage regulation is achieved by sampling the DC output voltage and comparing it to a reference. The resulting correction voltage is used to control the frequency or "ON" time of the switching transistor, which in turn delivers more or less power to the load.

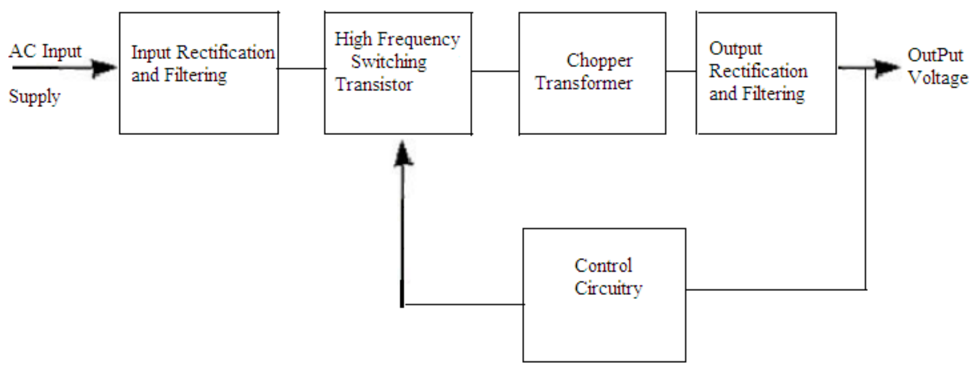


Fig 4.24. Basic Block diagram of SMPS

There are two types of regulators used in SMPS, such as pulse width modulated (PWM) and pulse rate modulated (PRM). TV receivers and computer monitors may use either type. PWM regulates by varying the "ON" or conduction time of the switching transistor.

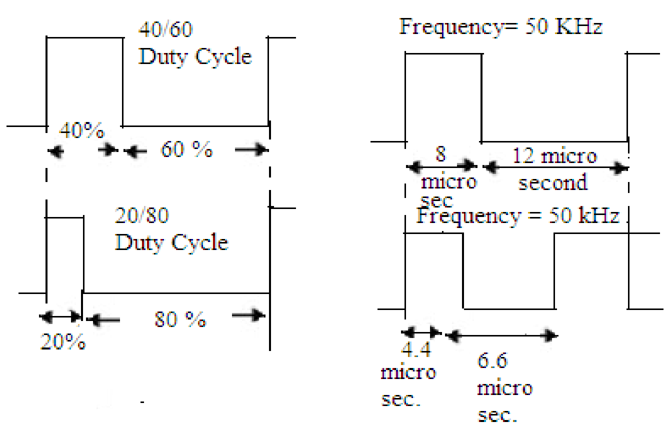


Figure 4.25. Shows an example of PWM and PRM.

The control circuit uses the feedback voltage to regulate the switching transistor.

Pulse width Modulation

As the width of the pulse is increased, the switching transistor stays on longer, and more energy is applied to the switching transformer. This produces an increase in the DC output voltage. Likewise, as the pulse width is made narrower, the transistor is on for a shorter amount of time, and less energy is applied to the transformer.

Pulse Rate Modulation

The PRM regulator varies the rate (frequency) at which the switching transistor or is turned off and on. The pulse rate increases, the “on time” decreases. Thus, if the output voltage is too high, the switching transistor is turned on and off at a faster rate.

4.1.4. Digital circuits

In electronics world there are many digital circuits. Among them the basics of digital circuits are:

- Arithmetic circuit (adder and substructure)
- Multiplexer/DE multiplexer
- Encoder/Decoder
- Flip/Flop
- Counter
- Shift register

1. Arithmetic circuit

Half Adder and Full Adder Circuit.

Half Adder

With the help of half adder, we can design circuits that are capable of performing simple addition with the help of logic gates.

Let us first take a look at the addition of single bits.

0+0 = 0

0+1 = 1

1+0 = 1

1+1 = 10

These are the least possible single-bit combinations. But the result for 1+1 is 10. Though this problem can be solved with the help of an EXOR Gate, if you do care about the output, the sum result must be re-written as a 2-bit output.

Thus the above equations can be written as

0+0 = 00

0+1 = 01

1+0 = 01

1+1 = 10

Here the output '1'of '10' becomes the carry-out. The result is shown in a truth-table below. 'SUM' is the normal output and 'CARRY' is the carry-out.

INPUTS		OUTPUTS	
A	B	SUM	CARRY
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

From the equation it is clear that this 1-bit adder can be easily implemented with the help of EXOR Gate for the output 'SUM' and an AND Gate for the carry. Take a look at the implementation below.

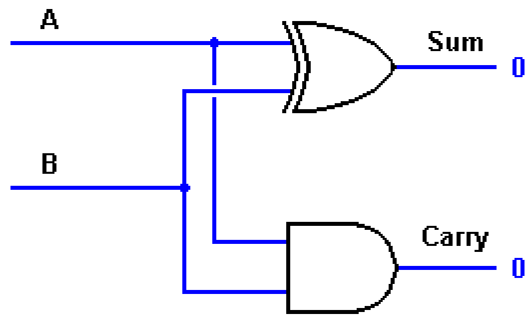


Fig 4.26. Half Adder Circuit

For complex addition, there may be cases when you have to add two 8-bit bytes together. This can be done only with the help of full-adder logic.

Full Adder

This type of adder is a little more difficult to implement than a half-adder. The main difference between a half-adder and a full-adder is that the full-adder has three inputs and two outputs. The first two inputs are A and B and the third input is an input carry designated as CIN. When a full adder logic is designed we will be able to string eight of them together to create a byte-wide adder and cascade the carry bit from one adder to the next.

The output carry is designated as COUT and the normal output is designated as S. Take a look at the truth-table.

INPUTS		OUTPUTS		
A	B	CIN	COUT	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

From the above truth-table, the full adder logic can be implemented. We can see that the output S is an EXOR between the input A and the half-adder SUM output with B and CIN inputs. We must also note that the COUT will only be true if any of the two inputs out of the three are HIGH.

Thus, we can implement a full adder circuit with the help of two half adder circuits. The first will half adder will be used to add A and B to produce a partial Sum. The second half adder logic can be used to add CIN to the Sum produced by the first half adder to get the final S output. If any of the half adder logic produces a carry, there will be an output carry. Thus, COUT will be an OR function of the half-adder Carry outputs. Take a look at the implementation of the full adder circuit shown below.

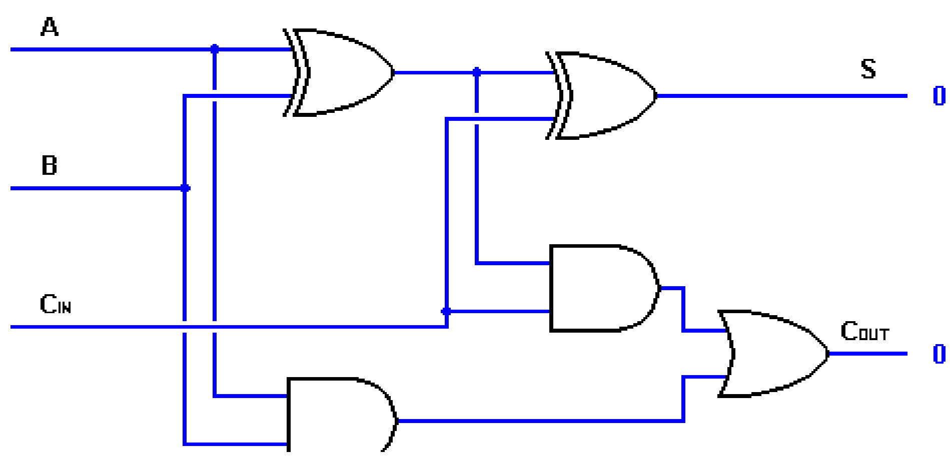


Fig 4.27. Full Adder Circuit

Though the implementation of larger logic diagrams is possible with the above full adder logic a simpler symbol is mostly used to represent the operation. Given below is a simpler schematic representation of a one-bit full adder.

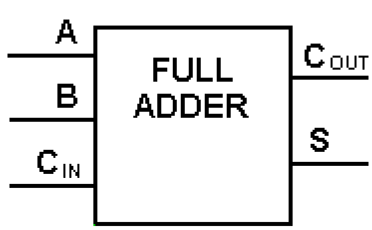


Fig 4.28. Single-bit Full Adder

With this type of symbol, we can add two bits together taking a carry from the next lower order of magnitude, and sending a carry to the next higher order of magnitude. In a computer, for a multi-bit operation, each bit must be represented by a full adder and must be added simultaneously. Thus, to add two 8-bit numbers, you will need 8 full adders which can be formed by cascading two of the 4-bit blocks. The addition of two 4-bit numbers is shown below.

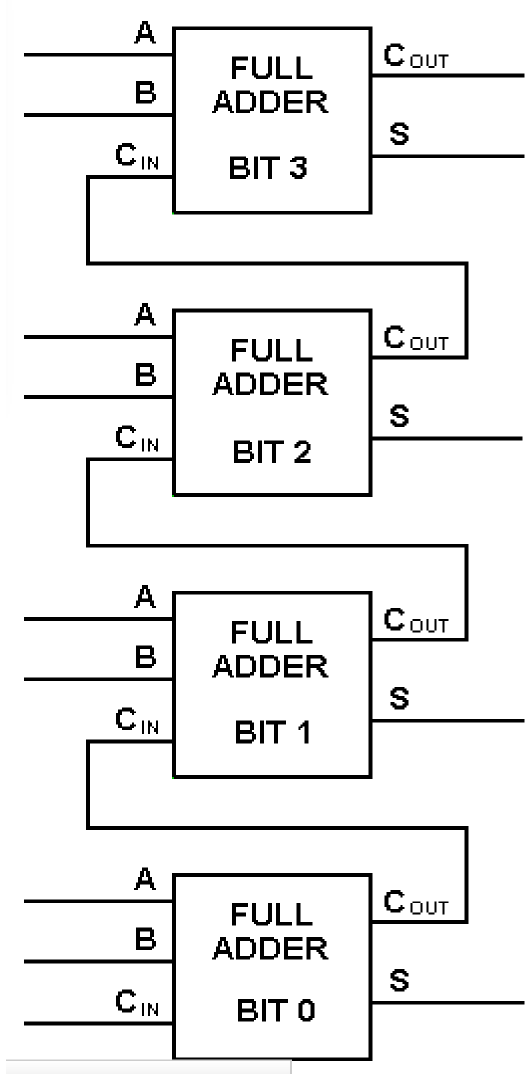


Fig 4.29. Multi-Bit Addition using Full Adder

Full Subtractors

The disadvantage of a half Subtractors is overcome by full Subtractors. The full Subtractors is combinational circuit with three inputs A, B, C and two output D and C'. A is the 'minuend', B is 'subtrahend', C is the 'borrow' produced by the previous stage, D is the difference output and C' is the borrow output.

Inputs			Output	
A	B	C	(A-B-C)	C'
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

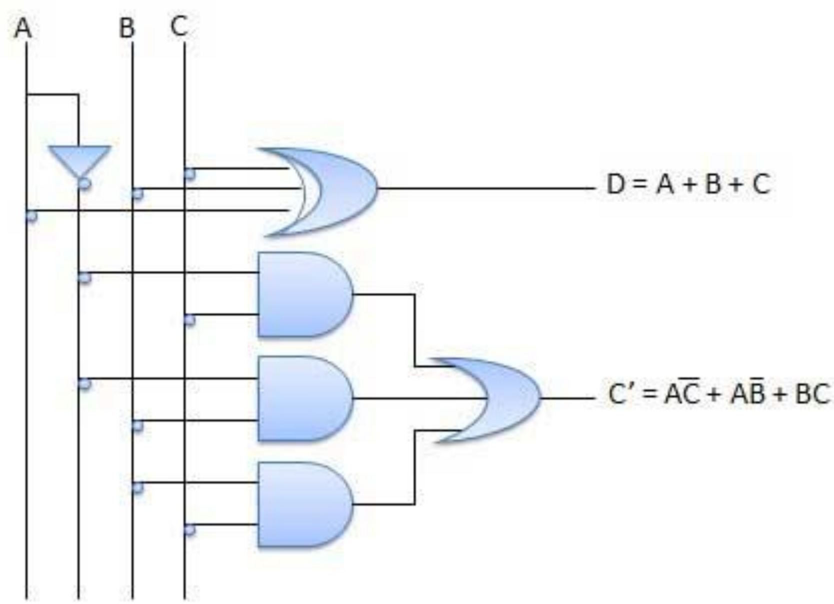


Fig 4.30. Full subtructor truth table and schematic circuit

2. **Multiplexers/Demultiplexers**

Multiplexers

Multiplexer is a special type of combinational circuit. There are n-data inputs, one output and select inputs with 2m = n. It is a digital circuit which selects one of the n data inputs and routes it to the output. The selection of one of the n inputs is done by the selected inputs. Depending on the digital code applied at the selected inputs, one out of n data sources is selected and transmitted to the single output Y. E is called the strobe or enable input which is useful for the cascading. It is generally an active low terminal that means it will perform the required operation when it is low.

Block diagram

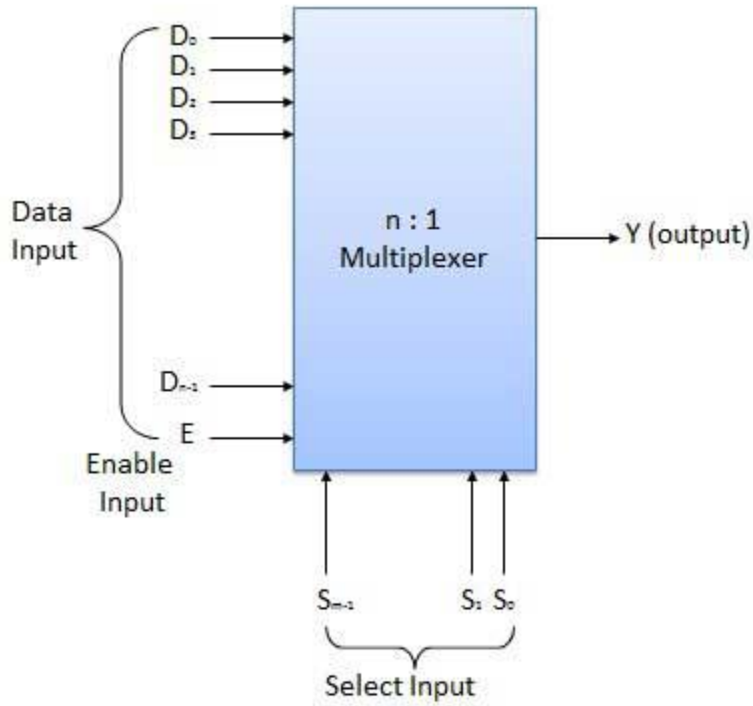
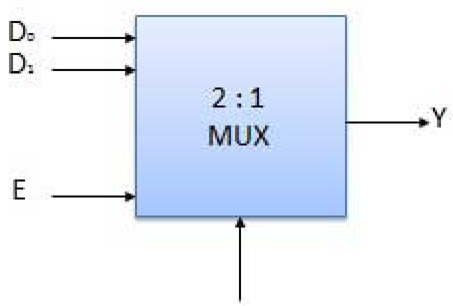


Fig 4.31. multiplexer block diagram

Multiplexers come in multiple variations

- 2 : 1 multiplexer
- 4 : 1 multiplexer
- 16 : 1 multiplexer
- 32 : 1 multiplexer

Block Diagram



Enable	Select	Output
E	S	Y
0	x	0
1	0	D_0
1	1	D_1

x = Don't care

Fig 4.32. multiplexer block diagram and truth table

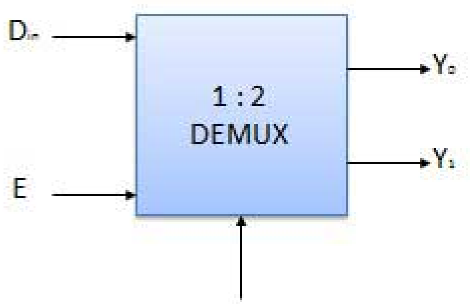
Demultiplexers

A Demultiplexer performs the reverse operation of a multiplexer i.e. it receives one input and distributes it over several outputs. It has only one input, n outputs, m select input. At a time only one output line is selected by the select lines and the input is transmitted to the selected output line. A de-multiplexer is equivalent to a single pole multiple way switch as shown in fig.

Demultiplexers come in multiple variations.

- 1 : 2 de multiplexer
- 1 : 4 de multiplexer
- 1 : 16 de multiplexer
- 1 : 32 de multiplexer

Block diagram



Enable	Select	Output	
E	S	Y0	Y1
0	x	0	0
1	0	0	D_{in}
1	1	D_{in}	0

x = Don't care

Fig 4.33. Demultiplexer block diagram and truth table

3. **Encoder/Decoder**

Decoder

A decoder is a combinational circuit. It has n input and to a maximum m = 2n outputs. Decoder is identical to a demultiplexer without any data input. It performs operations which are exactly opposite to those of an encoder.

Block diagram

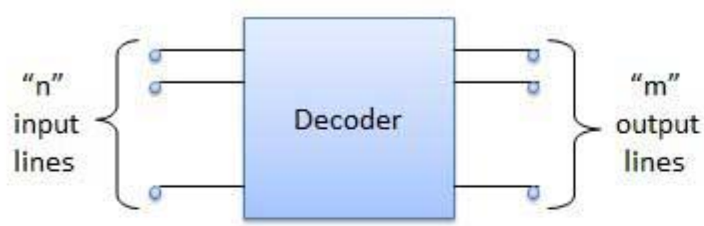
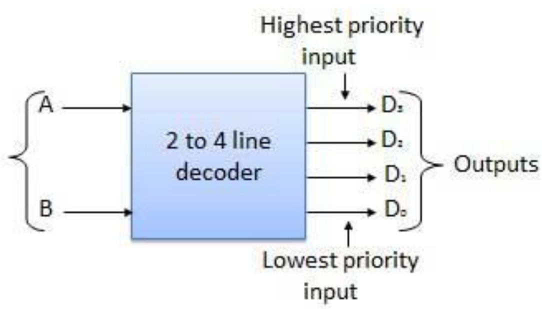


Fig 4.34. Decoder block diagram

Examples of Decoders are following.

- Code converters
- BCD to seven segment decoders
- Nixie tube decoders
- Relay actuator

Block diagram



Inputs		Output			
A	B	D_0	D_1	D_2	D_3
0	0	1	0	0	0
0	1	0	1	0	0
0	1	0	0	1	0
1	1	0	0	0	1

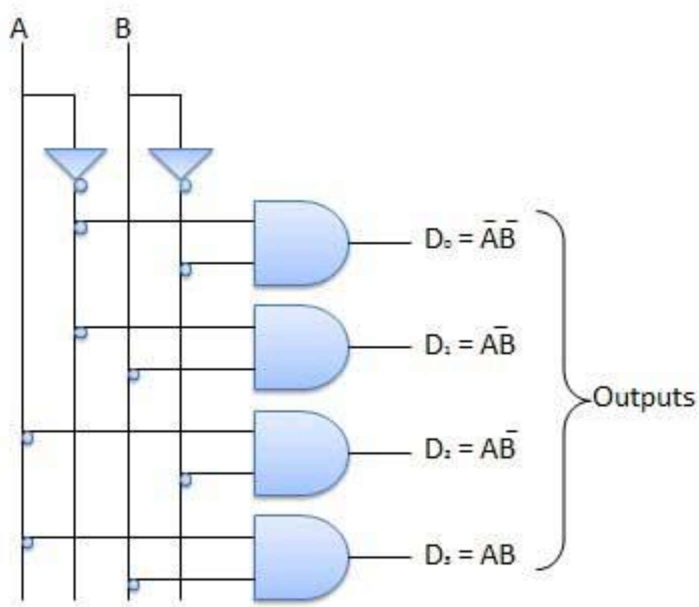


Fig 4.35. Decoder block diagram, truth table and schematic circuit

Encoder

Encoder is a combinational circuit, which is designed to perform the inverse operation of the decoder. An encoder has n number of input lines and m number of output lines. An encoder produces an m bit binary code corresponding to the digital input number. The encoder accepts an input digital word and converts it into an m bit another digital word.

Block diagram

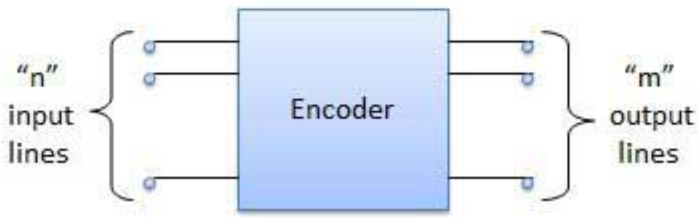


Fig 4.36. Encoder block diagram

Examples of Encoders are following.

- Priority encoders
- Decimal to BCD encoder
- Octal to binary encoder
- Hexadecimal to binary encoder

4. Counter

Counting is frequently required in digital computers and other digital systems to record the number of events occurring in a specified interval of time. Normally an electronic counter is used for counting the number of pulses coming at the input line in a specified time period.

The counter must possess memory since it has to remember its past states. As with other sequential logic circuits counters can be synchronous or asynchronous. As the name suggests, it is a circuit which counts. The main purpose of the counter is to record the number of occurrence of some input. There are many types of counter both binary and decimal.

Commonly used counters are

1. Binary Ripple Counter
2. Ring Counter
3. BCD Counter

4. Decade counter
5. Up down Counter
6. Frequency Counter

Ripple Counter

A counter that follows the binary number sequence is called a binary counter. An n -bit binary counter consists of n flip-flops and can count in binary from 0 through 2n – 1. Counters are available in two categories: ripple counters and synchronous counters. In a ripple counter, a flip-flop output transition serves as a source for triggering other flip-flops.

In other words, the C input of some or all flip-flops are triggered, not by the common clock pulses, but rather by the transition that occurs in other flip-flop outputs. In a synchronous counter, the C inputs of all flip-flops receive the common clock.

Binary Ripple Counter

A binary ripple counter consists of a series connection of complementing flip-flops, with the output of each flip-flop connected to the C input of the next higher order flip-flop. The flip-flop holding the least significant bit receives the incoming count pulses. A complementing flip-flop can be obtained from a JK flip-flop with the J and K inputs tied together or from a T flip-flop.

A third possibility is to use a D flip-flop with the complement output connected to the D input. In this way, the D input is always the complement of the present state, and the next clock pulse will cause the flip-flop to complement.

BCD Ripple Counter

A decimal counter follows a sequence of 10 states and returns to 0 after the count of 9.Such a counter must have at least four flip-flops to represent each decimal digit, since a decimal digit is represented by a binary code with at least four bits.

The sequence of states in a decimal counter is dictated by the binary code used to represent a decimal digit. If BCD is used a decimal counter is similar to a binary counter, except that the state after 1001 (the code for decimal digit 9) is 0000 (the code for decimal digit 0).   A ripple counter is an asynchronous sequential circuit.

Synchronous counters

Synchronous counters are different from ripple counters in that clock pulses are applied to the inputs of all flip-flops. A common clock triggers all flip-flops simultaneously, rather than one at a time in succession as in a ripple counter. The decision whether a flip-flop is to be complemented is determined from the values of the data inputs, such as T or J and K at the time of the clock edge. If T = 0 or J = K = 0, the flip-flop does not change state. If T = 1 or J = K = 1, the flip-flop complements.

Binary Counter

The design of a synchronous binary counter is so simple that there is no need to go through a sequential logic design process. In a synchronous binary counter, the flip-flop in the least significant position is complemented with every pulse. A flip-flop in any other position is complemented when all the bits in the lower significant positions are equal to 1.

For example, if the present state of a four-bit counter isA3A2A1A0 = 0011, the next count is 0100.A0 is always complemented.A1 is complemented because the present state of A0 = 1.A2 is complemented because the present state of A1A0 = 11. However, A3 is not complemented, because the present state of A2A1A0 = 011, which does not give an all-1's condition. Synchronous binary counters have a regular pattern and can be constructed with complementing flip-flops and gates.

Note that the flip-flops trigger on the positive edge of the clock. The polarity of the clock is not essential here, but it is with the ripple counter. The synchronous counter can be triggered with either the positive or the negative clock edge. The complementing flip-flops in a binary counter can be of either the JK type, the T type, or the D type with XOR gates.

Up–Down Binary Counter

A synchronous countdown binary counter goes through the binary states in reverse order, from 1111 down to 0000 and back to 1111 to repeat the count. It is possible to design a countdown counter in the usual manner, but the result is predictable by inspection of the downward binary count.

The bit in the least significant position is complemented with each pulse. A bit in any other position is complemented if all lower significant bits are equal to 0.

It has an up control input and a down control input. When the up input is 1, the circuit counts up, since the T inputs receive their signals from the values of the previous normal outputs of the flip-flops. When the down input is 1 and the up input is 0, the circuit counts down, since the complemented outputs of the previous flip-flops are applied to the T inputs. When the up and down inputs are both 0, the circuit does not change state and remains

Decade Counter

A decade counter is the one which goes through 10 unique combinations of outputs and then resets as the clock proceeds. We may use some sort of a feedback in a 4-bit binary counter to skip any six of the sixteen possible output states from 0000 to 1111 to get to a decade counter. A decade counter does not necessarily count from 0000 to 1001 it could count as 0000,0001, 0010, 1000, 1001, 1010, 1011, 1110, 1111, 0000, 0001 and so on.

Ring Counter

The ring counter is the simplest example of a shift register. The simplest counter is called a Ring counter. The ring counter contains only one logical 1 or 0 which it circulates. The total cycle length is equal to the number of stages. The ring counter is useful in applications where count has to be recognized in order to perform some other logical operation. Since only one output is ever at logic 1 at given time extra logic gates are not required to decode the counts and the flip flop outputs may be used directly to perform the required operation.

Up-Down Counter

An up down counter is a bi-directional counter and it can be made to count upwards as well as downwards. In other words an up down counter is one which can provide both count up and down counts operations in a single unit.

Frequency Counter

Frequency counter is a digital device, which can be used to measure the frequency of the periodic waveforms.

5. **Shift Register**

REGISTERS

A register is a group of binary storage cells capable of holding binary information. A group of flip-flops constitutes a register, since each flip-flop can work as a binary cell. An n-bit register, has n flip-flops and is capable of holding n-bits information. In addition to flip-flops a register can have a combinational part that performs data-processing tasks.

Register:

- A set of n flip-flops
- Each flip-flop stores one bit
- Two basic functions: data storage and data movement.

Shift Register: A register that allows each of the flip-flops to pass the stored information to its adjacent neighbor.

Counter: A register that goes through a predetermined sequence of states. Storage Capacity of a register

The storage capacity of a register is the total number of bits (1 or 0) of digital data it can retain. Each stage (flip flop) in a shift register represents one bit of storage capacity. Therefore the number of stages in a register determines its storage capacity.

Shift Register

A shift register is a storage device that used to store binary data. When a number of flip flop are connected in series it is called a register. A single flip flop is supposed to stay in one of the two stable states 1 or 0 or in other words the flip flop contains a number 1 or 0 depending upon the state in which it is. A register will thus contain a series of bits which can be termed as a word or a byte.

If in these registers the connection is done in such a way that the output of one of the flip flop forms in input to other, it is known as a shift register. The data in a shift register is moved serially (one bit at a time).

The shift register can be built using RS, JK or D flip-flops various types of shift registers are available some of them are given as under.

1. Shift Left Register
2. Shift Right Register
3. Shift Around Register
4. Bi-directional Shift Register

There are two ways to shift data into a register (serial or parallel) and similarly two ways to shift the data out of the register. This leads to the construction of four basic types of registers:-

1. Serial in/Serial out (SISO)
2. Serial in/Parallel out (SIPO)
3. Parallel in/Serial out (PISO)
4. Parallel in/Parallel out (PIPO

SERIAL-IN–-SERIAL-OUT SHIFT REGISTER

From the name itself it is obvious that this type of register accepts data serially, i.e., one bit at a time at the single input line. The output is also obtained on a single output line in a serial fashion.

The data within the register may be shifted from left to right using shift-left register, or may be shifted from right to left using shiftright register.

Shift-right Register

A shift-right register can be constructed with either J-K or D flip-flops as shown in Figure 8.3. A J-K flip-flop based shift register requires connection of both J and K inputs. Input data are connected to the J and K inputs of the left most (lowest order) flip-fl op. To input a 0, one should apply a 0 at the J input, i.e., J = 0 and K = 1 and vice versa.

With the application of a clock pulse the data will be shifted by one bit to the right. In the shift register using D flip-flop, D input of the left most flip-flop is used as a serial input line. To input 0, one should apply 0 at the D input and vice versa.

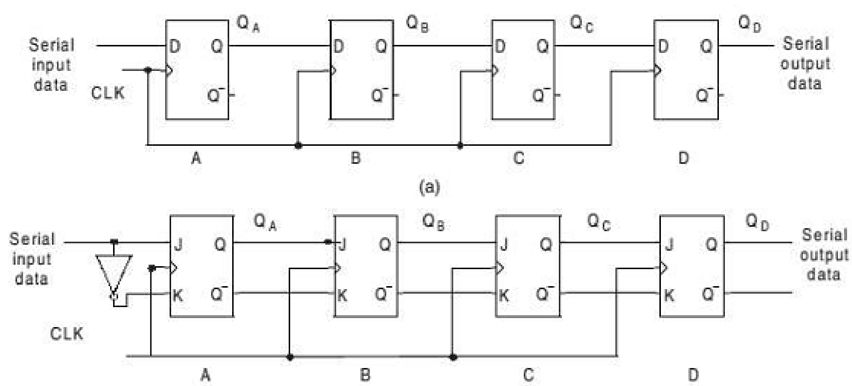


Fig 4.37. Shift-right register (a) using D flip-flops, (b) using J-K flip-flops

The clock pulse is applied to all the flip-flops simultaneously.

When the clock pulse is applied, each flip-flop is either set or reset according to the data available at that point of time at the respective inputs of the individual flip-flops. Hence the input data bit at the serial input line is entered into flip-flop A by the first clock pulse.

At the same time, the data of stage A is shifted into stage B and so on to the following stages. For each clock pulse, data stored in the register is shifted to the right by one stage. New data is entered into stage A, whereas the data present in stage D are shifted out (to the right).

Shift-left Register

A shift-left register can also be constructed with either J-K or D flip-flops as shown in Figure below. Let us now illustrate the entry of the 4-bit number 1110 into the register, beginning with the right-most bit. A 0 is applied at the serial input line, making D = 0. As the first clock pulse is applied, flip-fl op A is RESET, thus storing the 0.Next a 1 is applied to the serial input, making D = 1 for flip-flop A and D = 0 for flip-flop B, because the input of flip-flop B is connected to the QA output.

When the second clock pulse occurs, the 1 on the data input is “shifted” to the flip-flop A and the 0 in the flipflop A is “shifted” to flip-flop B. The 1 in the binary number is now applied at the serial input line, and the third clock pulse is now applied. This 1 is entered in flip-flop A and the 1 stored in flip- flop A is now “shifted” to flip-flop B and the 0 stored in flip- flop B is now “shifted” to flip-flop C.

The last bit in the binary number that is the 1 is now applied at the serial input line and the fourth clock pulse is now applied.

This 1 now enters the flipflop A and the 1 stored in flip-flop A is now “shifted” to flip-flop B and the 1 stored in flip-flop B is now “shifted” to flip-flop C and the 0 stored in flip-flop C is now “shifted” to flip-flop D. Thus the entry of the 4-bit binary number in the shift-right register is now completed.

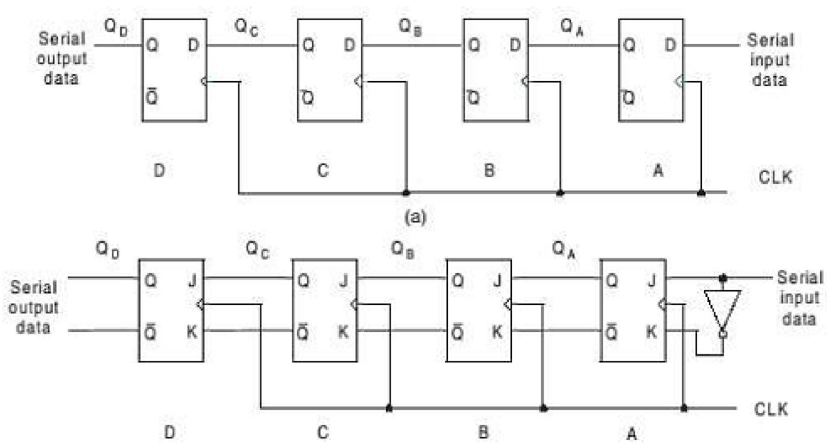


Fig 4.38. Shift-left register (a) using D flip-flops, (b) using J-K flip-flops

8-bit Serial-in–Serial-out Shift Register

The pinout and logic diagram of IC 74L91 is shown in Figure below. This IC is actually an example of an 8-bit serial-in– serial-out shift register. There are eight S-R flip-flops connected to provide a serial input as well as a serial output. The clock input at each flip-flop is negative edge-triggered.

However, the applied clock signal is passed through an inverter. Hence the data will be shifted on the positive edges of the input clock pulses. An inverter is connected in between R and S on the first flip-flop. This means that this circuit functions as a Dtype flip-flop. So the input to the register is a single liner on which the data can be shifted into the register appears serially. The data input is applied at either A (pin 12) or B (pin 11).

The data level at A (or B) is complemented by the NAND gate and then applied to the R input of the first flip-flop. The same data level is complemented by the NAND gate and then again complemented by the inverter before it appears at the S input. So, a 0 at input A will reset the first flip-flop (in other words this 0 is shifted into the first flip-flop) on a positive clock transition.

The NAND gate with A and B inputs provide a gating function for the input data stream if required, if gating is not required, simply connect pins 11 and 12 together and apply the input data stream to this connection.

A is held high: The NAND gate is enabled and the serial input data passes through the NAND gate inverted.

The input data is shifted serially into the register.

A is held low: The NAND gate output is forced high, the input data steam is inhibited, and the next clock pulse will shift a 0 into the first flip-flop. Each succeeding positive clock pulse will shift another 0 into the register.

After eight clock pulses, the register will be full of zeros.

PARALLEL-IN–SERIAL-OUT REGISTER

In the preceding two cases the data was shifted into the registers in a serial manner. Here we develop an idea for the parallel entry of data into the register. Here the data bits are entered into the flip-flops simultaneously, rather than a bit-by-bit basis

8-bit Parallel-in–Serial-out Shift Register

The data can be loaded into the register in parallel and shifted out serially at QH using either of two clocks (CLK or CLK inhibit). It also contains a serial input, DS through which the data can be serially shifted in.

PARALLEL-IN–PARALLEL-OUT REGISTER

The parallel input of data has already been discussed in the preceding section of parallel-in–serial-out shift register. Also, in this type of register there is no interconnection between the flip-flops since no serial shifting is required. Hence, the moment the parallel entry of the data is accomplished the data will be available at the parallel outputs of the register.

UNIVERSAL REGISTER

A register that is capable of transferring data in only one direction is called a 'unidirectional shift register' whereas the register that is capable of transferring data in both left and right direction is called a 'bidirectional shift register'. Now if the register has both the shift-right and shift-left capabilities, along with the necessary input and output terminals for parallel transfer, then it is called a shift register with parallel load or 'universal shift register'.

The most general shift register has all the capabilities listed below. Others may have only some of these functions, with at least one shift operation.

1. A shift-right control to enable the shift-right operation and the serial input and output lines associated with the shift-right.
2. A shift-left control to enable the shift-left operation and the serial input and output lines associated with the shift-left.
3. A parallel-load control to enable a parallel transfer and the input lines associated with the parallel transfer.
4. n parallel output lines.
5. A clear control to clear the register to 0.
6. A CLK input for clock pulses to synchronize all operations.
7. A control state that leaves the information in the register unchanged even though clock pulses are continuously applied.

SHIFT REGISTER COUNTERS

Shift registers may be arranged to form different types of counters. These shift registers use feedback, where the output last flip-flop in the shift register is fed back to the first flip-flop.

Based on the type of this feedback connection, the shift register counters are classified as (i) ring counter and (ii)twisted ring or Johnson or Shift counter.

Asynchronous and Synchronous Shift Registers Asynchronous circuits changes state each time the input changes the state, while synchronous circuit changes state only when triggered by a momentary change in the input signal. This momentary change is called triggering. Shift registers are made of flip flops and their operation depends upon the state at the flip flops.

Flip flops changes their states due to triggering when flip flop change their state on the base of input pulse then it is called Edge triggering.

In edge triggering flip flop change its state on the basses of Leading edge or trailing edge. When flip flop works on the bases of change in DC level, that is called Asynchronous Triggering. And the shift registers work on this principle is called Asynchronous shift registers. On the other hand, shift registers changes their state only when triggered by clock pulse are called Synchronous shift registers these type of shift registers usually used in counters.

4.1.5. Air conditioning control circuit

Control the various components to start and stop them in the correct sequence to maintain space temperature for comfort. The three main components controlled are the indoor fan, the compressor, and the outdoor fan. These components are used in air cooled air conditioning equipment. The control circuit uses low voltage for safety.

Usually a/c problems are electrical problems.

The most common type of electrical problem is the wires themselves. Where ever there is a connection to a wire there is a potential problem.

By connection I mean the factory crimped on connectors that attach to all the components. Over time the spot where the wire and the connector meet look for corrosion, heat damage, rust, ect.

The next most common electrical problem is the switches such as the main contactor (relay), fan relay, ect. They can stop working when the internal switches burn and pit. You need to use an electrical tester to check these.

To start off with, you must check to see if the power is on at the outlet where the cord plugs in (window units) or if its a central air conditioner, you must check inside the box (the circuit breaker on the side where the power cord comes out of the unit), the breaker box has a removable cover around the breaker. You must use an electric tester to make sure that the voltage is correct. Or if their is no meter use some kind of tester that emits a light.

All window units and central air conditioners have a switch of some type that the main power cord goes directly to after it enters the casing of the unit. On a window unit the power runs through a wire that is plugged into the wall outlet then passes through the metal cover. Inside the cover the cord is split, the ground wire (either green or a bare wire is screwed to the metal covering of the a/c).

You will need to remove the casing of the a/c to get to the internal wiring.

MAKE SURE THAT THE POWER IS CUT OFF OR THE UNIT IS UNPLUGGED, THEN CHECK AGAIN! You can never be to safe.

The other 2 wires are split up (we will call them #1 black, #2 white). #1 black wire goes to the selector switch on a window unit, this is the switch that has (off, high cool, low cool, high fan, low fan). From the selector switch things get buisy, looking at the back of the selector switch you will see many wires hooked to it, this is where the #1 black wire coming into the selector gets sent to the vital parts, compressor, fan motor.

The #2 white wire goes directly to each of the components (fan motor, compressor). Again on a window unit one of the wires, in our case the white wire comes in from the plug to inside of the unit after entering the unit the white #2 wire is connected to the wire connector on the back of the selector switch. The wires all are common to each other because they are the same leg (leg= each wire #1 and #2 are called #1 leg #2 leg)

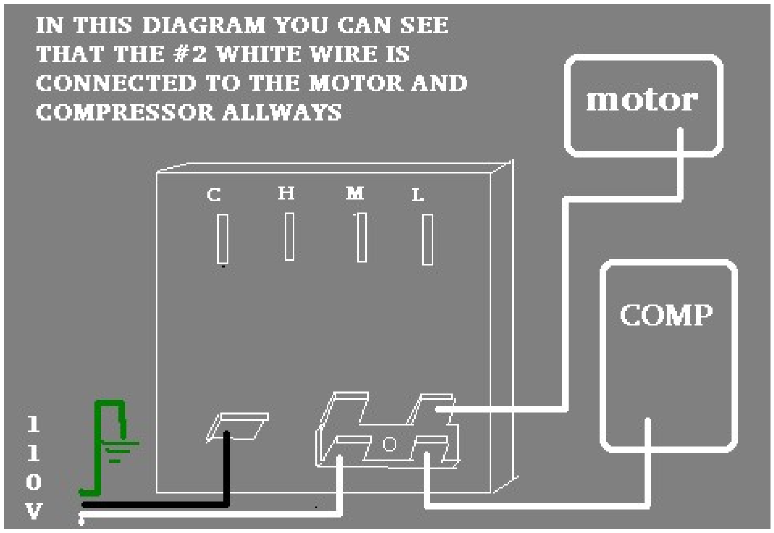


Fig 4.39. air conditioning Window units

Since the #2 white wire is allways connected to the fan and compressor, since it doesn't go through a switch. But in some cases as stated above, All that needs to happen to get the a/c to work is to get the #1 black wire to send power through the switch to the compressor and fan.

The selector switch is the way the power from #1 black wire gets to the fan and compressor. So when you turn the switch to cool the power that came in from the cord that connected to the selector (#1 black wire) goes through the switch to the fan (now the fan has both wires with power so the fan comes on).

But!!! The selector switch also sends the #1 black wire through the switch to the compressor, heres the BUT! But after going through the switch the wire connects to the thermostat (the thermostat acts like an on off switch depending what temperature you set it at) THE COLORS REPRESENTED ON MY IMAGES ARE FOR UNDERSTANDING THE BASIC WIRING OF THE GROUND, NEUTRAL, AND HOT WIRES ON on actual a/c's the wires are different colors.

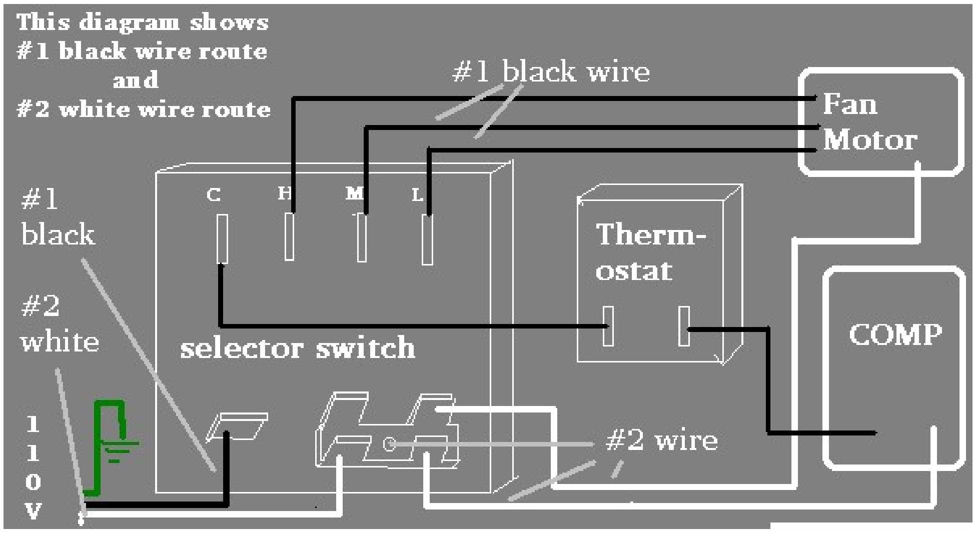


Fig 4.40. Air conditioning Central units.

Central Air Conditioners.

On central units the thermostat on the wall sends 24 volts (24 volts comes from a transformer in the blower housing) to relays and contactors that switch the power on and off to the compressor and motors.

The relay and contactors are like any other electric device, it needs both wires to work. Inside the blower unit (the unit that is inside the house on split systems) the transformer reduces the voltage from 220 down to 24 volts. The transformer has 2 wires coming out with 24 v. one of those wires goes to every relay (switch). The other wire (red) goes to the thermostat, then the thermostat sends the power to the relays (switches), as the temperature goes up and down the thermostat turns on and off the relays that power the compressor and fans.

The reason its only 24 volts is so if you touch a live thermostat wire you will not get electricuted.

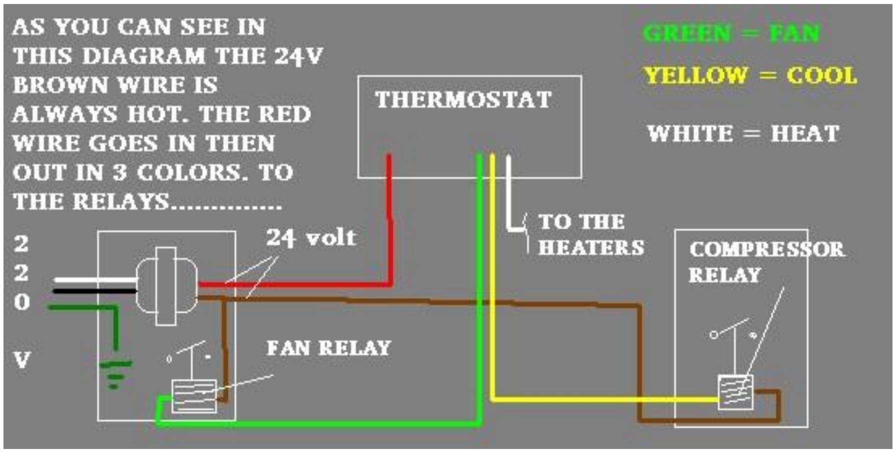


Fig 4.41. The 24-volt system

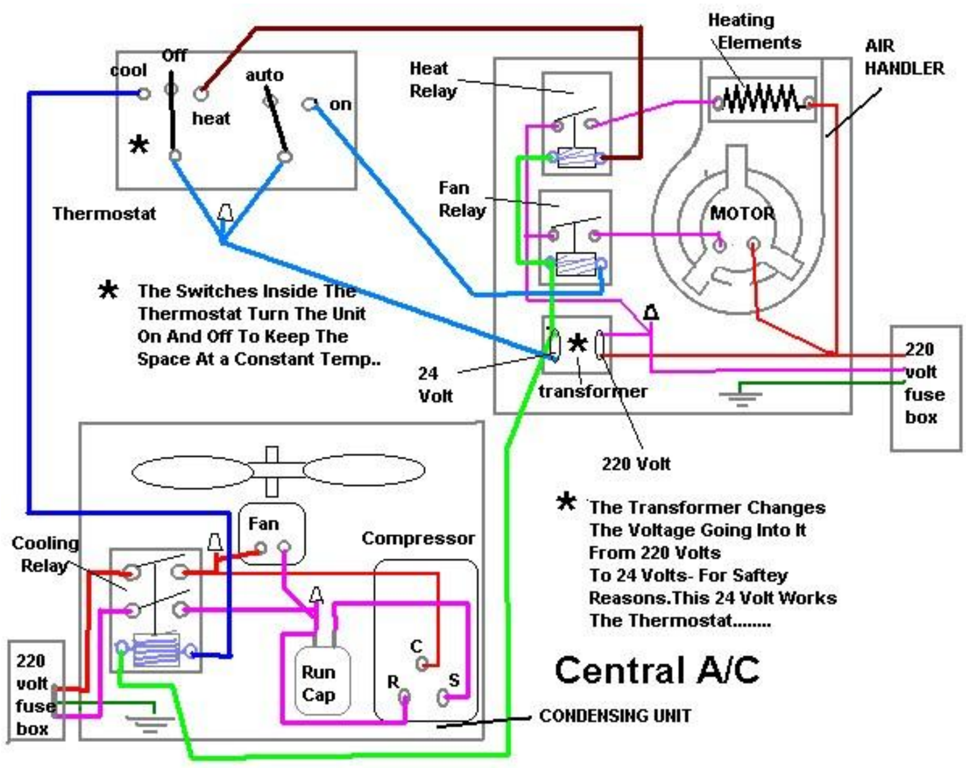


Fig 4.42. A central a/c commonly wired system

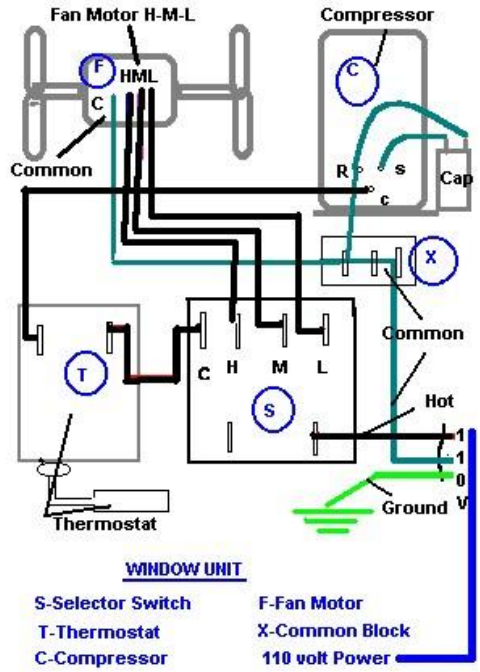


Fig 4.43. A window unit commonly wired system

4.2. methods in constructing electrical/electronics circuit

Terminating

Electrical termination is an electrical industry term used to describe the specific point at which a conductive device, such as wire or cable, ends or starts. The conductive device may or may not pass the carried electricity or signal onto another conductive device at this point. A common point of electrical termination is at a terminal block. A wire typically ends, or terminates, at the terminal block; but the electricity or signal may be passed onto the terminal connectors.

Pin connection and Plugs

Plug and socket connectors

Plug and socket connectors are usually made up of a male plug (typically pin contacts) and a female receptacle (typically socket contacts), although *hermaphroditic* connectors exist, such as the original IBM token ring LAN connector. Plugs generally have one or more pins or prongs that are inserted into openings in the mating socket. The connection between the mating metal parts must be sufficiently tight to make a good electrical connection and complete the circuit. When working with multi-pin connectors, it is helpful to have a pinout diagram to identify the wire or circuit node connected to each pin.

Jack commonly refers to a connector often with the female electrical contact or socket, and is the "more fixed" connector of a connector pair. *Plug* commonly refers to a movable connector, often (but not always) with the male electrical contact or pin, and is the movable (less fixed) connector of a connector pair.

Some connector styles may contain both pin and socket connection types.

**for more connection methods you can referee “Terminate and Connect Electrical Wirings and Electronics Circuit” of previous UC.

Self-Check -4	Written Test

Directions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Use the Answer sheet provided in the next page.

1. What is electrical/electronics circuit mean. (2 points)
2. Draw the block diagram of power supply (4 points)
3. Write the three types of amplifier circuit (3Points)
4. Discuss the function of power supply. (4 points)
5. Write types of oscillator circuit (4 points)

Note: - Satisfactory rating: 8.5 and above - Unsatisfactory Rating: below 8.5

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating: _____________

Name: ___________________________ Date: ________________

5.1. Construct linear power supply circuit (Transformer → Rectifier→ Filter → Regulator → Output)

A DC Power Supply Unit (commonly called a PSU) deriving power from the AC mains (line) supply performs a number of tasks:

- It changes (in most cases reduces) the level of supply to a value suitable for driving the load circuit.
- It produces a DC supply from a pure AC wave.
- It prevents any AC from appearing at the supply output.
- It will ensure that the output voltage is kept at a constant level, independent of changes in:
  - ✓ The AC supply voltage at the supply input.
  - ✓ The Load current drawn from the supply output

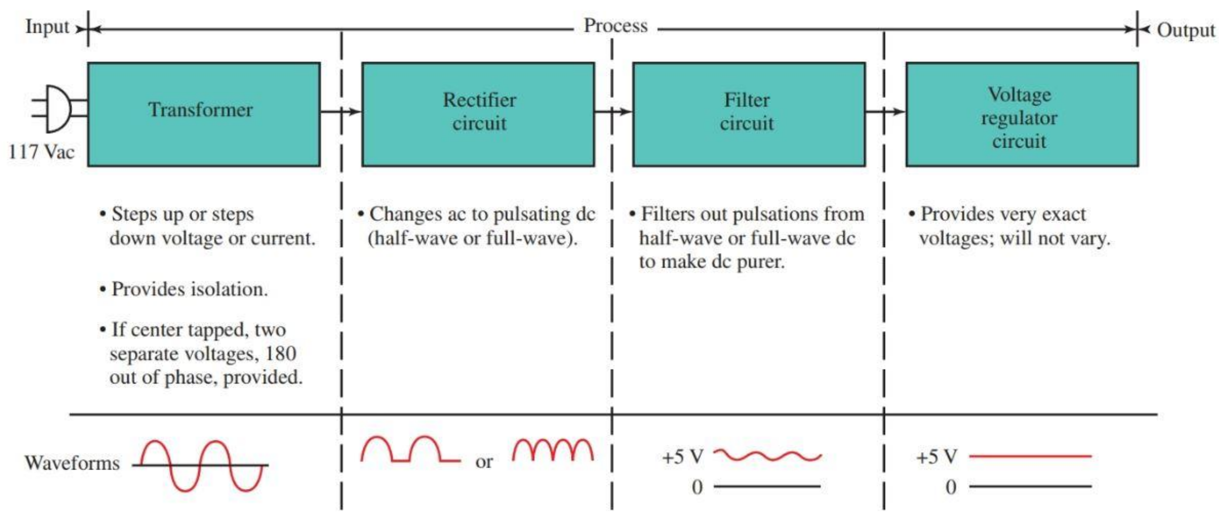


Fig 5.1. Power Supply Block Diagram

The basic building blocks of a regulated DC power supply are as follows:

1. A step-down/step-down transformer
2. A rectifier
3. A DC filter
4. A regulator

6. **The Transformer**

In a basic power supply the input power transformer has its primary winding connected to the mains (line) supply. A secondary winding, electro-magnetically coupled but electrically isolated from the primary is used to obtain an AC voltage of suitable amplitude, and after further processing by the PSU, to drive the electronics circuit it is to supply.

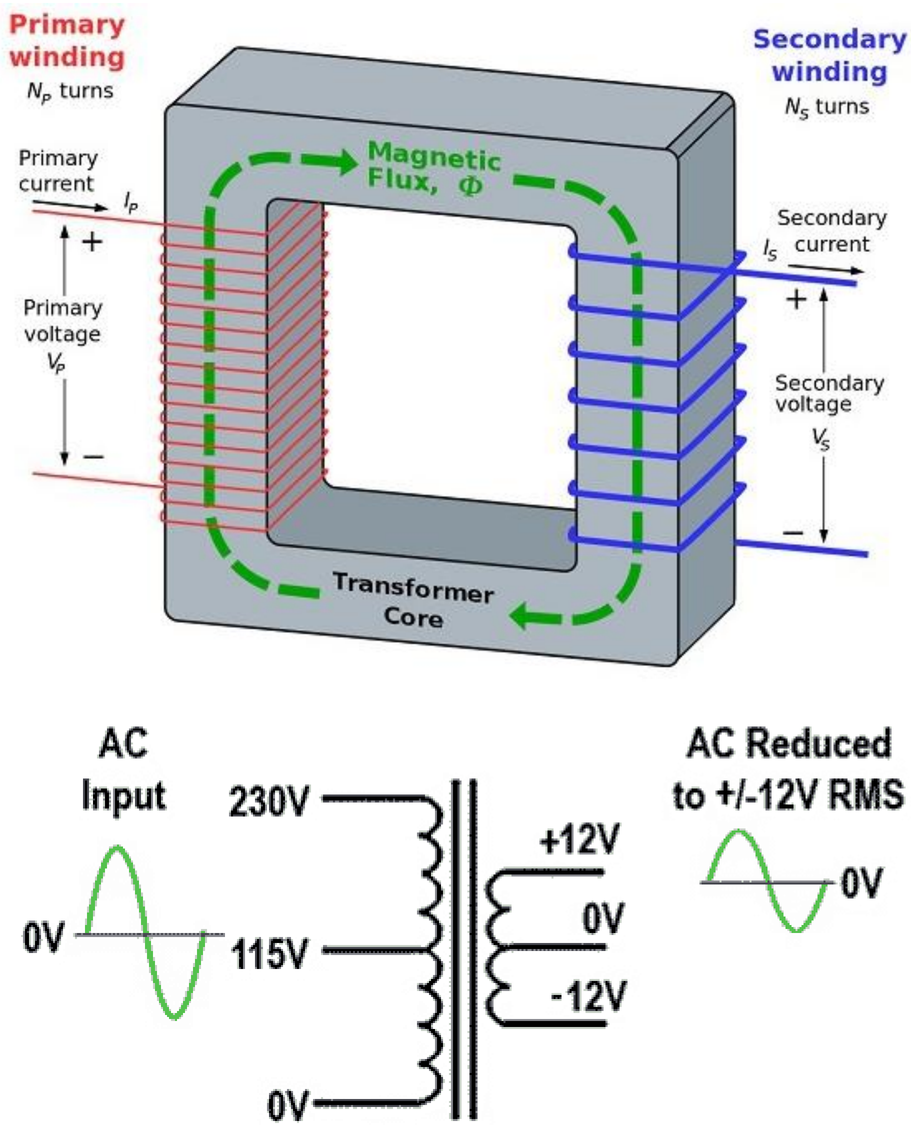


Fig 5.2. Typical Input Transformer

The transformer stage must be able to supply the current needed. If too small a transformer is used, it is likely that the power supply's ability to maintain full output voltage at full output current will be impaired. With too small a transformer, the losses will increase dramatically as full load is placed on the transformer.

As the transformer is likely to be the most costly item in the power supply unit, careful consideration must be given to balancing cost with likely current requirement. There may also be a need for safety devices such as thermal fuses to disconnect the transformer if overheating occurs, and electrical isolation between primary and secondary windings, for electrical safety.

7. The Rectifier Stage

After a voltage has gone through a power supply's transformer, the next step is rectification. The process of changing an alternating current to a pulsating direct current is called rectification.

When changing an ac signal to dc, there are two types of rectification: half-wave rectification and full-wave rectification. With the half-wave rectifier, only half of the input signal passes on through the rectifier. With the full-wave rectifier, the entire input wave is passed through.

Half Wave Rectification

In **Figure 5**, the output of a transformer is connected to a diode and a load resistor that are in series. The input voltage to the transformer appears as a sine wave.

The polarity of the wave reverses at the frequency of the applied voltage. The output voltage of the transformer secondary also appears as a sine wave. The magnitude of the wave depends on the turns ratio of the transformer. The output is 180 degrees out of phase with the primary.

The top of the transformer (point A) is joined to the diode anode. Note that the B side of the transformer is connected to ground.

During the **first half cycle**, point A is positive. The diode conducts, producing a voltage drop across resistor R equal to IR. During the **second half cycle**, point A is negative. The diode anode is also negative. No conduction takes place, and no IR drop appears across R.

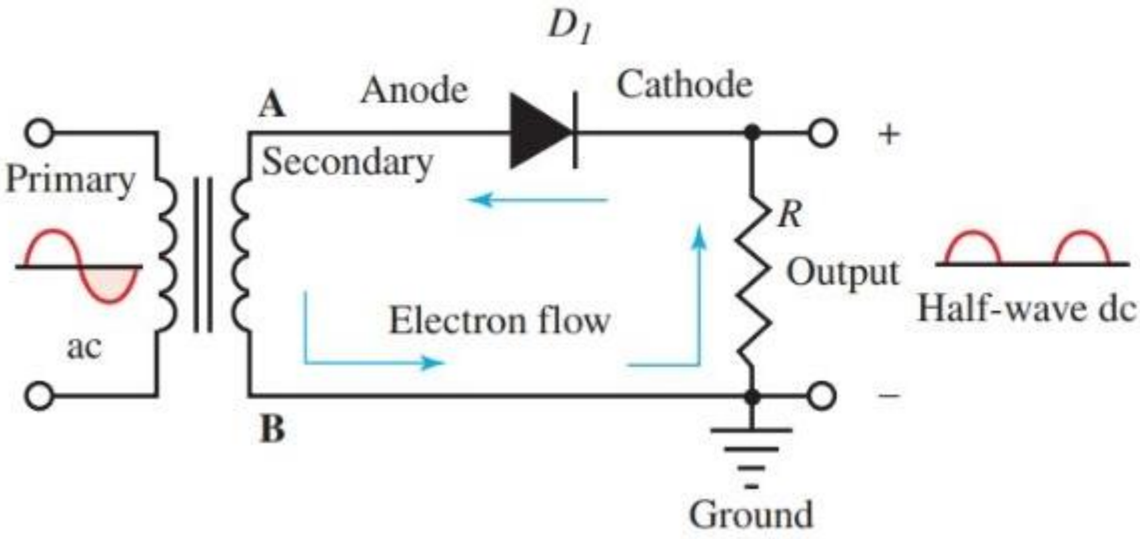


Figure 5. Basic diode rectifier schematic.

Only one half of the ac input wave is used to produce the output voltage. This type of rectifier is called a **half-wave rectifier**.

A **negative rectifier** can be made by reversing the diode in the circuit, **Figure 7**. The diode conducts when the cathode becomes negative causing the anode to become positive.

The current through R would be from the anode to ground making the anode end of R negative and the ground end of R more positive.

Voltages taken from across R, the output, would be negative with respect to ground. This circuit is called an **inverted diode**. It is used when a negative supply voltage is required.

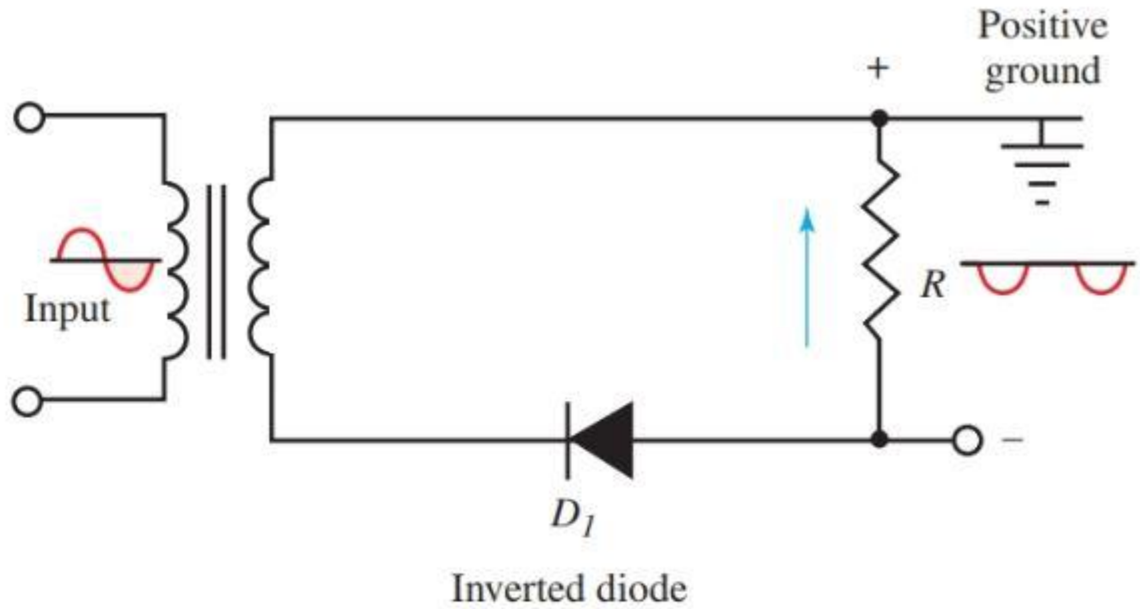


Figure 7. An inverted diode produces a negative voltage.

Full-Wave Rectification

The pulsating direct voltage output of a half-wave rectifier can be filtered to a pure dc voltage. However, the half-wave rectifier uses only one half of the input ac wave.

A better filtering action can be obtained by using two diodes. With this setup, both half cycles of the input wave can be used.

Both half cycles at the output have the same polarity in this full-wave rectifier. **Figure 9** follows the first half cycle. Figure 10 follows the second half cycle.

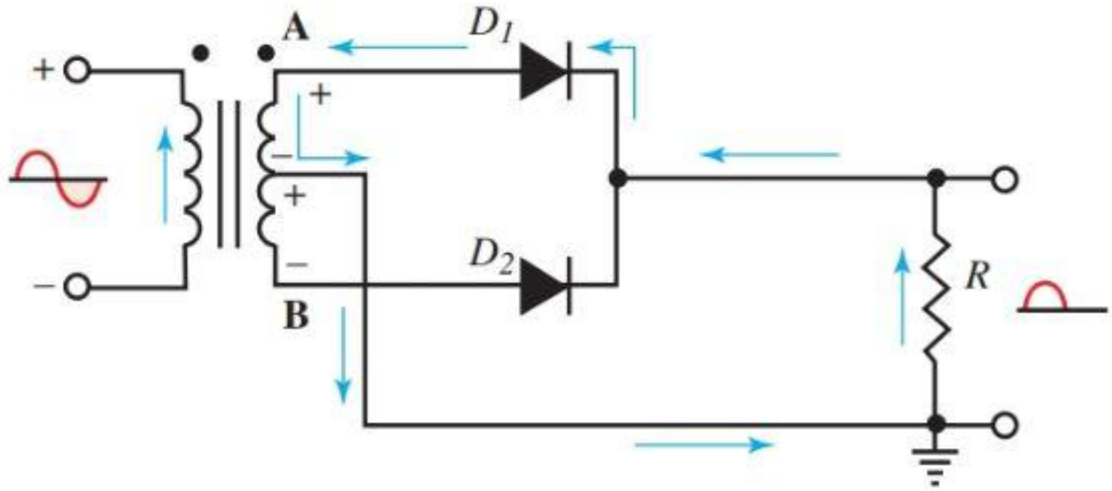


Figure 9. Arrows show current in full-wave rectifier during the first half cycle.

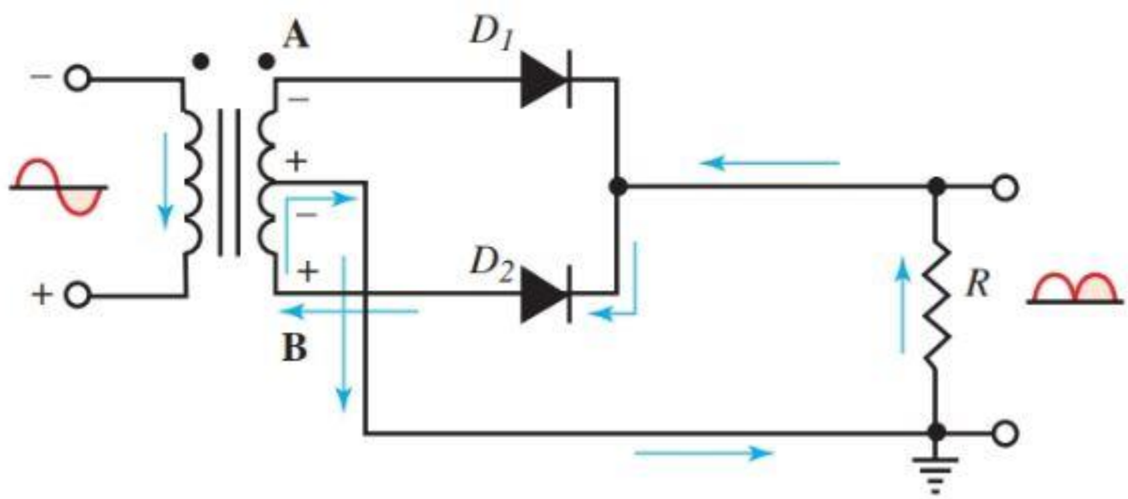


Figure 10. The direction of current during the second half cycle.

To produce this full-wave rectification, a center tap is made on the secondary winding. This tap is attached to the ground.

In **Figure 9**, point A is positive and diode anode D1 is positive. Electron flow is shown by the arrows. During the second half of the input cycle, point B is positive, diode anode D2 is positive, and current flows as shown in **Figure 10**.

No matter which diode is conducting, the current through load resistor R is always in the same direction. Both positive and negative half cycles of the input voltage cause the current through R in the same direction.

The **output voltage of this full-wave rectifier** is taken from across R. It consists of direct current pulses at twice the frequency of input voltage. To produce this full-wave rectification in this circuit, the secondary voltage was cut in half by the center tap.

The diodes, D_1 and D_2, used in Figures 9 and 10, are packaged both individually and in pairs. **Figure 12** shows a two rectifier package. The center lead is used as the connection for the cathodes. The cathodes are wired together.

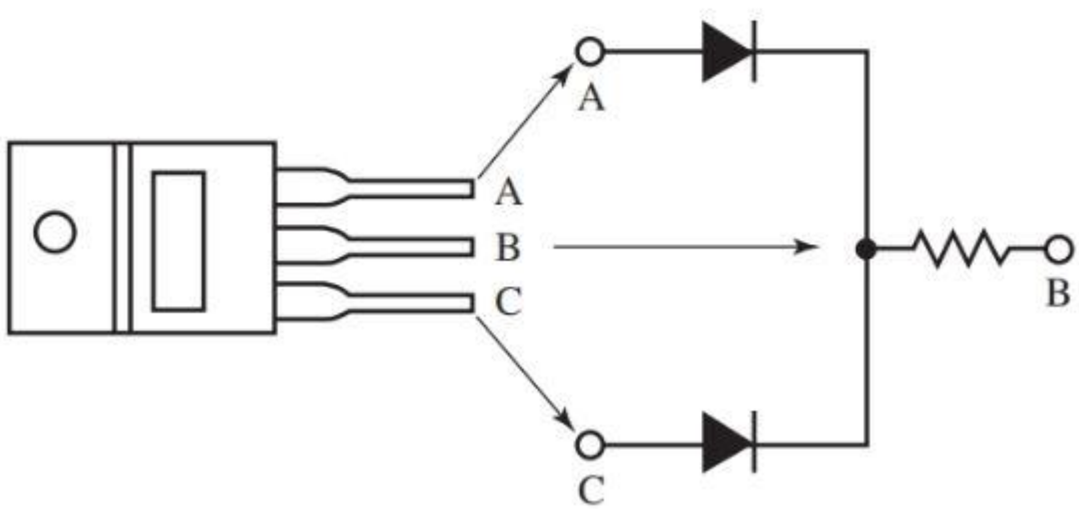


Figure 12. Dual diodes with a center tap.

Bridge Rectifiers

It is not always necessary to use a center-tapped transformer for full-wave rectification. Full secondary voltage can be rectified by using four diodes in a circuit called a **bridge rectifier**, Figure **13 and 14**. Two circuits are shown so that the current can be observed in each half cycle.

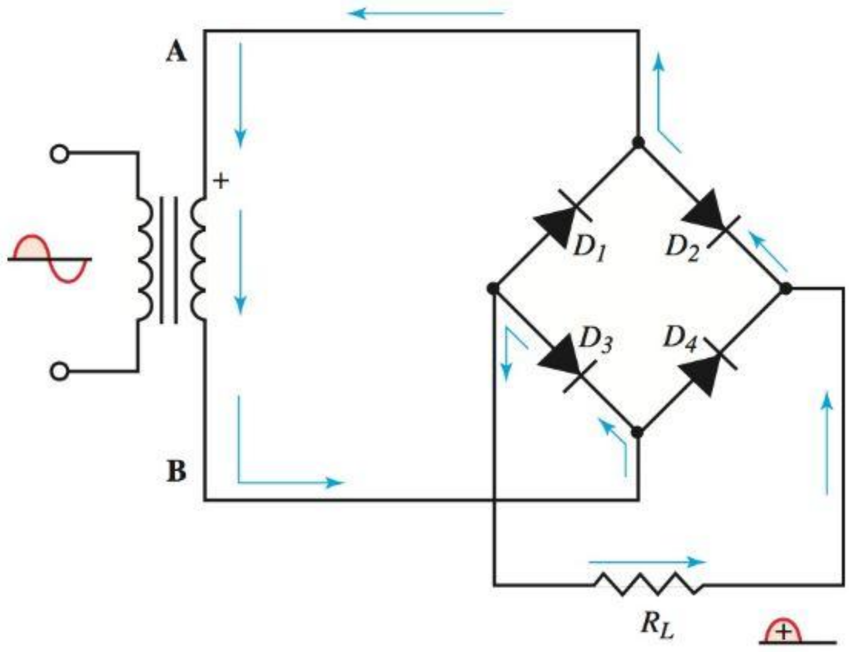


Figure 13. Current in bridge rectifier during the first half cycle.

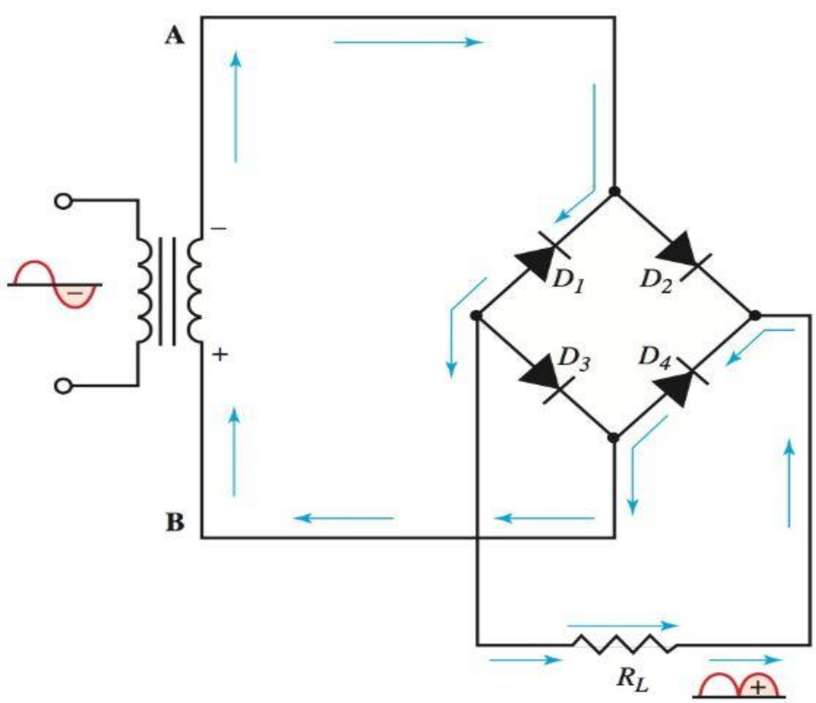


Figure 14. Current in bridge rectifier during the second half cycle.

In **Figure 13**, point A of the transformer secondary is positive. Current flows in the direction of the arrows. When point B is positive, current flows as in **Figure 14**.

Again, notice that the current through R is always in one direction. Both halves of the input voltage are rectified and the full voltage of the transformer is used.

Advantages of bridge rectifier over full wave rectifier

There are many advantages for a bridge full wave rectifier, such as −

- No need of center-tapping.
- The dc output voltage is twice that of the center-tapper full wave rectifier.
- PIV of the diodes is of the half value that of the center-tapper full wave rectifier.
- The design of the circuit is easier with better output.

8. A DC filter

The output of either the half-wave or the full-wave rectifier is a pulsating voltage. Before it can be applied to other circuits, the pulsations must be reduced. A steadier dc is needed. It can be obtained using a **filter network**.

In **Figure 16**, the line, E_{avg}, shows the average voltage of the pulsating dc wave. It is equal to 0.637 × peak voltage. The shaded portion of the wave above the average line is equal in area to the shaded portion below the line.

Movement above and below the average voltage is called the ac ripple. It is this ripple that requires filtering.

The percentage of ripple as compared to the output voltage must be kept to a small value. The ripple percentage can be found using the formula:

$$Percentage\ Ripple = \frac{E_{rms}\ of\ Ripple\ Voltage}{E_{avg}\ of\ Total\ Output\ Voltage} \times 100$$

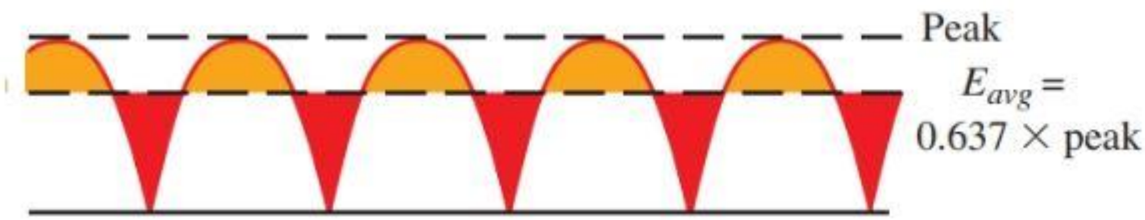


Figure 16. Average value of full-wave rectifier output.

Capacitor Filters

A capacitor connected across the rectifier output provides some filtering action, **Figure 17**. The capacitor is able to store electrons.

When the diode or rectifier is conducting, the capacitor charges rapidly to near the peak voltage of the wave. It is limited only by the resistance of the rectifier and the reactance of the transformer windings.

Between the pulsations in the wave, voltage from the rectifier drops. The capacitor then discharges through the resistance of the load.

The capacitor, in effect, is a storage chamber for electrons. It stores electrons at peak voltage and then supplies electrons to the load when rectifier output is low. See **Figure 18**.

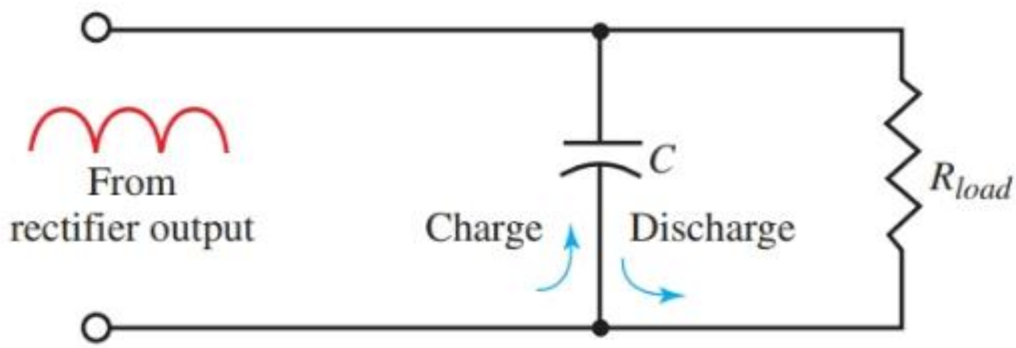


Figure 17. Filtering action of a capacitor.

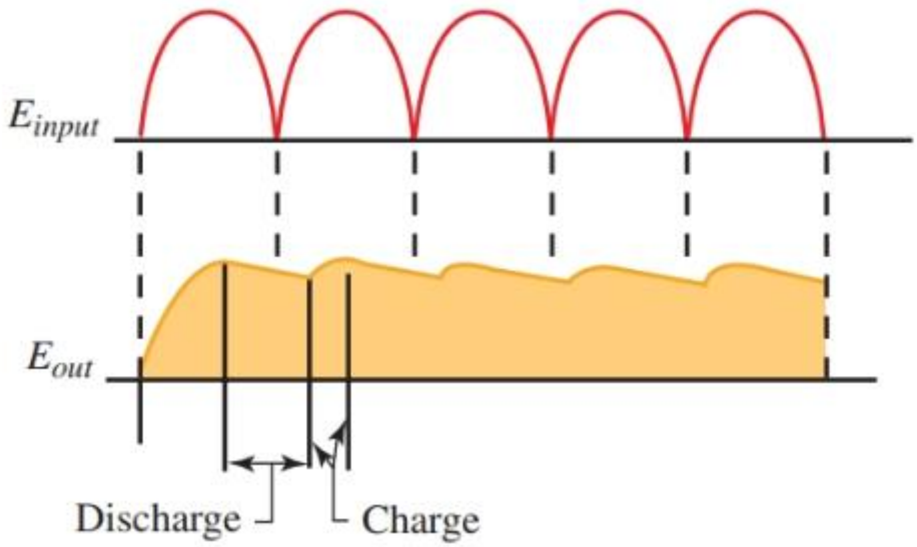


Figure 18. Input and output of the capacitor filter showing the change in the waveform.

Capacitors used for this purpose are **electrolytic types** because large capacitances are needed in a limited space. Common values for the capacitors range from 4 to 2000 microfarads. Working voltages of capacitors should be in excess of the peak voltage from the rectifier.

LC Filters

The filtering action can be improved by adding a choke in series with the load. This LC filter circuit appears in **Figure 19**. The filter choke consists of many turns of wire wound on a laminated iron core.

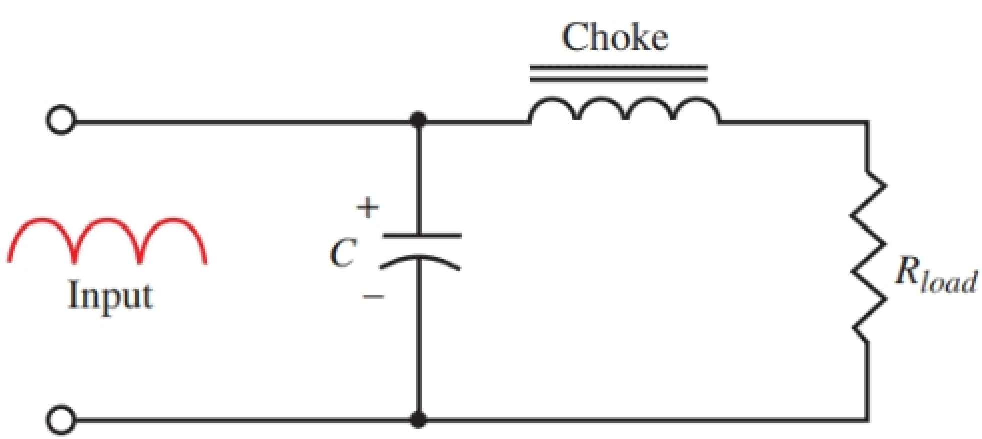


Figure 19. Further filtering is produced by the choke in series with the load.

Recall that **inductance** was that property of a circuit that resisted a change in current. A rise in current induced a counter emf that opposed the rise. A decrease in current induced a counter emf that opposed the decrease. As a result, the choke constantly opposes any change in current. Yet, it offers very little opposition to a direct current.

Chokes used in radios have values from 8 to 30 henrys. Current ratings range from 50 to 200 milliamperes.

Larger chokes can be used in transmitters and other electronic devices. Filtering action as a result of the filter choke is shown in **Figure 20**.

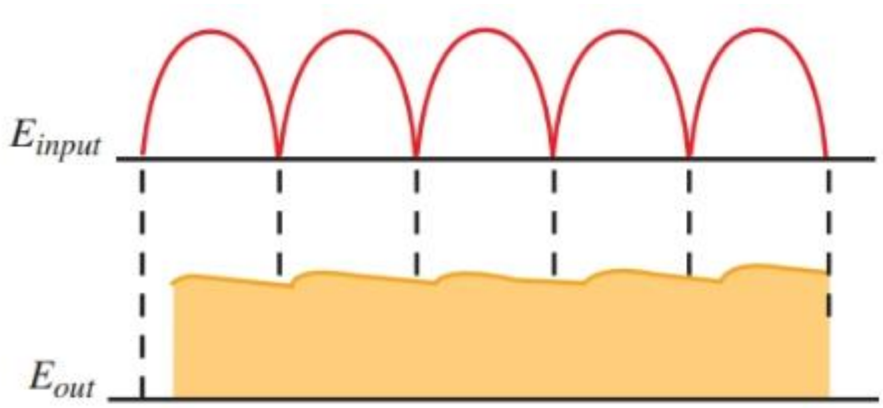


Figure 20. Waveforms show the filtering action of the capacitor and choke together.

A second capacitor can be used in the filter section after the choke, to provide more filter action. See **Figure 21**. The action of this capacitor is similar to the first capacitor. The circuit configuration appears as the Greek letter π. The filter is called a **pi (π) section filter**.

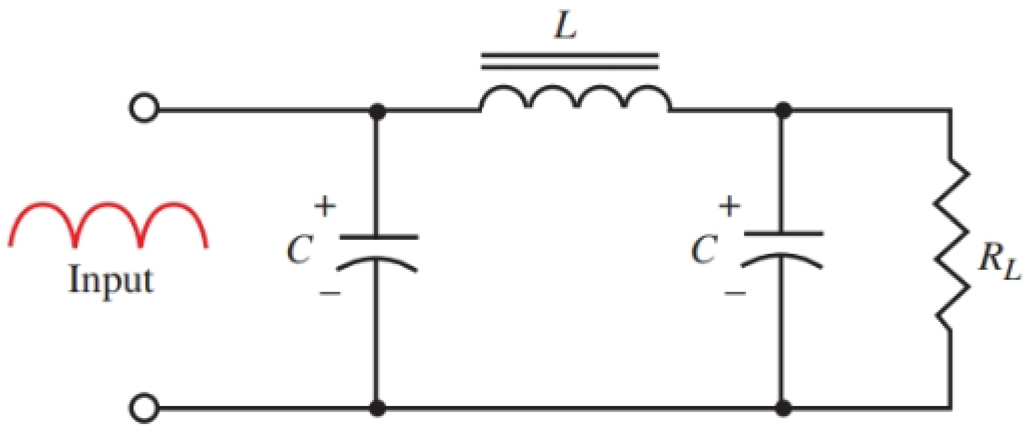


Figure 21. Pi (π) section filter.

When the first filtering component is a capacitor, the circuit is called a **capacitor input filter**. When the choke is the first filtering component, it is called a choke input filter, **Figure 22**. The choke input filter looks like an inverted L, so it is also called an L section filter. Several of these filter sections can be used in series to provide added filtering.

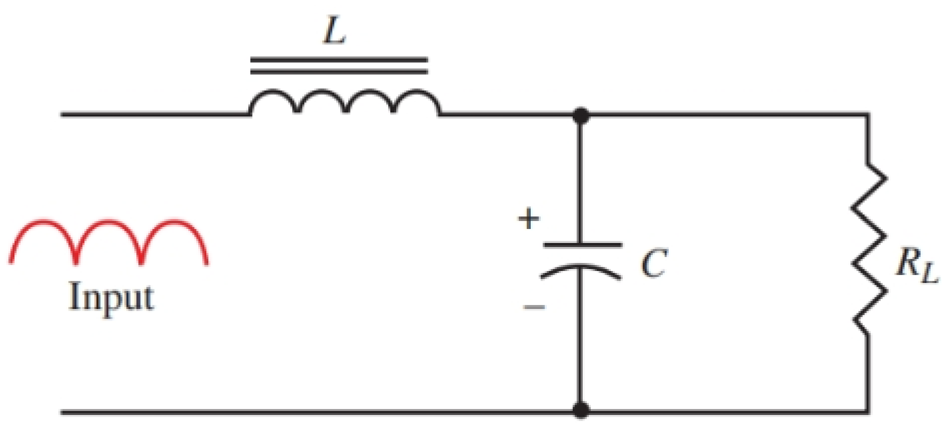


Figure 22. Choke input L filter

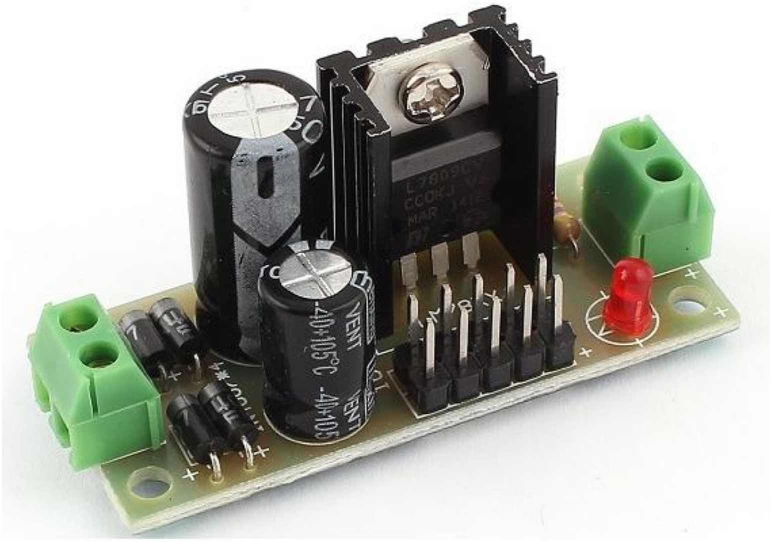
In the capacitor input filter, the capacitor charges to the peak voltage of the rectified wave. In the choke input, the charging current for the capacitor is limited by the choke. The capacitor does not charge to the peak voltage. **As a result,** the output voltage of the power supply using the capacitor input filter is higher than one using the choke input filter.

9. A regulator

The next and the last stage before load, in a power supply system is the Regulator part. The part of electronics that deal with the control and conversion of electric power can be termed as **Power Electronics**. A regulator is an important device when it comes to power electronics as it controls the power output.

For a Power supply to produce a constant output voltage, irrespective of the input voltage variations or the load current variations, there is a need for a voltage regulator.

A **voltage regulator** is such a device that maintains constant output voltage, instead of any kind of fluctuations in the input voltage being applied or any variations in current, drawn by the load. The following image gives an idea of what a practical regulator looks like.



Types of Regulators

Regulators can be classified into different categories, depending upon their working and type of connection.

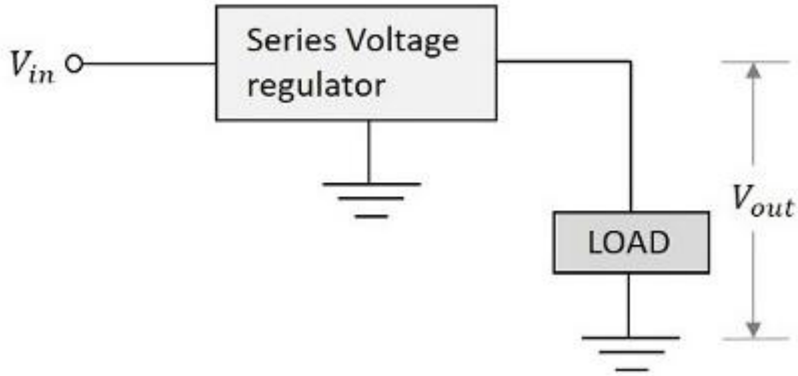
Depending upon the type of regulation, the regulators are mainly divided into two types namely, line and load regulators.

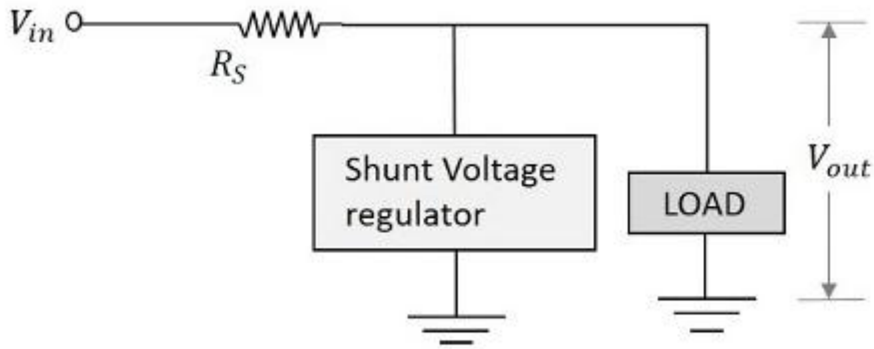
- **Line Regulator** − The regulator which regulates the output voltage to be constant, in spite of input line variations, it is called as **Line regulator**.
- **Load Regulator** − The regulator which regulates the output voltage to be constant, in spite of the variations in load at the output, it is called as **Load regulator**.

Depending upon the type of connection, there are two type of voltage regulators. They are

- Series voltage regulator
- Shunt voltage regulator

The arrangement of them in a circuit will be just as in the following figures.

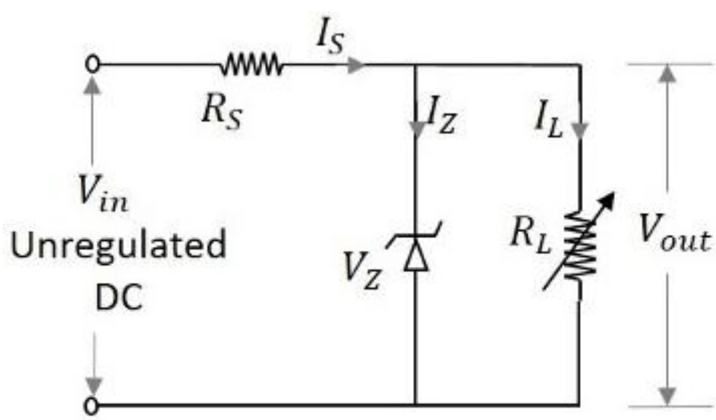




Zener Voltage Regulator

A Zener voltage regulator is one which uses Zener diode for regulating the output voltage. We have already discussed the details regarding Zener diode in BASIC ELECTRONICS tutorial.

When the Zener diode is operated in the breakdown or **Zener region**, the voltage across it is substantially **constant** for a **large change of current** through it. This characteristic makes Zener diode a **good voltage regulator**.



The applied input voltage V_i when increased beyond the Zener voltage V_z, then the Zener diode operates in the breakdown region and maintains constant voltage across the load. The series limiting resistor R_S limits the input current.

Working of Zener Voltage Regulator

The Zener diode maintains the voltage across it constant in spite of load variations and input voltage fluctuations. Hence we can consider 4 cases to understand the working of a Zener voltage regulator.

Case 1 − If the load current I_L increases, then the current through the Zener diode I_Z decreases in order to maintain the current through the series resistor R_S constant. The output voltage Vo depends upon the input voltage V_i and voltage across the series resistor R_S.

This is can be written as

$$Vo = Vin - I\,R_S$$

Where I is constant. Therefore, Vo also remains constant.

Case 2 − If the load current I_L decreases, then the current through the Zener diode I_Z increases, as the current I_S through R_S series resistor remains constant. Though the current I_Z through Zener diode increases it maintains a constant output voltage V_Z, which maintains the load voltage constant.

Case 3 − If the input voltage V_i increases, then the current I_S through the series resistor R_S increases. This increases the voltage drop across the resistor, i.e. V_S increases. Though the current through Zener diode I_Z increases with this, the voltage across Zener diode V_Z remains constant, keeping the output load voltage constant.

Case 4 − If the input voltage decreases, the current through the series resistor decreases which makes the current through Zener diode I_Z decreases. But the Zener diode maintains output voltage constant due to its property.

Limitations of Zener Voltage Regulator

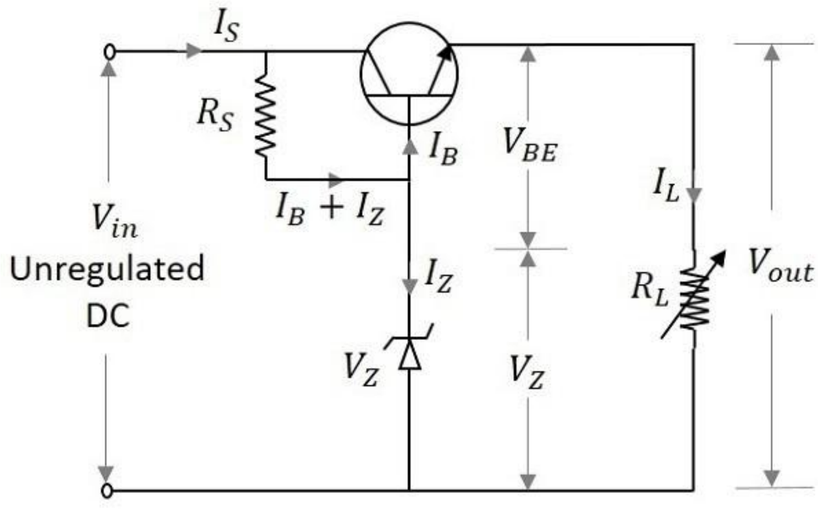
There are a few limitations for a Zener voltage regulator. They are −

- It is less efficient for heavy load currents.
- The Zener impedance slightly affects the output voltage.

Hence, a Zener voltage regulator is considered effective for low voltage applications.

Transistor Series Voltage Regulator

This regulator has a transistor in series to the Zener regulator and both in parallel to the load. The transistor works as a variable resistor regulating its collector emitter voltage in order to maintain the output voltage constant. The figure below shows the transistor series voltage regulator.



With the input operating conditions, the current through the base of the transistor changes. This effects the voltage across the base emitter junction of the transistor V_{BE}. The output voltage is maintained by the Zener voltage V_Z which is constant. As both of them are maintained equal, any change in the input supply is indicated by the change in emitter base voltage V_{BE}.

Hence, the output voltage Vo can be understood as

$$V_O = V_Z + V_{BE}$$

Working of Transistor Series Voltage Regulator

The working of a series voltage regulator shall be considered for input and load variations. If the input voltage is increased, the output voltage also increases. But this in turn makes the voltage across the collector base junction V_{BE} to decrease, as the Zener voltage V_Z remains constant. The conduction decreases as the resistance across emitter collector region increases. This further increases the voltage across collector emitter junction V_{CE} thus reducing the output voltage V_O. This will be similar when the input voltage decreases.

When the load changes occur, which means if the resistance of the load decreases, increasing the load current I_L, the output voltage V_O decreases, increasing the emitter base voltage $V_{BE.}$

With the increase in the emitter base voltage V_{BE} the conduction increases reducing the emitter collector resistance. This in turn increases the input current which compensates the decrease in the load resistance. This will be similar when the load current increases.

Limitations of Transistor Series Voltage Regulator

Transistor Series Voltage Regulators have the following limitations −

- The voltages V_{BE} and V_Z are affected by the rise in temperature.
- No good regulation for high currents is possible.
- Power dissipation is high.
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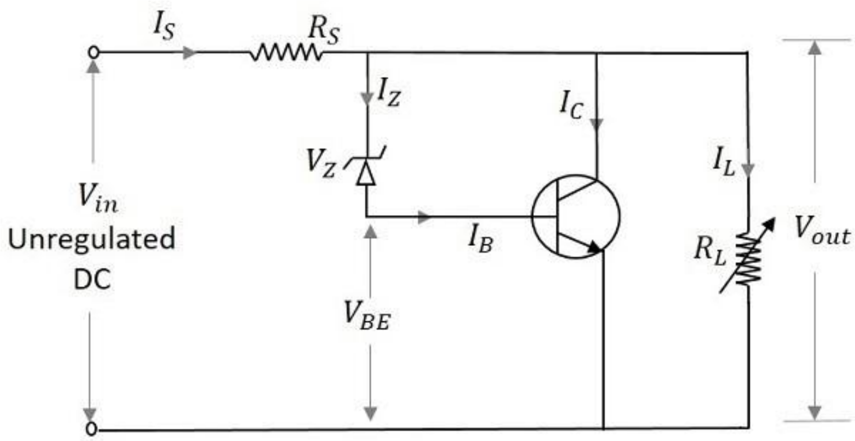
- Less efficient.

To minimize these limitations, transistor shunt regulator is used.

Transistor Shunt Voltage Regulator

A transistor shunt regulator circuit is formed by connecting a resistor in series with the input and a transistor whose base and collector are connected by a Zener diode that regulates, both in parallel with the load. The figure below shows the circuit diagram of a transistor shunt regulator.



Working of Transistor Shunt Voltage Regulator

If the input voltage increases, the V_{BE} and V_O also gets increased. But this happens initially. Actually when Vin increases, the current Iin also increases. This current when flows through R_S, causes a voltage drop V_S across the series resistor, which also gets increased with Vin. But this makes V_O to decrease. Now this decrease in V_O compensates the initial increase maintaining it to be constant. Hence V_O is maintained constant. If the output voltage decreases instead, the reverse happens.

If the load resistance decreases, there should be decrease in the output voltage V_O. The current through the load increases. This makes the base current and collector current of the transistor to decrease. The voltage across the series resistor becomes low, as the current flows heavily. The input current will be constant.

The output voltage appears will be the difference between the applied voltage Vi and the series voltage drop Vs. Hence the output voltage will be increased to compensate the initial decrease and hence maintained constant. The reverse happens if the load resistance increases

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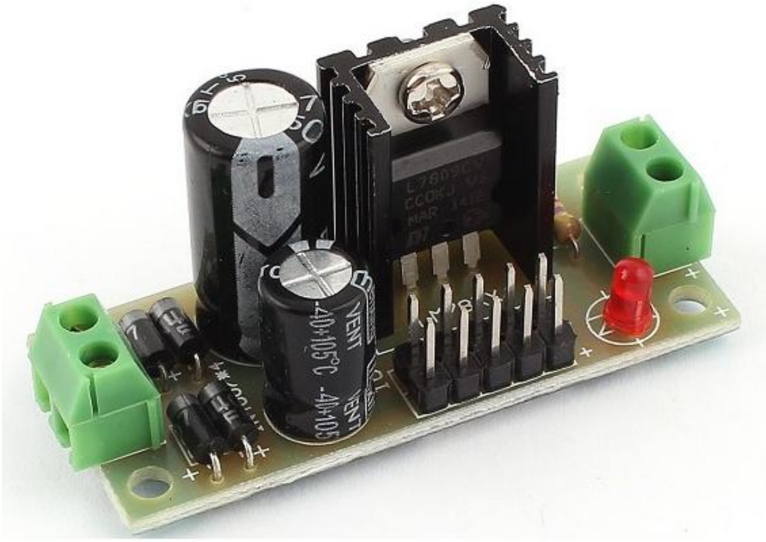

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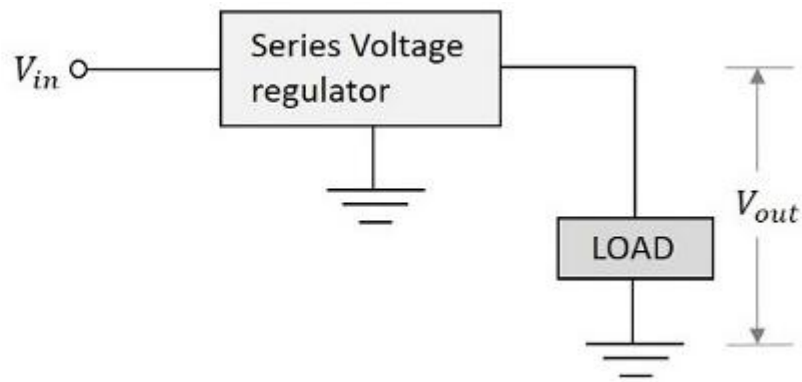

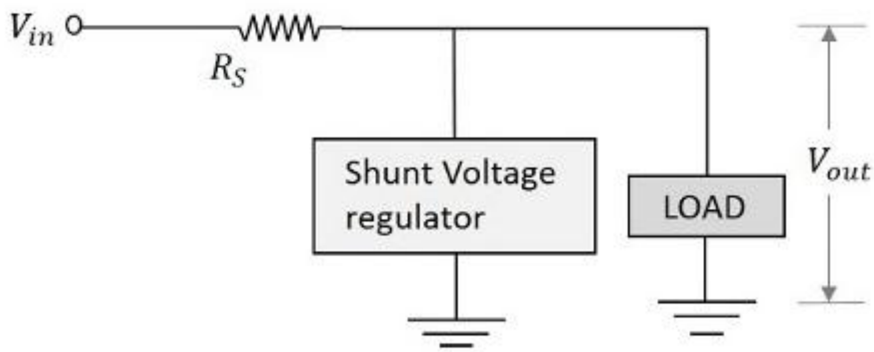

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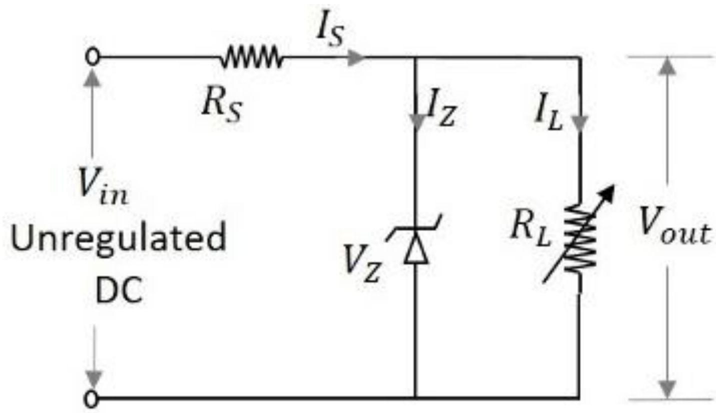

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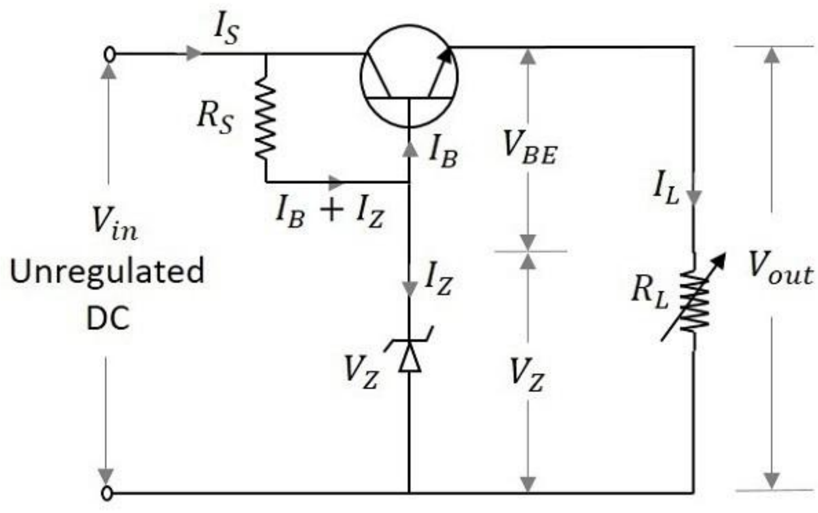

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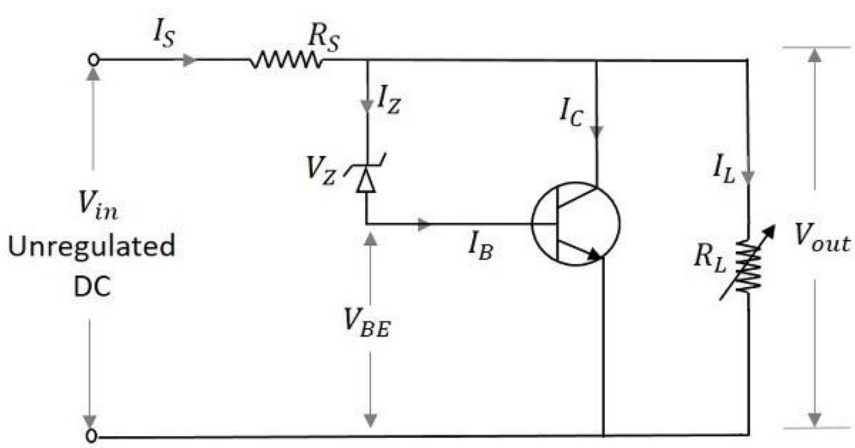

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The output voltage appears will be the difference between the applied voltage Vi and the series voltage drop Vs. Hence the output voltage will be increased to compensate the initial decrease and hence maintained constant. The reverse happens if the load resistance increases

IC Regulators

Voltage Regulators are now a days available in the form of Integrated Circuits (ICs). These are in short called as IC Regulators.

Along with the functionality like a normal regulator, an IC regulator has the properties like thermal compensation, short circuit protection and surge protection which are built into the device.

Types of IC regulators

IC regulators can be of the following types −

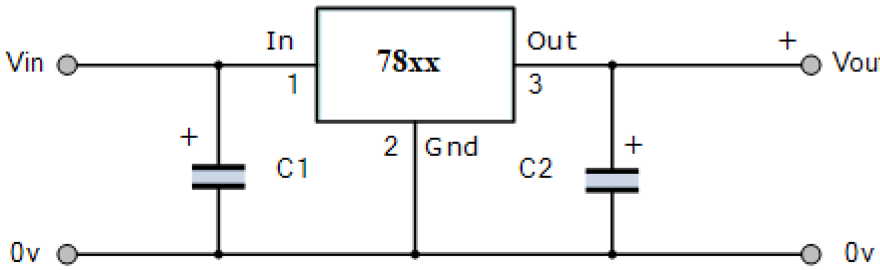
- Fixed Positive voltage regulators
- Fixed Negative voltage regulators
- Adjustable voltage regulators
- Dual-tracking voltage regulators

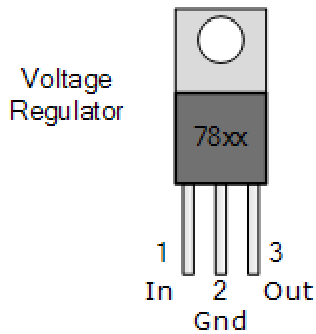
Let us now discuss them in detail.

Fixed Positive Voltage Regulator

The output of these regulators is fixed to a specific value and the values are positive, which means the output voltage provided is positive voltage.

The most used series is 78xx series and the ICs will be like IC 7806, IC 7812 and IC 7815 etc. which provide +6v, +12v and +15v respectively as output voltages.





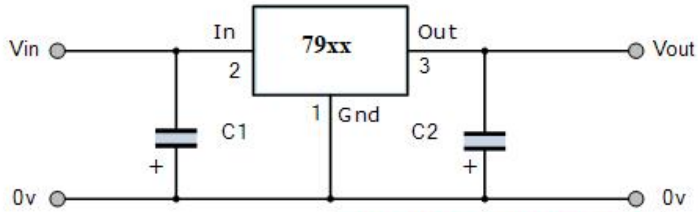
Type	Min Input Voltage	Output Voltage
7805	7V	+5V
7806	8V	+6V
7808	10V	+8V
7809	11V	+9V
7812	15V	+12V
7815	18V	+15V
7818	22V	+18V
7824	30V	+24V

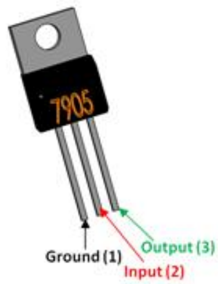
In the above figure, the input capacitor C1 is used to prevent unwanted oscillations and the output capacitor C2 acts as a line filter to improve transient response.

Fixed Negative Voltage Regulator

The output of these regulators is fixed to a specific value and the values are negative, which means the output voltage provided is negative voltage.

The most used series is 79xx series and the ICs will be like IC 7906, IC 7912 and IC 7915 etc. which provide -6v, -12v and -15v respectively as output voltages.



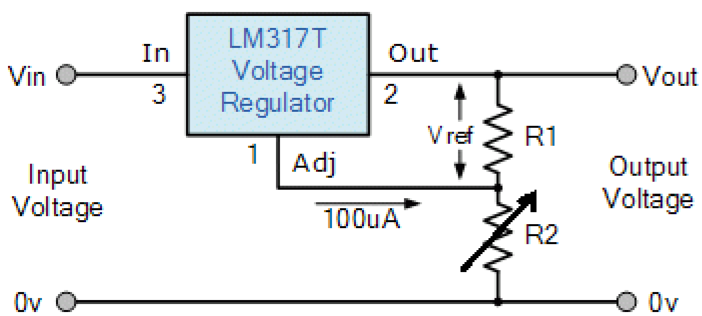


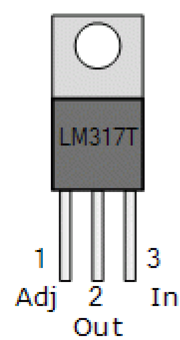
Type number	Output voltage
7905	−5.0 V
7905.2	−5.2 V
7906	−6.0 V
7908	−8.0 V
7912	−12.0 V
7915	−15.0 V
7918	−18.0 V
7924	−24.0 V

In the above figure, the input capacitor C1 is used to prevent unwanted oscillations and the output capacitor C2 acts as a line filter to improve transient response.

Adjustable Voltage Regulators

An adjustable voltage regulator has three terminals IN, OUT and ADJ. The input and output terminals are common whereas the adjustable terminal is provided with a variable resistor which lets the output to vary between a wide range.

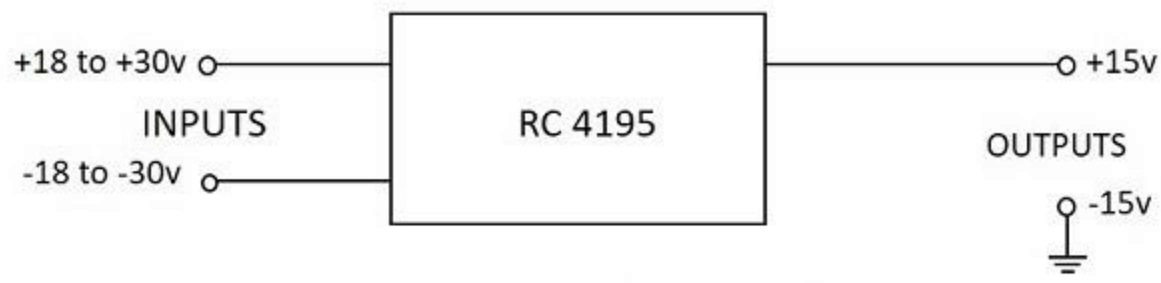




The above figure shows an unregulated power supply driving a LM 317 adjustable IC regulator which is commonly used. The LM 317 is a three terminal positive adjustable voltage regulator and can supply 1.5A of load current over an adjustable output range of 1.25v to 37v.

Dual-Tracking Voltage Regulators

A dual-tracking regulator is used when split-supply voltages are needed. These provide equal positive and negative output voltages. For example, the RC4195 IC provides D.C. outputs of +15v and -15v. This needs two unregulated input voltages such as the positive input may vary from +18v to +30v and negative input may vary from -18v to -30v.



The above image shows a dual-tracking RC4195 IC regulator. The adjustable dual-tacking regulators are also available whose outputs vary between two rated limits.

5.2. PCB construction process (Manually and using software)

PCB construction process

A PCB is used to connect electronic components electrically. This is done by making conductive path ways for circuit connections by etching tracks from copper sheet laminated onto a non-conductive substrate.

A PCB consists of a conducting layer that is made up of thin copper foil. The most commonly used PCB type is the FR-4. Boards may be single sided or double sided. Double sided PCB can be used to connect electronic components on both sides through through-hole plating. This is done by copper plating the walls of each hole so as to connect the conductive layers of the PCB.

Advantages of PCB over Bread-board

1. You can get a much higher density board with PCB.
2. You will find the PCB design to be more reliable than the one made on a bread board. The circuit will look neat without any wires popped up and will not fall apart.

3. You can have very precise control over the circuit component you are using, and you can comfortably fit in odd shaped components that are difficult to fix on a bread board.

4. For production of large volume of circuit boards, the costs become less and the soldering can be done by fully automated machines.

For PCB fabrication, some basic steps have to be followed. The detailed description on how to make PCB is explained below. The step by step procedure can be obtained by checking the following links

Once you have decided which electronic circuit is to be made on a PCB, you will have to make the design for the board on your PC. You can use different PCB designing CAD soft ware like EAGLEAND PROTUES. The most important point to note is that everything has to be designed in reverse because you are watching the board from above. If you need the circuit to be designed on a PCB, the layout must have a 360 degree flip.

The next step is to print out the layout using a laser printer. You must take special care in the type of paper that you are going to use. Though a little expensive, photo basic gloss transparent papers are known to be the most suitable for the process.

You must also make sure that you are able to fit all your components on to the print. First take a copy of the print on ordinary paper and lay down all the IC's and other components. The size of the layout must also fit the size of the PCB. Try to get the highest resolution when you are printing i on the paper. Always use black ink to take the layout. Increase the contrast and make the print more dark and thick. Do not take the print as soon as it comes out. Wait for some time for the ink to dry out.

The above said method is a little unprofessional, and thus the color may not b dark enough that you may be able to see through it. There might also be a few spots here and there. But this is more than enough as long as it can block UV light compared to the blank area.

Cut the layout by leaving a generous amount of blank space. Place the paper layout on the PCB and apply some heat by pressing an iron box on top of the paper on to the printed circuit board. Apply pressure for some time and keep the PCB intact for a few minutes. Now the layout is attached to both the board and the paper. We have to get rid of the paper, so that it gets permanently attached to the board. The only way to do this is to soak it in water. After two minutes, peel off the first layer of paper. After two to three hours of soaking, take it out and rub it with your finger to remove all the paper bits off.

PCB Etching Process

All PCB's are made by bonding a layer of copper over the entire substrate, sometimes on both sides. Etching process has to be done to remove unnecessary copper after applying a temporary mask, leaving only the desired copper traces.

Though there are many methods available for etching, the most common method used by electronics hobbyists is etching using ferric chloride ir hydrochloric acid. Both are abundant and cheap. Dip the PCB inside the solution and keep it moving inside. Take it out at times and stop the process as soon as the copper layer has gone. After etching, rub the PCB with a little acetone to remove the black colour, thus giving the PCB a shining attractive look. The PCB layout is now complete.

PCB Drilling

The components that have to be attached to the multi-layered PCB can be done only by VIAS drilling. That is, a pated-through hole is drilled in the shape of annular rings. Small drill bits that are made out of tungsten carbide is used for the drilling. A drill press is normally used to punch the holes. Usually, a 0.035 inch drill bit is used. For high volume production automated drilling machines are used.

Sometimes, very small holes may have to be drilled, and mechanical methods may permanently damage the PCB. In such cases, laser drilled VIAS may be used to produce an interior surface finish inside the holes.

Conductor Plating

The outer layer of the PCB contains copper connections (the part where the components are placed) which do not allow solder ability of the components. To make it solderable, the surface of the material has to be plated with gold, tin, or nickel.

Solder Resist

The other areas which are not to be solderable are covered with a solder resist material. It is basically a polymer coating that prevents the solder from bringing traces and possibly creating shortcuts to nearby component leads.

PCB Testing

In industrial applications, PCB's are tested by different methods such as Bed of Nails Test, Rigid Needle adaptor, CT scanning test, and so on. The basic of all tests include a computer program which will instruct the electrical test unit to apply a small voltage to each contact point, and verify that a certain voltage appears at the appropriate contact points.

PCB Assembling

PCB assembling includes the assembling of the electronic components on to the respective holes in the PCB. This can be done by through-hole construction or surface-mount construction. In the former method, the component leads are inserted into the holes drilled in the PCB. In the latter method, a pad having the legs similar to the PCB design is inserted and the IC's are placed or fixed on top of them. The common aspect in both the methods is that the component leads are electrically and mechanically fixed to the board with a molten metal solder.

Ways to make a Circuit Board

There are in all three basic methods to make PCB:

1. Iron on Glossy paper method (circuit designed using CAD software)
2. Circuit by hand on PCB (circuit drawn manually)
3. Laser cutting edge etching.

In the first and the second method of making PCB, most of the steps are similar but the only difference between them is at the way of transferring the circuit to the PCB. In the first method the circuit to be constructed is designed on circuit making CAD software and in the 2^{nd} method the circuit is directly designed on the PCB by hand using permanent black marker. Since laser method is industrial method to make PCB we will get in detail of first two methods to make PCB at home.

PCB Design:

PCB design is usually done by converting your circuit's schematic diagram into a PCB layout using PCB layout software or manually by hand. There are many cool open source software packages for PCB layout creation and design.

Materials required for making Circuit Board

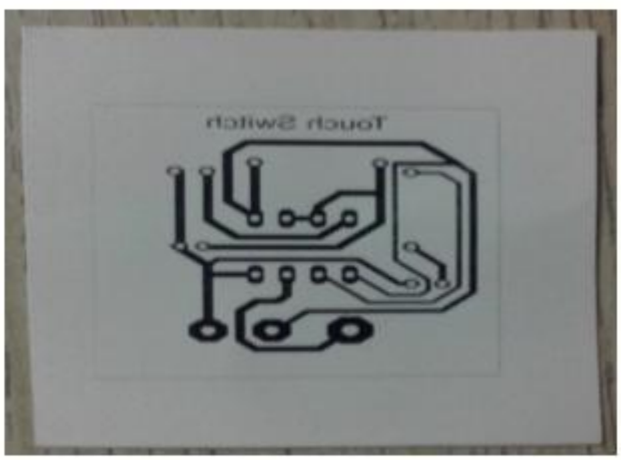
- FeCl3 powder/solution (same as etching solution),
- photo/glossy paper, permanent black marker,
- blade cutter,

- sandpaper,
- kitchen paper and
- Cotton wool.

STEP 1: Take printout of circuit board layout

Take a print out of your PCB layout using the laser printer and the A4 photo paper/glossy paper. Keep in mind the following points:

- You should take the mirror print out.
- Select the output in black both from the PCB design software and printer driver settings.
- Make sure that the printout is made on the glossy side of the paper.



PCB print on glossy paper

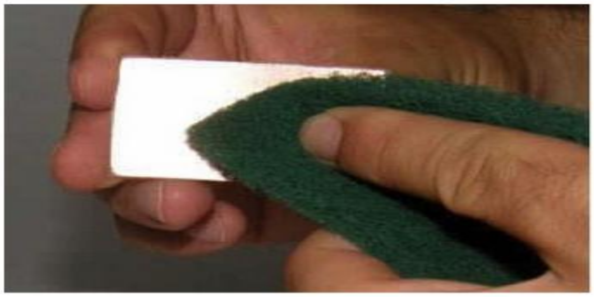
STEP 2: Cutting the copper plate for the circuit board

Cut the copper board according to the size of layout using a hacksaw or a cutter.

Copper clad plate

Cutting the plate

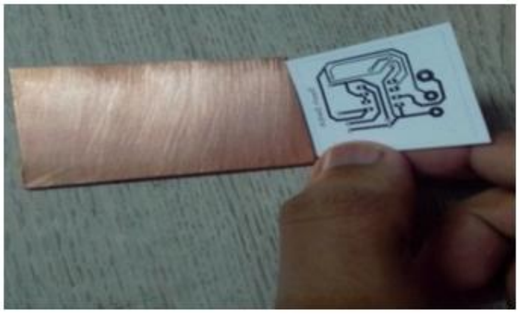
Next, rub the copper side of PCB using steel wool or abrasive spongy scrubs. This removes the top oxide layer of copper as well as the photo resists layer. Sanded surfaces also allow the image from the paper to stick better**.**



Rubbing away the top oxide layer

STEP 3: Transferring the PCB print onto the copper plate

Method 1 Iron on glossy paper method (for complex circuits): Transfer the printed image (taken from a laser printer) from the photo paper to the board. Make sure to flip top layer horizontally. Put the copper surface of the board on the printed layout. Ensure that the board is aligned correctly along the borders of the printed layout. And use tape to hold the board and the printed paper in the correct position.



Place the printed side of the paper on the plate

Method 2 Circuit by hand on PCB (for simple and small circuits): Taking the circuit as reference, draw a basic sketch on copper plate with pencil and then by using a permanent black marker.

Using the permanent marker
for sketching the PCB

STEP 4: Ironing the circuit from the paper onto the PCB plate

After printing on glossy paper, we iron it image side down to copper side. Heat up the electric iron to the maximum temperature. Put the board and photo paper arrangement on a clean wooden table (covered with a tablecloth) with the back of the photo paper facing you.

Using pliers or a spatula, hold one end and keep it steady. Then put the hot iron on the other end for about 10 seconds. Now, iron the photo paper all along using the tip and applying little pressure for about 5 to 15 mins.

Pay attention towards the edges of the board – you need to apply pressure, do the ironing slowly. Doing a long hard press seems to work better than moving the iron around. Here, the heat from the iron transfers the ink printed on the glossy paper to the copper plate.

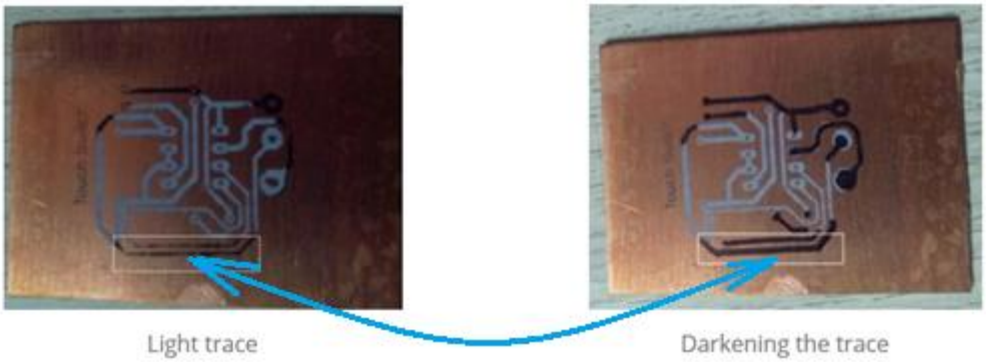
Iron the paper onto the plate

CAUTION: Do not directly touch copper plate because it is very hot due to ironing.

After ironing, place printed plate in Luke warm water for around 10 minutes. Paper will dissolve, then remove paper gently. Remove the paper off by peeling it from a low angle.

Peeling the paper

In some cases while removing the paper, some of the tracks get fainted. In the figure below, you can see that the track is light in color hence we can use a black marker to darken it as shown.

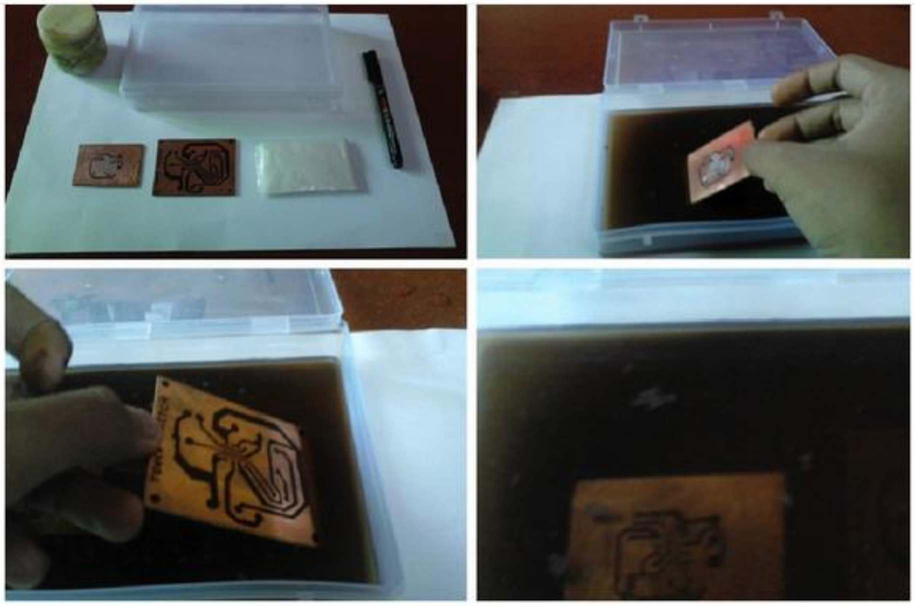


STEP 5: Etching the plate

You need to be really careful while performing this step.

- First put rubber or plastic gloves.
- Place some newspaper on the bottom so that the etching solution does not spoil your floor.
- Take a plastic box and fill it up with some water.
- Dissolve 2-3 tea spoon of ferric chloride power in the water.
- Dip the PCB into the etching solution (Ferric chloride solution, $FeCl_3$) for approximately 30 mins.
- The $FeCl_3$ reacts with the unmasked copper and removes the unwanted copper from the PCB.

This process is called as Etching. Use pliers to take out the PCB and check if the entire unmasked area has been etched or not. In case it is not etched leave it for some more time in the solution.



Etching the plate

Gently move the plastic box to and fro so that etching solution reacts with the exposed copper. The reaction is given as:

$$\mathbf{Cu + FeCl3 = CuCl3 + Fe}$$

After every two minutes check if all the copper has been removed. If it hasn't then place it back in the solution and wait.

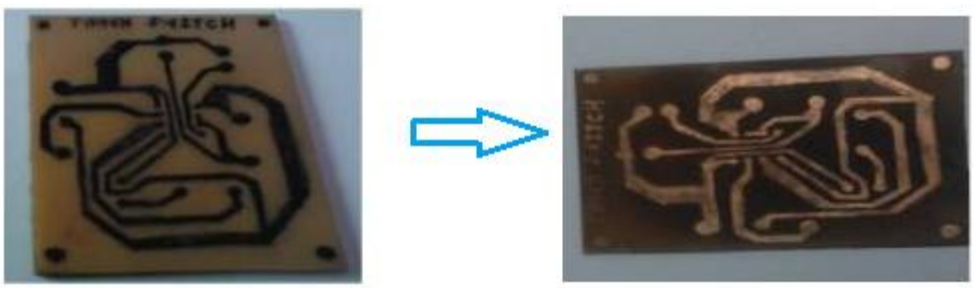
CAUTION: Always use gloves while touching the plate having the solution.

Etched copper plate

STEP 6: Cleaning, disposing and final touches for the circuit board

Be careful while disposing the etching solution, since its toxic to fish and other water organisms. And don't think about pouring it in the sink when you are done, it is **illegal** to do so and might damage your pipes. So dilute the etching solution and then throw it away somewhere safe.

A few drops of thinner (nail polish remover works well) on a pinch of cotton wool will remove completely the toner/ink on the plate, exposing the copper surface. Rinse carefully and dry with a clean cloth or kitchen paper. Trim to final size and smoothen edges with sandpaper



Removing the ink

Now, drill holes using a PCB driller like this: PCB driller and solder all your cool components. If you want that traditional green PCB look, apply solder resist paint on top: PCB lacquer. And finally! Your super cool circuit board would be ready!

Step 7: Drilling the etched PCB

Place the PCB on support for raising some height from the table surface, Use PCB hand drill or electrical pcb drill to make holes into the PCB.

After this, the PCB is ready for component placement and soldering.

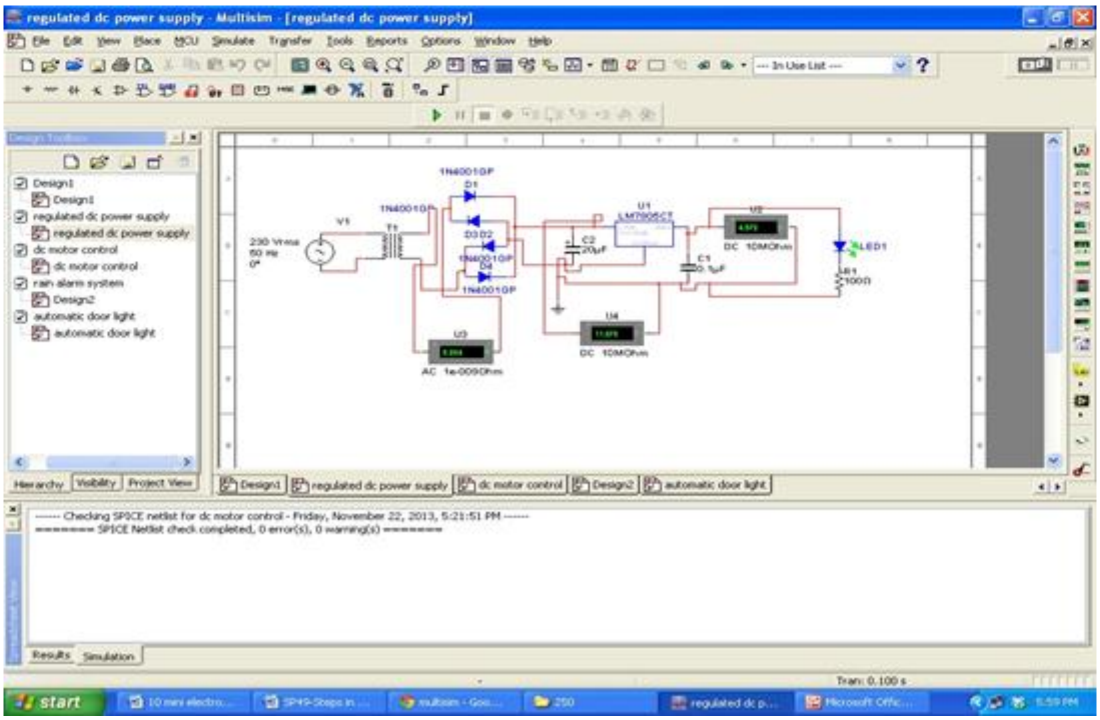
Preparation of PCB by using software

For more practice to preparation of PCB by using software, we should follow below steps. Materials and Equipment's

•Laser printer
•Copper clad board
•Scotch pads or fine steel wool
•Laminator
•Ferric chloride or ammonium per sulfate
•Plastic or glass tray

•Sharply marker
•Drill press
•Wire gauge drill bits
•Magazines

Step– 1 Make a design using Multisim software on PCs



Below are the given steps to draw a circuit using Multisim and simulation step

1. On your windows panel, click on the following link: Start >>> Programs –> National –> Instruments –> Circuit design suite 11.0 –> multisim 11.0.
2. A multisim software window appears with a menubar and blank space resembling a breadboard, to draw the circuit.
3. On the menu bar, select place –> components
4. A window appears with the title-‘select the components’
5. Under the heading ‘Database’ – select ‘Master Database’ from the drop down menu.
6. Under the heading ‘group’- select the required group. If you want to go for voltage or current source or ground. If you want to go for any basic component

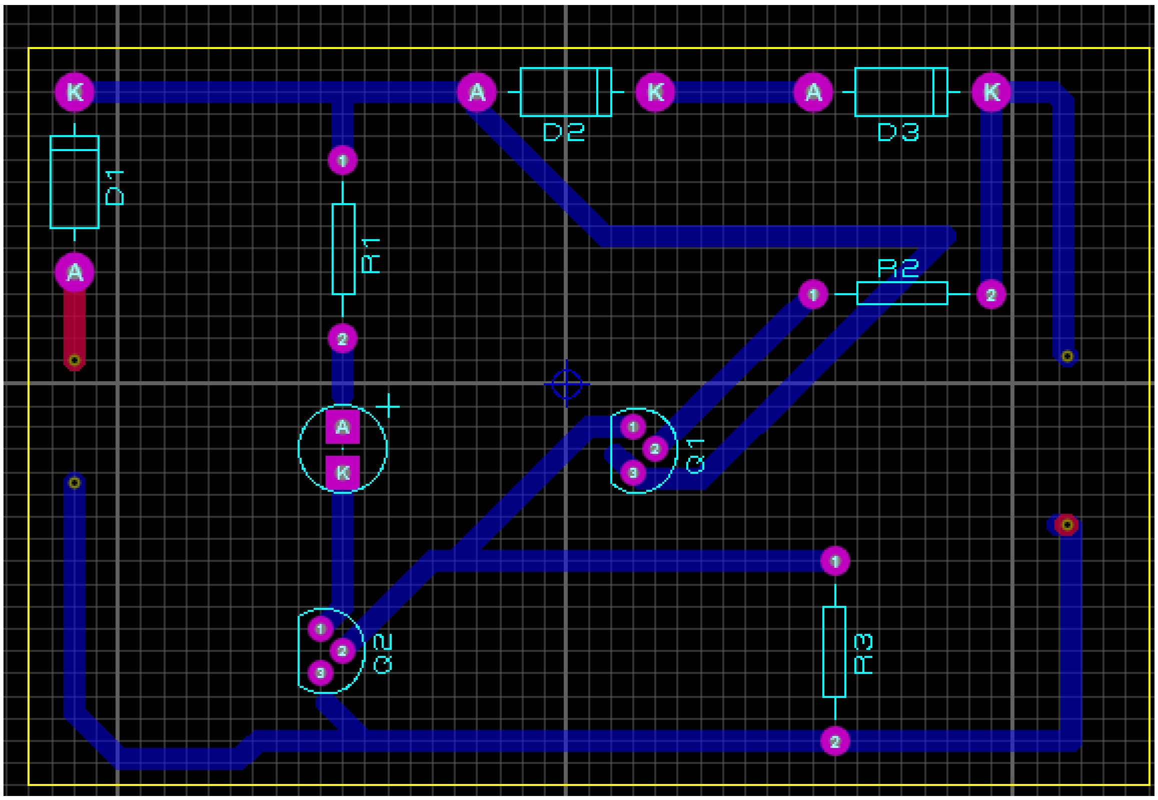
like a resistor, a capacitor etc. Here first we have to place the input AC supply source, hence select Source –>Power Sources –> AC_power. After the component is placed (by clicking the 'ok' button), set the value of RMS voltage to 230 V and frequency to 50Hz.

7. Now again under the components window, select basic, then transformer, then select TS_ideal. Since for an ideal transformer, the inductance of both coils is same, to achieve our output we have the change the secondary coil inductance. Now we know ratio of inductance of the transformer coils is equal to square of the ratio of turns. Since turns ratio required in this case is 19, therefore we have to set the secondary coil inductance to 0.27mH. (Primary coil inductance is at 100mH).
8. Under the components window, select basic, then diodes, and then select the diode IN4003. Select 4 such diodes and place them in a bridge rectifier arrangement.
9. Under the components windows, select basic, then Cap _Electrolytic and select the value of capacitor to be 20microFarad.
10. Under the components window, select power, then Voltage_ Regulator and then select 'LM7805' from the drop down menu.
11. Under the components window, select diodes, then select LED and from the drop down menu, select LED_green.
12. Using the same procedure, select a resistor with the value of 100 Ohms.
13. Now that we have all the components and have an idea about the circuit diagram, let us get into drawing the circuit diagram on the multisim platform.
14. To draw the circuit, we have to make proper connections between the components using wires. To select wires, go to Place, then wire. Remember to connect the components only when a junction point appears. In multisim, the connecting wires are indicated by red color.
15. To get an indication of the voltage across the output, follow the given steps. Go to Place, then 'Components', then 'indicator', then 'Voltmeter', then select the first component.
16. Now your circuit is ready to be simulated.
17. Now click on 'Simulate' then select 'Run'.

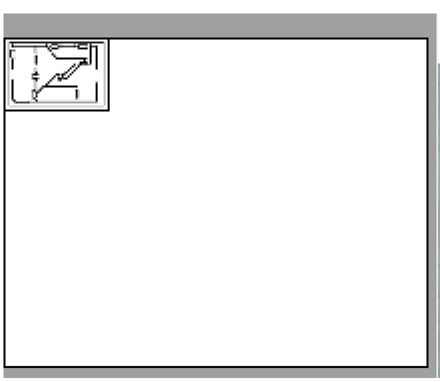
18. Now you can see the LED at the output blinks, which is indicated by the arrows going green in color.

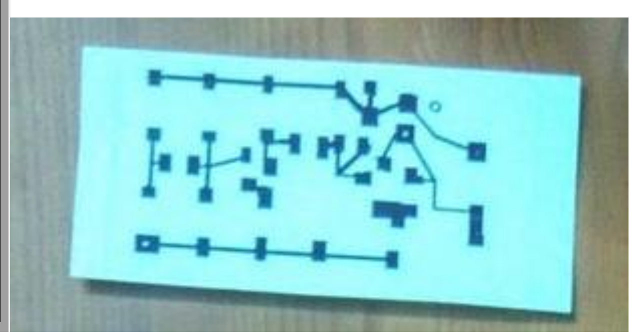
19. You can verify whether you are getting correct value of voltage across each component by placing a Voltmeter in parallel.

Step 2: convert the design into PCB layout using the software



Step 3. Print out the circuit from PC



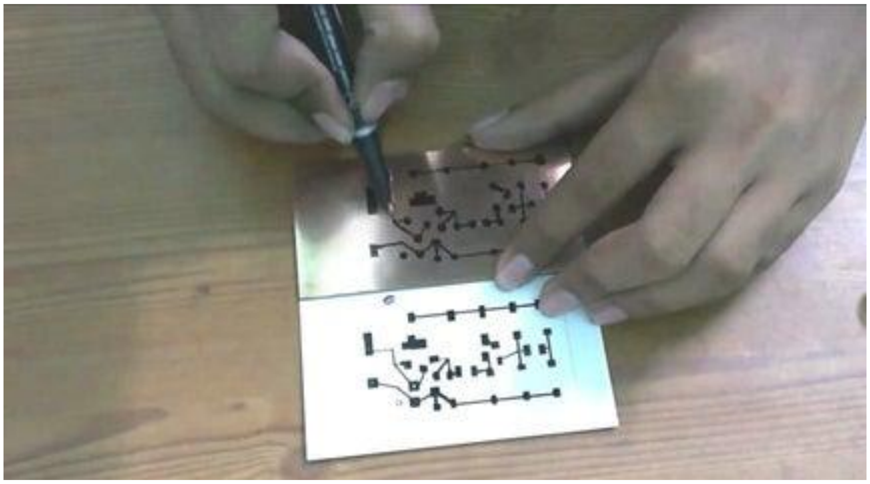


Step 4: Cleaning Copper Clad

Scrub the copper clad with scrubber until it becomes shines.

Step 5: transferring the printed circuit to the Copper Clad

Method 1 Circuit by hand on PCB (for simple and small circuits): Taking the circuit as reference, draw a basic sketch on copper plate with pencil and then by using a permanent black marker.



Method 2 Iron on glossy paper method (for complex circuits): Transfer the printed image (taken from a laser printer) from the photo paper to the board. Make sure to flip top layer horizontally. Put the copper surface of the board on the printed layout. Ensure that the board is aligned correctly along the borders of the printed layout. And use tape to hold the board and the printed paper in the correct position.

- warm up the laminator

- Transfer the Image

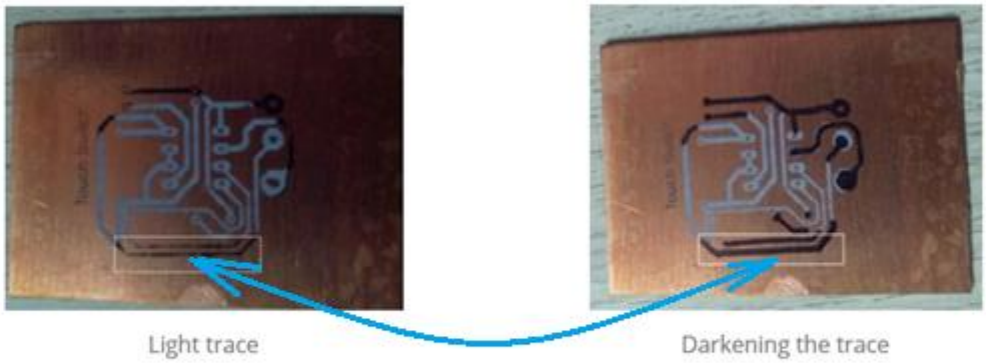
Place your printout face down on the copper clad board. While holding it as flat against the board as possible, begin feeding it into the laminator faceup. Once the roller in the laminator grabs the board let it slip through your fingers while maintaining enough drag to keep the paper flat against the board. After about 2seconds the board will exit the other side of the laminator. Rotate the board 180 degrees and pass it back through the laminator again face up. After it finishes its second pass put the very hot board to the side to cool to room temperature. THE BOARD WILL BE VERY HOT FOR THE NEXT 10 MINS!

- Removing the Paper

Once your board has cooled to room temperature place the board in a bowl of warm soapy water and let is soak until the paper is soft and mushy (a few minutes). Depending on the magazine paper you may have to peel off the paper or even rub the board with your fingers to remove the part. With the Parts Express magazine it practically falls off. Remove the paper and as much paper residue as you can and lightly dry the PCB with a paper towel.

Step 6: Inspect and Correct

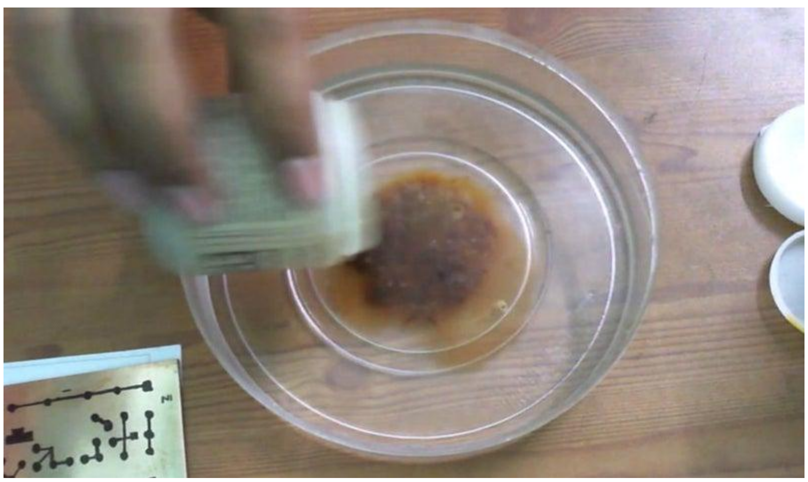
Inspect the PCB for any areas that the toner didn't adhere to or flaked off during the paper removal. Using a Sharpie marker fill in those areas, Chances are you'll have to fill in a few spots on your boards until you find a paper that works for you. If your PCB is beyond repair with a Sharpie then go back at step two and start over. The beauty is that you aren't wasting expensive specialty paper, chemicals, or copper clad board when these rare mistakes happen. After making your repairs let the ink from the Sharpie dry.



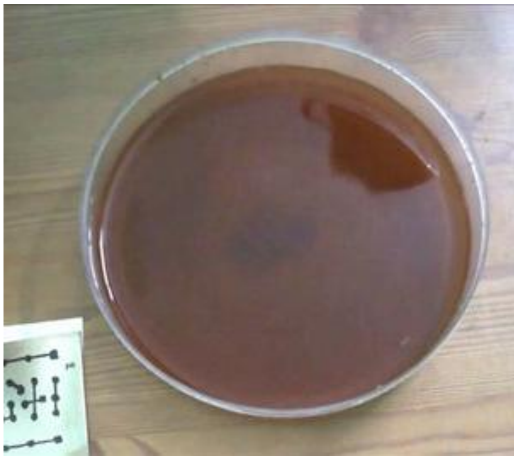
Step 7: transferring the printed circuit to the Copper Clad

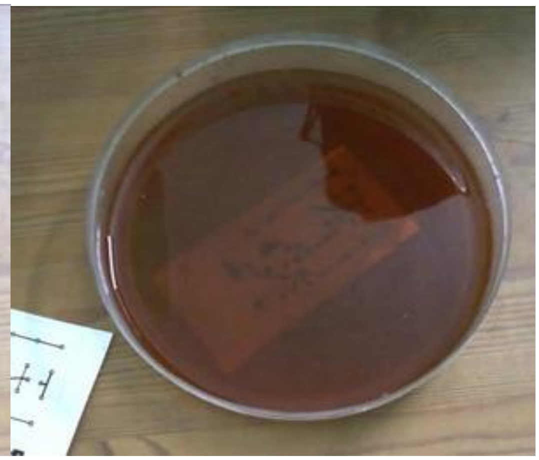
Add sufficient amount of ferric chloride powder to the water and stir it well to make ferric chloride solution for PCB etching.

The most common etchants Ferric chloride Others include ammonium per sulfate and home brew mixtures of muriatic acid and hydrogen per oxide. Follow the instructions provided with the type of etchant that you select.



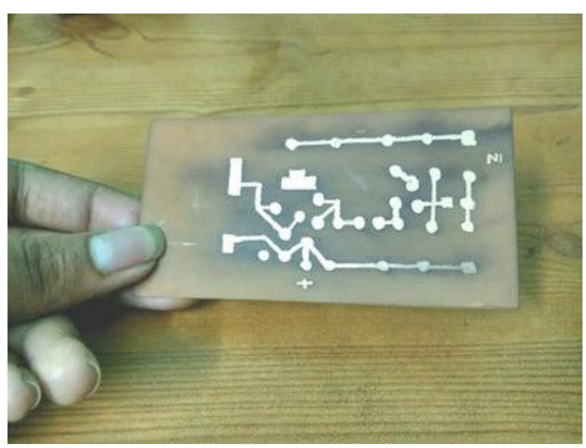
Place the copper clad in the solution such that layout facing upward and wait for few minutes until etching is completed.





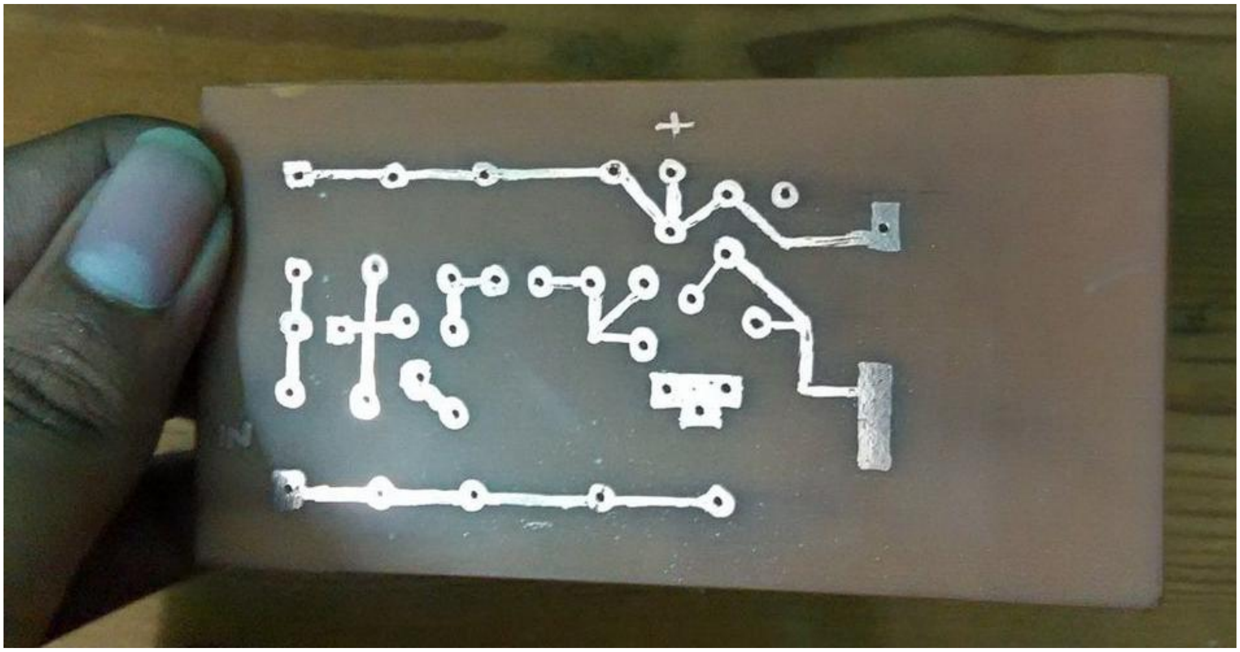
Step 8: Cleaning Marker Traces

After the etching is completed, place the PCB in water and clean it. Clean the permanent marker traces by using nail polish remover or petrol.



Step 9: Drilling the etched PCB

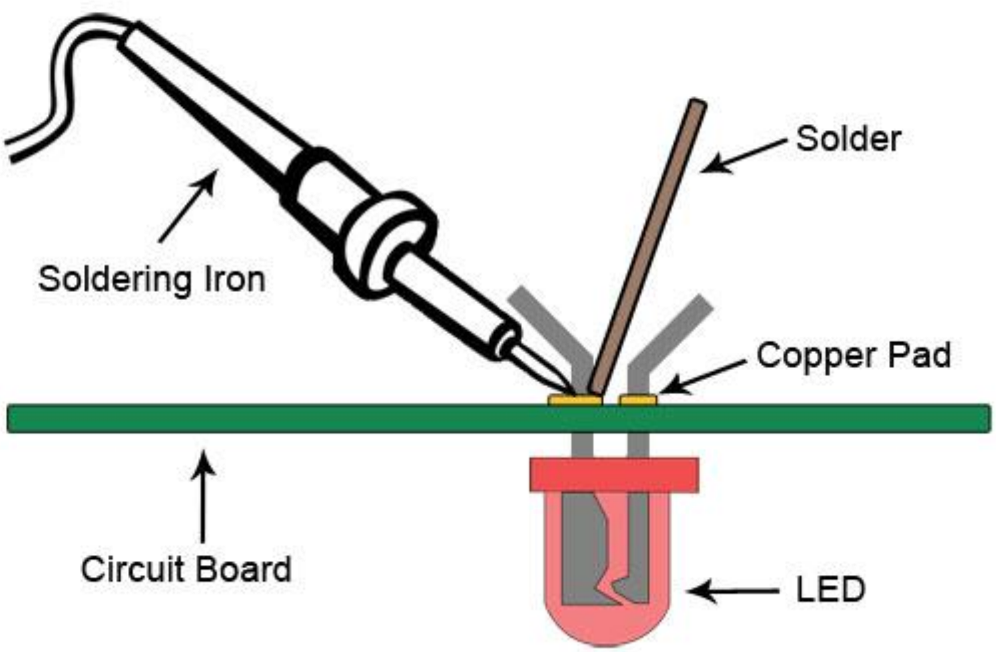
Place the PCB on support for raising some height from the table surface, Use PCB hand drill or electrical pcb drill to make holes into the PCB.



After this, the PCB is ready for component placement and soldering.

5.3. Soldering/de-soldering method and techniques

If you were to take apart any electronic device that contains a circuit board, you'll see the components are attached using soldering techniques. Soldering is the process of joining two or more electronic parts together by melting solder around the connection. Solder is a metal alloy and when it cools it creates a strong electrical bond between the parts. Even though soldering can create a permanent connection, it can also be reversed using a desoldering tool as described below.



Soldering is a process in which two or more metal items are joined together by melting and then flowing a filler metal into the joint—the filler metal having a relatively low melting point. Soldering is used to form a permanent connection between electronic components.

The metal to be soldered is heated with a soldering iron and then solder is melted into the connection.

- Only the solder melts, not the parts that are being soldered.
- Solder is a metallic "glue" that holds the parts together and forms a connection that allows electrical current to flow.
- You can use a solderless breadboard to make test circuits, but if you want your circuit to last for more than a few days, you will want to solder the components together.

Safety Precautions

1. **Caution:** A soldering iron can heat to around 400°C, which can burn you or start a fire, so use it carefully.
2. Unplug the iron when it is not in use.

3. Keep the power cord away from spots where it can be tripped over.

4. Take great care to avoid touching the tip of the soldering iron on a power line. If a power cord is touched by a hot iron, there is a serious risk of burns and electric shock.

5. Always return the soldering iron to its stand when it is not in use.

6. Never put the soldering iron down on your work bench, even for a moment!

7. Work in a well-ventilated area.

8. The smoke that will form as you melt solder is mostly from the flux and can be quite irritating. Avoid breathing it by keeping your head to the side of, not above, your work.

9. Solder contains lead, which is a poisonous metal. Wash your hands after using solder.

Preparation for Soldering:

- Warm-up

Allow the soldering iron to reach adequate temperature. The recommended temperature setting is between 600 and 750° F. Some tips may have recommended operating temperatures that should be observed.

- ***Clean Tip***

A clean tip promotes heat transfer and helps to prevent unwanted "solder bridges" from forming. A heavily oxidized tip will make it impossible to solder properly.

The steps to maintain clean tips are as follows:

- Moisten sponge.
- Wipe tip on sponge.
- "Wet" tip with solder – just enough for a very thin coating.
- Repeat if necessary to obtain a clean, shiny tip surface. Also, repeat between each solder operation to maintain a clean tip (See Figure 3).

Fig3. A properly cleaned and “wetted” soldering iron tip.

Tinning the Tip

Before you can start soldering, you need to prep your soldering iron by tinning the tip with solder. This process will help improve the heat transfer from the iron to the item you’re soldering. Tinning will also help to protect the tip and reduce wear.

Step 1: Begin by making sure the tip is attached to the iron and screwed tightly in place.

Step 2: Turn on your soldering iron and let it heat up. If you have a soldering station with an adjustable temp control, set it to 400′ C/ 752′ F.

Step 3: Wipe the tip of the soldering iron on a damp wet sponge to clean it. Wait a few seconds to let the tip heat up again before proceeding to step 4.

Step 4: Hold the soldering iron in one hand and solder in the other. Touch the solder to the tip of the iron and make sure the solder flows evenly around the tip.

You should tin the tip of your iron before and after each soldering session to extend its life. Eventually, every tip will wear out and will need replacing when it becomes rough or pitted.

1. Component mounting. Components are pushed through from the top side of the board and the leads are bent slightly to hold the component while soldering.

2. Components are then soldered to the board as shown in Figures 4.

    a. The soldering iron tip should be placed in contact with both the trace (foil)and the lead. The two should be heated only enough to melt solder in order to avoid damaging sensitive components and to avoid delaminating of the PCB traces.

    b. Solder is then touched to the area and allowed to flow freely around the lead and to cover the solder pad. A minimal amount of solder should be applied. Only enough solder to cover the joint and to form a smooth fillet should be used.

    c. The iron should be removed after the solder has flowed properly and wetted all surfaces. The component and the board should not be moved until the solder has hardened (up to several seconds, depending on the lead and trace

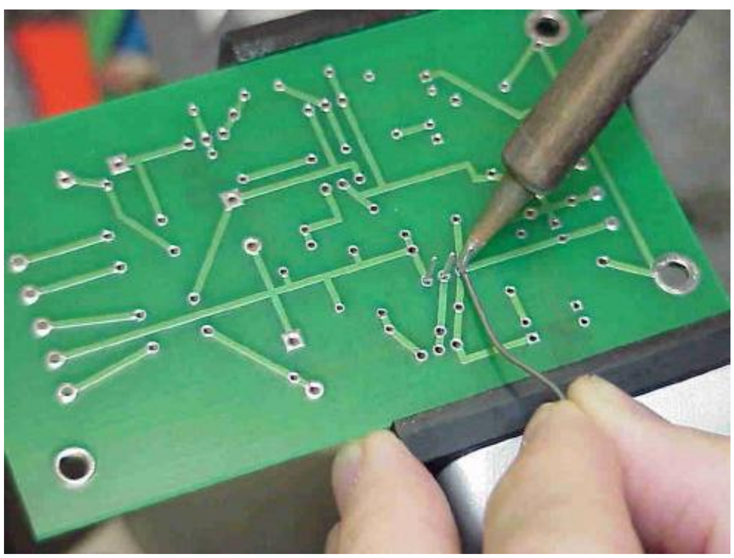
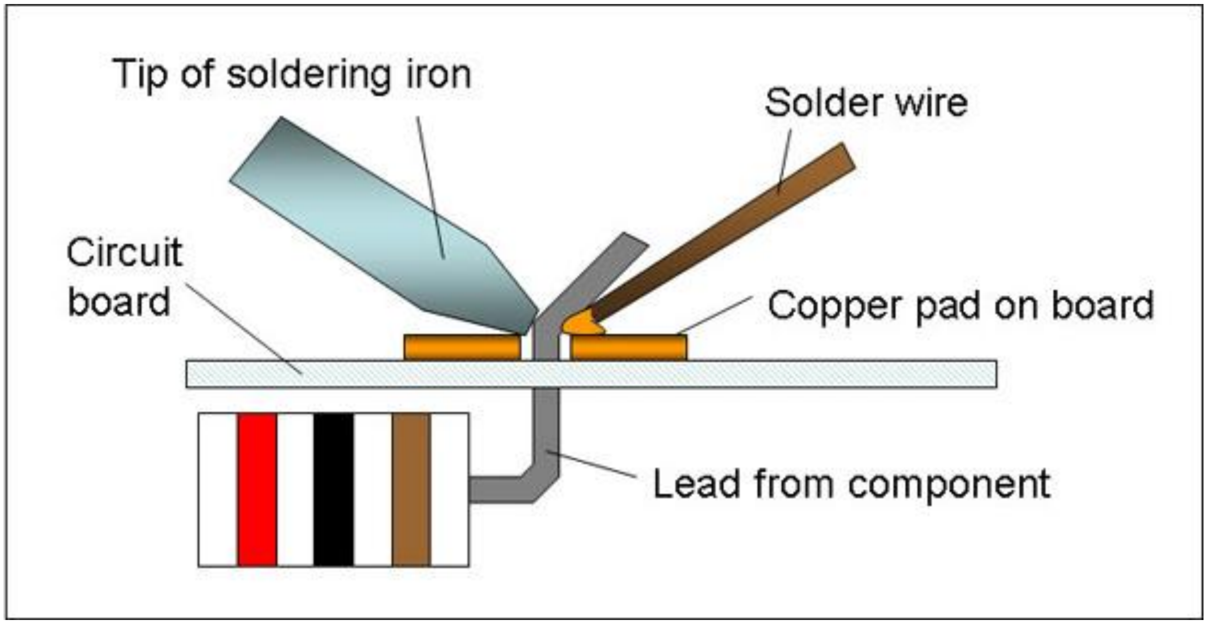
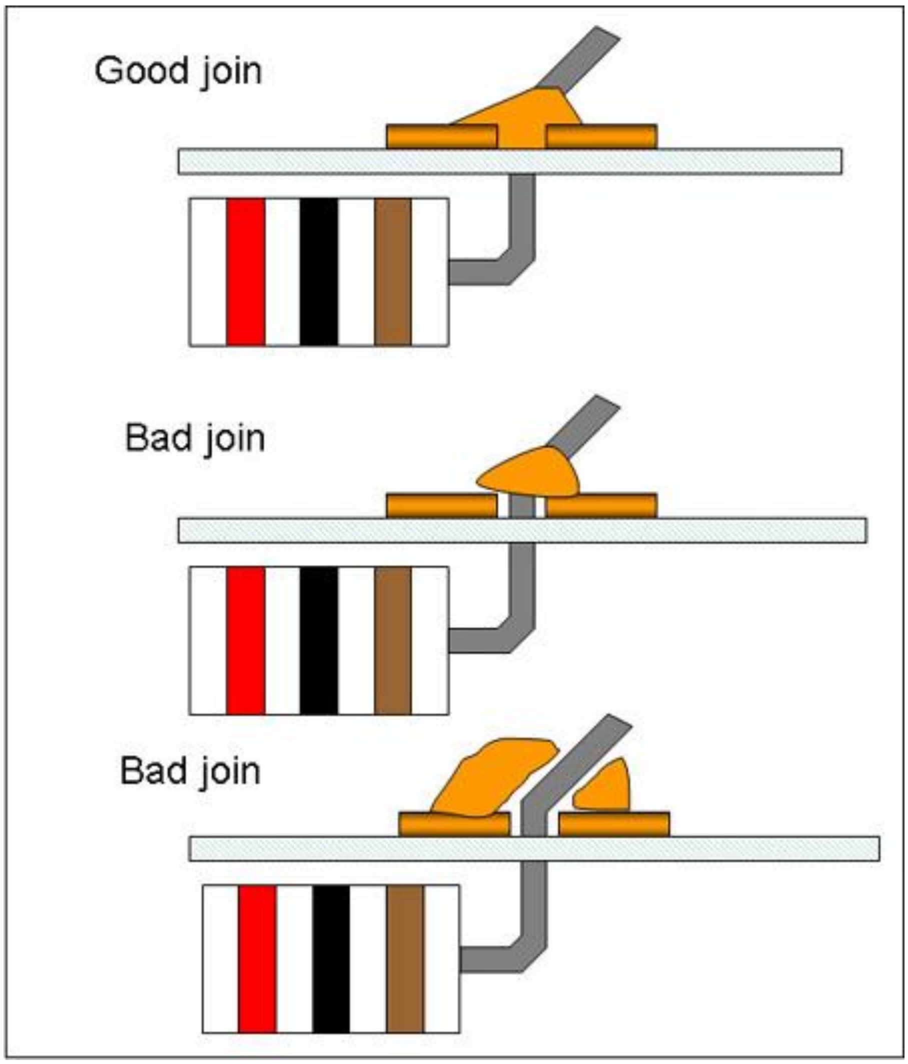


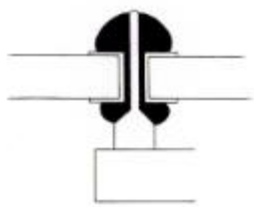
Figure 4. Soldering a component to a PCB

Good soldering and Bad soldering Joints

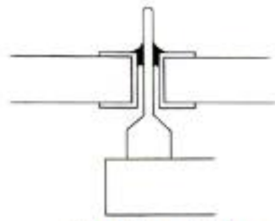
Here are some example of Good soldering and Bad soldering joint.


Tip of soldering iron
Solder wire
Circuit board
Copper pad on board
Lead from component

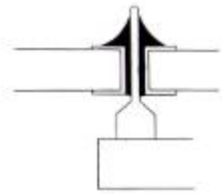

Good join
Bad join
Bad join



Too much soldering



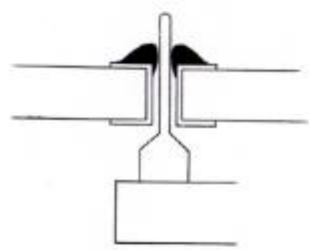
Too little soldering



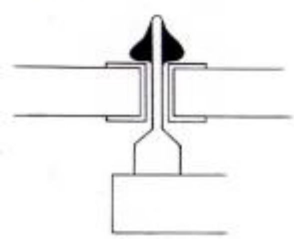
Good soldering

Cold Solder joints: A cold joint is a joint in which the solder does not make good contact with the component lead or printed circuit board pad. Cold joints occur when the component lead or solder pad moves before the solder is completely cooled. Cold joints make a really bad electrical connection and can prevent your circuit from working.

Cold joints can be recognized by a characteristic grainy, dull gray color, and can be easily fixed. This is done by first removing the old solder with a Disordering tool or simply by heating it up and flicking it off with the iron. Once the old solder is off, you can re-solder the joint, making sure to keep it still as it cools.



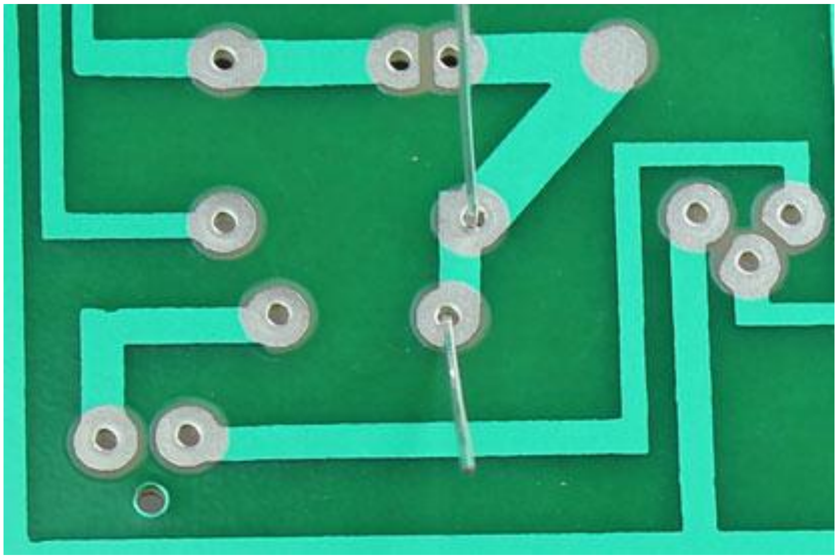
Cold soldering joints



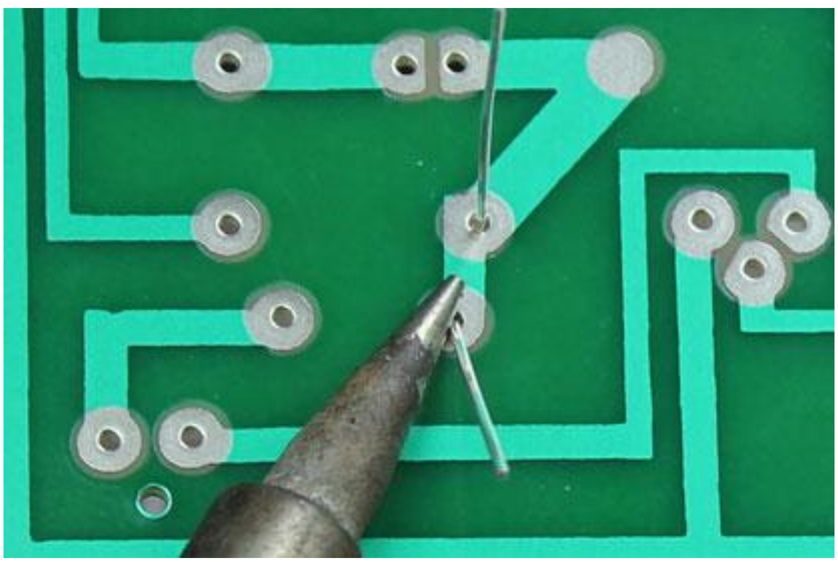
How to Solder

To better explain how to solder, we're going to demonstrate it with a real world application. In this example, we're going to solder an LED to a circuit board.

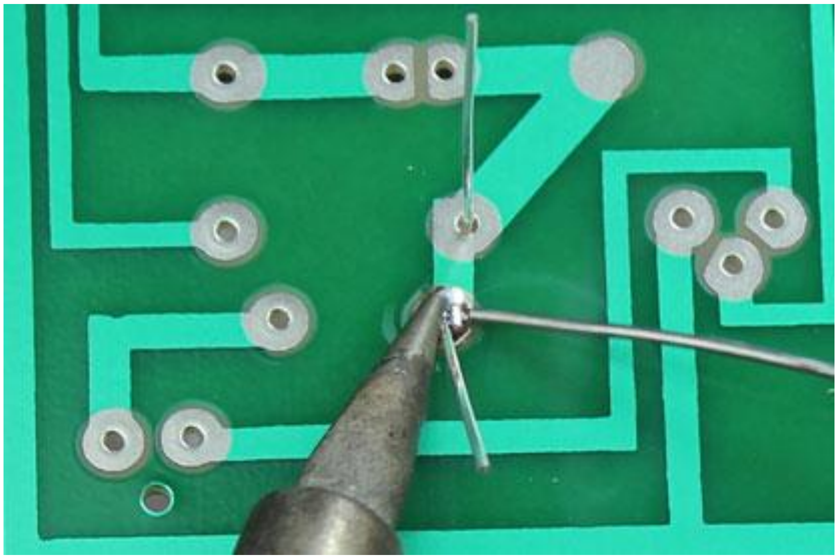
Step 1: Mount the Component – Begin by inserting the leads of the LED into the holes of the circuit board. Flip the board over and bend the leads outward at a 45′ angle. This will help the component make a better connection with the copper pad and prevent it from falling out while soldering.



Step 2: Heat The Joint – Turn your soldering iron on and if it has an adjustable heat control, set it to 400'C. At this point, touch the tip of the iron to the copper pad and the resistor lead at the same time. You need to hold the soldering iron in place for 3-4 seconds in order to heat the pad and the lead.

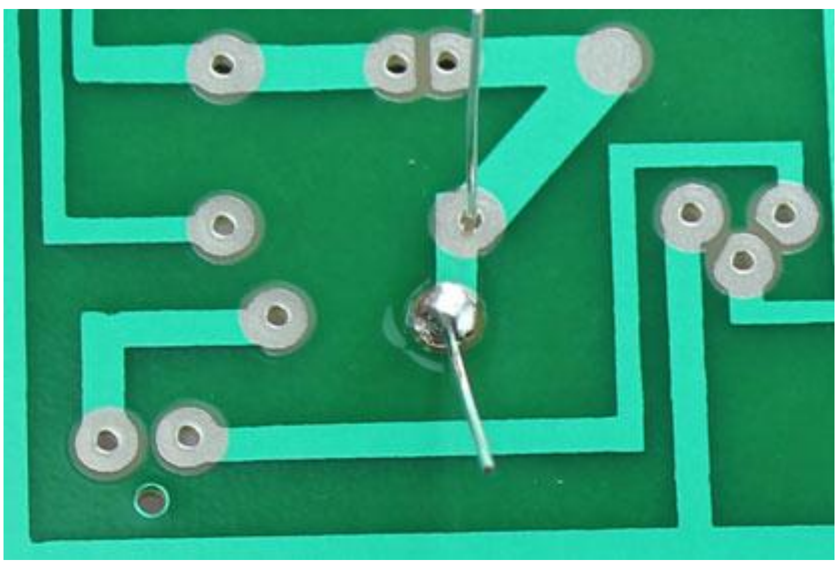


Step 3: Apply Solder To Joint – Continue holding the soldering iron on the copper pad and the lead and touch your solder to the joint. **IMPORTANT** – Don't touch the solder directly to the tip of the iron. You want the joint to be hot enough to melt the solder when it's touched. If the joint is too cold, it will form a bad connection.



Step 4: Snip The Leads – Remove the soldering iron and let the solder cool down naturally. Don't blow on the solder as this will cause a bad joint. Once cool, you can snip the extra wire from leads.

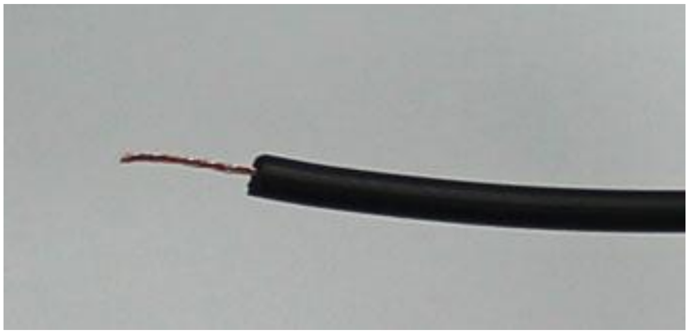
A proper solder joint is smooth, shiny and looks like a volcano or cone shape. You want just enough solder to cover the entire joint but not too much so it becomes a ball or spills to a nearby lead or joint.



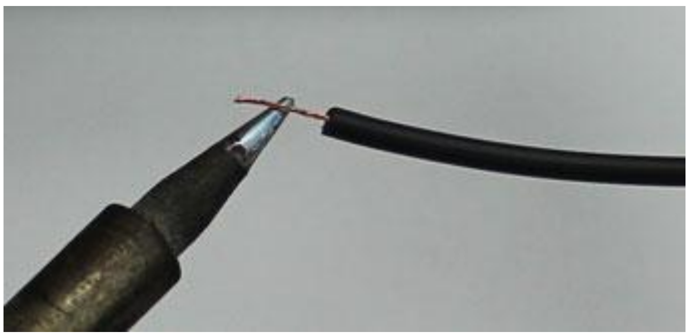
How To Solder Wires

Now it's time to show you how to solder wires together. For this process, it's recommended to use helping hands or other type of clamp device.

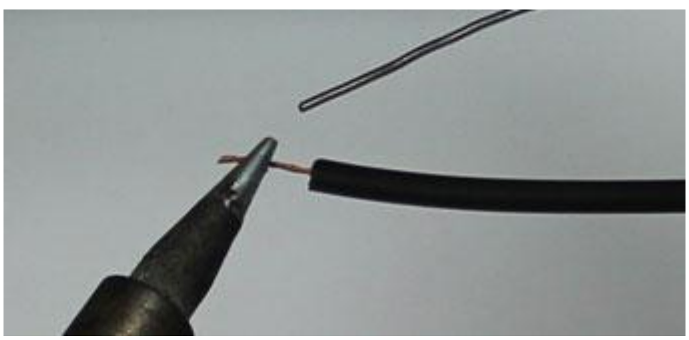
Begin by removing the insulation from the ends of both wires you are soldering together. If the wire is stranded, twist the strands together with your fingers.



Make sure your soldering iron is fully heated and touch the tip to the end of one of the wires. Hold it on the wire for 3-4 seconds.



Keep the iron in place and touch the solder to the wire until it’s fully coated. Repeat this process on the other wire.

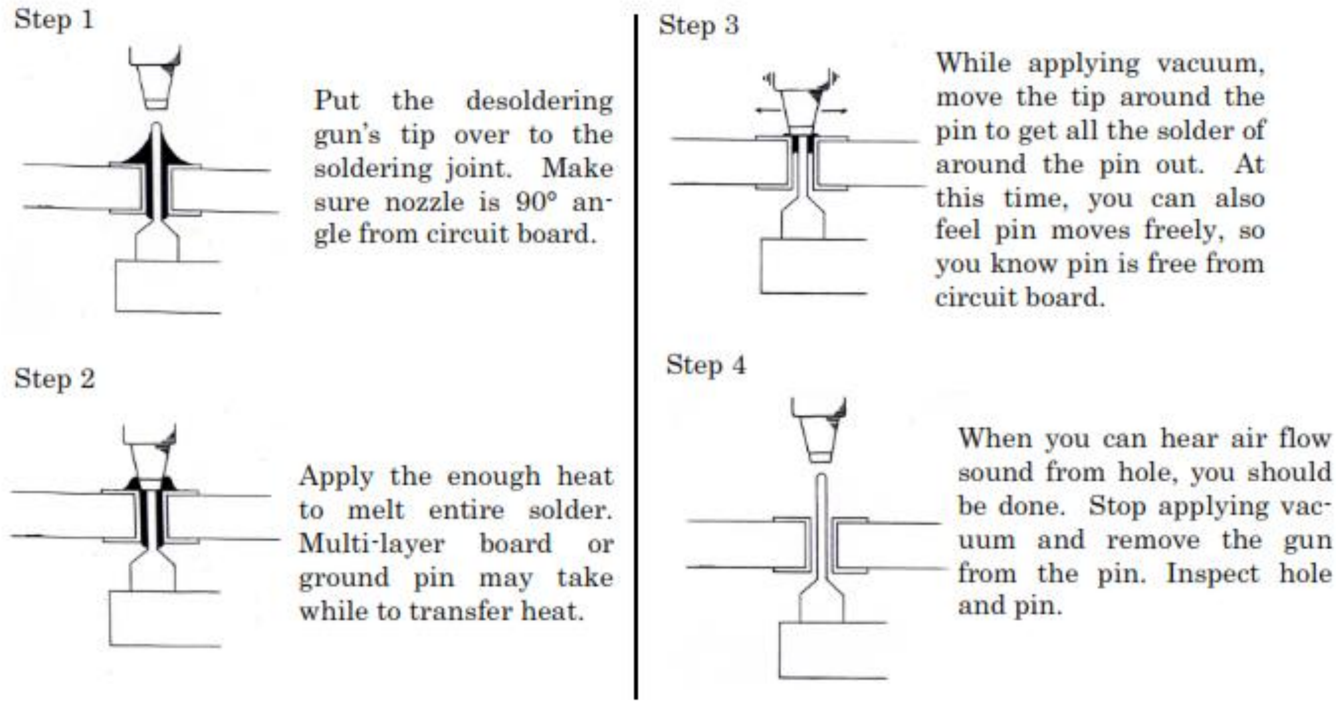


Hold the two tinned wires on top of each other and touch the soldering iron to both wires. This process should melt the solder and coat both wires evenly.

Remove the soldering iron and wait a few seconds to let the soldered connection cool and harden. Use heat shrink to cover the connection.

De soldering

De soldering is removing the solder from a joint and components from a circuit board for troubleshooting, repair and replacement. De-soldering is required when electronic components need to be removed from circuit, usually because they are faulty. It may sometimes be necessary during testing or assembly, if a wrong part has been fitted or a modification has to be made. In the field, it's not uncommon for faulty electronic components to be swapped out, or poor joints(perhaps "dry" or gray joints) to need re-making properly, months or years after manufacture.



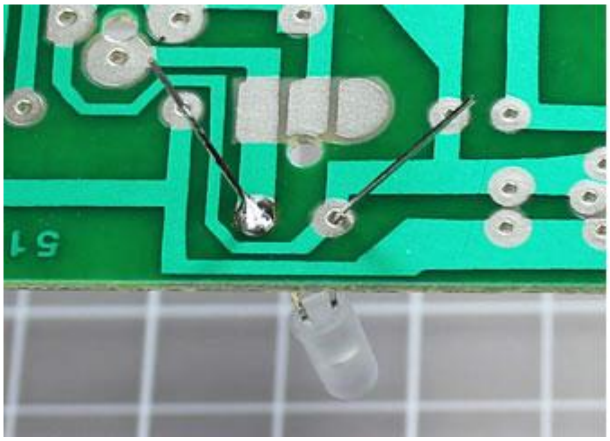
When you done with Desoldering, the parts that you are trying to remove should move freely. Ifit doesn't, find which pin is still has solder left, and re-apply fresh solder to it and try Desoldering process again. The multi-layer circuit board requires more heat to get solder to melt. Make sure pin start to move freely by moving the tip of soldering gun before you apply vacuum to it.

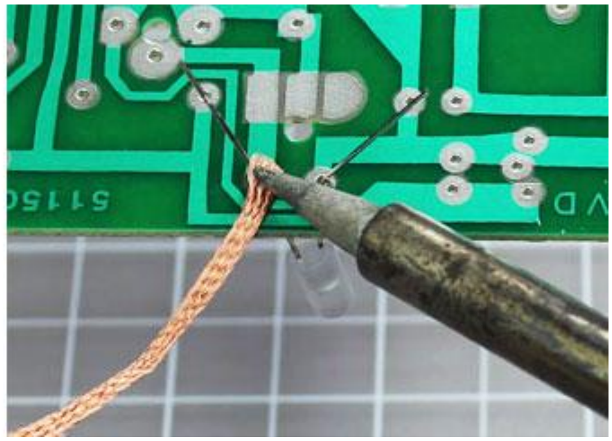
Desoldering using desoldering braid

To desolder a joint, you will need solder wick which is also known as desoldering braid.

Step 1 – Place a piece of the desoldering braid on top of the joint/solder you want removed.

Step 2 – Heat your soldering iron and touch the tip to the top of the braid. This will heat the solder below which will then be absorbed into the desoldering braid. You can now remove the braid to see the solder has been extracted and removed. Be careful touching the braid when you are heating it because it will get hot.





Self-Check -5	Written Test

Directions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Use the Answer sheet provided in the next page.

1. Distinguish the difference between the half wave and full wave rectifier. (4 points)
2. Write the steps to follow when preparing PCB for electrical electronic circuit construction (both using CAD software and manually) (10 points)

Note: - Satisfactory rating: 7 and above - Unsatisfactory Rating: below 7

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating: _____________

Name: ___________________________ Date: ________________

Desoldering in theory should utilize the same temperatures as soldering. Flux present during soldering helps reduce the required temperature. The same is true for desoldering, apply some flux to remove contaminants.

The melting point (per Weller) for various solder compositions is as follows:

Tin/Lead	Melting Point °C (°F)
40/60	230 (460)
50/50	214 (418)
60/40	190 (374)
63/37	183 (364)
95/5	224 (434)

Please note, these temperatures are melting points, ***not*** recommended soldering or desoldering iron temperatures.

Most guides recommend starting with the lowest temperature that will work in a short amount of time. This is a matter of opinion, but generally no less than 260°C (500°F).

The following factors will greatly affect desoldering performance:

- The type of solder used (lead-free requires higher temperatures)
- The age of the board and amount of contamination
- The number of layers in the board
- Size of ground/power/thermal planes connected to joint being desoldered
- Mass of component, leads, heatsink, etc.

For example, desoldering a small through-hole component with small traces on a 2-layer board is much easier than desoldering the same component on a multi-layer board with large copper pours connected to the component. A larger component with more mass will require more time or more heat.

Think of it this way, if you set your temperature to 370°C (700°F) (a starting temperature recommended by Weller), the mass of solder and copper closest to the iron tip will heat quickly, but it will take some time for that heat to spread. If you are desoldering something with a heat sink or a ground plane, the extra mass will conduct heat away from the area of interest, and you must either apply the iron for a longer duration, or increase the temperature. The danger is that you may damage components if you exceed their temperature tolerance.

The Hakko 808 desoldering gun (which I use) ranges from 380-480°C (715-895°F). It does a remarkable job for most things, but I've occasionally needed to preheat a board for stubborn components that have a lot of mass or are connected to a heatsink.

Your temperature selection of 400°C (750°F) seems good. You could start at a lower temperature since you have the option, depending on the above factors.

Self-Check - 6	Written Test

Directions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Use the Answer sheet provided in the next page.

1. Write the correct melting point in C^o for the following solder compositions (5 points)

   40/60 = _______

   50/50 = _______

   60/40 = _______

   63/37 = _______

   95/05 = _______

2. What are the factors that will greatly affect desoldering performance? (5 points)

Note: - Satisfactory rating: 7 and above - Unsatisfactory Rating: below 7

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet - 7	Undertaking confirmation of construction successfully

Once the joint is made you should inspect it. Check for cold joints (described a little above and at length below), shorts with adjacent pads or poor flow. If the joint checks out, move on to the next. To trim the lead, use a small set of side cutters and cut at the top of the solder joint. After you have made all the solder joints, it is good practice to clean all the excess flux residue from the board. Some fluxes are hydroscopic (they absorb water) and can slowly absorb enough water to become slightly conductive. This can be a significant issue in a hostile environment such as an automotive application. Most fluxes will clean up easily using methyl hydrate and a rag but some will require a stronger solvent. Use the appropriate solvent to remove the flux, then blow the board dry with compressed air.

Common Problems and Troubleshooting

1. Solder will not flow.
   - The parts to be joined may be dirty. Remove the solder and clean the parts.
2. The connection looks grainy or crystalline.
   - Parts were moved before the solder was allowed to cool.
   - Reheat to form a good joint. You may need a larger soldering iron to heat connections adequately.
3. The tip is oxidized.
   - Soldering is much easier with a shiny, clean tip.
   - Clean the tip with a damp synthetic sponge while the iron is hot.
   - To avoid oxidizing the tip, do not leave the iron plugged in when not in use.
   - Do not use the iron at a higher temperature than is necessary to melt solder.
   - Clean the tip of the iron on a damp synthetic sponge as soon as it starts to change from a silver color.
4. There is too much or too little solder.
   - Using too much solder can cause a solder bridge, which means that two adjacent joints are accidentally connected.
   - Using too little solder might result in poor electrical continuity between the board and component. The connection should be smooth, shiny, and rigid

Self-Check - 7	Written Test

Directions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Use the Answer sheet provided in the next page.

1. What are the common problems that are caused during soldering and measures taken for correction? (10 points)

Note: - Satisfactory rating: 5 and above - Unsatisfactory Rating: below 5

You can ask you teacher for the copy of the correct answers.

Answer Sheet

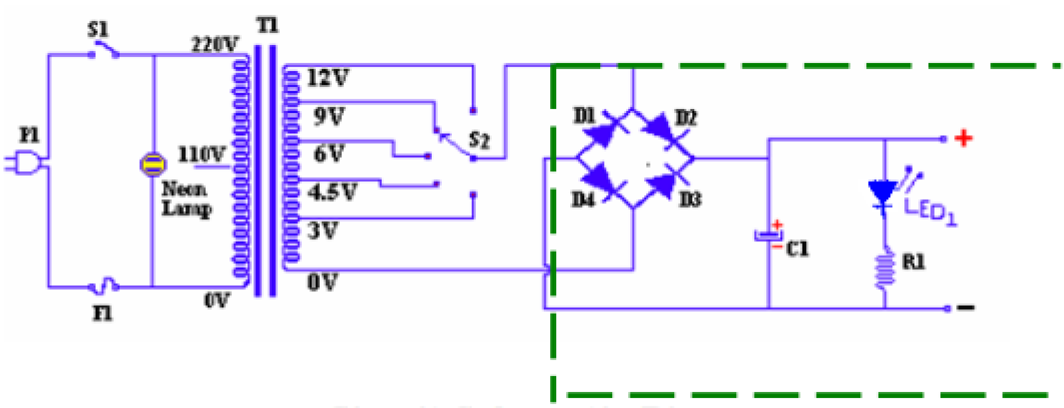
Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Operation Sheet 1	Techniques of Following correct sequence of operation in Designing and Preparing PCB of AC-DC Power Supply

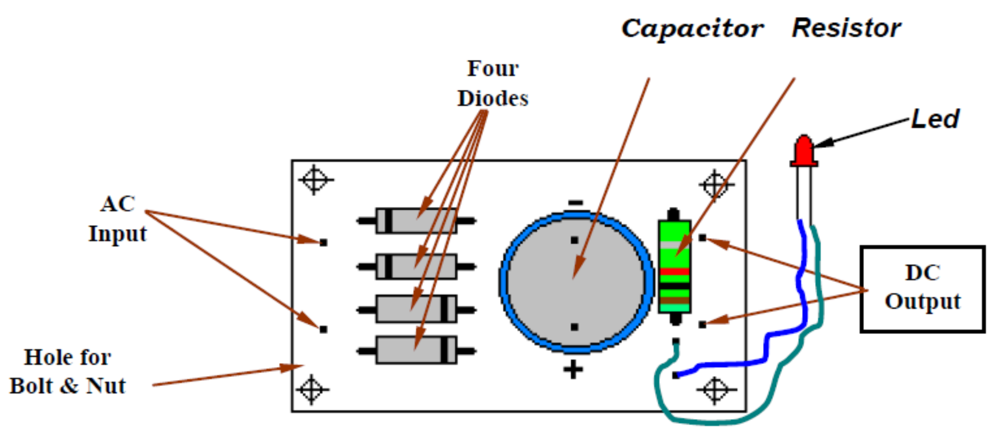
Techniques for Following correct sequence of operation in Preparing the Layout Diagram in the PCB

1. Prepare the schematic diagram of the circuit.



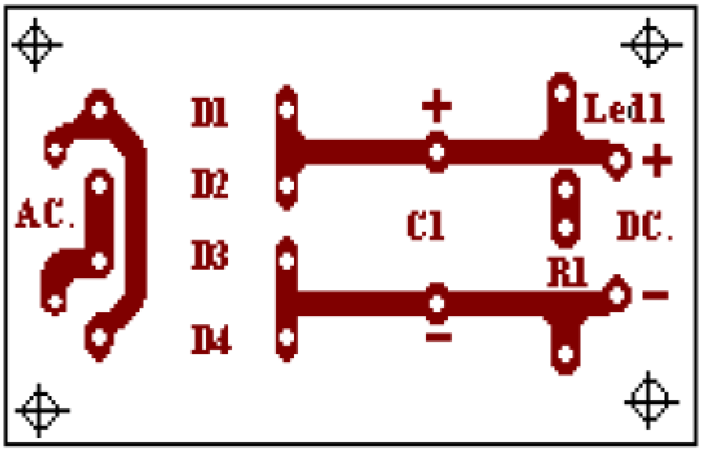
Circuit Schematic Diagram

2. Arrange the component circuit in a graphing paper to show/illustrate the same design factor in PCB lay outing. Note: Actual size of the component should be adapted for component arrangement and mounting.



PCB Layout

3. Interconnect each component by copying the connection in the schematic diagram.



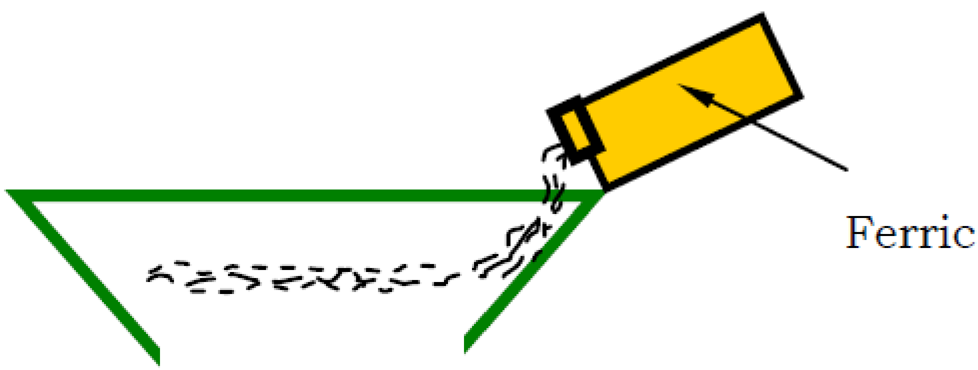
Schematic Diagram

4. Double-check the connection.
5. Trace the designed PCB by using a carbon paper and mark it on the copper side of the clad board.
6. And use a high point permanent marker for marking. Do the marking three times and be careful not to shorten each line marking.

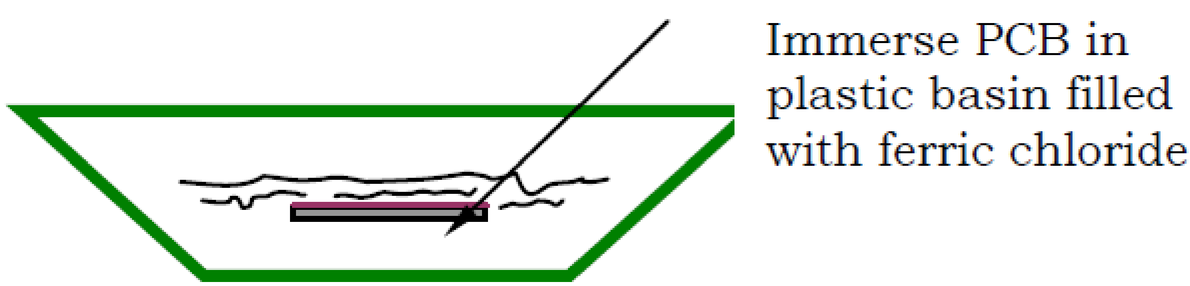
Operation Sheet - 2	Techniques of Following correct sequence of operation in Designing and Preparing PCB of AC-DC Power Supply

Techniques of Following correct sequence of operation in PCB Etching Steps in PCB Etching

1. Prepare the necessary tools and materials needed in PCB etching.
2. Wear your apron and surgical gloves in order to prevent accidental splash of the solution on your clothes or on your skin.
3. Pour the ferric chloride in the plastic basin.

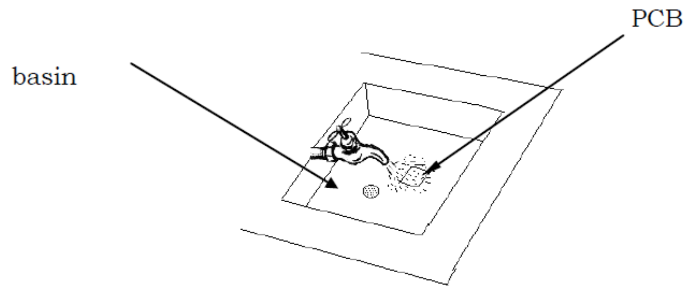


4. Etch the PCB by immersing it in a basin filled with ferric chloride until the uncovered part of the copper clad is totally etched.



5. After 10 - 15 minutes, check the PCB if all the parts needed to be removed are totally etched (using the two popsicle sticks in hauling). If not yet, return it into the plastic basin filled with ferric chloride. After 3 – 5 minutes check it again.

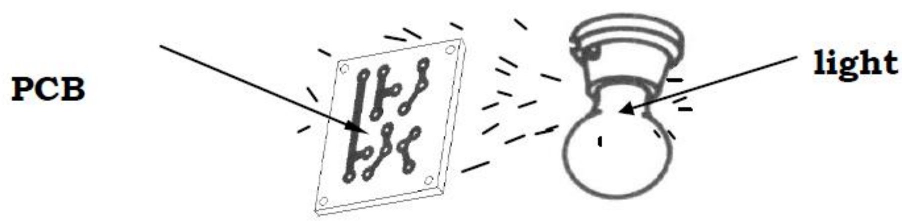
6. Haul the PCB from the plastic basin and wash it in a free flowing water to remove the remaining residue in the PCB.



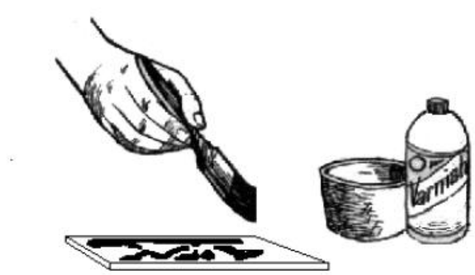
7. With a clean and dry piece of cloth, wipe the wet PCB.

8. Pour a little amount of lacquer thinner on a clean dry piece of cloth and wipe the markings of the permanent marker pen in the copper clad. (Note: In doing this, you should wear your surgical gloves.)

9. Aided by bright light, inspect the PCB for possible hairline break or short. If there is a hairline path between the copper conductors, cut it by a knife or cutter. And if there is a break between the copper conductors, solder it.



10. Apply plastic varnish to the newly etched PCB to prevent corrosion or rust, and let it dry before touching it.



Operation Sheet - 3	Techniques of Following correct sequence of operation in Designing and Preparing PCB of AC-DC Power Supply

Techniques of Following correct sequence of operation in *Mini Drill Setup*

1. Loosen the chuck by using a long metal tool and change the drill bit. This is done in a counter clockwise movement.

2. Insert the drill bit 1mm diameter in size and attach it to the chuck of the unit.

3. Turn the long metal tool clockwise to tighten the jaw of the unit. Be sure that the drill bit is well secured on the chuck.

4. Before inserting the 12 volts adaptor, you should turn off the unit.

5. Test the rotation of the unit if it is well aligned. If not, align it following the steps no. 1 and 2.

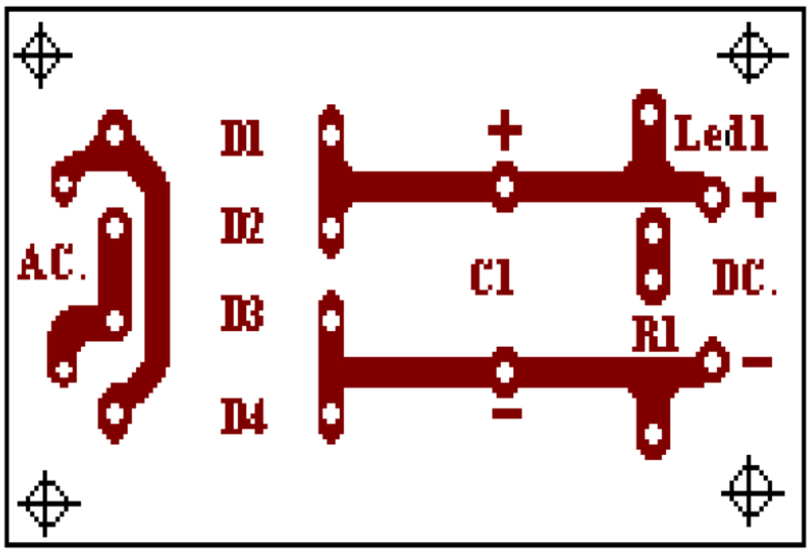
Operation Sheet - 4	Techniques of Following correct sequence of operation in Designing and Preparing PCB of AC-DC Power Supply

Techniques of Following correct sequence of operation in Boring prepared PCB

1. Prepare all the materials needed.

   - Mini drill

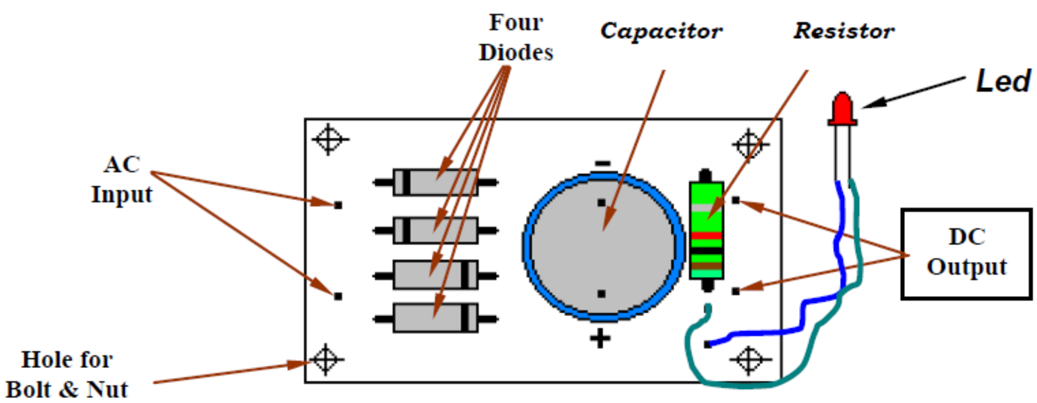
   - Designed PCB



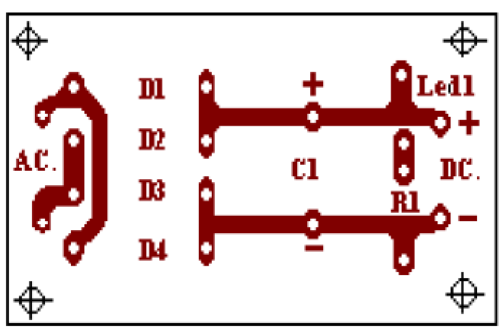
2. Mark where the holes are to be drilled.
3. Using the mini drill, bore hole perpendicularly to the surface of the PCB.
4. Clean the surface of the PCB and look for open line or short circuit.
5. Apply varnish on the clad surface to prevent it from corrosion.

Techniques of following correct sequence of operation in Mounting and Soldering AC-DC Power Supply Project

1. Prepare all the materials needed.
2. Clean the terminals of the components to be soldered and the PCB copper side.
3. Mount the components into the PCB as per the schematic diagram of the circuit.



Top View of PCB Layout



PCB LAYOUT

4. Solder components.
5. Cut the excess terminals of the component.
6. Test the circuit using the multi-tester.

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 8-12 hours.

Task 1: Observe safety procedures in using hand tools/equipment's and PPE

Task 2: Undertake work safely in accordance with the workplace and standard procedures

Task 3: Identify important Electrical/Electronic Components

Task 4: Use appropriate range of methods in constructing electrical/electronics circuit

Task 5: Follow correct sequence of operation **according to job specifications**

Task 6: Adjust Accessories used, if necessary

Task 7: Undertake confirmation of construction successfully

List of Reference Materials

1) Reference Designations for Electrical and Electronics Parts and Equipment: ASME Y14.44-2008 : Section 2.1.5.3 (2). ASME, Fairfield, NJ. 2008.

2) Graphic Symbols for Electrical and Electronics Diagrams (Including Reference Designation Letters): IEEE-315-1975 (Reaffirmed 1993): Section 22. IEEE and ANSI, New York, NY. 1993.

3) Reference Designations for Electrical and Electronics Parts and Equipment: ASME Y14.44-2008 : Section 2.1.5.3 (1). ASME, Fairfield, NJ. 2008.

4) The Art of Electronics, 2nd Edition, p56. Cambridge University Press. 1989.

5) https://smallbusiness.chron.com/workplace-safety-43459.html

6) http://examradar.com/logic-gates/

7) https://www.sciencebuddies.org/science-fair-projects/references/how-to-solder#troubleshooting

8) https://www.youtube.com/watch?v=6Maq5IyHSuc

9) https://www.youtube.com/watch?v=6UTOTgbJ_8E

10) https://www.youtube.com/watch?v=huEM80IlSFs

11) https://youtu.be/N8_1wb0r0DQ

12) https://youtu.be/95kv5BF2Z9E?t=27

13) https://www.youtube.com/watch?v=RhS-AL2ZcyE

14) https://www.youtube.com/watch?v=q2OBYz3K6PM

15) https://youtu.be/drtUkvtxp6s

16) https://youtu.be/sTwRQDVHNiw

Instruction Sheet	LG41:- Test the construction of electrical/ electronic circuits

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Conducting test of the completed construction of electrical/electronic circuits.
- Checking the accurate operation of the constructed circuit.
- Responding unplanned events or conditions.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:

- Conduct testing of the completed construction of electrical/electronic circuits.
- ***Check the accurate operation*** of the constructed circuit
- Respond to unplanned events or conditions.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information "Sheet 1, Sheet 2, and Sheet 3".
4. Accomplish the "Self-check 1, Self-check 2, and Self-check 3" **in page 215, 218, and 221** respectively.
5. If you earned a satisfactory evaluation from the "Self-check" proceed to "Operation Sheet 1" **in page 222.**
6. Do the "LAP test" **in page – 223** (if you are ready).

Information Sheet - 1	Conducting test of the completed construction of electrical/electronic circuits.

1.1. Verification and testing

Once a circuit has been designed, it must be both verified and tested. Verification is the process of going through each stage of a design and ensuring that it will do what the specification requires it to do. This is frequently a highly mathematical process and can involve large-scale computer simulations of the design. In any complicated design it is very likely that problems will be found at this stage and may involve a large amount of the design work be redone in order to fix them.

Testing is the real-world counterpart to verification, testing involves physically building at least a prototype of the design and then (in combination with the test procedures in the specification or added to it) checking the circuit really does do what it was designed to.

1.2. Functional test

In this test method electrical signals typical of the operation of the circuit are applied to the connectors on the PCB. The responses to these signals are recorded and compared to the correct response.

Advantages of functional test:

- The components are tested in their operating environment.
- Design faults may be found.
- Timing problems may be found.

Disadvantages of functional testing:

- Necessary software development is time consuming.
- Requires highly skilled personnel.
- Will normally not localise the fault.
- Long testing time.
- New faults may be generated in the test.
- Limited fault coverage.

1.3. In-circuit test

In this test method each component is tested individually with test probes. Neighboring components must be isolated by guarding techniques in analogue circuits or latching in digital circuits [6.3].

Advantages of in-circuit testing:

- Short testing time: The test localises the fault.
- Many faults may be found simultaneously.
- Less time consuming software development.
- The PCB does not need to be powered up, and the danger of generating faults by the test is reduced.

Disadvantages:

- Time consuming test.
- The interactions between components are not tested.
- Require expensive test fixture.
- Access to all nodes in the circuit is necessary.

The circuit complexity and production volume are important factors in the decision of test method. Therefore the typical extra board area needed for the test points for in circuit testing is less than 5 %, and the cost of area is rarely an important argument against in-circuit test. A combination of the two methods is also common: Smaller functional blocks may be functionally tested, and critical components may be in circuit tested.

Self-Check - 1	Written Test

Directions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Use the Answer sheet provided in the next page.

1. Write at list three advantage and disadvantage of functional testing. (6 points)
2. Write at list three advantage and disadvantage of in-circuit testing. (6 points)

Note: - Satisfactory rating: 6 and above - Unsatisfactory Rating: below 6

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating: _____________

Name: ____________________________ Date: ________________

Information Sheet - 2	Checking the accurate operation of the constructed circuit

There are various factors that determine the quality of the power supply like the load voltage, load current, voltage regulation, source regulation, output impedance, ripple rejection, and so on. Some of the characteristics are briefly explained below:

1. **Load Regulation** – The load regulation or load effect is the change in regulated output voltage when the load current changes from minimum to maximum value.

$$\textbf{Load regulation} = V_{no\text{-}load} - V_{full\text{-}load}$$

Vno-load refers to the Load Voltage at no load

Vfull-load refers to the Load voltage at full load.

From the above equation we can understand that when Vno-load occurs the load resistance is infinite, that is, the out terminals are open circuited. Vfull-load occurs when the load resistance is of the minimum value where voltage regulation is lost.

$$\textbf{\% Load Regulation} = [(V_{no\text{-}load} - V_{full\text{-}load})/V_{full\text{-}load}] * 100$$

2. **Minimum Load Resistance** – The load resistance at which a power supply delivers its full-load rated current at rated voltage is referred to as minimum load resistance.

$$\textbf{Minimum Load Resistance} = V_{full\text{-}load}/I_{full\text{-}load}$$

The value of Ifull-load, full load current should never increase than that mentioned in the datasheet of the power supply.

3. **Source/Line Regulation** – In the block diagram, the input line voltage has a nominal value of 230 Volts but in practice, here are considerable variations in ac supply mains voltage. Since this ac supply mains voltage is the input to the ordinary power supply, the filtered output of the bridge rectifier is almost directly proportional to the ac mains voltage.

The source regulation is defined as the change in regulated output voltage for a specified rage of lie voltage.

4. **Output Impedance** – A regulated power supply is a very stiff dc voltage source. This means that the output resistance is very small. Even though the external load resistance is varied, almost no change is seen in the load voltage. An ideal voltage source has an output impedance of zero.

5. Ripple Rejection – Voltage regulators stabilize the output voltage against variations in input voltage. Ripple is equivalent to a periodic variation in the input voltage. Thus,a voltage regulator attenuates the ripple that comes in with the unregulated input voltage. Since a voltage regulator uses negative feedback, the distortion is reduced by the same factor as the gain.

Self-Check - 2	Written Test

Directions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Use the Answer sheet provided in the next page.

1. What are the factors that affect the quality of the power supply? List at list four of them and explain. (8 points)

Note: - Satisfactory rating: 4 and above - Unsatisfactory Rating: below 4

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating: _____________

Name: ___________________________ Date: ________________

Information Sheet - 3	Responding unplanned events or conditions.

3.1. Electrical Hazard

The risk of an electrical hazard has the potential to interact with terrestrial environment and socioeconomic environment.

Live high voltage conductors pose the risk of injury or death to individuals or wildlife if contacted directly or indirectly. Mitigation measures to minimize the risk of electrical injuries to those in or proximate to a power transmission corridor are not generally a requirement for land-based transmission, given the height of conductors. Downed conductors can allow for the potential interaction of live electrical cables with personnel or wildlife in the area. Unauthorized access to secure locations can also put individuals at risk of electrocution. Avifauna can also interact with high voltage conductors by landing on and touching energized conductors and grounded hardware at the cable riser stations and can become electrocuted in certain circumstances.

3.2. Risk Management and Mitigation

The following mitigation measures will be applied to reduce the probability of an electrical hazard and associated environmental effects.

- During the operation phase of the Project, Project components will be inspected periodically and repaired as required.
- Safe operating procedures will be established for all work activities, both during the construction and operation phases of the Project.
- NB Power’s safety and environmental policies will be followed.
- Proper signage and public warning will be installed around project land-based components/facilities (e.g., “High Voltage”).
- Access to the work site during construction and energizing activities will be limited to NB Power and their consultants and required contractor crews.
- Physical safeguards such as security fences surrounding facilities will be implemented.
- Access to facilities will be restricted to authorized personnel only.

- The use of appropriate down lighting will be incorporated around Project components (e.g., cable riser stations) to discourage vandalism and loitering.

3.3. Potential Residual Environmental Effects and their Significance

If an electrical hazard incident were to occur, the terrestrial environment and socioeconomic environment could be affected.

As the submarine cables will be buried in the nearshore environment (i.e., between the shore and the cable riser stations) and the cable riser stations will be fenced in, the probability of an electrical hazard incident is low because there is limited opportunity for individuals or wildlife to be exposed to them.

Therefore, potential environment effects arising from electrical hazards on the terrestrial or socioeconomic environments are not anticipated to be substantive.

In consideration of the buried nature of the cables in areas accessible to the public and wildlife, and in light of the mitigation to be implemented, the residual environmental effects of an electrical hazard during all Project phases are rated not significant for all potentially affected VCs. This determination is made with a high level of confidence. There is the potential that a protected species or person could be harmed or even killed were they to come in contact with the energized electrical components of the Project, and this would represent a significant residual environmental effect; however, given the safeguards in place, this is a highly unlikely scenario. Consequently, a significant environmental effect arising from this possibility is also considered to be unlikely to occur.

Self-Check - 3	Written Test

Directions: Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers. Use the Answer sheet provided in the next page.

1. Discuss on unplanned events or conditions caused during construction of electrical/electronics circuit. (7 points)

Note: - Satisfactory rating: 3.5 and above - Unsatisfactory Rating: below 3.5

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Operation Sheet - 1	Techniques of Test the construction of electrical/ electronic circuits

Techniques for testing the construction of electrical/ electronic circuits are:

1. Select the testing equipment.
2. Testing the continuity of construction of electrical/electronic circuit.
3. Testing short and open circuit.
4. Testing the Input and output voltage.
5. Test the conduct of electrical/electronic circuit.

LAP Test	Practical Demonstration

Name: _______________________________ Date: _________________

Time started: _________________________ Time finished: _________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 8-12 hours.

Task 1: Conduct testing of the completed construction of electrical/electronic circuits.

Task 2: Check the accurate operation of the constructed circuit

Task 2: Respond to unplanned events or conditions.

Referenc

- Scott P. Schneider (1998). "Tools". In Jeanne Mager Stellman (ed.). Chemical, industries and occupations. Encyclopaedia of Occupational Health and Safety. 3 (4th ed.). International Labour Organization. pp. 93.33–93.34. ISBN 978-92-2-109816-4.

- Cacha, Charles A. (1999). Ergonomics and Safety in Hand Tool Design. CRC. ISBN 1566703085.

- Salaman, R. A. (1997 edition revised by Philip Walker; first published in 1975 by George Allen & Unwin [Publishers] Ltd). Dictionary of Woodworking Tools, c. 1700–1970 Mendham, NJ: Astragal Press ISBN 978-1-879335-79-0.

- Salaman, R. A. (1996). Dictionary of Leather-working Tools, c.1700–1950, and the Tools of Allied Trades Mendham, NJ: Astragal Press ISBN 978-1-879335-72-

- https://www.slideshare.net/rodericklamban/basic-hand-tools-electronics-technology
- https://www.sheffield.ac.uk/bms/research/facilities/electronics/index

- https://www.youtube.com/watch?v=2nZ9lS6VHFU

- https://www.youtube.com/watch?v=zdNG3r119qs&t=5s

- https://www.youtube.com/watch?v=aR-1kKCvmLE

- Refer https://www.youtube.com/watch?v=2nZ9lS6VHFU

- https://www.youtube.com/watch?v=zdNG3r119qs&t=5s

- https://www.youtube.com/watch?v=aR-1kKCvmLE