Industrial Electrical/Electronic Control Technology LEVEL – II

Based on March, 2022 Curriculum Version I

Module Title: - Designing and Constructing Simple Printed Circuit Board

Module code: EIS IEC2 M05 0322

Nominal duration: 120Hour

Prepared by: Ministry of Labour and Skill

August, 2022

Addis Ababa, Ethiopia

Table of Content

Acknowledgment

Ministry of Labor and Skills wish to extend thanks and appreciation to the many representatives of TVET instructors and respective industry experts who donated their time and expertise to the development of this Teaching, Training and Learning Materials (TTLM).

Acronym

PCB -Printed Circuit Board (i.e., a “board”)

PWB - Printed Wiring Board (same as PCB)

PCA -PCB Assembly, a PCB that is loaded with components

Fab - the process of creating the PCB

Load - the process of attaching the components to the PCB

OSH - Occupational safety and health

WHO - World Health Organization

AC – Alternative current

DC – Direct current

RMS – Root mean square

Introduction to the Module

Electronic devices saturate the modern world. Whether it is a device that silently monitors vitals or a smart phone with an endless stream of notifications, all contain a PCB circuit board at the heart of their design. Over the years, printed circuit board manufacturing has continued to grow in order to keep up with the increasing demands of newer, faster, and more complex electronic circuitry.

This module is designed to meet the industry requirement under the Industrial Electrical/Electronic Control Technology occupational standard, particularly for the unit of competency: Design and Construct Simple Printed Circuit Board.

This module covers the units:

- Plan and prepare to construct/ electrical/electronic circuits
- Construct electrical /electronic circuits on PCB
- Test the construction of electrical/ electronic circuits

Learning Objective of the Module

- Perform Plan and prepare to construct/ electrical/electronic circuits
- Carry out Construct electrical /electronic circuits on PCB
- Perform Test the construction of electrical/ electronic circuits

Module Instruction

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the “LAP test” giver at the end of each unit and
5. Read the identified reference book for Examples and exercise

Unit one: Plan and prepare to construct/ electrical/electronic circuits
This unit is developed to provide you the necessary information regarding the following content coverage and topics: • Plan tasks to ensure occupational health and safety (OHS) • Observe and Undertake safety procedures and sequence • Use personal protective equipment • Check tasks and materials • Select appropriate tools and equipment • Prepare Electrical/electronic circuits for connecting and soldering This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Understand Plan tasks to ensure occupational health and safety (OHS) • Follow Observe and Undertake safety procedures and sequence • Understand Use personal protective equipment • Understand Check tasks and materials • Do Select appropriate tools and equipment • Understand Prepare Electrical/electronic circuits for connecting and soldering

1. Ensure occupational health and safety (OHS)

1.1. 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

1.2. Safety and health hazards

1.2.1. 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.

1.2.2. 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.

1.2.3. 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.

2. Safety procedures and sequence

2.1 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…

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.

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

- All tools must be kept in good condition with regular maintenance.
- Right tool must be used for job.
- Each tool must be examined before use and damaged or defective tools not to be used.
- Tools must be operated according to manufacturer's instruction.
- The right protective equipment for the tool and activity must be used.

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

- Cleaning the tools after use is highly recommended.
- All tools and equipment must be placed in a clean and dry place.
- The work area must always be kept neat and tidy.
- Lubricants must also be applied after tightening to reduce the friction.
- 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.

- 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.

3. Use personal protective equipment

3.1 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.

3.1.1 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.

Figure 1.1: helmet

3.1.2 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!

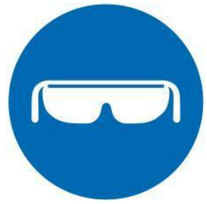


Figure 1.2: goggles

3.1.3 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.

Figure 1.3: earmuffs

3.1.4 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.

Figure 1.4: full-face mask

3.1.5 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:

Figure 1.5: gloves

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

3.1.6 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.

Figure 1.6: Safety shoes

3.1.7 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.

Figure 1.6: high-visibility jacket

Benefits of PPE

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).

Standard of PPE

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.

The right PPE for the job

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

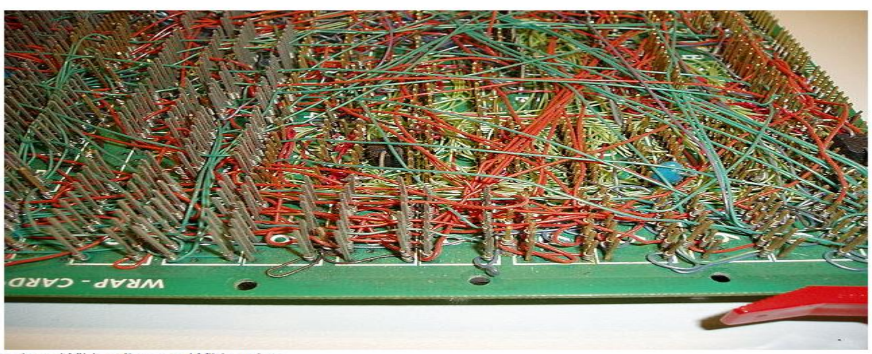
- a detailed evaluation of the risk and performance requirements for the PPE

- 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.

4. Tasks and Material

4.1 Printed circuit board(BCB)

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



courtesy Wikipedia user Wikinaut

Figure 1.7: Printed circuit board wire wrapping

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

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

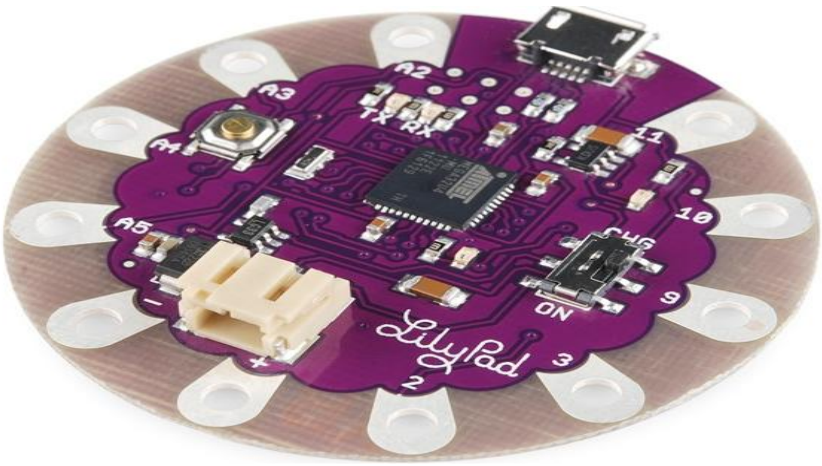


Figure 1.8: Printed circuit board

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

4.2 Composition

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

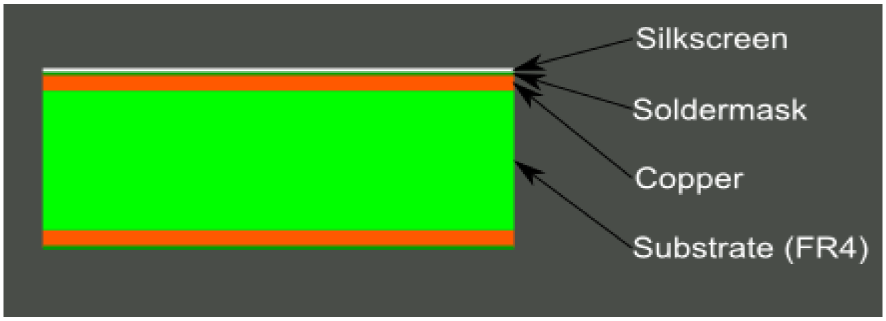


Figure 1.9: Composition

4.2.1 Fiber glass substrate FR4

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

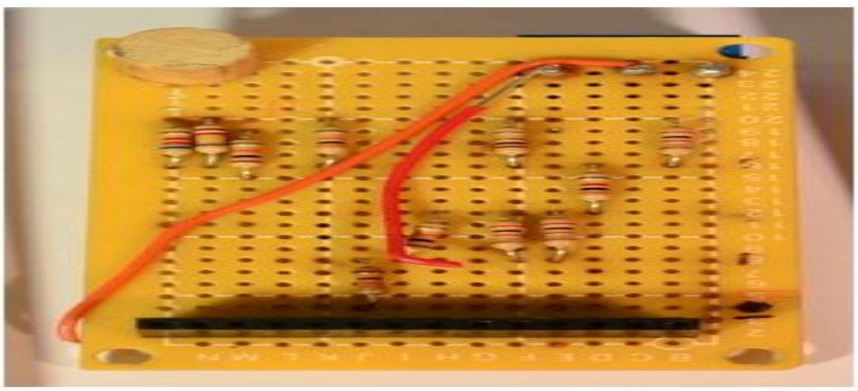


Figure 1.10: flexible high-temperature plastic

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

4.2.2 Copper

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

Figure 1.11: PCB with copper exposed, no solder mask or silkscreen.

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

4.2.3 Solder mask

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

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

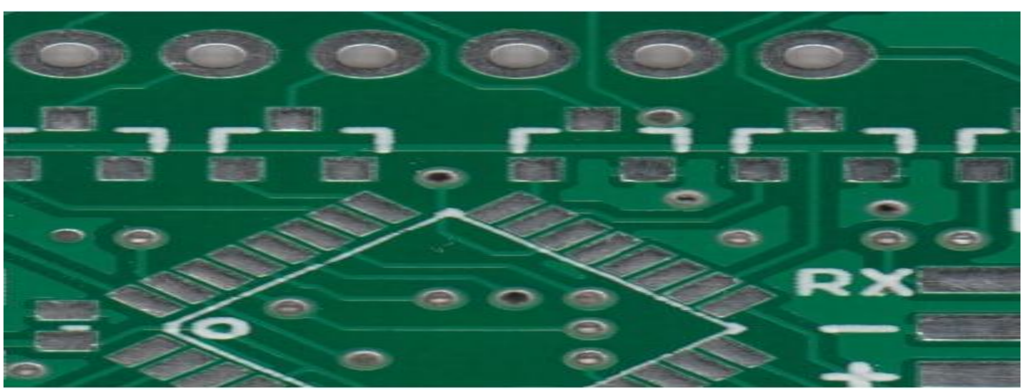


Figure 1.12: solder mask layer

Solder mask is most commonly green in color but nearly any color is possible.

4. 2.4 Silkscreen

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

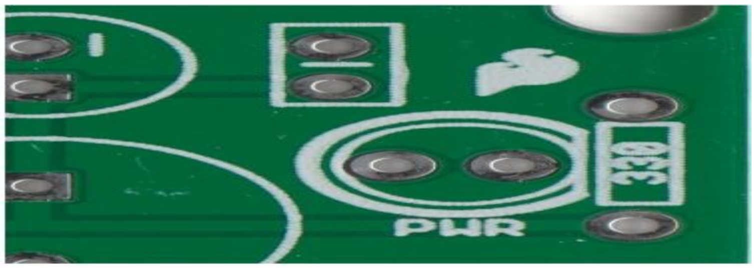


Figure 1.13: Silk screen layer

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

4.3 Materials

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

4.3.1 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.

Figure 1.14: 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.

4.3.2 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.

Figure 1.15: flux

4.3.3 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.

Figure 1.16: Jumper wire

4.3.4 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.

Figure 1.17: Ferric chloride

4.3.5 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.

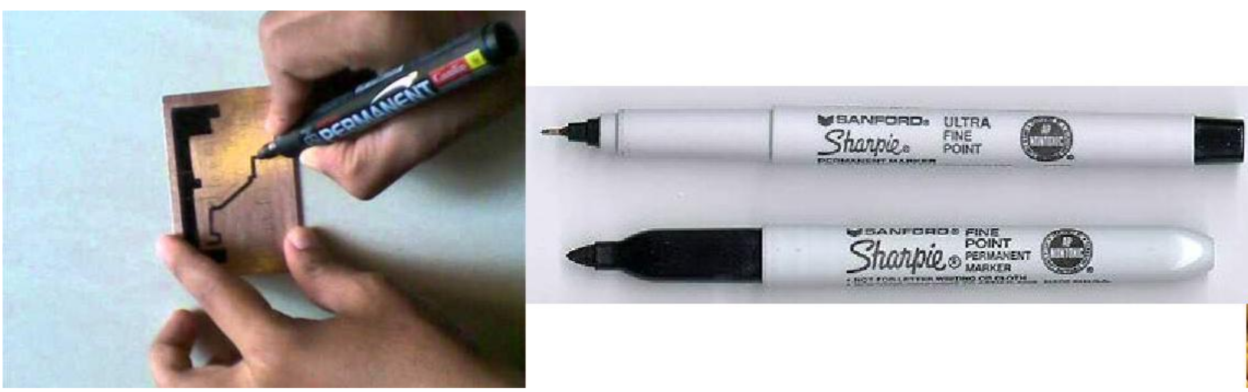


Figure 1.18: Permanent marker (ink)

4.3.6 Different method to make PCB

There are in all three basic methods to make PCB

I. Iron on Glossy paper method
II. Circuit by hand on PCB
III. 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.

4.3.7. 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

I. Un insulated breadboard
II. Insulated bread board

I. Strip board (uninsulated breadboard)

Strip board 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 fibre glass. 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.

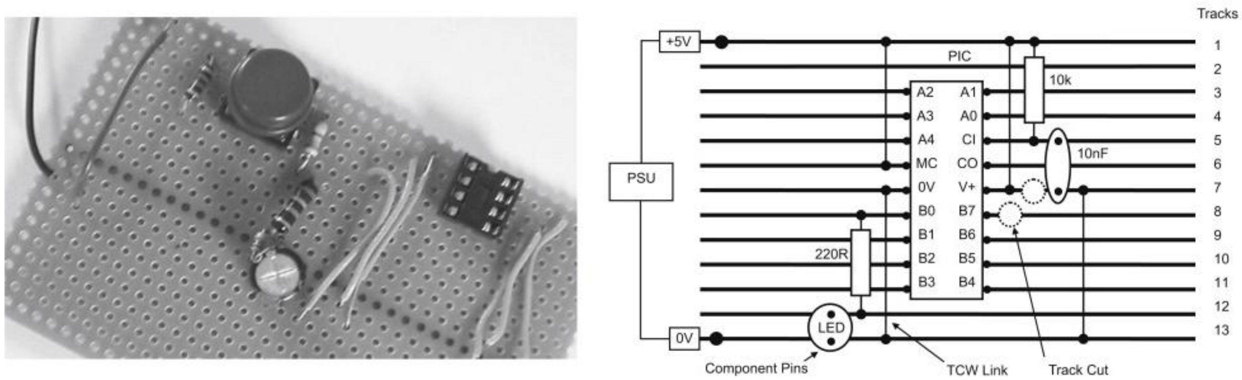


Figure 1.19: Stripboard (uninsulated breadboard)

II. 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.

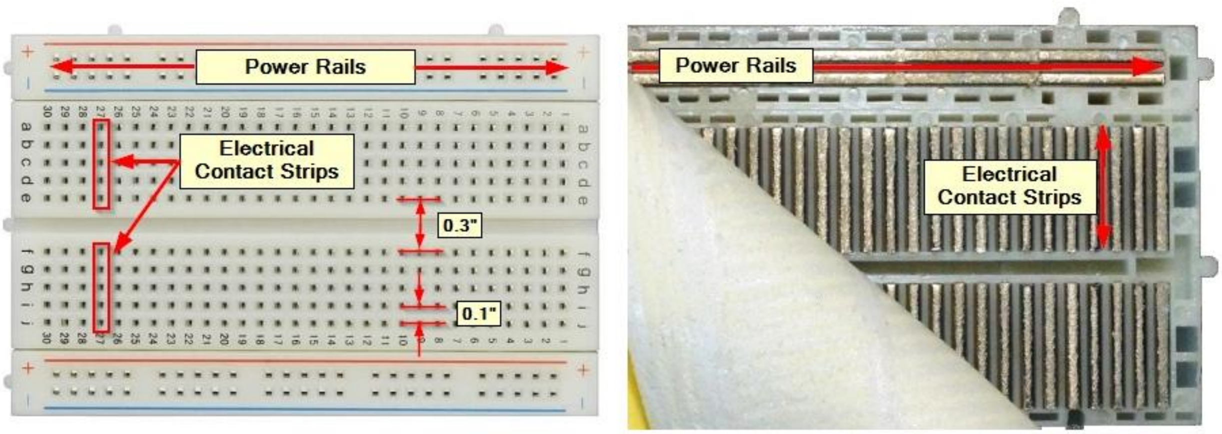


Figure 1.20: Breadboard (insulated breadboard)

5. Selections of appropriate tools and equipment

5.1. Introduction on electrical/electronic 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.

5.2. 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.

Drivers

Screw driver. 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.

Figure 1.21: driver

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

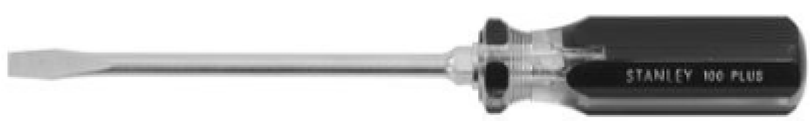


Figure 1.22: flat

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.

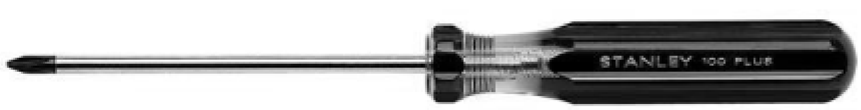


Figure 1.23: Philips

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.

Figure 1.24: hex (Allen wrench)

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

Figure 1.25: Screwdriver set

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 works

Figure 1.26: 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 1.27: 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.

Figure 1.28: 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.

Figure 1.29: 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.

Figure 1.30 sucker

Splicing Tools

Long Nose

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

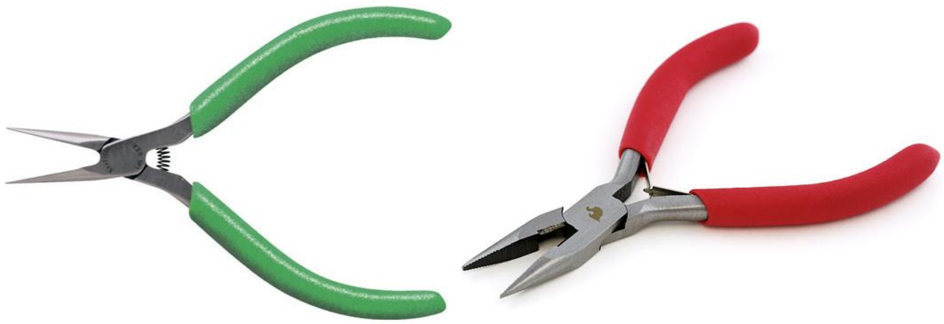


Figure 1.31: Long nose

Side Cutter.

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

Figure 1.32: 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.

Figure 1.33: Wire striper (a) manual (b) automatic

Boring Tools

12 Volt Mini-Drill

It is used to bore or drill holes in the printed circuit board (PCB).

Figure 1.34: 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.

Figure 1.35: Portable electric drill

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.

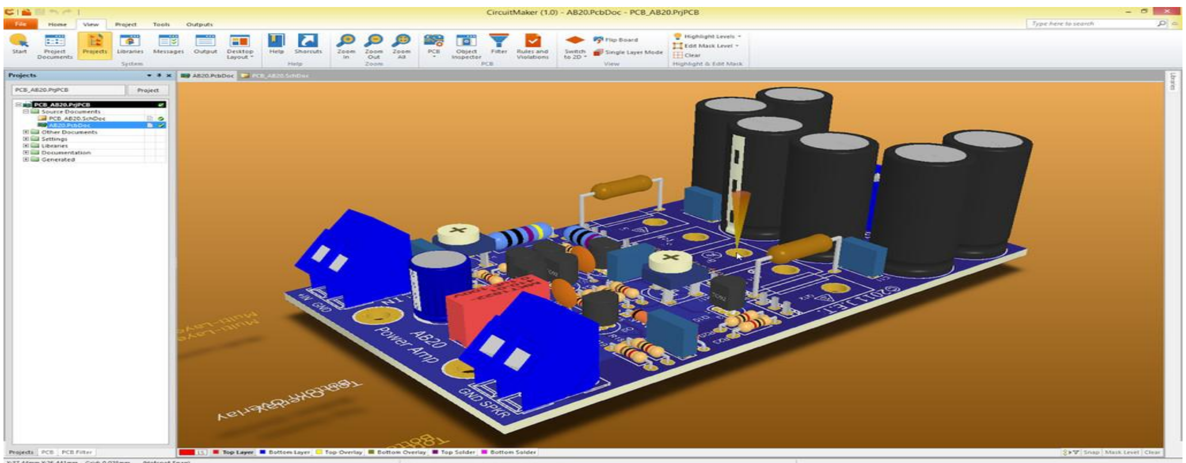


Figure 1.36: circuit simulation on circuit-maker CAD software

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:

Circuit Maker

Open Circuit Design Software

KiCad EDA

ADS Circuit Design Software

SuperSim Circuit Design Software

Portus

Computers

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.

Figure 1.37: Computer (desktop and laptop)

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

Figure 1.38: magnifying glass

Anti-Static Brush

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

Figure 1.38: Anti-static brush

Tweezers

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

Figure 1.39: Tweezer

6. Connect and solder electrical/electronic circuits

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.

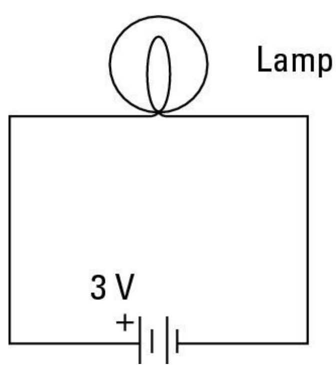


Figure 1.40: simple circuit

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

a) **Voltage source:** A voltage source causes current to flow like a battery, for instance.

b) **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.

c) **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.

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:

a) Material and equipment selection
b) Placing the components in the project board according to the design of the circuit
c) Removing the insulation of wires.

Self-Check -1.1

Test I: short Answer writing

Instruction: write short answer for the given question. You are provided 4 minute for each question and each point has 5 Points.

1. -------------is a device used for applying heat to melt solder in attaching two metal parts.
2. -------------is a place of the soldering iron to keep them away from flammable materials.
3. ------------- is used for the removal of solder and components from a circuit when troubleshooting, repair purposes and to save components.
4. --------------is a convex lens which is used to produce a magnified image of an object.
5. List out same of the materials used to construct electrical electronics circuits.
6. Identify the listed components below as active and passive components.

- 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.

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

a. ________________________________

b. ________________________________

Operation Sheet 1. 1

: Techniques to select appropriate *tools and equipment's* to construct electrical/electronic circuit.

Operation title: Procedures of select appropriate tools for to construct electrical/electronic circuit.

Purpose: To practice and demonstrate the knowledge and skill required to select tools to construct electrical/electronic circuit on PCB.

Instruction:

Step 1: prepare clean and safe work station

Step 2: analyze and understand the given task

Step 3: list out tools, materials and equipment's necessary for the specific task

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

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

Tools and requirement:

Soldering lead

Flux

Jumper wire

Ferric chloride

chloride

Permanent marker (ink)

Printed circuit board (PCB)

Bread board or Solder less breadboard

Strip board (uninsulated breadboard)

Driving of Tools

Flat Screwdriver

Phillips Screwdriver

Soldering station

Brass Sponge -

Sucker

Portable Electric Drill

LAP Test – 1.1

Instructions: Given necessary templates, tools, materials and equipment 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 equipment's 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

- **Precautions:** select necessary templates, tools, materials and equipment before constructing electrical /electronics circuit on PCB t on the given format
- **Quality Criteria:** the given constructing electrical /electronics circuit on PCB is with Correct specification.

Unit Two: Construct electrical /electronic circuits on PCB
This unit to provide you the necessary information regarding the following content coverage and topics: • Electrical/electronic components • Correct sequence of operation • Construct electrical/electronic circuits • Confirm adjustments of accessories This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Identify important electrical/electronic components • Follow Correct sequence of operation • Construct electrical/electronic circuits • Confirm adjustments of accessories

2. Electrical/electronic components

2.1 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.

2.2 Active Component

Definition - *Active Component*

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.

2.3. Passive Component

Definition - *Passive Component*

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.

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 **Differencebetween Active** and **PassiveComponents** is given below in the tabulated form.

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	They are incapable of providing

BASIS	ACTIVE COMPONENTS	PASSIVE COMPONENT
	power gain.	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 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.

2.4. 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.

2.4.1. 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

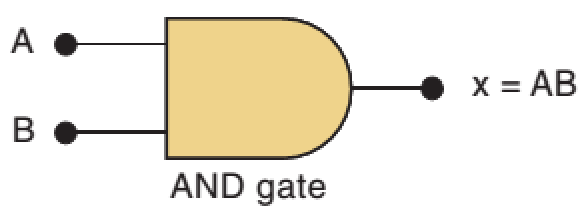
1. AND gate

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)

Figure 2.1: AND gate (a) truth table (b) symbol

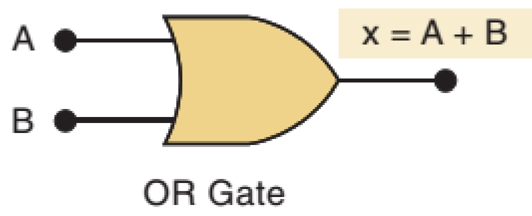
2. OR gate

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)

Figure 2.2: 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.

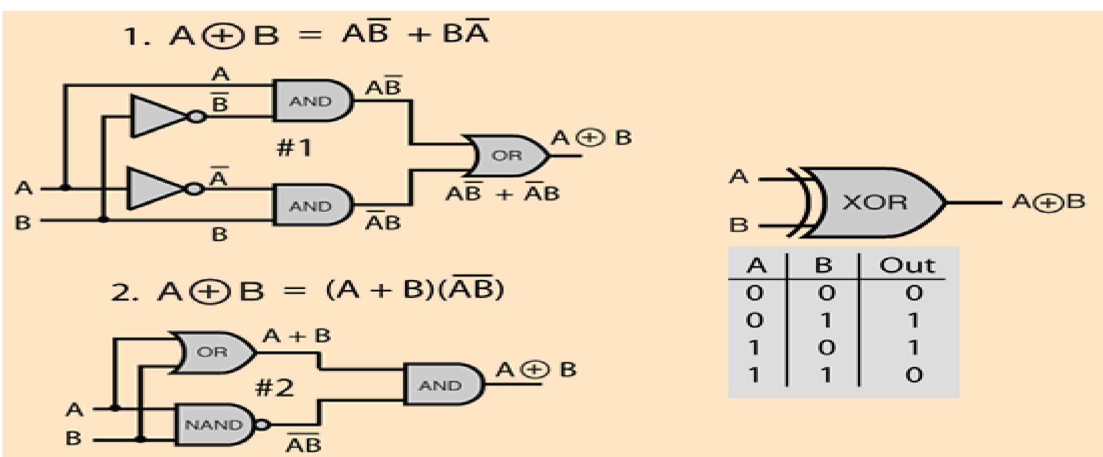


Figure 2.3: XOR gate (a) truth table (b) symbol

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.

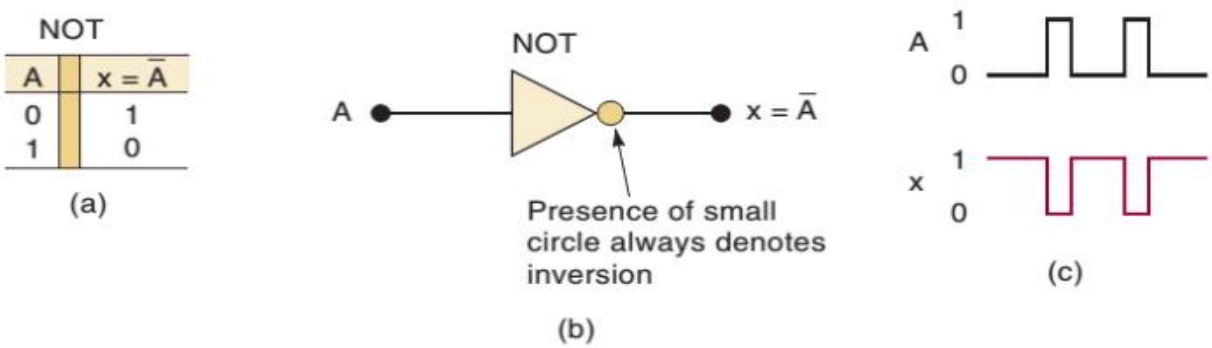


Figure 2.4: NOT gate (a) truth table (b) symbol (c) output signal

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."

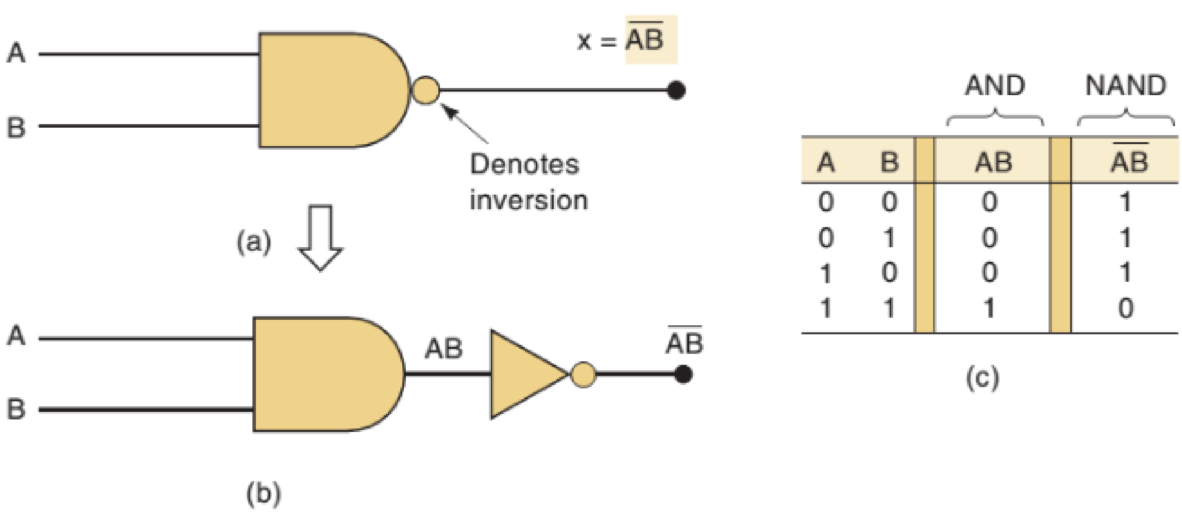
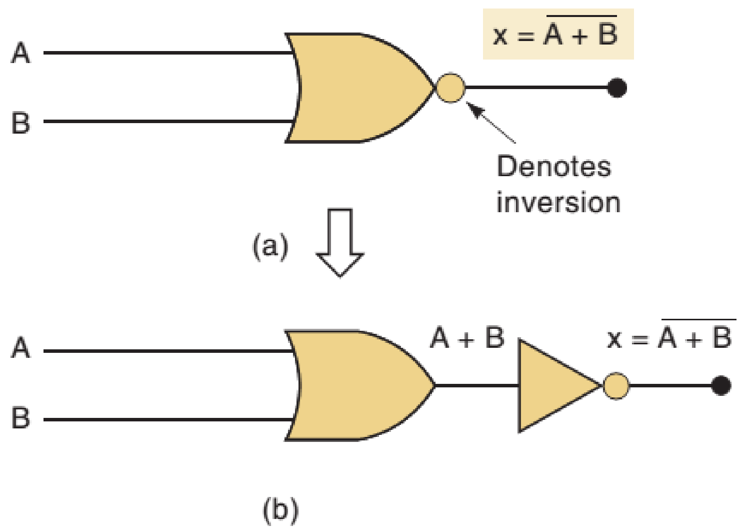


Figure 2.5: NAND gate (a&b) symbol (c) truth table

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."



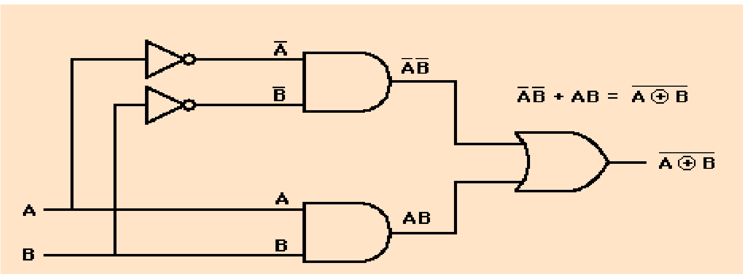
		OR	NOR
A	B	A + B	$\overline{A + B}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

(c)

Figure 2.6: 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

Figure 2.7: XNOR gate (a) truth table (b) symbol

2.5. 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.

2.6. 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).

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.)

Figure 2.8: 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.

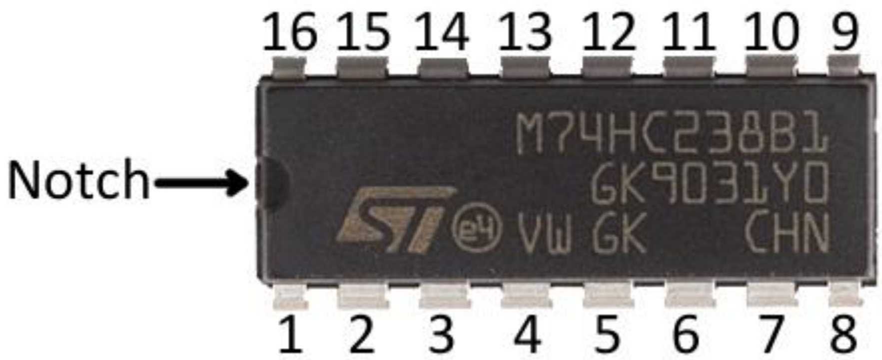


Figure 2.9: Polarity and pin numbering of ICs

2.7. 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.

3 Correct sequence of operation

Following correct sequence of operation in Preparing the Layout Diagram in the PCB

1. Prepare the schematic diagram of the circuit.

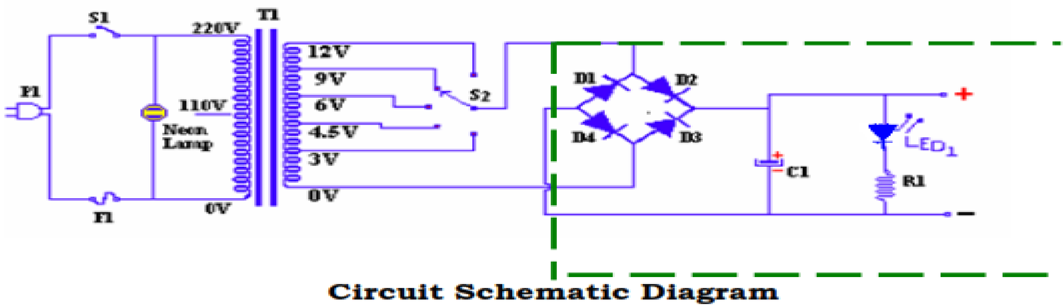


Figure 2.10: schematic diagram

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.

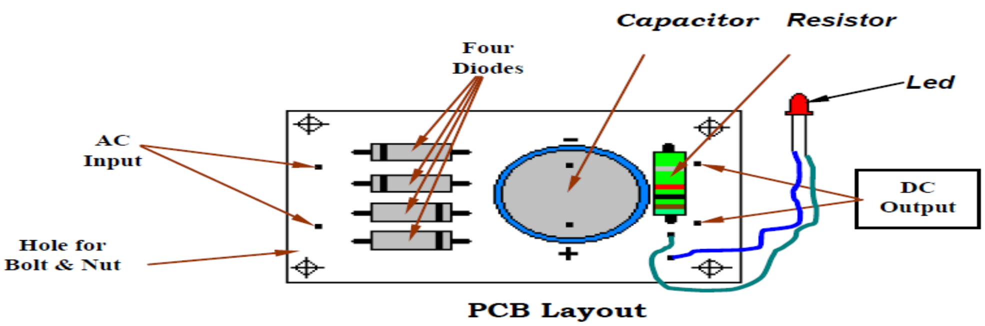


Figure 2.11: component circuit

3. Interconnect each component by copying the connection in the schematic diagram.

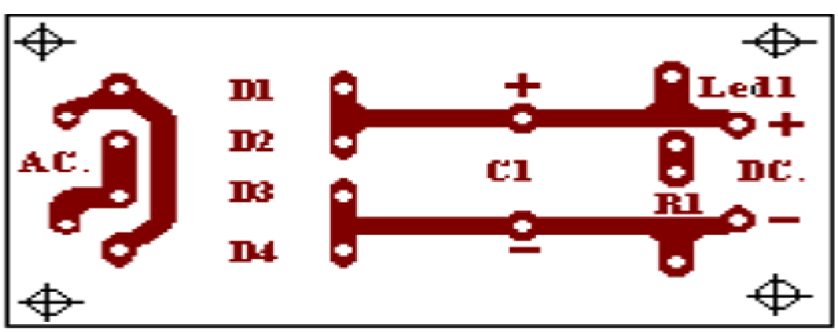


Figure 2.12: connection in the schematic diagram

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.

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.

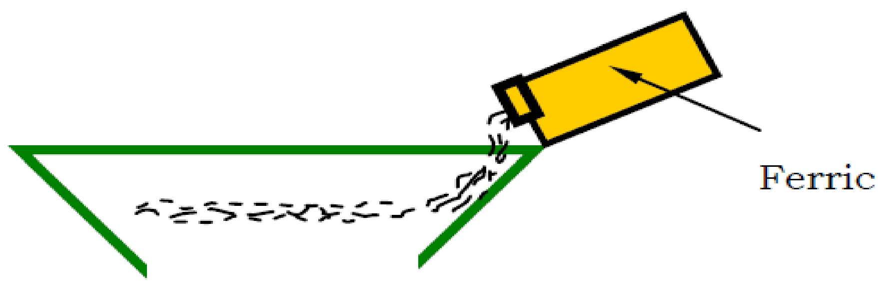


Figure 2.13: ferric chloride

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.

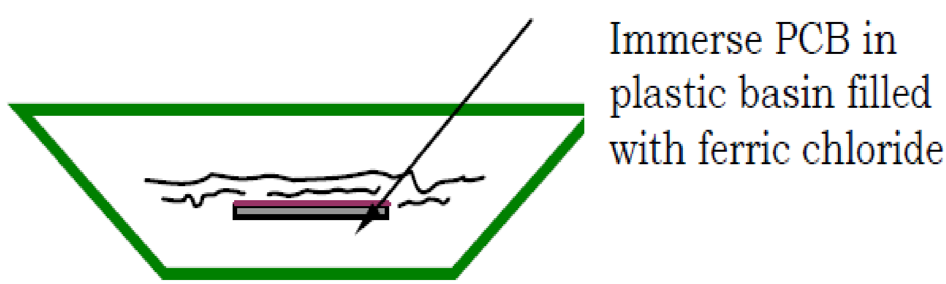


Figure 2.14: PCB by immersing

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.

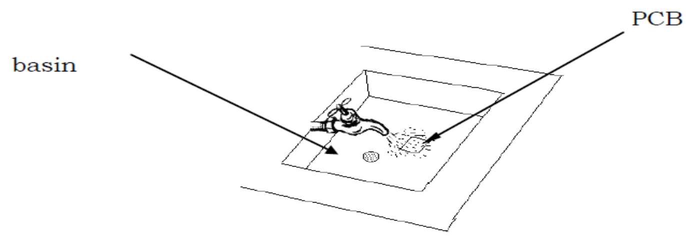


Figure 2.15: plastic basin

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.

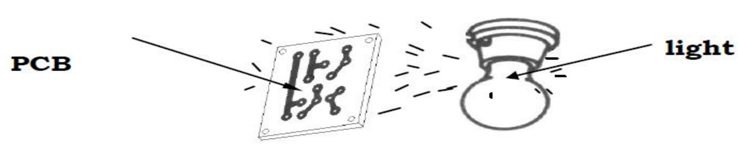


Figure 2.16: hairline break or short

10. Apply plastic varnish to the newly etched PCB to prevent corrosion or rust, and let it dry before touching it.

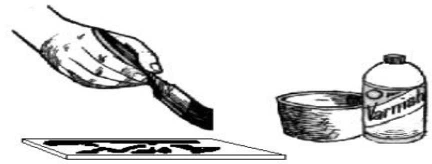


Figure 2.17: plastic varnish

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.

Figure 2.18: long metal tool

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.

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.

Mount and Solder AC-DC Power Supply Project

- ❖ Prepare all the materials needed.
- ❖ Clean the terminals of the components to be soldered and the PCB copper side.
- ❖ Mount the components into the PCB as per the schematic diagram of the circuit.
- ❖ Solder components.
- ❖ Cut the excess terminals of the component.
- ❖ Test the circuit using the multi-tester.

4. 1 Construct electrical/electronic circuits

4.2. 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.

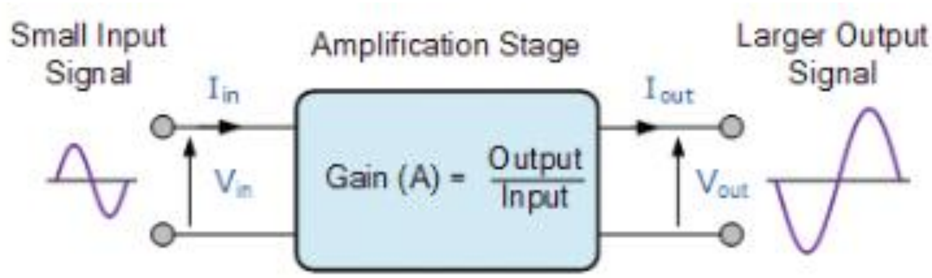


Figure 2.19. amplifier block diagram

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 2. 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.

4.3 Ideal Amplifier Model

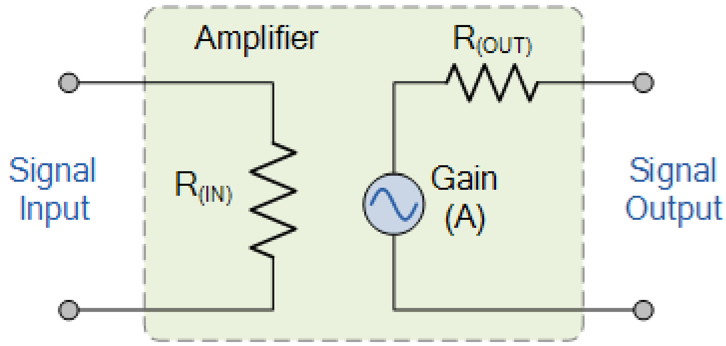


Figure 2.20: Simple representation of ideal amplifier

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”.

4.4 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

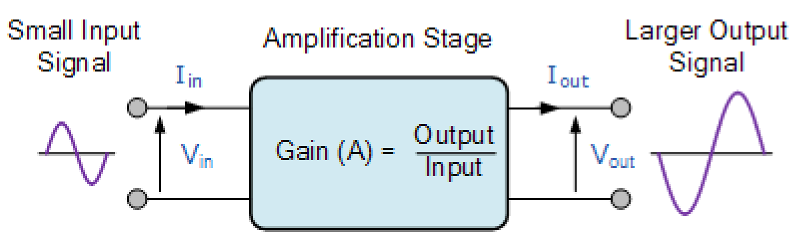


Figure 2.21 different types of gains

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

$$Power\,Gain\,(A_p) = A_v \ x\ A_i \quad \text{............(1)}$$

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.

4.5 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.

4.6 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.

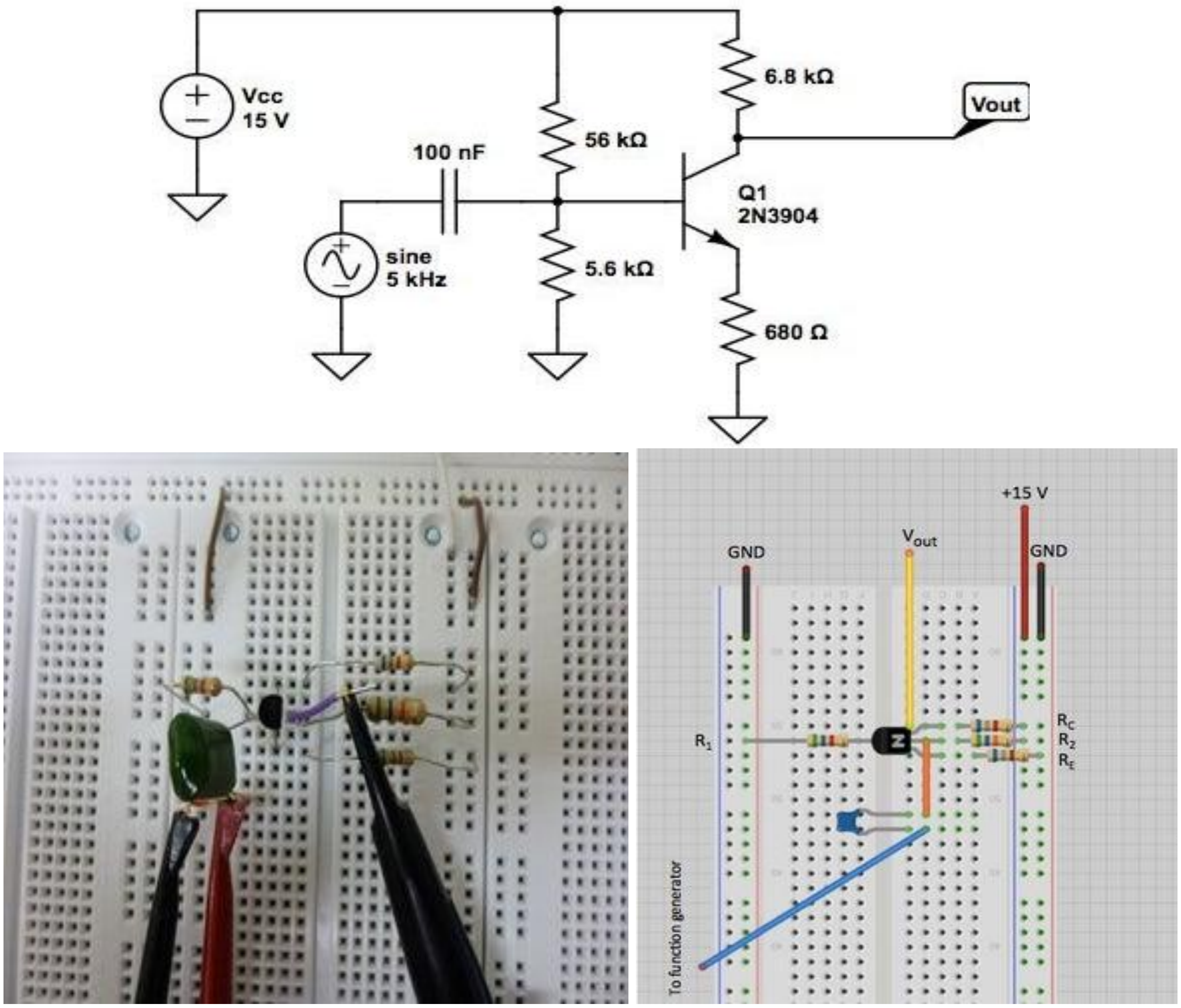


Figure 2.22:Voltage amplifier circuit schematic diagram and component arrangement on breadboard

4.7 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.

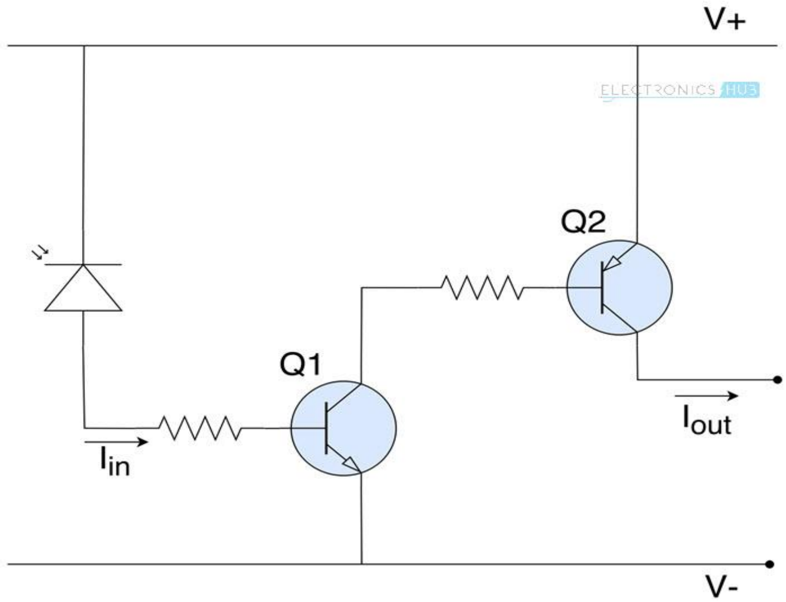


Figure2.23 :current amplifier circuit

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.

4.8 Applications of Current Amplifiers

The 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.

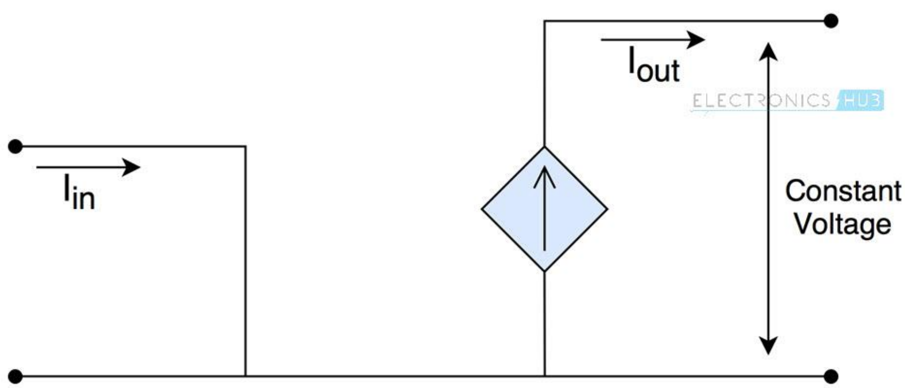


Figure 2.24. Ideal current buffer

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.

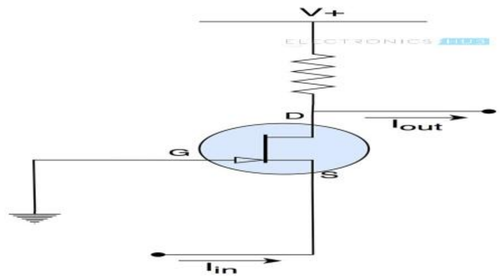


Figure 2.25 A simple MOSFET current buffer circuit

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.

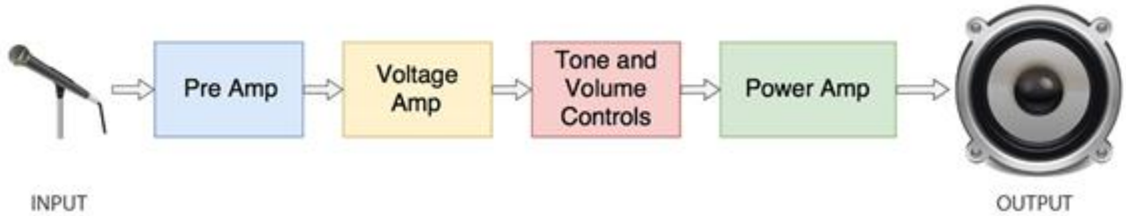


Figure 2.26. Block diagram of an audio amplifier

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.

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.

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.

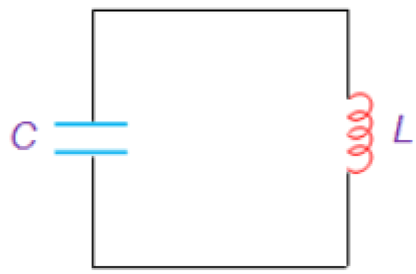


Figure 2.27. LC tank circuit

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 73a) 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 73b) leading to unsustainable oscillations.

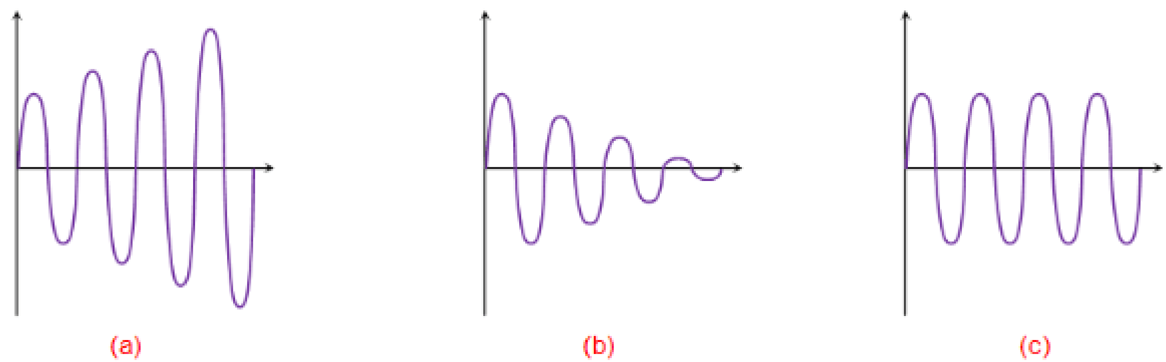


Figure 2.28 *:(a)Increasing oscillations (b)Decaying oscillations (c)Constant-Amplitude oscillation*

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.

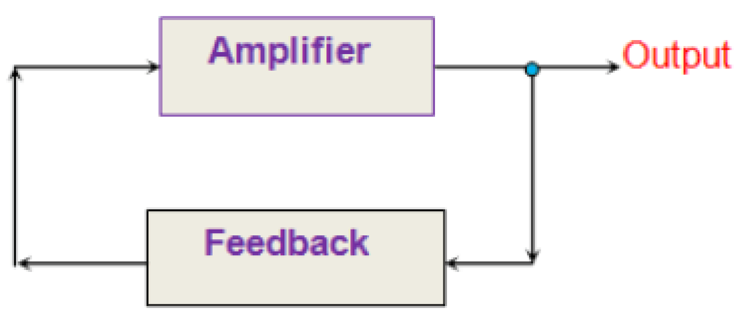


Figure 2.29 typical oscillator

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:

$$G = \frac{A}{1 + A\beta} \quad \text{……………………..(2)}$$

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:

Table 3

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)

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

You can get a much higher density board with PCB.

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.

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.

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:

Iron on Glossy paper method (circuit designed using CAD software)

Circuit by hand on PCB (circuit drawn manually)

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 2nd 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

$FeCl_3$ powder/solution (same as etching solution),

photo/glossy paper, permanent black marker,

blade cutter,

sandpaper,

kitchen paper and

Cotton wool.

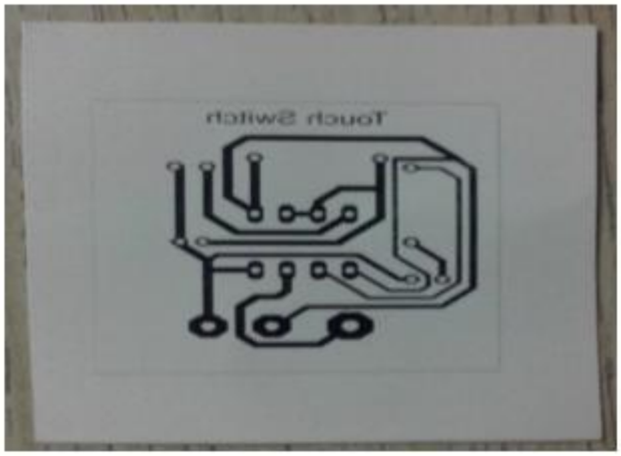
STEP 1: Take printout of circuit board layout

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.

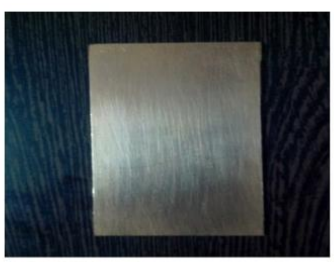


PCB print on glossy paper

Figure 2.31 mirror print out

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

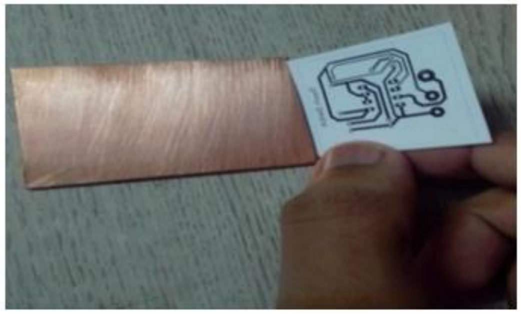
Cutting the plate

Figure 2.32 cut the copper board

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.

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

Figure 2.33 Transfer the printed

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

Figure 2.34 copper plate with pencil

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

Figure 2.35 electric iron

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

Figure 2.36 peeling

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.

Figure 2.37 black marker to darken

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.

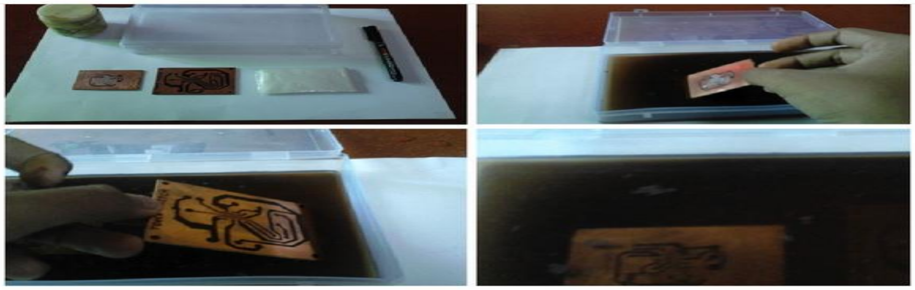
Take a plastic box and fill it up with some water.

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

Figure 2.38 Etching

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

Cu + FeCl3 = CuCl3 + Fe…………..(4)

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

Figure 2.39 plate having the solution.

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

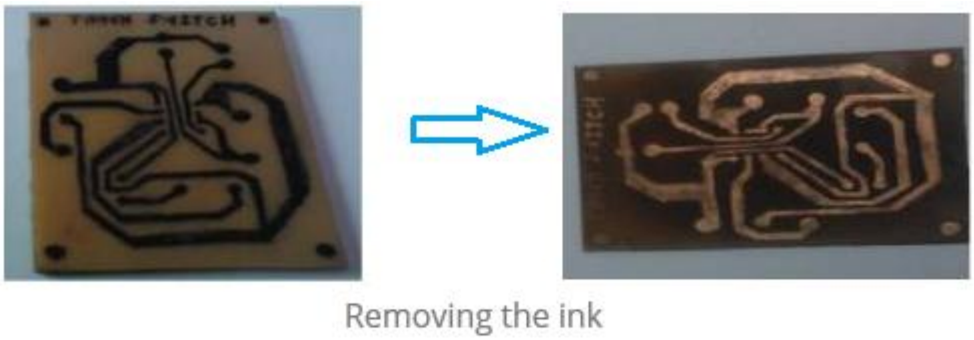


Figure 2.40 Trim to final size and smoothen edges with sandpaper

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

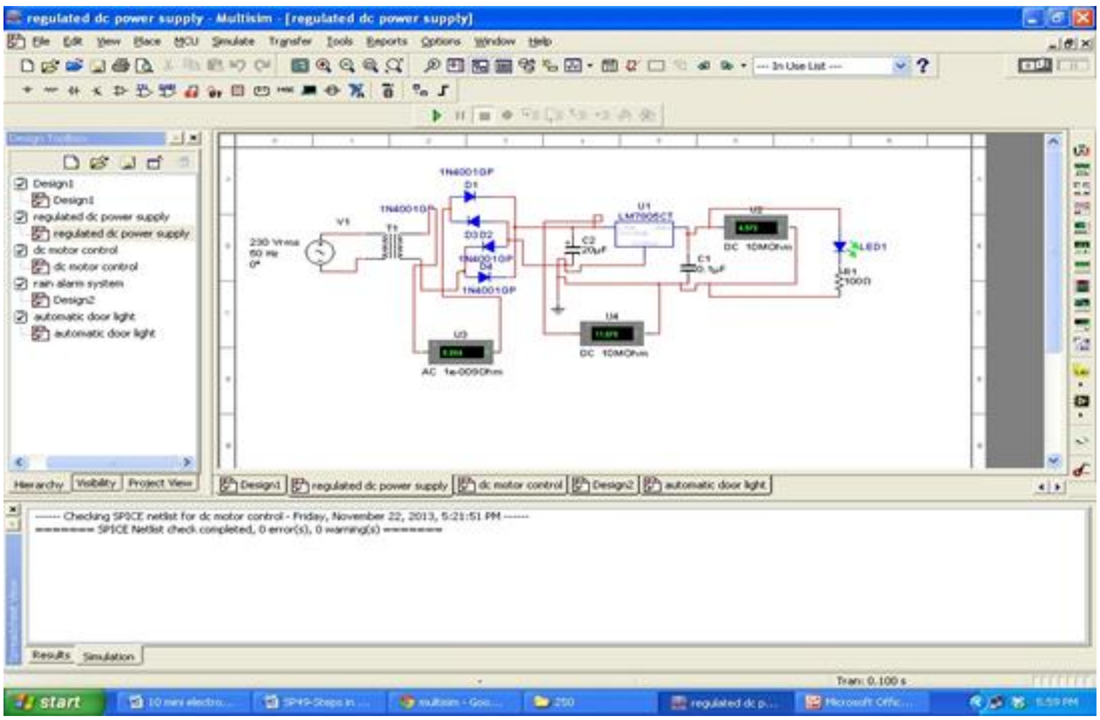


Figure 2,41 Multisim and simulation

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

On your windows panel, click on the following link: Start >>> Programs –> National –> Instruments –> Circuit design suite 11.0 –> multisim 11.0.

A multisim software window appears with a menubar and blank space resembling a breadboard, to draw the circuit.

On the menu bar, select place –> components

A window appears with the title-'select the components'

Under the heading 'Database' – select 'Master Database' from the drop down menu.

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.

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).

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.

Under the components windows, select basic, then Cap _Electrolytic and select the value of capacitor to be 20microFarad.

Under the components window, select power, then Voltage_ Regulator and then select 'LM7805' from the drop down menu.

Under the components window, select diodes, then select LED and from the drop down menu, select LED_green.

Using the same procedure, select a resistor with the value of 100 Ohms.

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.

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.

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.

Now your circuit is ready to be simulated.

Now click on 'Simulate' then select 'Run'.

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

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

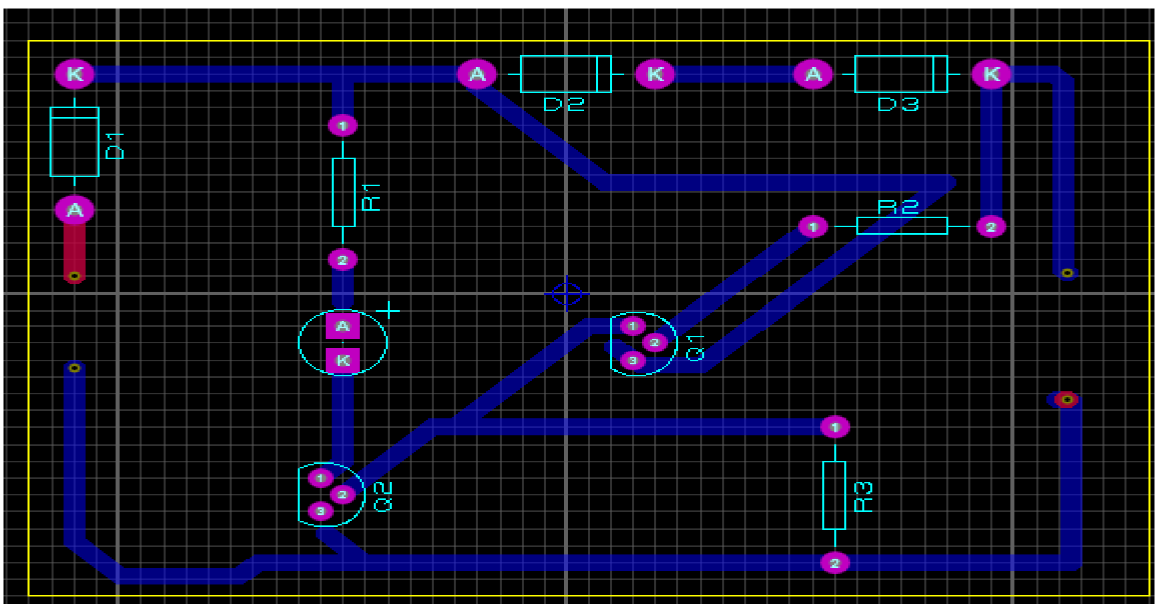


Figure 2.42 PCB layout

Step 3. Print out the circuit from PC

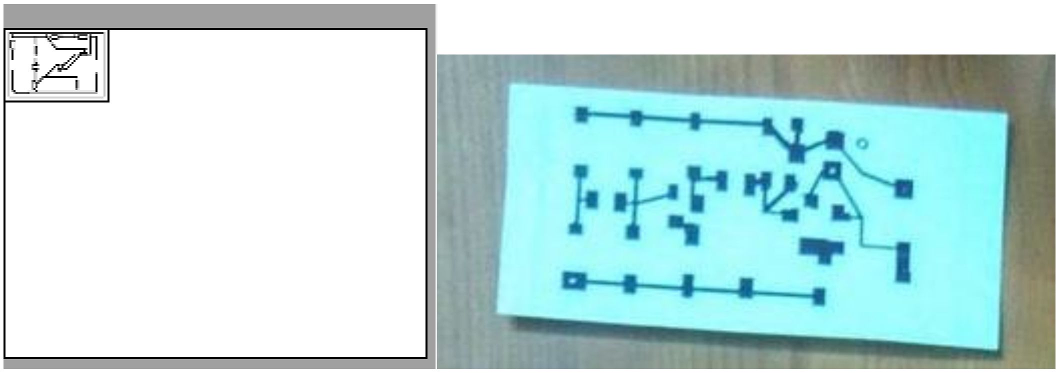


Figure 2.43 printout

Step 4: Cleaning Copper Clad

Scrub the copper clad with scrubber until it becomes shines.

Figure 2.44 Scrub the copper

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.

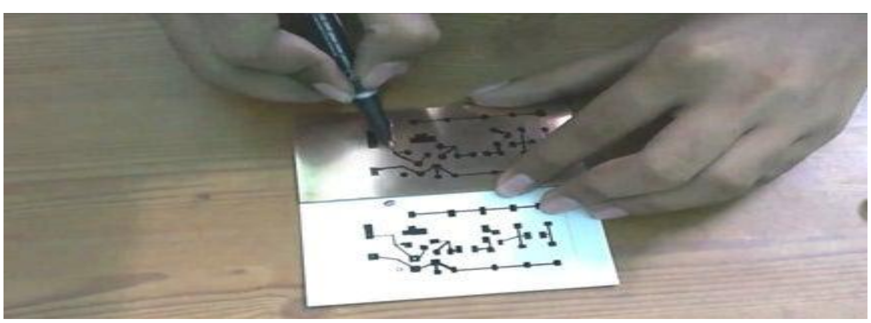


Figure 2.45 *Circuit by hand*

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!

Figure 2.46 transfering

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.

Figure 2.47 peel off the paper

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.

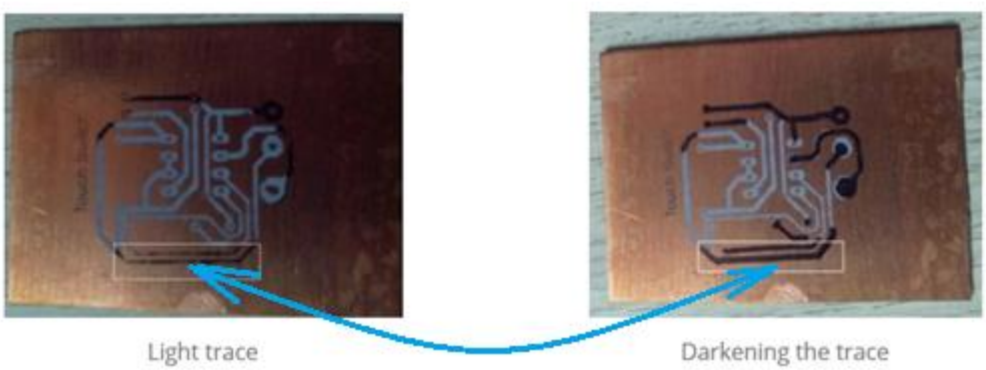


Figure 2.48 Inspect the PCB

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.

Figure 2.49 etchants Ferric chloride

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

Figure 2.50 Ferric chloride

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.

Figure 2.51 Clean the permanent marker

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.

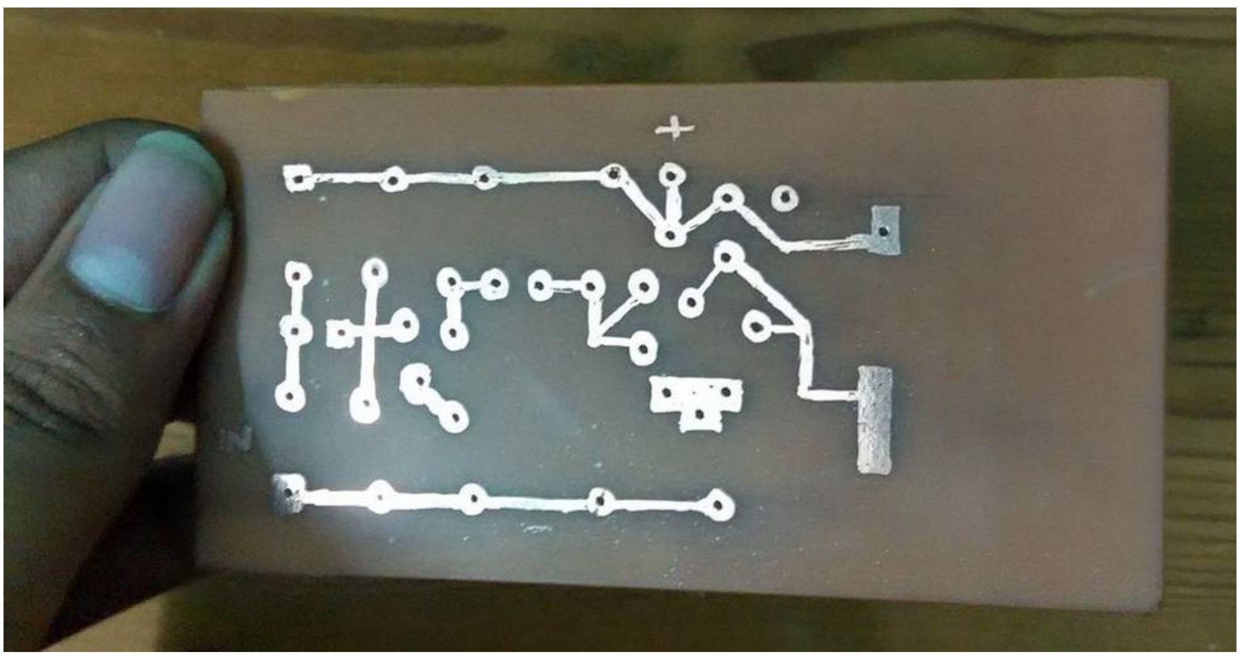


Figure 2.52 component placement and soldering.

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

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.

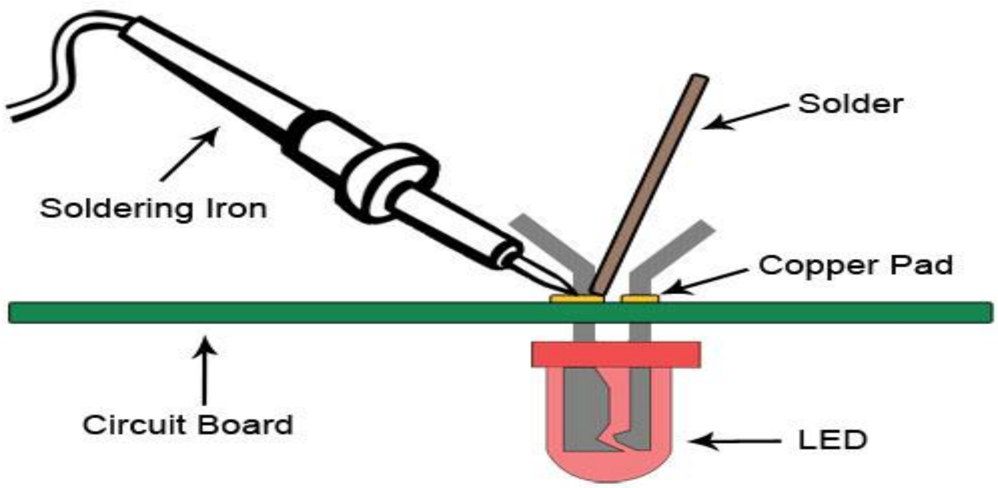


Figure 2.53 Soldering

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

Caution: A soldering iron can heat to around 400°C, which can burn you or start a fire, so use it carefully.

Unplug the iron when it is not in use.

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

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.

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

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

Work in a well-ventilated area.

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.

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

Figure 2.53.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.

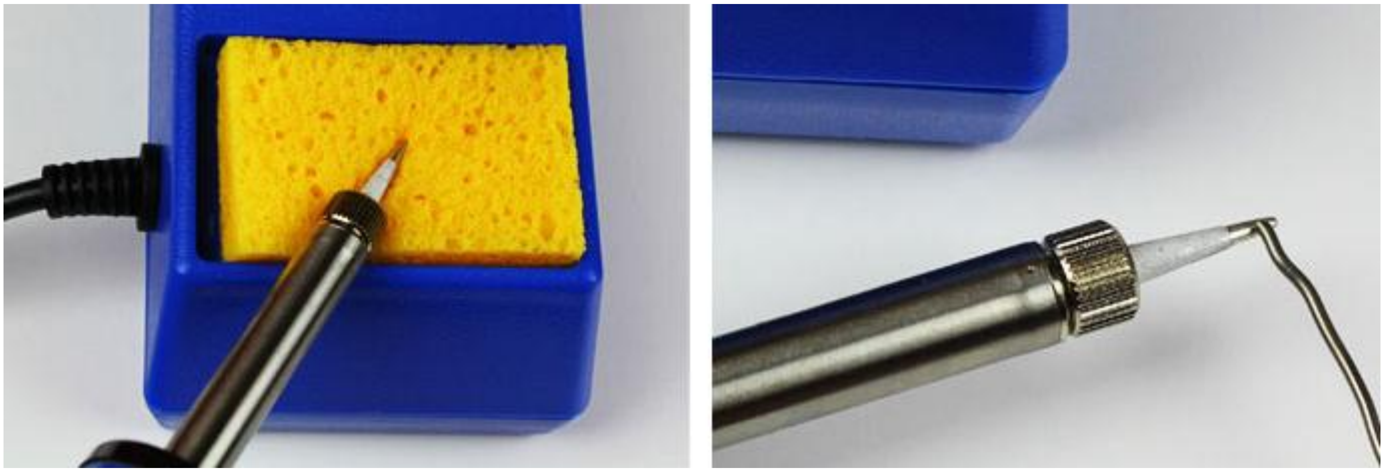


Figure 2.54 tinning the tip with solder.

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.

Construction and Soldering Techniques

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.

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

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.

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.

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

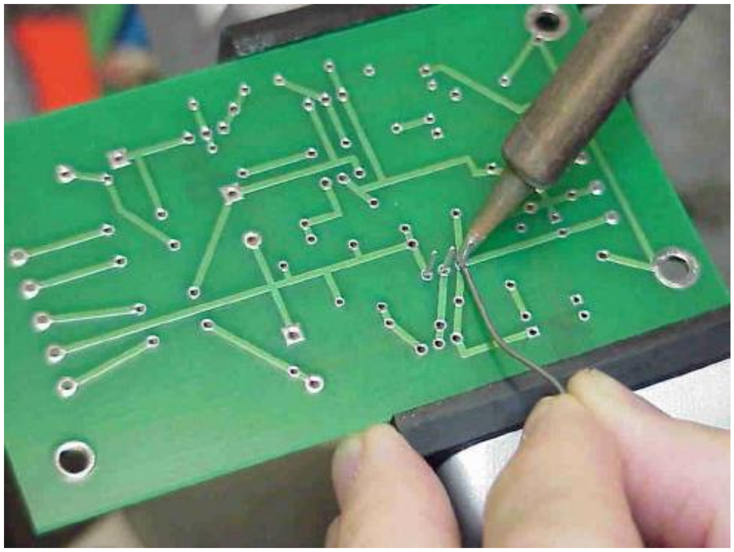
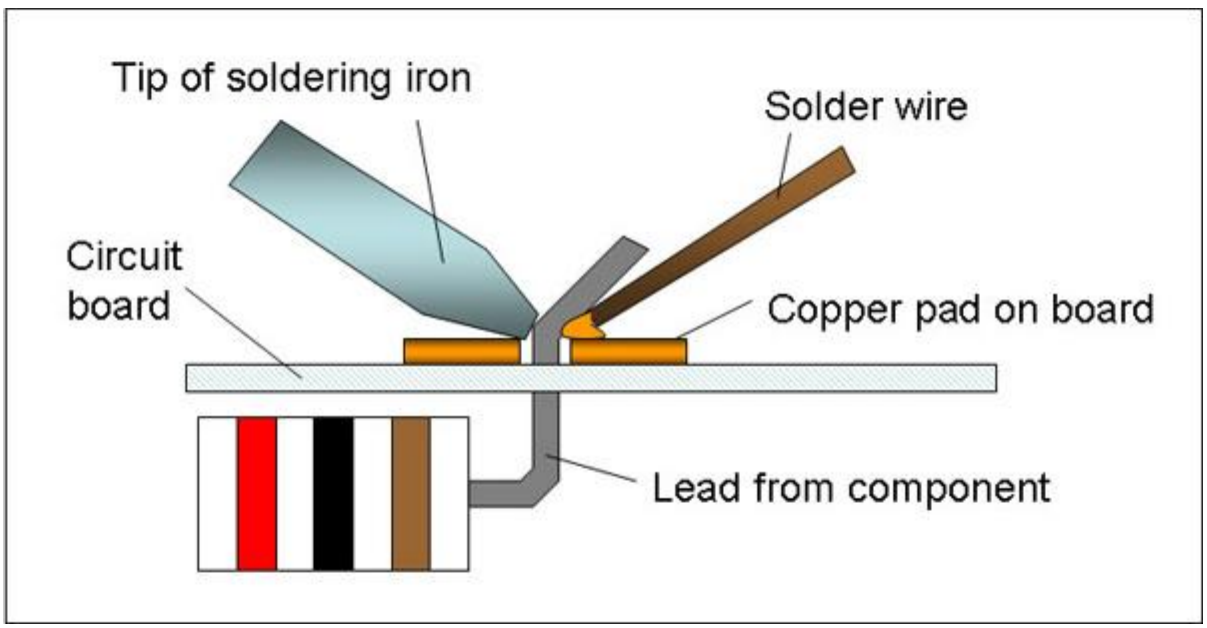
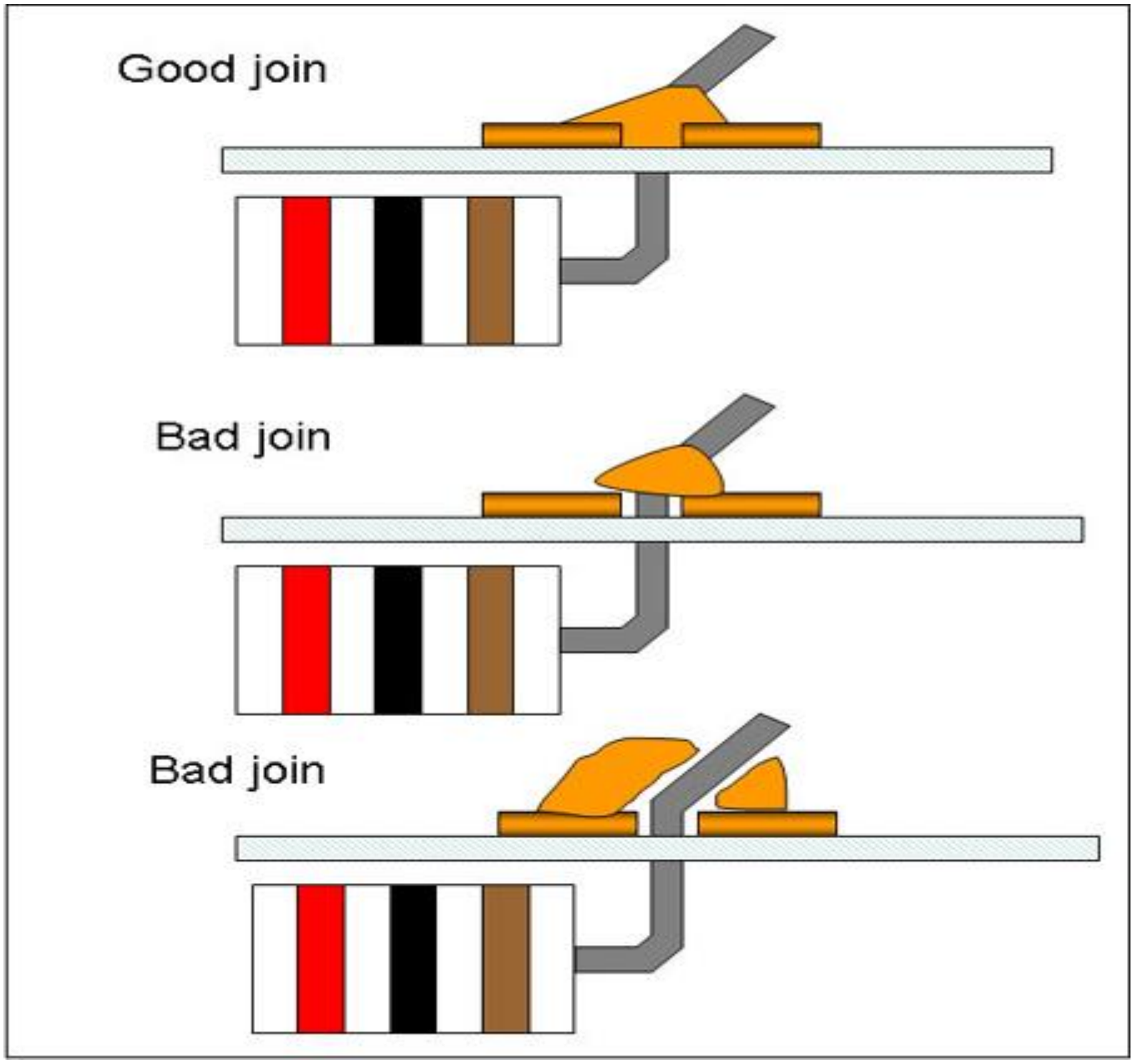


Figure 102. Soldering a component to a PCB

Good soldering and Bad soldering Joints

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





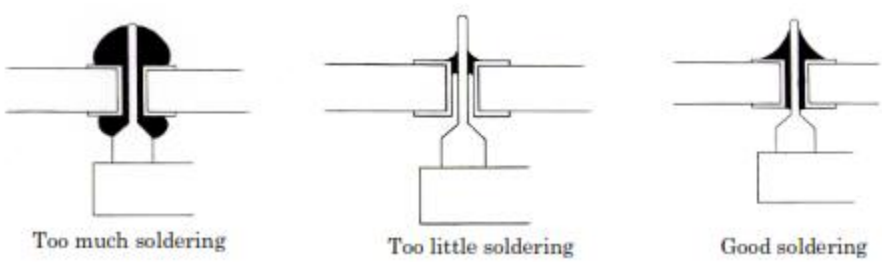


Figure 2.55 Good soldering and Bad soldering joint

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.

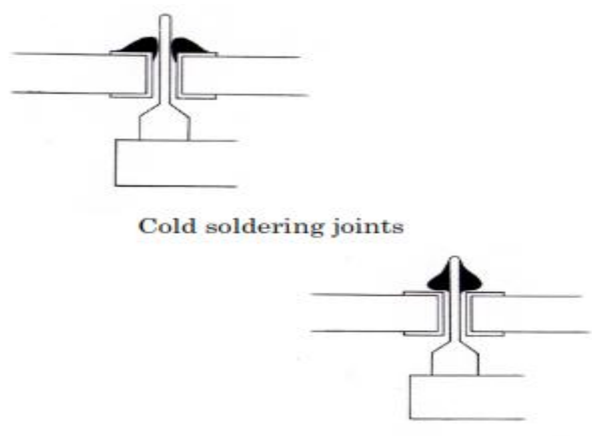


Figure 2.56 cold joint

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.

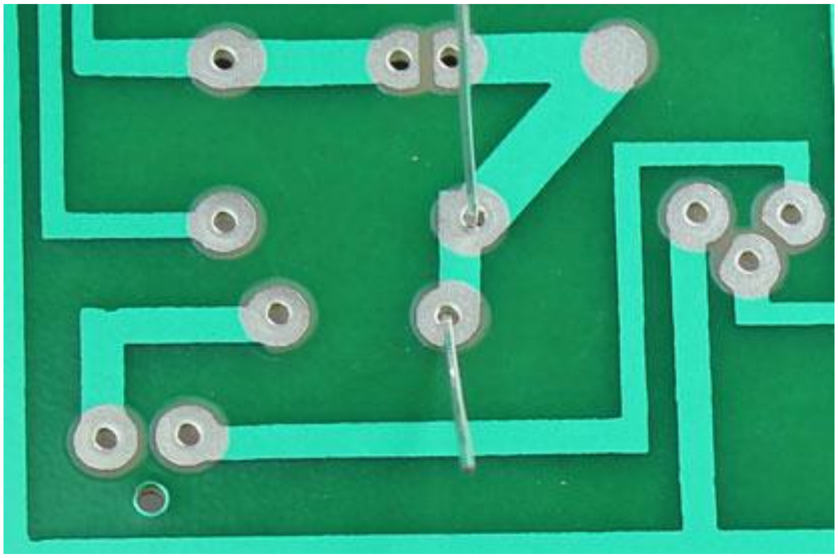


Figure 2.57 inserting

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.

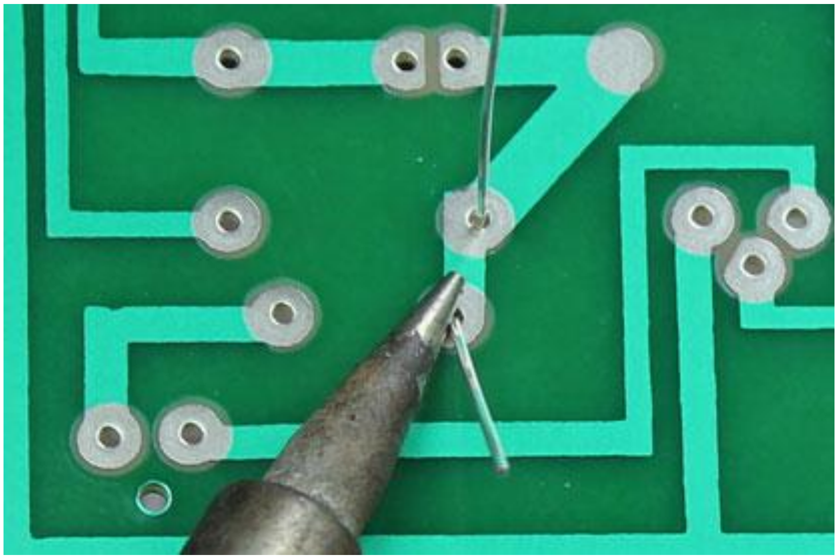


Figure 2.58 heating

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.

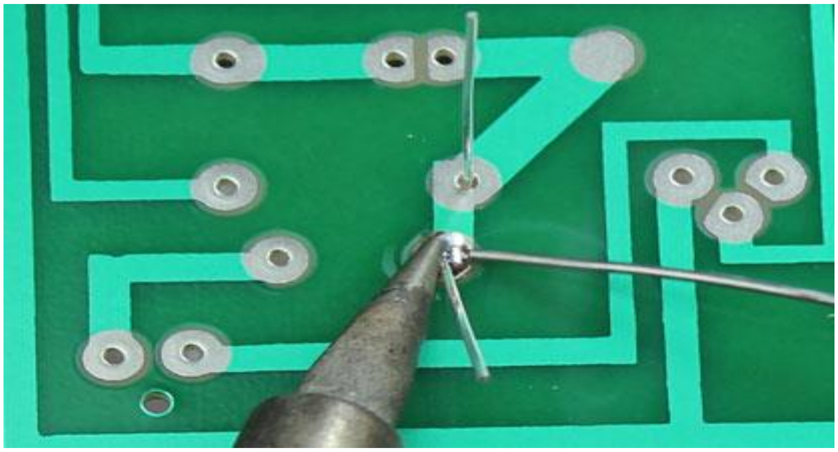


Figure 2.59 melt the solder

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.

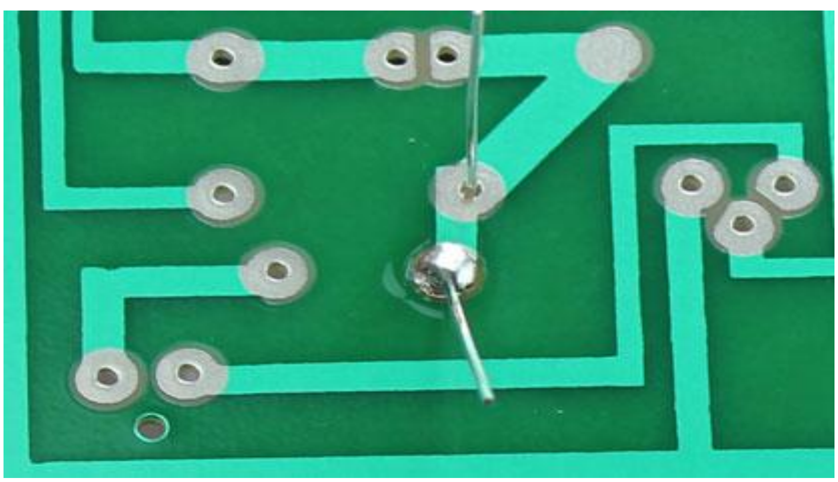


Figure 12.60 snip the extra wire

5 Confirming adjustments of accessories

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

Solder will not flow.

The parts to be joined may be dirty. Remove the solder and clean the parts.

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.

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.

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 -2.1

Test II: <u>short Answer writing</u>

Instruction: write short answer for the given question. You are provided 4 minute for each question and each point has 5 Points.

1. Before we begin our tasks in our workplace, what do we ask ourselves for safety?
2. What is Personal Protective Equipment?
3. When does PPE used?
4. Match the different PPEs with their uses. Write the letter on a separate provided. (5 points)
5. Write three that are included under common measures to control electrical risks at a workplace.
    - ______________________________
    - ______________________________
    - ______________________________
    - ______________________________
6. On completion of electrical work, workers should
    - ______________________________
    - __________
7. Maching from column "B" to Column "A"

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

Operation Sheet 2. 1

Design and construct printed circuit board (PCB)

- **Operation title:** Procedures of design and construct printed circuit board (PCB)
- **Purpose:** To practice and demonstrate the knowledge and skill required design and construct printed circuit board (PCB) to construct electrical/electronic Components.

Instruction: Use the given select tools and equipment so that design is usually done by converting your circuit's schematic diagram into a PCB layout using PCB layout software. For this operation you have given 3Hour and you are expected to provide the answer on the given steps.

STEP 1: Take printout of circuit board layout

STEP 2: **Cutting the copper plate for the circuit board**

STEP 3: **Transferring the PCB print onto the copper plate**

STEP 4: Circuit by hand on PCB (for simple and small circuits)

STEP 5: Ironing the circuit from the paper onto the PCB plate

STEP 6: Etching the plate

STEP 7: **Cleaning, disposing and final touches for the circuit board**

- **Tools and requirement:**
  - FeCl3 powder/solution (same as etching solution),
  - photo/glossy paper, permanent black marker,
  - blade cutter,
  - sandpaper,
  - kitchen paper and
  - Cotton wool.
  - 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

LAP Test -2.1

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

Task -1: Prepare coated circuit board layout.

Task -2

- **Precautions:** select necessary templates, tools, materials and equipment before constructing electrical /electronics circuit on PCB t on the given format
- **Quality Criteria:** the given constructing electrical /electronics circuit on PCB is with Correct specification

Unit Three: 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: • Test constructed electrical/electronic circuits • Check the accurate operation of the constructed circuit • Respond to unplanned events This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to: • Apply Test constructed electrical/electronic circuits • Check the accurate operation of the constructed circuit • Respond to unplanned events

3.1 Conducting test

Key Points:

- ❖ A list of basic tools for circuit board testing.
- ❖ Learn various ways to test a circuit board.
- ❖ Explore PCB optimization ideas to aid future testing.

Figure 3.1. multimeter for circuit board testing.

The same confidence is reflected during times when I need to test a circuit board. While there's no steering wheel involved, I have other tools that help in identifying faults in the circuit. It can be a struggle but when you have a systematic test procedure you're bound to locate the fault eventually.

3.2 Tools You'll Need to Test a Circuit

You'll need to be well prepared before testing a circuit. Here's a checklist of basic tools you should have:

- Analog/Digital multimeter.
- Soldering gun.
- De-soldering station.
- Magnifying glass.

These are tools that will solve common problems like short circuits, broken traces, or faulty components.

How to Test a Circuit Board That Stops Working

Start with a Visual Inspection

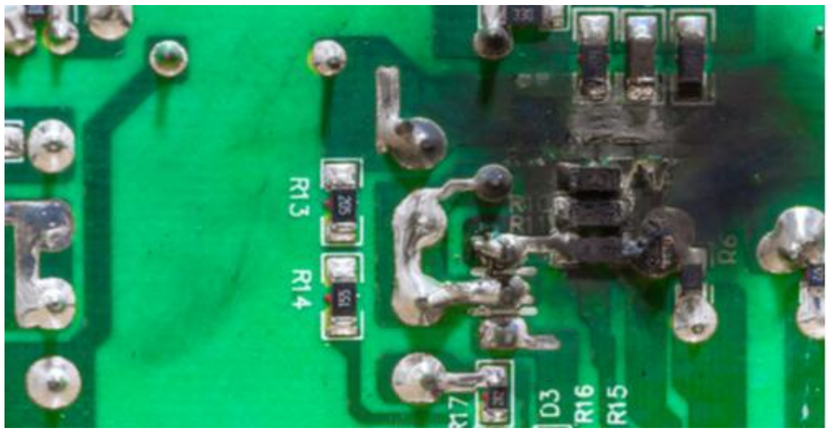


Figure 3.2. components during your visual inspection.

When a circuit board suddenly stops working, there are sometimes obvious signs of what went wrong. You'll need to rely on your vision to spot faulty components or broken traces. Often, circuit boards deployed in the field are damaged by electrical surges and there are telltale signs on the PCB. Look for a burnt spot, particularly on the power supply module or I/O and connectivity ports. Pay attention to cracked ICs, broken traces, and blown capacitors. Sometimes, you could trace the damaged components by their acrid scent.

3.3 Check the Power Module

If the components look fine, you'll need to power up the circuit board. Measure the voltage of the power rails with the multimeter. Both the input and output of the voltage regulator need to show the expected values. Check the fuse if the input voltage measured at the voltage regulator is 0V. If the fuse is replaced and immediately breaks after power-up, it means other components are shorted and draining a huge amount of current.

A voltage of 0V, or below Vcc, at the output often means that the regulator or a component along the voltage rail has a short circuit. If that's the case, the damaged component will heat up quickly. Bring your hand close to the components to feel if one is giving off excessive heat. Be careful to not directly touch the component when it's powered on, as it can be extremely hot. Remove the overheated components and confirm that the voltage has returned to the expected value. If voltage observed is still different than the expected voltage, there could be more components that are damaged down the voltage line. Refer to the schematic and remove the next component that is near the edge of the PCB. If there aren't signs of overheated components then look for broken traces. A broken trace could result in the voltage being detected at some points of the trace but not in others. Use your multimeter to narrow down where the discontinuity is.

3.4 Check the Input/output Ports

The I/O are also common points of failure. Damage on I/O ports seldom shuts down the whole circuit, but it usually results in anomalies in the system. For example, an alarm controller that always senses an open door even if it's closed or a motor that is continuously activated. If the I/O is protected by fuses, Zener diodes, or varistors, ensure that they are functioning well. If so, the logic IC or the microcontroller is likely damaged. The only way to find out is to replace the parts with good ones.

3.5 Check Communication Ports

Circuit boards with communication ports like Ethernet and RS485 have an increased risk of failure. When communication failure is detected, check for burns or cracked communication ICs or protective components like Zeners. Optimizing Circuit Boards for Troubleshooting

3.6 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.

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.

3.7 Check 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:

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.

Load regulation = $V_{no\text{-}load} - V_{full\text{-}load}$……………………………..(5)

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.

% Load Regulation = $[(V_{no\text{-}load} - V_{full\text{-}load})/V_{full\text{-}load}] * 100$………(6)

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.

Minimum Load Resistance = $V_{full\text{-}load}/I_{full\text{-}load}$…………………(7)

The value of I full-load, full load current should never increase than that mentioned in the datasheet of the power supply.

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.

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.

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.

3.8 Respond unplanned events or conditions

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.

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.

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 – 3.1	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. What are the factors that affect the quality of the power supply? List at list four of them and explain. (8 points)
2. Discuss on unplanned events or conditions caused during construction of electrical/electronic circuit. (7 points)

Write at list three advantage and disadvantage of functional testing. (6 points

List of Reference Materials

1. *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.*
2. *Cacha, Charles A. (1999). Ergonomics and Safety in Hand Tool Design. CRC. ISBN 1566703085.*
3. 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.
4. Salaman, R. A. (1996). *Dictionary of Leather-working Tools, c.1700–1950, and the Tools of Allied Trades* Mendham, NJ: Astragal Press ISBN 978-1-879335-72-1.
5. https://www.slideshare.net/rodericklamban/basic-hand-tools-electronics-technology
6. https://www.sheffield.ac.uk/bms/research/facilities/electronics/index
7. https://www.youtube.com/watch?v=2nZ9lS6VHFU
8. https://www.youtube.com/watch?v=zdNG3r119qs&t=5s
9. https://www.youtube.com/watch?v=aR-1kKCvmLE
10. https://www.youtube.com/watch?v=6Maq5IyHSuc
11. https://www.youtube.com/watch?v=6UTOTgbJ_8E
12. https://www.youtube.com/watch?v=huEM80IlSFs
13. https://youtu.be/N8_1wb0r0DQ

14. https://youtu.be/drtUkvtxp6s
15. https://youtu.be/sTwRQDVHNiw
16. http://lrf.fe.uni-lj.si/fkkt_ev/Literatura/Electrical_and_Electronics_Measurment.pdf
17. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19720011865.pdf
18. http://s1.nonlinear.ir/epublish/book/Electronic_Troubleshooting_0071819908.pdf
19. https://www.clemson.edu/cecas/departments/ece/document_resource/undergrad/electronics/CInquiryLabManual.pdf
20. https://www.youtube.com/watch?v=GW_-ycgJXhg
21. https://www.youtube.com/watch?v=s9g-I3t_Ki8&t=20s
22. https://www.youtube.com/watch?v=i4jTHhXuKLA&t=25s
23. https://www.youtube.com/watch?v=gkeJzRrwe5k

Participants of this Module (training material) preparation

No	Name	Qualification (Level)	Field of Study	Organization/ Institution	Mobile number	E-mail
1		A(MSC)				
2						
3						
4						
5						
6						
7						

የሥራና ክህሎት ሚኒስቴር
Ministry of Labor and Skills