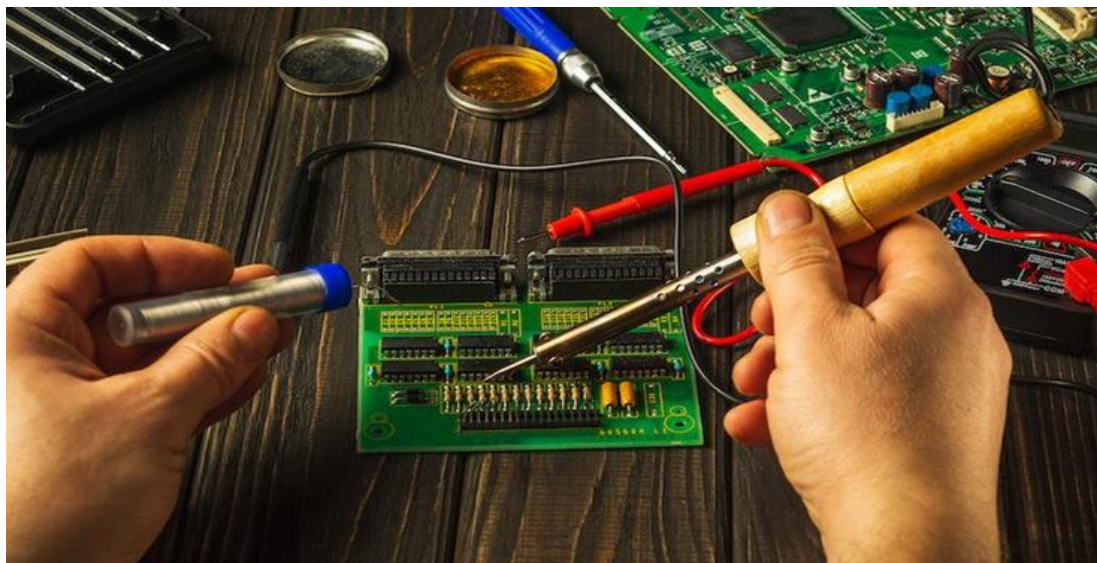


Biomedical Equipment Servicing

Level – II

Based on September 2021, curriculum Version-II



MODULE TITLE: Construct Simple Circuit on Printed Circuit Board

MODULE CODE: HLT BES2 M06 0822

NOMINAL DURATION: 80 Hours

August, 2022

Prepared By: Ministry of Labor and Skills

Addis Ababa, Ethiopia

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Acronyms

AC	Alternating Current
DC	Direct Current
EU	European Union
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MoLS	ministry of labor and skills
OHS	occupational health and safety
PCB	Printed Circuit Board
PPE	personal protective equipment
SMD	Surface mounted devices
WHO	World Health Organization

Introduction

A PCB is a rigid structure that contains electrical circuitry made up of embedded metal surfaces called traces and larger areas of metal called planes. Components are soldered to the board onto metal pads, which are connected to the board circuitry. This allows components to be interconnected. A board can be composed of one, two, or multiple layers of circuitry.

In general, boards can be categorized into one of three categories: rigid, flex, or metal-core boards. One of the high points for a beginning electronics hobbyist is putting his first circuit board together. Other than some light electronics soldering, the work is about getting components into the right places. Double-checking parts placement and orientation before you solder will save you rework time later. Place and solder sockets first, then components, and do the wiring last. When the parts are all connected, and wires soldered in, the board is ready to test.

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Module units:

- preparation to **construct electronics circuits**
- Constructing electronics circuits on PCB
- Testing the constructed electronic circuits

Learning objectives of the Module

At the end of this session, the students will able to:

- Plan and prepare to construct electronics circuits
- Construct electronics circuits on PCB
- Check and Test the constructed electronic circuits

Module Learning Instructions:

- Read the specific objectives of this Learning Guide.
- Follow the instructions described below.
- Read the information written in the information Sheets
- Accomplish the Self-checks
- Perform Operation Sheets
- Do the “LAP test”

Unit one: preparation to construct electronics circuits

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Materials to construct circuit on PCB
- Range of tools and equipment
- OHS guidelines
- Reading and interpreting circuit diagram

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:

- Check Materials
- Select tools and equipment
- Plan task to ensure OHS guidelines
- Prepare circuit parts and components for connecting and soldering
- Read and interpret circuit diagram

1.1 Materials to construct circuit on PCB

1.1.1 Soldering lead

It is a fusible metal alloy used to create a permanent bond between metal work pieces. Solder is melted in order to wet the parts of the joint, where it adheres to and connects the pieces after cooling. Metals or alloys suitable for use as solder should have a lower melting point than the pieces to be joined. The solder should also be resistant to oxidative and corrosive effects that would degrade the joint over time. Solder used in making electrical connections also needs to have favorable electrical characteristics.

Soft solder typically has a melting point range of 90 to 450 °C (190 to 840 °F; 360 to 720 K),[3] and is commonly used in electronics, plumbing, and sheet metal work. Alloys that melt between

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180 and 190 °C (360 and 370 °F; 450 and 460 K) are the most commonly used. Soldering performed using alloys with a melting point above 450 °C (840 °F; 720 K) is called "hard soldering", "silver soldering", or brazing.

In specific proportions, some alloys are eutectic — that is, the alloy's melting point is the lowest possible for a mixture of those components, and coincides with the freezing point. Non-eutectic alloys can have markedly different solidus and liquids temperatures, as they have distinct liquid and solid transitions. Non-eutectic mixtures often exist as a paste of solid particles in a melted matrix of the lower-melting phase as they approach high enough temperatures. In electrical work, if the joint is disturbed while in this "pasty" state before it fully solidifies, a poor electrical connection may result; use of eutectic solder reduces this problem. The pasty state of a non-eutectic solder can be exploited in plumbing, as it allows molding of the solder during cooling, e.g. for ensuring watertight joint of pipes, resulting in a so-called "wiped joint".



Figure 1.1: soldering lead

1.1.2 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 oxidizing 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 1.2: Flux

1.1.3 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.

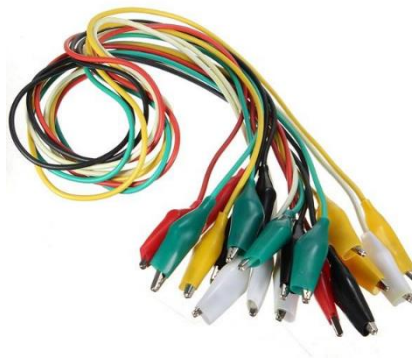


Figure1.3: Jumper wire

1.1.4 Ferric chloride

Usually to etch the copper from the PCB, an aqueous solution of ferric chloride (also called iron (III) chloride, FeCl_3) is used. It works quite well but it's terribly slow: a fresh solution will probably

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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 1.4: Ferric chloride

1.1.5 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.

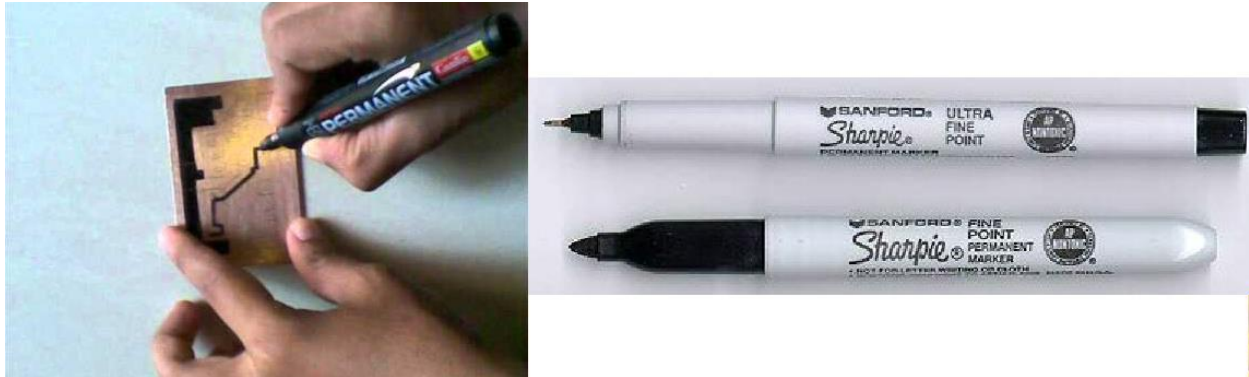


Figure 1.5: Permanent marker (ink)

1.1.6 PCB

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

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



Figure 1.6: PCB

Bread board or Solder less breadboard

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

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

1. Insulated bread board
2. Un insulated breadboard

Strip board (uninsulated breadboard)

Stripboard is one of the commonly-used types of prototyping board. These boards are intended for permanently assembling one-off circuits, especially prototypes. The board is made from insulating material, usually a resin-bonded plastic or fiberglass. 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.

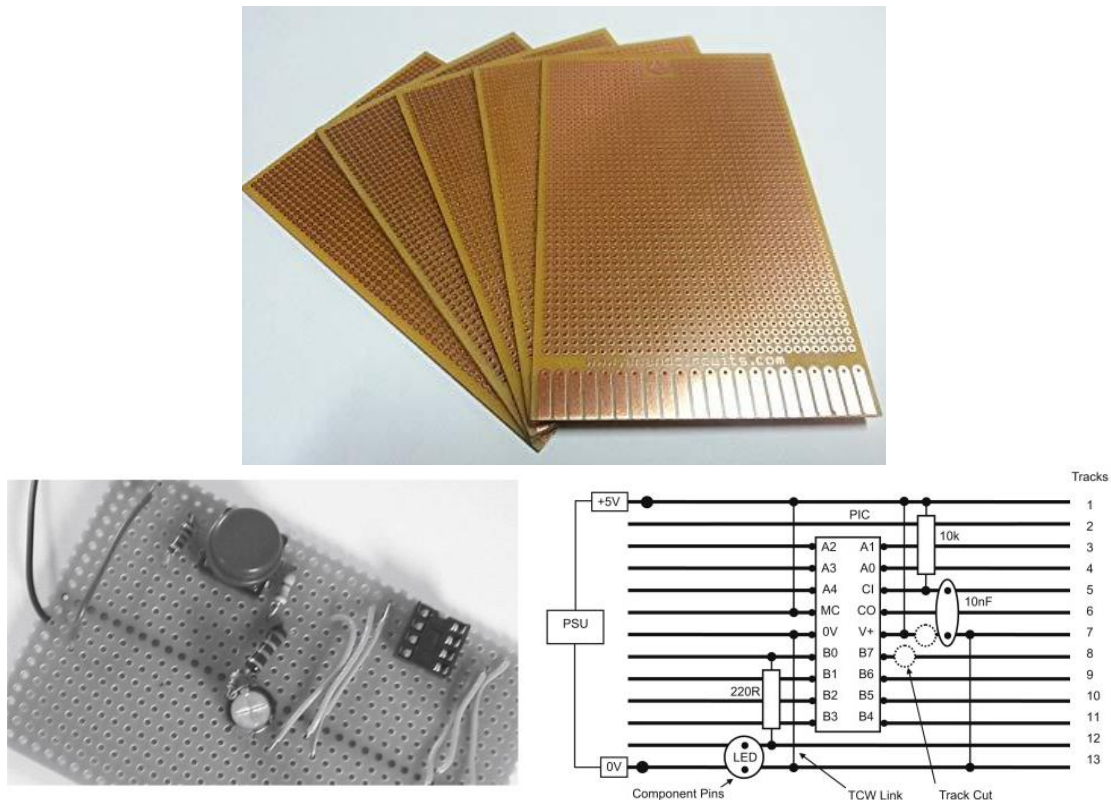


Figure 1.7: Stripboard (uninsulated breadboard)

Breadboard (insulated breadboard)

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

These rows of contacts are then arranged into two columns. These two columns of contacts are separated by a 0.3" space to form a breadboard. This spacing is chosen because the typical DIP style IC has leads on a 0.3" spacing from one side of the IC to the other. By placing the IC across

this space in the middle of the breadboard, each of the pins of the IC is connected to its own separate row of 5 contacts.

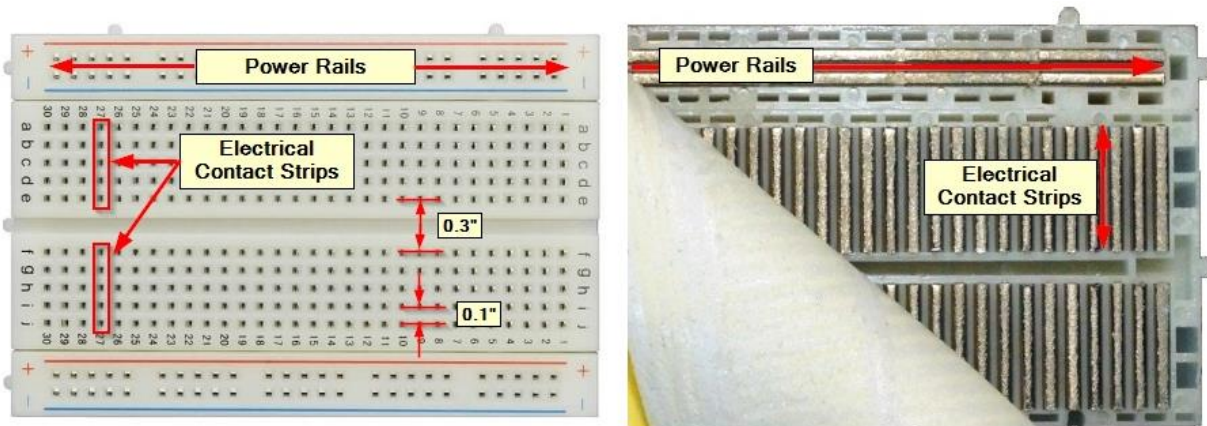


Figure1.8: Breadboard (insulated breadboard)

1.2 Electrical/electronic tools, equipment's 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.

1.2.2. Selecting appropriate tools and equipment's

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

- **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 PCBs, other wires, or small terminals. A low-power iron (1530 Watts) is suitable for this work.



Figure 1.11: 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 1.12: 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 1.13: 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 1.13: 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 1.16: sucker

- **Splicing Tools**

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

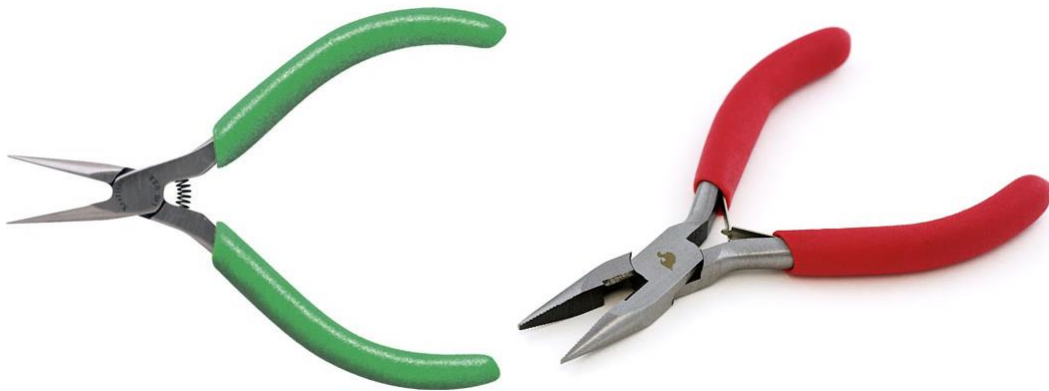


Figure 1.17: Long nose

- **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 1.19: 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 1.20 : Wire striper (a) manual (b) automatic

- **Cutting Tools**

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



Figure 1.21: Utility knife

- **Auxiliary Tools**

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



Figure 1.22: Ballpin hammer

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

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



Figure 1.23: 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. 30: Anti-static brush

- **Tweezers**

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






Figure 1.24: Tweezer

1.2.3. Testing instrument

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

Types of test equipment




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

<p>1. <u>Voltmeter</u> (Measures <u>voltage</u>)</p>	
<p>2. <u>Ohmmeter</u> (Measures <u>resistance</u>)</p>	
<p>3. <u>Ammeter</u>, e.g. <u>Galvanometer</u> or Milli Ammeter (Measures <u>current</u>)</p>	

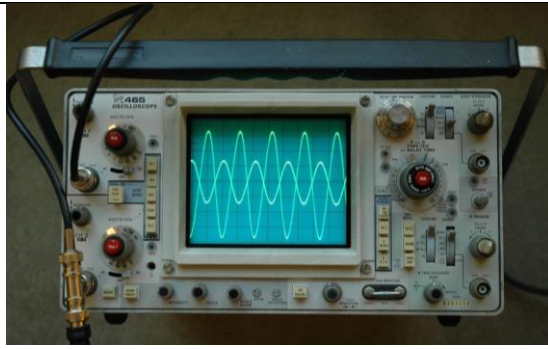
<p>4. <u>Multimeter</u> e.g., VOM (Volt-Ohm-Millimeter) or DMM (Digital Multimeter) (Measures all of the above)</p>	
<p>5. <u>LCR Meter</u> e.g., LCR meter or Resistance, Inductance and capacitance meter (measure LCR values)</p>	

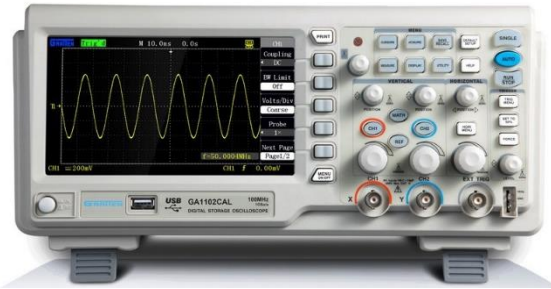


1. The following are used for stimulus of the circuit under test

<p>1. <u>Power supplies</u></p>	
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2. <u>Signal generator</u>	
3. <u>Digital pattern generator</u>	
4. <u>Pulse generator</u>	


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

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

Advanced or less commonly used equipment Meters

<p><u>Solenoid voltmeter</u> (Wiggly)</p>	
<p><u>Clamp meter</u> (current transducer)</p>	
<p><u>Wheatstone bridge</u> (Precisely measures <u>resistance</u>)</p>	

<p><u>Capacitance meter</u> (Measures capacitance)</p>	
<p><u>EMF Meter</u> (Measures Electric and Magnetic Fields)</p>	
<p><u>Electrometer</u> (Measures charge)</p>	

1.3 OHS guidelines

1.3.1. Introduction to occupational health and safety

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

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

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

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

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

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

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

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

1.3.2. Identifying safety and health hazards

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.

1.4 Preparing Electrical/electronic circuits correctly for connecting and soldering

1.4.1 Active and Passive components in electronics

Active components include transistors, while passive components include transformers, inductors, resistors, capacitors. Transformers are commonly used to step up or step down power. A resistor restricts current flow. It is used in thermistors and potentiometers. Similar to a low capacity battery, a capacitor allows delays to occur in circuits. Inductors are used to control frequencies.

When building electronic circuits, you will work with a number of basic electronic components, including resistors, capacitors, diodes, transistors, inductors and integrated circuits. Below is a brief overview of the components and their functions.

1. **Resistors:** A resistor is one of the components you will come across in an integrated circuit. Like the name suggests, the device resists the flow of current. Resistors are graded based on their power ratings (amount of power they can handle without exploding) and resistance values (capacity to resist current). The measurement is done in units known as ohms. The electronic symbol of the unit is Ohm
2. **Capacitors:** These components can store electric charge temporarily. The components come in different varieties, with the most common ones being electrolytic and ceramic disk. The capacity of a component is usually measured in microfarads (μF).
3. **Diodes:** Diodes allow electric current to flow in a single direction only. Each diode has two terminals known as the anode and cathode. When the anode is charged with positive voltage and the cathode with a negative one, electric current can flow. Reversing these voltages will prevent the current from flowing.
4. **Transistors:** These components are easy to identify through their three terminals. For the components to work, voltage has to be applied to one of them; the base terminal. The base can then control current flow in the two other terminals (the emitter and collector).
5. **Inductors:** These are passive components that store energy in form of a magnetic field. An inductor simply consists of a coil of wire wound around some kind of core. The core could be a magnet or air. When current passes through the inductor, a magnetic field is created around it. The magnetic field is stronger if a magnet is used as the core.
6. **Integrated Circuits:** An integrated circuit refers to a special device that has all the components required in an electronic circuit. The component has diodes, transistors, and other devices, all of which are etched on a tiny piece of silicon. The components are used in many electronic devices, including watches and computers.
7. **Microcontrollers:** Microcontrollers are small computers used to control a multitude of devices, such as power tools, remote controls, medical equipment and office machines.
8. **Transformers:** Built with two coils of wire, transformers are commonly used to step up or step down power.
9. **Batteries:** Batteries convert chemical energy to electrical energy. The two different cells of a battery are anode (+) and cathode (-).

10. **Fuses:** Fuses help preserve components from overloading with excessive current. A fuse consists of connection body, support, contacts, and metal-fuse material such as zinc or copper.
11. **Relays:** These electromechanical switches shut power on or off. A relay includes an electromagnet, an armature, a series of electrical contacts and a spring.
12. **Switches:** Switches interrupt current. The four types of switches are: single pole single throw (SPST), single pole double throw (SPDT), double pole single throw (DPST), and double pole double throw (DPDT).
13. **Motors:** Motors convert electrical energy into mechanical energy. Key components include a rotor, stator, bearings, conduit box, enclosure, and eye bolt.
14. **Circuit Breakers:** As a protective device, a circuit breaker can be controlled with a remote switch. It is designed to protect the circuit from overloading or a short circuit.

1.4.2 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.

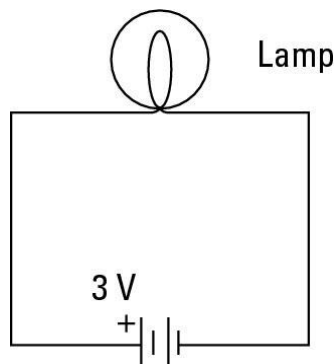


Figure 2.45 series circuit

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

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

Rectifier circuit

Now we come to the most popular application of the diode: *rectification*. Simply defined, rectification is the conversion of alternating current (AC) to direct current (DC). This involves a device that only allows one-way flow of electric charge. As we have seen, this is exactly what a semiconductor diode does. The simplest kind of rectifier circuit is the *half-wave* rectifier. It only allows one half of an AC waveform to pass through to the load. (Figure below)

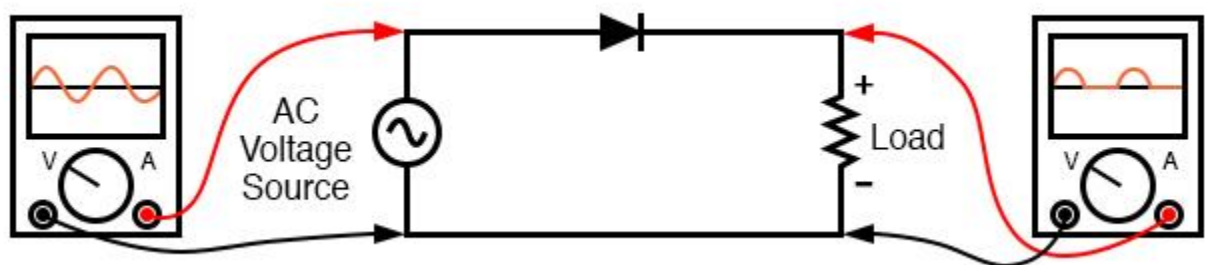


Figure: Half-wave rectifier circuit.

For most power applications, half-wave rectification is insufficient for the task. The harmonic content of the rectifier's output waveform is very large and consequently difficult to filter. Furthermore, the AC power source only supplies power to the load one half every full cycle, meaning that half of its capacity is unused. Half-wave rectification is, however, a very simple way to reduce power to a resistive load. Some two-position lamp dimmer switches apply full AC power to the lamp filament for “full” brightness and then half-wave rectify it for a lesser light output.

Full-Wave Rectifiers

If we need to rectify AC power to obtain the full use of *both* half-cycles of the sine wave, a different rectifier circuit configuration must be used. Such a circuit is called a *full-wave* rectifier. One kind of full-wave rectifier, called the *center-tap* design, uses a transformer with a center-tapped secondary winding and two diodes, as in the figure below.

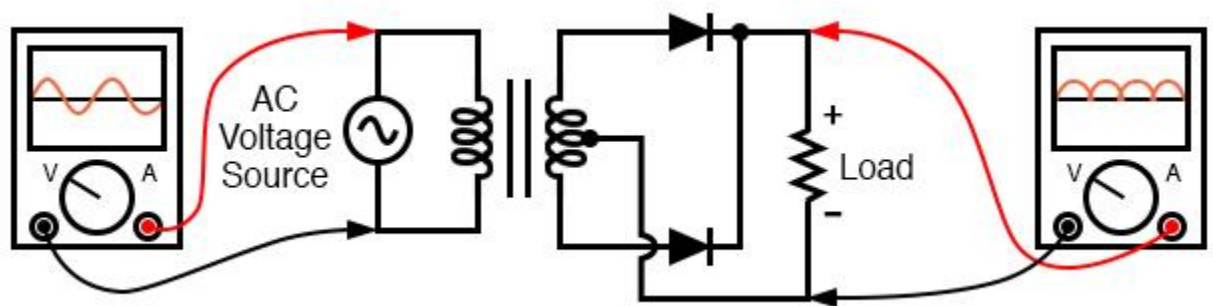


Figure: Full-wave rectifier, center-tapped design.

Positive Half-Cycle

This circuit's operation is easily understood one half-cycle at a time. Consider the first half-cycle, when the source voltage polarity is positive (+) on top and negative (-) on bottom. At this time, only the top diode is conducting; the bottom diode is blocking current, and the load “sees” the first half of the sine wave, positive on top and negative on

bottom. Only the top half of the transformer's secondary winding carries current during this half-cycle as in the figure below.

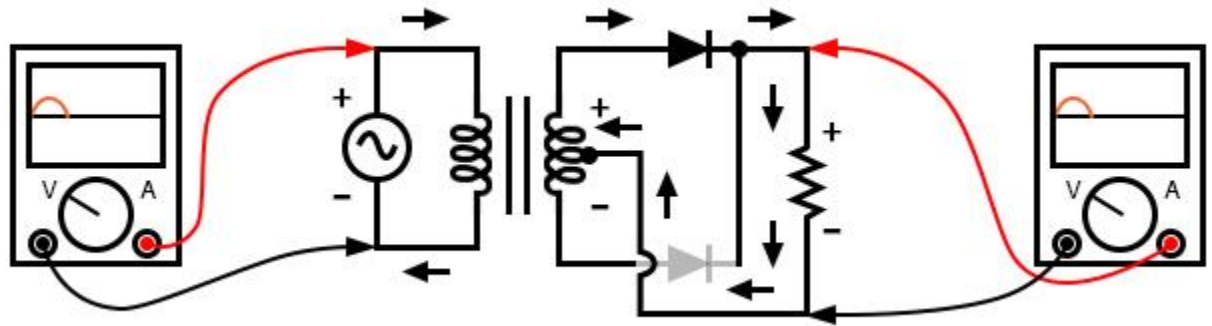


Figure 3.1 Full-wave center-tap rectifier: Top half of secondary winding conducts during positive half-cycle of input, delivering positive half-cycle to load.

Negative Half-Cycle

During the next half-cycle, the AC polarity reverses. Now, the other diode and the other half of the transformer's secondary winding carry current while the portions of the circuit formerly carrying current during the last half-cycle sit idle. The load still "sees" half of a sine wave, of the same polarity as before: positive on top and negative on bottom.

Full-wave center-tap rectifier: During negative input half-cycle, bottom half of secondary winding conducts, delivering a positive half-cycle to the load.







1.5 Reading and interpreting circuit diagram

- How to read the electrical diagram?

In order to read any of the electrical diagrams, we must be familiar with the graphical symbols which is used to represent the electrical components. In most of the electrical diagrams, the symbols which is used to represent the electrical component would be the same. So it is really important that one should have an idea about the graphical symbols to read the electrical diagram.

- Graphical symbols in the electrical diagram

Graphical symbols are required in an electrical diagram to show the electrical device connections and their terminals. The electrical devices would be represented by symbols. The symbol orientation in an electrical diagram won't change its meaning or purpose.

Electrical equipment	Graphical representation of the electrical device
Circuit breaker	
Resistor	
Potentiometer	
Fuses	
Relays	<div>Normally Open Contact </div> <div>Normally Closed Contact </div>

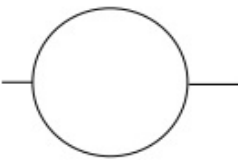
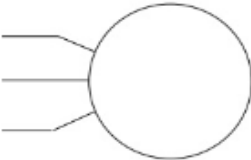


Coil	
3-phase motor	
Capacitors	  Polarized

Table: graphical symbol

Table 1 .Graphical symbols in the electrical diagram

Self-Check –1

Directions: Answer all the questions listed below:

Test 1: short answer

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

Test 2: Matching

Directions: Answer all the questions listed below. Match the different hand tools with their actual pictures. Write the letter on a separate provided.

- | | |
|----------------------------------|----------------------------------|
| _____ 1. Desoldering Sucker | _____ 6. For soldering |
| _____ 2. Soldering Stand | _____ 7. Long Nose Pliers |
| _____ 3. For drilling small hole | _____ 8. Portable Electric Drill |
| _____ 4. For cutting metal | _____ 9. For cutting wires |
| _____ 5. Wire Splicer | _____ 10. Magnifying Glass |



a



b



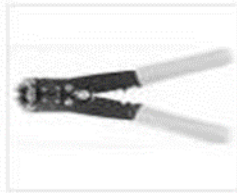
g



h



c



d



i



j



e



f



k



l

Test 3: Fill in the blank for questions listed below.

1. Write two measuring instruments used to measure voltage.
2. Write two instruments that are used for stimulus of the circuit under test.
3. What is the instrument used to measure LCR values?
4. What is meant by risk assessment? (4 points)

Unit Two: Construction of electronic circuits on PCB

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Safety procedures in using hand tools
- Circuit construction techniques
- Constructing electrical /electronic circuits and confirming with the diagram

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning unit , you will be able to:

- Observe safety procedures
- Identify appropriate range of methods in constructing electrical /electronic circuits
- Adjust accessories used, if applicable
- Perform process of conforming the construction undertaken

2.1 Safety procedures in using hand tools

Safety is 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 equipment's, unsafe work areas, operating machines without knowing how to operate and using materials out of their intended purpose etc.

2.1.1 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:

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- 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.

2.1.2 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 its do's and don'ts?

Safety Precautions in Using Hand Tools and Equipment

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

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

1. Cleaning the tools after use is Mandatory.
2. All tools and equipment must be placed in a clean and dry place.
3. The work area must always be kept neat and tidy.
4. Lubricants must also be applied after tightening to reduce the friction.
5. Before cleaning any tool, be sure to wear the proper personal protective equipment (PPE).
For example, gloves, masks and goggles are usually worn when cleaning tools since most cleaning agents and solutions are harmful to the human body.
6. Only use cleaning agents as prescribed by the tool or equipment's manufacturer. Follow the cleaning procedures as well to make sure that no damage will be inflicted on the tools.

2.1.3 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

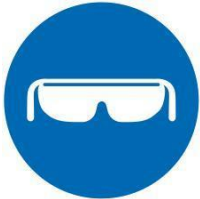
includes boots (safety shoes, facemasks, hard hats (helmet), earplugs, respirators, gloves, safety harnesses and high visibility clothing.

1. Safety for the head



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

2. Protect your eyes



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

3. Hearing protection



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

4. Maintain a good respiration



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

5. Protect your hands with the right gloves



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

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

6. Protection for the feet



Even your feet need solid protection. **Safety shoes** (type Sb, S1, S2 or S3) **and boots** (type S4 or S5) are the ideal solution to protect the feet against heavy weights. An **antiskid sole** is useful when working in a damp environment, definitely if you know that 16,2% of all industrial

accidents are caused by tripping or sliding. On slippery surfaces, such as snow and ice, **shoe claws** are recommended. Special socks can provide extra comfort.

7. Wear the correct work clothing



Preventing accidents is crucial in a crowded workshop. That is why a good visibility at work is necessary: 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.

2.4.1 When does PPE used?

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

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

2.2 Circuit construction techniques

2.2.1 Terminating Technique

There is a variety of termination methods for cable. The termination method utilized depends on the system installed, type of cable used and type of connector; Using the proper termination method allows for good mechanical and electrical integrity. No matter what type of termination you will be performing, the most important thing is to use the proper tools and materials for the type of termination. For example, a crimp using pliers will work, but using a crimp tool and the proper tie designed for your type of cable and connector is better. Using the proper solder type and the right temperature for solder type connections will ensure a lasting connection. We will review four basic termination techniques. This is just to provide some general guidelines. The termination method may vary somewhat based on system requirements and connector manufacture design methods.

2.2.2 Soldering Technique

The following information will aid you in learning basic soldering skills. It should enable you to solder wires to electrical connectors, splices, and terminal lugs. Special skills and training are required for the soldering techniques used in PCBs and micro-miniature component repair.

➤ Soldering Process

- Cleanliness is essential for efficient, effective soldering. Solder will not adhere to dirty, greasy, or oxidized surfaces.
- Heated metals tend to oxidize rapidly. This is the reason the oxides, scale, and dirt must be removed by chemical or mechanical means. Grease or oil films can be removed with a suitable solvent.
- Connections to be soldered should be cleaned just prior to the actual soldering operation.
- Items to be soldered should normally be "tinned" before making a mechanical connection.
- Tinning is the coating of the material to be soldered with a light coat of solder. When the surface has been properly cleaned, a thin, even coating of flux should be placed over the surface to be tinned. This will prevent oxidation while the part is being heated to soldering temperature.

Rosin-core solder is usually preferred in electrical work. However, a separate rosin flux may be used instead. Separate rosin flux is frequently used when wires in cable fabrication are tinned.

2.7 Pin Connection

Components of an electrical circuit are electrically connected if an electric current can run between them through an electrical conductor. An electrical connector is an electromechanical device used to create an electrical connection between parts of an electrical circuit, or between different electrical circuits, thereby joining them into a larger circuit. Most electrical connectors have a gender – i.e. the male component, called a plug, connect to the female component, or socket. The connection may be removable (as for portable equipment), require a tool for assembly and removal, or serve as a permanent electrical joint between two points. An adapter

can be used to join dissimilar connectors. Thousands of configurations of connectors are manufactured for power, data, and audiovisual applications. Electrical connectors can be divided into four basic categories, differentiated by their function:

- *Inline* or *cable* connectors permanently attached to a cable, so it can be plugged into another terminal (either a stationary instrument or another cable)
- *Chassis* or *panel* connectors permanently attached to a piece of equipment so users can connect a cable to a stationary device
- *PCB mount* connectors soldered to a PCB, providing a point for cable or wire attachment. (e.g. pin headers, screw terminals, board-to-board connectors)
- *Splice* or *butt* connectors (primarily insulation displacement connectors) that permanently join two lengths of wire or cable

In computing, electrical connectors are considered a physical interface and constitute part of the physical layer in the OSI model of networking.

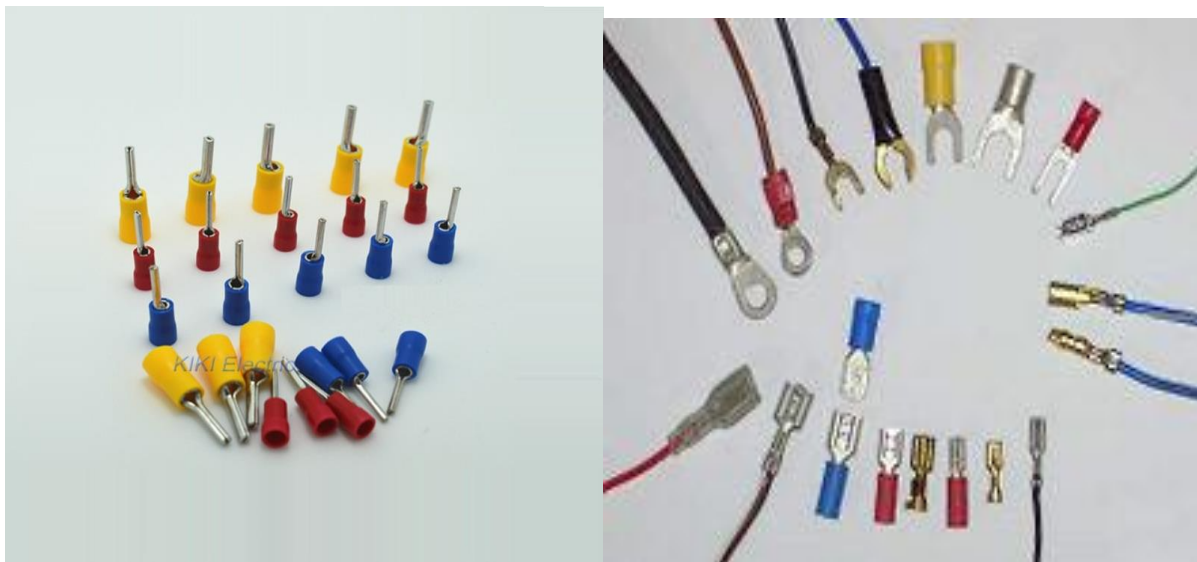


Figure 2.1: Pin Connectors

2.2.3 plugs

AC power plugs and sockets connect electric equipment to the alternating current (AC) mains electricity power supply in buildings and at other sites. Electrical plugs and sockets differ from

one another in voltage and current rating, shape, size, and connector type. Different standard systems of plugs and sockets are used around the world.

Plugs and sockets for portable appliances became available in the 1880s, to replace connections to light sockets with wall-mounted outlets. A proliferation of types developed for both convenience and protection from electrical injury. Today there are about 20 types in common use around the world, and many obsolete socket types are found in older buildings. Coordination of technical standards has allowed some types of plug to be used across large regions to facilitate trade in electrical appliances, and for the convenience of travelers and consumers of imported electrical goods.

Some multi-standard sockets allow use of several types of plug; improvised or unapproved adaptors between incompatible sockets and plugs may not provide the full safety and performance of an approved socket-plug combination.



Figure 2.2: Different types of Plugs

2.2.4 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.

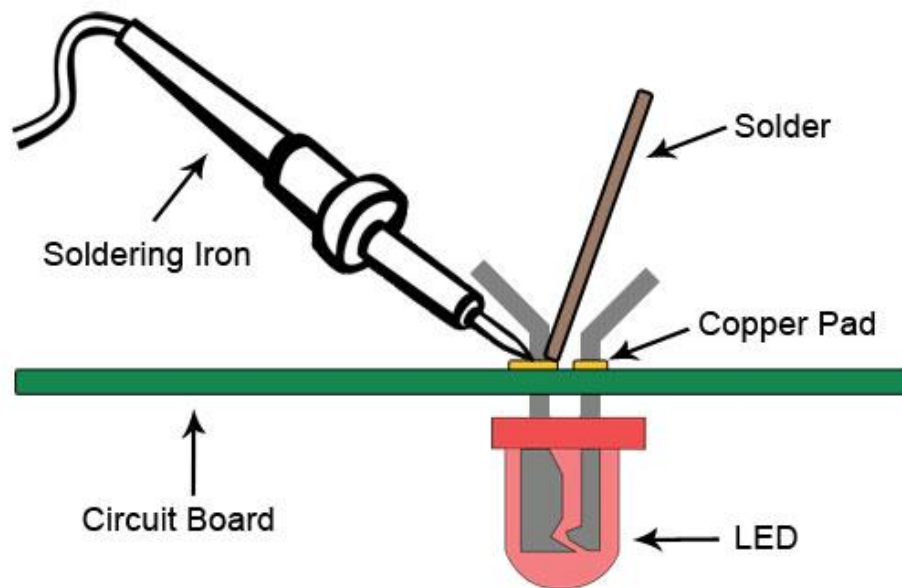


Figure 2.3 Soldering electronic components

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 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 (See Figure 3.2).



Figure 2.4: 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: **Tinning the Tip**

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

Construction and Soldering Techniques

1. Component mounting. Components are pushed through from the top side of the board and the leads are bent slightly to hold the component while soldering.
2. Components are then soldered to the board as shown in Figures 4.
 - a. The soldering iron tip should be placed in contact with both the trace (foil) and the lead. The two should be heated only enough to melt solder in order to avoid damaging sensitive components and to avoid delaminating of the PCB traces.
 - b. Solder is then touched to the area and allowed to flow freely around the lead and to cover the solder pad. A minimal amount of solder should be applied. Only enough solder to cover the joint and to form a smooth fillet should be used.
 - c. The iron should be removed after the solder has flowed properly and wetted all surfaces. The component and the board should not be moved until the solder has hardened (up to several seconds, depending on the lead and trace

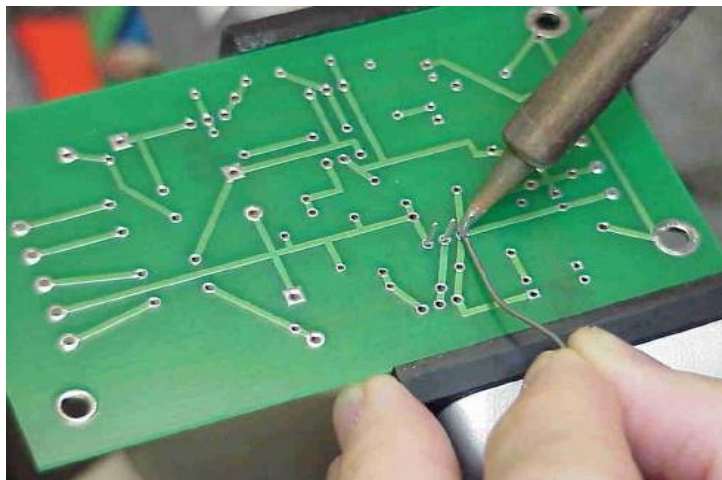


Figure 2.5: Soldering a component to a PCB

- **Good soldering and bad soldering joints**

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

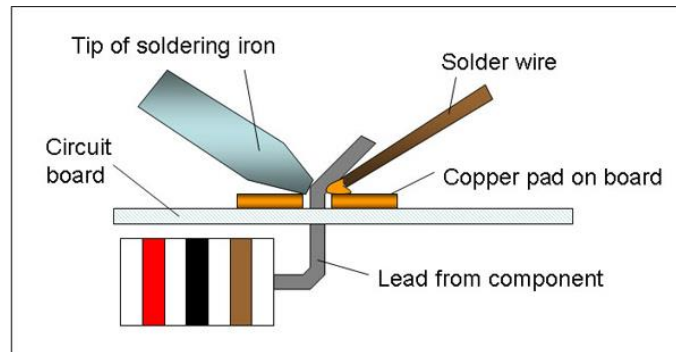
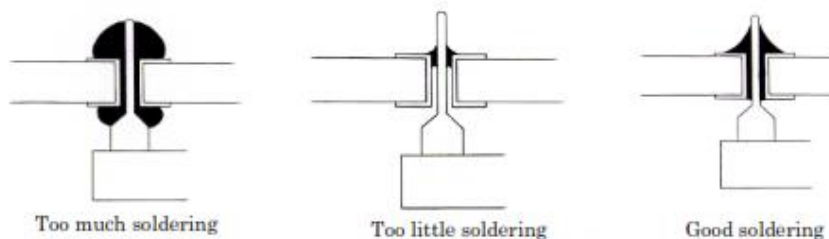


Figure 2.6: Good soldering and bad soldering joints

- Cold Solder joints:** A cold joint is a joint in which the solder does not make good contact with the component lead or PCB 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 Desoldering 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.

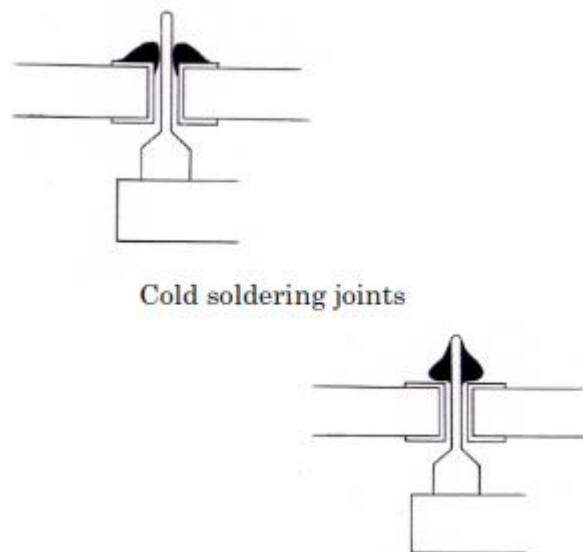


Figure 2.7: Cold soldering joints

- **How to Solder**

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

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

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

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

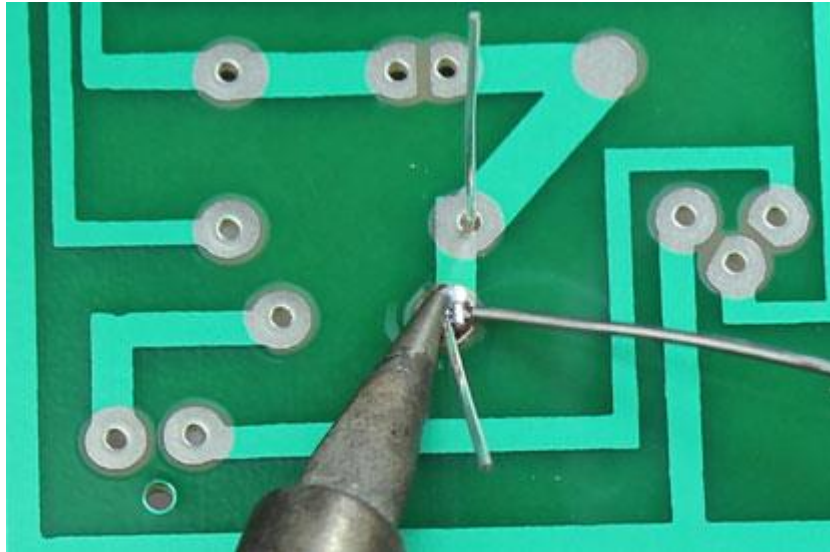


Figure: Apply Solder to Joint

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

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

How to Solder Wires

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

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

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

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

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



Figure: joining two tips of wire

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

- **De soldering**

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

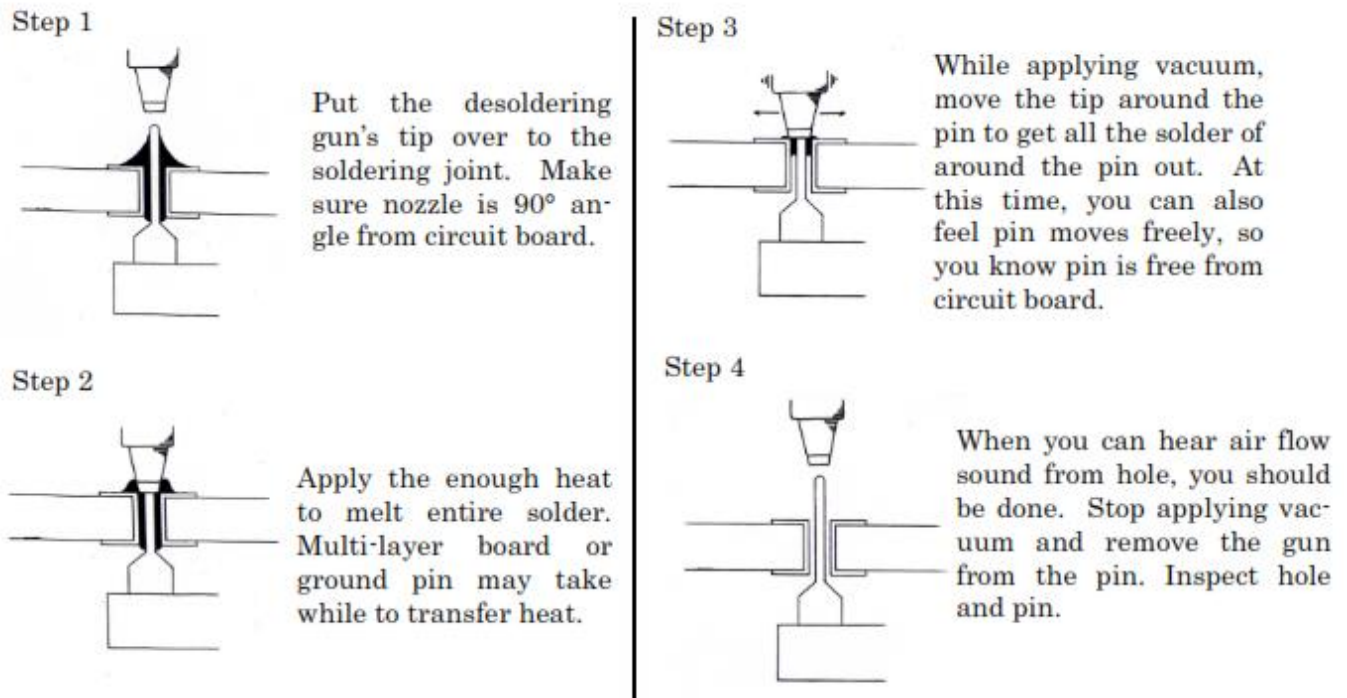


Figure: Desoldering steps

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

Desoldering using desoldering braid

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



Figure 2.8 Desoldering braid

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

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

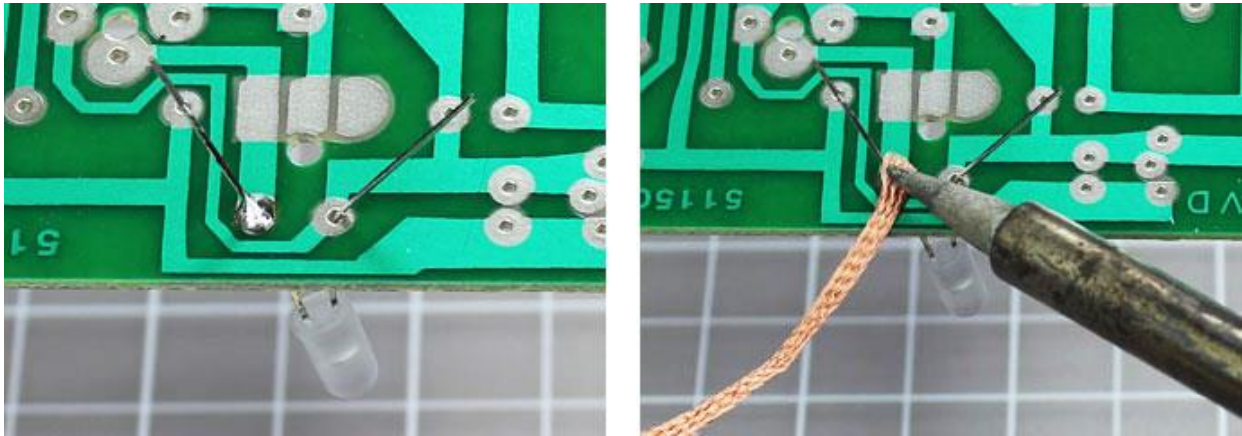


Figure: Desoldering using desoldering braid

Self-Check -2

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.

Test 1: short answer

1. Distinguish the difference between the half wave and full wave rectifier. (4 points)
2. Write the steps to follow when preparing PCB for electrical electronic circuit construction (both using CAD software and manually) (10 points)
3. List the technique used in electrical component construction on PCB
4. Before we begin our tasks in our workplace, what do we ask ourselves for safety? (2 points)
5. What is Personal Protective Equipment? (3 points)
6. When does PPE used? (3 points)
7. Match the different PPEs with their uses. Write the letter on a separate provided. (5 points)

Test 2: Matching

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 dust

Test 3: fill in the blank

1. To attach an 'OUT OF SERVICE' tag a worker must:
 - a. _____
 - b. _____
 - c. _____

- d. _____
- e. _____
2. Write three that are included under common measures to control electrical risks at a workplace.
- a. _____
- b. _____
- c. _____
- d. _____
3. On completion of electrical work, workers should:
- a. _____
- b. _____

Operation sheet-1

Operation Title: Constructing simple circuits on PCB

Instruction: In workshop, construct the given electronic components on printed circuit.

Purpose: To construct, solder and disorder the given circuit on PCB

Required tools and equipment: PCB, LED, Resistor ($1k\Omega$), battery (9V), and connector, soldering iron, lead, and sucker

Precautions:

- Never touch the element of the soldering iron
- Hold wires to be heated with tweezers or clamps.
- Always return the soldering iron to its stand when not in use.
- Never put soldering iron down on the workbench.
- Turn unit off and unplug when not in use.

Procedures:

Step 1. Check the functionality of the each component using multimeter.

Step 2. Follow the correct sequence of the operation.

Step 3. Insert the components thoroughly

Step 4. Read soldering technique carefully

Step 5. Solder the components by applying soldering technique

Step 6. Check the functionality of the soldered component

Step 7. Check the continuity of the circuit starting from input to output

Step 8. After you finished testing finally desolder each component

Step 9. Clean working area and return back the tools to their place.

Quality criteria:

- Proper component selection
- correct sequence of the operation
- Proper Soldering and desoldering skills

LAP Test	Practical Demonstration
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Name: _____

Date: _____

Time started: _____

Time finished: _____

Instruction I: Given necessary templates, tools and materials you are required to perform the following tasks within 3 hours.

Task 1: check the functionality of the given components

Task 2: Follow the correct sequence of the operation.

Task 3: Insert the components thoroughly

Task 4: Solder it carefully

Task 5: Check the functionality of the circuit

Task 6: Desolder each component

Unit three: Test the constructed electrical/ electronic circuits

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Testing the constructed electrical/electronic circuits.
- Checking the accurate operation of the constructed circuit.
- Responding unplanned events or conditions.

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:

- Test the constructed electrical/electronic circuits.
- Check the accurate operation of the constructed circuit
- Respond to unplanned events or conditions.

3.1. Testing the constructed electronic circuits.

Introduction

Electrical testing can be used to identify suspect parts and aid in counterfeit mitigation. It can also be used to determine that parts moving through the supply chain have been handled or stored correctly. However, not all components need to be fully powered up to be examined. For these parts, low power methods are used. In the following lesson, we cover key information about low power electrical testing, highlighting component applications and the different testing options

3.1.1. Verification and testing

Once a circuit has been designed, it must be both verified and tested. Verification is the process of going through each stage of a design and ensuring that it will do what the specification requires it to do. This is frequently a highly mathematical process and can involve large-scale computer simulations of the design. In any complicated design it is very likely that problems will be found at this stage and may involve a large amount of the design work be redone in order to fix them.

Testing is the real-world counterpart to verification, testing involves physically building at least a prototype of the design and then (in combination with the test procedures in the specification or added to it) checking the circuit really does do what it was designed to.

3.1.2. Functional test

In this test method electrical signals typical of the operation of the circuit are applied to the connectors on the PCB. The responses to these signals are recorded and compared to the correct response.

Advantages of functional test:

- The components are tested in their operating environment.
- Design faults may be found.
- Timing problems may be found.

Disadvantages of functional testing:

- Necessary software development is time consuming.
- Requires highly skilled personnel.

- Will normally not localize the fault.
- Long testing time.
- New faults may be generated in the test.
- Limited fault coverage.

3.1.3. In-circuit test

In this test method each component is tested individually with test probes. Neighboring components must be isolated by guarding techniques in analogue circuits or latching in digital circuits.

Advantages of in-circuit testing:

- Short testing time: The test localizes 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.

Checking the accurate operation of the constructed circuit

There are various factors that determine the quality of the power supply like the load voltage, load current, voltage regulation, source regulation, output impedance, ripple rejection, and so on. Some of the characteristics are briefly explained below:

1. Load Regulation – The load regulation or load effect is the change in regulated output voltage when the load current changes from minimum to maximum value.

$$\text{Load regulation} = V_{\text{no-load}} - V_{\text{full-load}}$$

$V_{\text{no-load}}$ refers to the Load Voltage at no load

$V_{\text{full-load}}$ refers to the Load voltage at full load.

From the above equation we can understand that when $V_{\text{no-load}}$ occurs the load resistance is infinite, that is, the out terminals are open circuited. $V_{\text{full-load}}$ occurs when the load resistance is of the minimum value where voltage regulation is lost.

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

2. Minimum Load Resistance – The load resistance at which a power supply delivers its full-load rated current at rated voltage is referred to as minimum load resistance.

$$\text{Minimum Load Resistance} = V_{\text{full-load}}/I_{\text{full-load}}$$

The value of $I_{\text{full-load}}$, full load current should never increase than that mentioned in the datasheet of the power supply.

3. Source/Line Regulation – In the block diagram, the input line voltage has a nominal value of 230 Volts but in practice, there 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 range of line voltage.

4. Output Impedance – A regulated power supply is a very stiff dc voltage source. This means that the output resistance is very small. Even though the external load resistance is varied, almost no change is seen in the load voltage. An ideal voltage source has an output impedance of zero.

5. Ripple Rejection – Voltage regulators stabilize the output voltage against variations in input voltage. Ripple is equivalent to a periodic variation in the input voltage. Thus, a voltage regulator attenuates the ripple that comes in with the unregulated input voltage. Since a voltage regulator uses negative feedback, the distortion is reduced by the same factor as the gain.

3.2. Responding unplanned events or conditions.

Introduction

Electricity is a powerful force and it has the potential to cause harm or even death. **Electrical hazards** are the most dangerous threats workers can face. Working near an **electrical** hazard is dangerous and can cause fatalities.

Promoting electrical safety in the workplace is the best method to reduce electrical hazards. Fatality and injury statistics increase every year all over the world due to the dangers of electricity.

Electricity travels in closed circuits, normally through a conductor. But sometimes a person's body an efficient conductor of electricity mistakenly becomes part of the electric circuit. This can cause an electrical shock.

An **electrical hazard** is a dangerous condition where a worker could make electrical contact with energized equipment or a conductor. From that contact, the person may sustain an injury from shock, and there is a potential for the worker to receive an arc flash (electrical explosion) burn, thermal burn, or blast injury.

3.2.1. Electrical Hazard

The risk of an electrical hazard has the potential to interact with terrestrial environment and socioeconomic environment.

Live high voltage conductors pose the risk of injury or death to individuals or wildlife if contacted directly or indirectly. Mitigation measures to minimize the risk of electrical injuries to those in or proximate to a power transmission corridor are not generally a requirement for land-based transmission, given the height of conductors. Downed conductors can allow for the potential interaction of live electrical cables with personnel or wildlife in the area. Unauthorized access to secure locations can also put individuals at risk of electrocution. Avifauna can also interact with high voltage conductors by landing on and touching energized conductors and grounded hardware at the cable riser stations and can become electrocuted in certain circumstances.

3.2.2. Risk Management and Mitigation

The following mitigation measures will be applied to reduce the probability of an electrical hazard and associated environmental effects.

- During the operation phase of the Project, Project components will be inspected periodically and repaired as required.
- Safe operating procedures will be established for all work activities, both during the construction and operation phases of the Project.
- NB Power's safety and environmental policies will be followed.
- Proper signage and public warning will be installed around project land-based components/facilities (e.g., "High Voltage").
- Access to the work site during construction and energizing activities will be limited to NB Power and their consultants and required contractor crews.
- Physical safeguards such as security fences surrounding facilities will be implemented.
- Access to facilities will be restricted to authorized personnel only.
- The use of appropriate down lighting will be incorporated around Project components (e.g., cable riser stations) to discourage vandalism and loitering.

3.2.3. Potential Residual Environmental Effects and their Significance

If an electrical hazard incident were to occur, the terrestrial environment and socioeconomic environment could be affected.

As the submarine cables will be buried in the nearshore environment (i.e., between the shore and the cable riser stations) and the cable riser stations will be fenced in, the probability of an electrical hazard incident is low because there is limited opportunity for individuals or wildlife to be exposed to them.

Therefore, potential environment effects arising from electrical hazards on the terrestrial or socioeconomic environments are not anticipated to be substantive.

In consideration of the buried nature of the cables in areas accessible to the public and wildlife, and in light of the mitigation to be implemented, the residual environmental effects of an electrical hazard during all Project phases are rated not significant for all potentially affected VCs. This determination is made with a high level of confidence. There is the potential that a protected species or person could be harmed or even killed were they to come in contact with the energized electrical components of the Project, and this would represent a significant residual environmental effect; however, given the safeguards in place, this is a highly unlikely scenario. Consequently, a significant environmental effect arising from this possibility is also considered to be unlikely to occur.

Self-Check 3

Directions: Answer all the questions listed below.

Test 1: MCQ

1. Which one of the following is advantage of functional testing
 - A. **The components are tested in their operating environment**
 - B. Will normally not localize the fault.
 - C. Long testing time.
 - D. Limited fault coverage

Test 2: List

2. Write at list three advantage and disadvantage of in-circuit testing. (6 points)
3. What are the factors that affect the quality of the power supply? List at list four of them and explain.
4. Discuss on unplanned events or conditions caused during construction of electrical/electronic circuit

Test 3: True/False

1. Testing is the process of going through each stage of a design
2. In circuit test method each component is tested individually with test probes
3. If an electrical hazard incident were to occur, the terrestrial environment and socioeconomic environment could be affected.

Operation sheet 2

Operation title: Testing the constructed electrical/ electronic circuits

Instruction: Test the constructed electrical/ electronic circuits

Purpose: to ensure the correct functionality of the constructed electrical/ electronic circuits

Required tools and equipment: Multimeter, PPE, oscilloscope,

Precautions: use PPE, check proper input power, and use calibrated testing equipment

Procedures:

Step 1: Using proper PPE

Step2: Selecting the testing equipment.

Step 3: Testing the continuity of constructed electrical/electronic circuit.

Step 4: Testing short and open circuit.

Step 5: Supplying the circuit with proper input power

Step 6: Testing the Input and output voltage.

Quality criteria:

- PPE selection
- Testing method
- Safety

LAP Test	Practical Demonstration
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Name: _____ Date: _____

Time started: _____ Time finished: _____

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 8-12 hours.

Task 1: Continuity test

Task 2: short and open circuit test

Task 3: Input and output voltage test

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NFPA 70E Standard for Electrical Safety in the Workplace®

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