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Ministry of Social Justice & Empowerment

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Participant Handbook

Sector:
Electronics

Sub-Sector:
LED Lighting

Occupation:
LED Light Testing and Quality Assurance

Reference ID:
ELE/Q9302

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LED Light Repair Technician (Divyangjan)

for Speech and Hearing Impairment
for Locomotor Disability

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For LD- 2021/PWD/SCPWD/04138
For SHI- 2021/PWD/SCPWD/04139

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"Skilling is building a better India. If we have to move India towards development then Skill Development should be our mission."

Shri Narendra Modi
Prime Minister of India


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The need for having a standard curriculum for the Job Role based Qualification Packs under the National Skills Qualification Framework was felt necessary for achieving a uniform skill based training manual in the form of a Participant Handbook.

I would like to take the opportunity to thank everyone who contributed in developing this Handbook for the QP LED Light Repair Technician.

The Handbook is the result of tireless pursuit to develop an effective tool for imparting the Skill Based training in the most effective manner.

I would like to thank the team of KontentEdge for their support to develop the content, the SME and the team at the ESSCI along with the industry partners for the tireless effort in bringing the Handbook in the current format.

CEO

Electronics Sector Skills Council of India

About this Book

This Participant Handbook is designed to enable training for the specific Qualification Pack (QP). Each National Occupational (NOS) is covered across Unit/s.

Key Learning Objectives for the specific NOS mark the beginning of the Unit/s for that NOS. The symbols used in this book are described below.

Symbols Used


Key Learning Outcomes


Steps


Time


Tips


Notes


Unit Objectives

Table of Contents

The book on New Employability Skills is available at the following location: https://eskillindia.org/Home/handbook/NewEmployability

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1. Basics of Electronics and LED

Key learning Outcomes

At the end of this module, you will be able to:

- Identify basic electronic components and its functions
- List the uses of current, voltage, power and energy in LED Lighting products
- Demonstrate the process of soldering
- Explain about LED working principle
- List the parameter which affect the overall life of LED
- Identify the LED power sources
- Describe series and parallel connection of LED
- Explain the passive thermal design and heat transfer procedure in an LED
- Describe constant current of LED Driver

UNIT 1.1: Basics of Electronic Components and Electricity

Unit Objectives

At the end of this unit, you will be able to:

- Identify basic electronic components
- Explain the function of electronic components

1.1.1 Component Classifications

Electronic equipment is made of electronic parts. Each electronic component will always comprise of electrical terminals, either two or more than two. These terminals are generally soldered onto a PCB in order to form a circuit that can perform a particular function, such as amplifier, radio, mobile phones, and so on.

Classification of electronic components

An electronic component may be classified into three categories active, passive, or electro-mechanic.

Active components

Active components are those which are capable of amplifying (increasing the power of a signal) or processing electrical signals. They derive power from the direct current (DC) source and increase the power of signals. These include components such as transistors, diode and so on.

Passive components

A component is defined as a passive component it does not require a separate power source for its operation. The only thing that is required for its operation is the alternating current (AC) flowing in the circuit. A passive component does not produce any power gain. Examples of passive components are inductor, resistor, transformer, and capacitor.

Electromechanical switches

A switch which has a manual operation is an electromechanical part. However, the term electromechanical component is generally used for devices such as relays and vibrators which permit a voltage or current to regulate other separate voltages and currents using mechanical switching of sets of contacts and solenoids. By this process a voltage can activate a moving linkage. Vibrators change DC to AC by utilizing vibrating sets of contacts.

1.1.2 Resistor

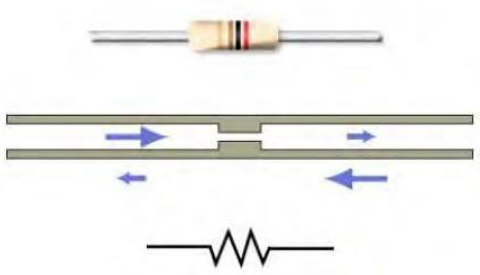
A resistor is a component in an electronic circuit which is built to resist or limit the flow of current in that circuit. This passive component reduces current flow, and lowers voltage levels within circuits, simultaneously. It can modify signal levels and cut off transmission lines. High-power resistors may be utilized in motor controls, in systems for power distribution or in generators as test loads. Variable resistors are typically used for altering circuit elements (such as to control the level of volume). It can also be utilized as a device to sense heat, light, humidity and so on.

Types of Resistors

Resistors can be of two types:

i. Fixed resistors – These comprise of metal films, wires having high resistance or carbon constituents.

ii. Variable resistors – These possess terminal resistance that can be changed by moving a dial, a screw, or something similar and appropriate.



Resistance is measured in Ohms (Ω) 1000Ω = 1kΩ, 1,000,000Ω = 1MΩ

A resistor can also be rated according its capacity to carry power, such as 1/4W, 0.5W, 1W, 5W etc.

1.1.3 Resistance Colour Coding Table

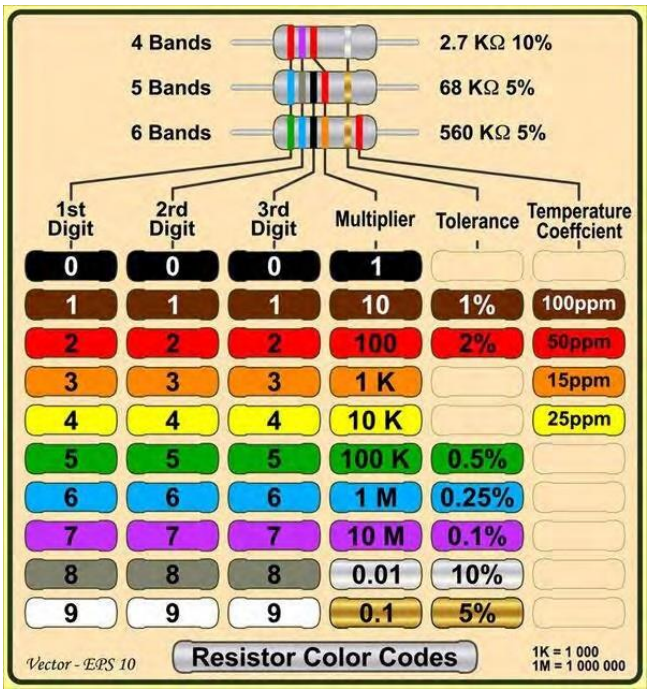
Colour coding was formulated to identify small sized resistors on which the resistance value could not be printed.

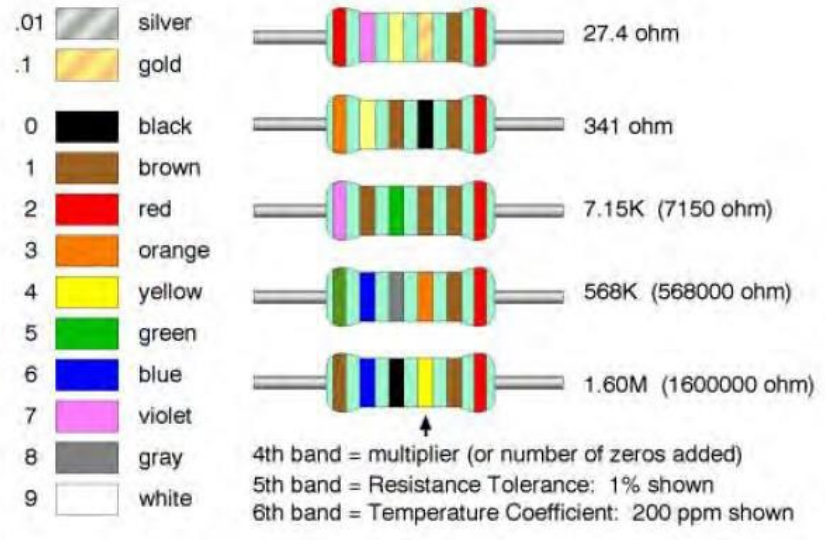
i. Colour bands should be read from that end which has the bands nearest to it.

ii. The 1st and 2nd bands stand for the first two digits.

iii. The 3rd band represents the power-of-ten multiplier (the number of zeroes after the second digit).

iv. The 4th band represents the manufacturer's tolerance (accuracy of the resistor).





1.1.4 Capacitor

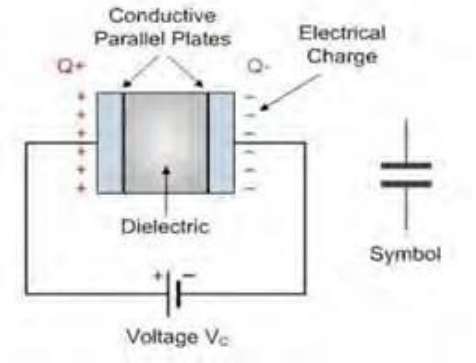
A capacitor is a device which is made up of one or more pairs of conductors and an insulator separating them. It is a passive electrical component with two terminals and is utilized to store energy in an electric field. The conductors can be made of thin films, foils, a conductive electrolyte and so on. The non-conducting dielectric functions to raise the charge capacity of the capacitor. It can be made of glass, plastic film, air, paper, an oxide layer and so on. Capacitors are extensively used in electrical circuits of general electrical devices.

Types of capacitors –

- Polarized
  Examples are electrolytic capacitors.
- Non-polarized
  Examples are film capacitors, ceramic capacitors, paper capacitors etc.

1.1.5 Capacitor Construction

The parallel plate capacitor is the simplest form of a capacitor, which is typically made by placing two metal or metalized foil plates in parallel with a gap between them. The value of the capacitance of such capacitors is determined using the surface area of the plates and their distance. The capacitance gets affected if any of these two values are altered changes.



The plates store the energy of the electrons as electrical charge on, which means, greater the plates and lesser the distance, more will be the capacitance.

If V is the voltage of a capacitor and Q is the charge on the plates, the ratio of the charge Q to the voltage V is the capacitance of the capacitor. It is written as: $C = Q/V_T$.

There is an electrostatic field between the two conducting plates which stores the energy within the charge. When electric current passes into a capacitor it gets charged and the energy is stored in the electrostatic field, making it stronger. When the current flows out of the capacitor it gets discharged and the electrostatic field becomes weak. A capacitor is like a battery having low capacity. A capacitor in series allows DC to pass through it while resisting DC. It is generally utilized for eradicating noise or stabilizing the supply voltage of a circuit.

1.1.6 The Capacitance of a Capacitor

The capacitor's ability to store an electrical charge on its plates is called its capacitance. The unit of capacitance is Farad (F) and it is denoted by the symbol C. It is always positive. A capacitor is said to have the capacitance of one Farad when a charge of one Coulomb is stored on the plates by a voltage of one volt. Sub-multiples of Farad are commonly used, such as micro-farads, Nano-farads and pico-farads, as Farad is a big unit of measurement.

Standard Units of Capacitance

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

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

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

1.1.7 Inductors

An inductor consist of a coil or a wire loop. This component is used to store energy in form of a magnetic field. The more the turns in the coil, the more will be the inductance. It resists changes in the electric current passing through it by inducing a voltage in the conductor.

Inductance is the ratio of the voltage to the rate of change of current. Its unit is Henries (H). Inductors generally range from 1 µH (10−6H) to 1 H. Most of the inductors have a magnetic centre within the coil, which strengthens the magnetic fields and thus the inductance. Inductors are extensively used in AC electronic equipment, especially radio equipment. They are used to allow DC to flow but not AC. Inductors specifically made for this function are known as chokes, which are also used in electronic filters to divide signals having different frequencies. When these inductors are combined with capacitors, they form tuned circuits, typically used to tune radio and television receivers.

The different types of Inductors are as follows:

- Air Core Inductor
- Ferromagnetic Core Inductor
- Variable Inductor

1.1.8 Diodes

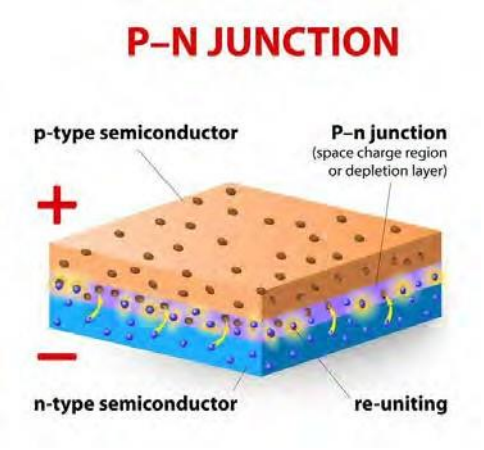
A diode is a specialized electronic component with two terminals known as the anode and the cathode. It is also called as PN-junction diode and is formed by joining together n-type and p-type silicon. The p-side is the anode and the n-side is the cathode. It has asymmetric conductance, which means that it conducts mainly in one direction. It has very less resistance (ideally zero), to the flow of current in one direction. It has high resistance (ideally infinite), in the other direction.

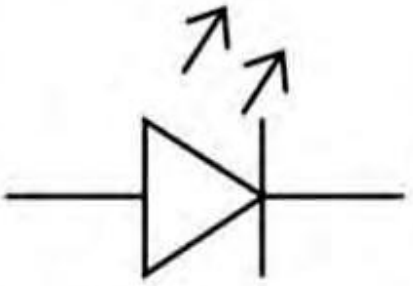
The diode is said to be forward biased when the potential at anode is more than the potential at cathode. The current is permitted to flow through the device in this type of diode. When the potential at anode is less than the potential at cathode, the diode is said to be reverse biased. The current is not allowed to flow in this type of diode.

Diodes are usually made up of semiconductor materials such as germanium, silicon or selenium.

1.1.9 Light Emitting Diode (LED)

A LED is a p-n junction diode which gives out light when it is activated. It is a two-lead semiconductor source of light. Energy is released as photons when a suitable voltage is applied to the leads. It gives a visual feedback for the circuit. LEDs can be seen on laptops, mobile phones, cameras, and in cars. Nowadays, LEDs are even used for general lighting.





1.1.10 Transistors

A transistor is an electronic device, made up of semiconductor material. Usually, it has at least three terminals to connect to an external circuit. It is used to amplify or switch electrical power and electronic signals. It can be seen as a switch controlled by an electrical signal, but unlike a switch which has just two states (on and off), it can be “a bit on” by regulating the current that passes through its base. A little amount of voltage/current applied at the control lead controls a larger amount of current flow through the other two leads.

The different types of transistors are as follows:

- Bipolar Junction Transistor (BJT) – It is utilized in LED Driver for current control
  –NPN and PNP
- Junction Field Effect Transistor (JFET) – It is utilized in LED Driver for voltage control
  –N-channel and P-channel
- Metal Oxide Semiconductor FET (MOSFET) – It is also utilized to control the voltage in LED Driver
  –Depletion type (n- and p-channel) and enhancement type (n- and p-channel)

1.1.11 Integrated Circuit(IC)

An IC, also known as a microchip, is a semiconductor wafer on which a number of small resistors, capacitors and transistors are fabricated. It can work as an oscillator, an amplifier, a timer, a counter, a microprocessor or as computer memory.

The two main advantages of ICs over discrete circuits are cost and performance. The cost of ICs is low because photolithography is used to print the chips along with all their components as a unit instead of each transistor being constructed at a time. Also, packaged ICs utilize less material than discrete circuits. Their performance is high as their components switch quickly and use up less power than the components of a discrete circuit. This happens because of the small size and closeness of the components.

ICs are utilized in almost all electronic equipment nowadays and have brought a revolution in the world of electronics. It could be an amplifier or a microprocessor or a USB to serial converter. The low cost of ICs has made computers, mobile phones and other digital home appliances an essential and familiar part of modern society.

UNIT 1.2: Basic of Electricity

Unit Objectives

At the end of this unit, you will be able to:

- Identify the use of current, voltage, power and energy in LED Lighting products
- Explain the difference between AC and DC

1.2.1 Introduction

On completion of the session, the trainee will be able to explain:

- What electricity is
- The basic terms used in electricity

Let us understand some important definitions:

When electrons inside any material move, flow of electricity takes place. This flow is called current.

Despite using electricity in our daily life, many of us do not understand its basics terms and people find it difficult to learn about electricity. The main terms associated with electricity are as follows:

- Current
- Voltage
- Power
- Energy
- AC and DC power

In an electrical circuit, the current flows only when there is a voltage source.

1.2.2 Current

Electricity is a natural force that comes into existence whenever there is a flow of electric charge between any two components. The flow of electric charge is called current. Thus, electrical current is the amount of charge flowing past a fixed point. The unit of current is Ampere.

Voltage:

Voltage is the force pushing electrons through the wire.

Power:

The electrical energy transferred by an electrical circuit, per unit time is its power. The unit of power is watt. When electricity passes through an electrical circuit, it results in some work done. For example, when electricity flows through a fan, the blades of fan rotate, and

when the electricity flows through a refrigerator, it cools the items stored inside. Thus, when electricity flows through an appliance, it results in some work done.

Energy:

Electrical energy is the total amount of work done during a given time period. It is product of power of electrical appliance and duration of its usage.

There are standard formulas that describe the relationship between voltage, current, resistance, power, and energy.

1.2.3 Ohm's Law

On completion of the session, the trainee will be able to explain:

- What Ohm's law is
- How Ohm's law is applied in the conduction of electricity
- The relationship between voltage, current, and resistance
- The basic difference between power and energy
- The basic difference between AC and DC power and its uses

According to Ohm's law, current flowing through a conductor is directly proportional to the voltage across the conductor. The mathematical equation of Ohm's law is as follows:

$$I=V/R$$

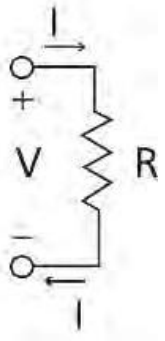
Where,

I is current flowing through the conductor,

V is the potential difference or voltage across the conductor, and

R is proportionality constant, known as the resistance of the conductor.

Resistance of the conductor is independent of current flowing through it as shown in the following figure:



1.2.4 Electric Power

Electric power can be defined as the rate at which electrical energy is transferred by an electric circuit. Its SI unit is watt, which is one joule per second.

Electric power is generally supplied by electric generators, but can also be produced by other sources such as electric batteries. Generally, the power industry supplies power to businesses and homes using a power grid. It is generally sold by kilowatt hour, which is the product of power in kilowatts multiplied by running time in hours. Electrical utilities measure the consumed power with the help of an electricity meter, which keeps track of the total electricity supplied to a customer.

Similar to mechanical power, electric power is the rate of doing work and is denoted by the letter P. The electric power in watts produced by an electric current I, consisting of a charge of Q coulombs every t seconds passing through an electric potential (voltage) difference of V is

$$\mathrm{P} = \text{work done per unit time} = \frac{\mathrm{VQ}}{\mathrm{t}} = \mathrm{VI}$$

1.2.5 Electrical Energy

Energy is another important terminology related to the use of electricity. If the electrical power represents the rate or speed of work done, then the term “electrical energy” represents the total amount of work done. Therefore, electrical energy can be denoted as:

Electrical Energy: Power x Duration of usage Energy (E) = Power (watt) x Time (hour)

E (Wh) = P (W) x T (h)

Power = Energy/Time

1.2.6 Electric Circuit

In the application of electricity, several components are required to be connected to get the desired function. The interconnection of various electrical components is an electrical circuit. In an electrical circuit, power flows in two forms. These forms are referred as follows:

1. Direct current or DC power
2. Alternating current or AC power

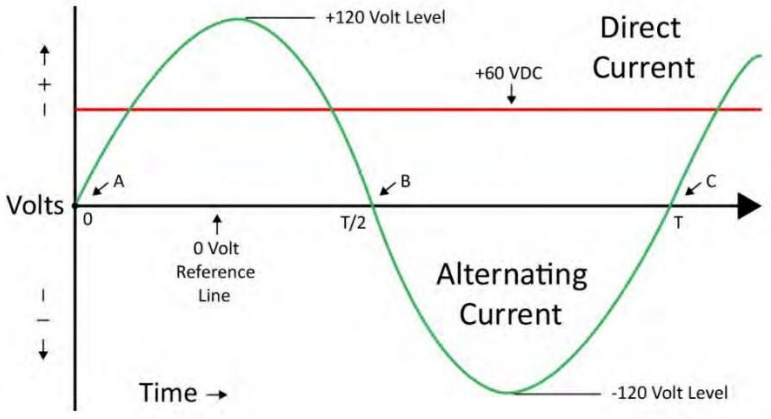
Let us now learn more about the AC power and DC power, their characteristics, the difference between them, and their measurements.

1.2.7 DC Power and AC Power

DC power flows in a DC circuit. A DC circuit is a circuit in which current flows in only one direction. The direction of current does not change with time.

In an AC circuit, current flows in both the directions; clockwise and counter clockwise. For the time period 0 to T/2, current flows in clockwise direction and for time period T/2 to T, charge flow reverses to counter clockwise direction as shown in the figure below. It is not only the direction but also the value of current that keeps changing with time.

The AC current changes its direction 50 times in one second (in this situation it is said that the current has a frequency of 50 Hertz). Most of our home appliances like light bulbs, TVs, and fans operate on AC power at 220 volts.



UNIT 1.3: Manual Soldering

Unit Objectives

At the end of this unit, you will be able to:

- Explain the process of soldering
- Identify the types of solder and flux
- Describe the working of solder iron
- List the selection criteria of a suitable tip

1.3.1 Introduction

On completion of the session, the trainee will be able to explain:

- What soldering is and what the main components of manual solder are
- What the different types of solder are
- The differences between leaded solder and lead-free solder

Soldering is one of the most basic skills needed in electronics. With technology developing at a fast pace, people should possess the ability to build, modify and repair their devices. Soldering is one such skill that empowers everyone.

1.3.2 What is Solder?

Solder, as a word, can be interpreted in two ways. Solder as a noun refers to the alloy which is available as a long, thin wire coiled in a spool or tube. Solder, the verb, connotes joining together of two pieces of metal into a solder joint.

Solder in spool form

Solder in tube form

Types of Solder:

1. Tin-Lead Solder
2. Lead Free Solder

1.3.3 Leaded vs. Lead-free Solder

Earlier, solder was composed of mostly lead (Pb), in (Sn) along with a few other trace metals. This solder is known as leaded solder.

Lead is very convenient to use in soldering as it has a low melting point and creates good solder joints. However, due to its harmful effects, several countries decided to discontinue the use of leaded solder. Lead-free solder is now being used in electronics manufacturing.

Lead-free solder is made up of metals such as silver and copper. This solder typically has the RoHS symbol to assure potential buyers that it has been made as per the standard.

1.3.4 Soldering Irons

On completion of the session, the trainee will be able to explain:

- part of manual soldering station
- function of each component of solder station

Soldering irons are available in various form factors and range from simple tools to complex ones. But they all function almost in a similar manner.

Basic parts of a soldering iron

Solder Iron Tips

The tip is the end portion of the iron that gets heated and enables the solder to flow down and surround the two components which have to be joined. The tip transfers heat to the metal components increasing their temperature to the melting point of the solder, and the solder melts accordingly. The tips can be replaced with a new one or one with a different style. They come in different sizes and shapes and can be chosen according to the component.

In the images, various types of tips have been shown:

From left to right, the bevel tip, two conical tips with different widths, and the chisel tip.

The tip can be changed by an easy process that involves either unscrewing the wand or applying pressure inwards and pulling out the tip.

Wand

The wand which holds the iron tip is generally made of insulating materials (especially rubber). Wands prevent burns by preventing the transfer of heat of the iron tip to the outside. They facilitate transferring of heat from the base to the tip.

The irons consisting of only a wand to be plugged into a wall outlet, do not offer any control for varying temperature and the wands have heating element, directly built into it.

Base

The base, comprised of several control electronics and a transformer allows adjusting the heat and temperatures of the tip. The base can be of two types:

- Analog base (Right): It contains a dial for temperature control
- Digital bases (Left): It contains a digital display and buttons for setting and displaying the temperature.

Some bases offer heat profiles features that allow changing the amount of heat of the tip for facilitating soldering of different components.

Stand (Cradle)

The iron stand, also known as a cradle is used to hold the iron when it is idle. The stand sometimes offers an auto-shutoff feature which allows a gradual reduction in the tip's temperature when the wand is kept in it. This also helps in preventing the wearing of the tip over time.

A cradle may contain a regular sponge or a brass sponge.

Brass Sponge

While soldering the tip turns black and cannot accept solder due to oxidization caused by impurities in the solder. Hence, building up the impurities on the tip needs to be wiped off. But, using a wet sponge for cleaning the tip causes wearing of it as this leads to expansion and contraction of the tip due to the temperature variation. Brass sponge extracts the excess solder from the iron tip and also allows the tip to maintain the level of heat. If brass sponge is not available, a regular sponge is used.

1.3.5 Tip Selection

On completion of the session, the trainee will be able to explain:

- the importance of the shape and size of the tip of a soldering iron
- wattage (operating power) of a solder iron
- how to maintain a solder tip in good condition

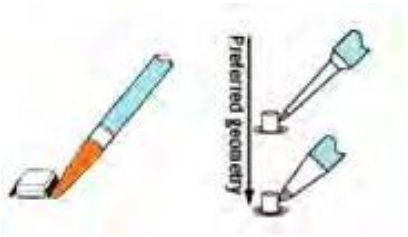
Choice of the correct tip is very important for the application. A correct fit of the tip in the joint will result in increased power delivery (as per the thermal requirement of the joint) and tip life and higher efficiency.

- Using a too small tip does not pass power to the load efficiently and it make the process slow.

- A large tip may damage the PCB, and also cause a hole at the tip.
- Short, blunt tips suitable for heavy loads, cannot be used for fine pitch rework.
- For fine terminals and hard-to-reach applications, long and fine tips are suitable. But, these are unable to deliver power efficiently, due to the distance between the heater and the solder joint.
- Heat transfer is considerably slowed down in long tips.

- Larger tips are more robust under coarse conditions since they contain more iron plating.

For a specific surface mount technology (SMT) application, such as pad cleaning or multi-lead soldering, an iron tip designed to accommodate those types application must be used. It requires the tip to last longer, and less stress on the board.



1.3.6 Flux Selection

On completion of the session, the trainee will be able to explain:

- the function of flux in solder process
- types of fluxes
- effect of flux on solder quality

Flux, usually an acidic material, acts as a reducing agent that facilitates the process of soldering by that preventing oxidisation and cleaning the impurities from the solder joint. It thus helps in transferring heat to the solder joint and keeps it robust under abrasive conditions.

Flux can already be present in the solder core wire, or it can be added in the form of liquid or paste to the solder joint. The process engineer must be able to understand:

- the purpose and function of flux
- how they differ in performance
- how they affect the quality of the PCB quality and the life of the solder tip.

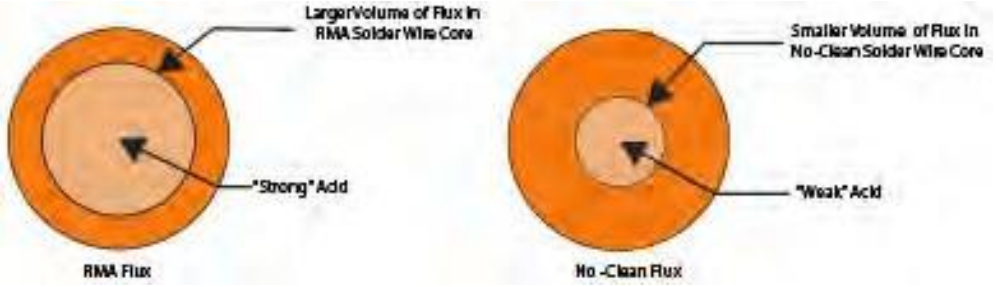
In general, flux can be classified in three groups:

1. Clean (Rosin Mildly Activated or RMA): It has more acidic content and while soldering a heavy residue is left on the PCB that needs to be wiped off. It is a good choice for the solder tip as the core solder wire protects the tip from oxidation by covering it while soldering.
2. No-Clean: It has weaker acid than the clean flux. It requires the temperature of the tip to be low. It is popular as it omit the process of cleaning after the work. It is not suitable for solder tip as burns off quickly leaving a less of it and thus leads to faster oxidization of the tip.
3. OA (Aqueous): It contains inorganic acid that is more active than the one in RMA flux.

For through-hole soldering, there is no need to add extra flux as there remains sufficient flux in the wire core solder.

More flux makes the process of soldering easier, but for using too much flux:

- The board may be contaminated



- The tip gets affected because when flux activates, it attacks oxides as well as the iron plating on the tip.

This figure represents why solder with No-Clean flux works as well as the solder with RMA one.

1.3.7 How to Solder

Soldering is a process of joining two or more objects that are usually metal by melting and pouring a filler metal, called solder, into the joint. The solder component has a lower melting point than the other two metals that are to be joined. A strong mechanical as well electrical connection is formed when the joint cools.

The steps of soldering technique are as follows:

Step 1: Heat up the soldering iron sufficiently.

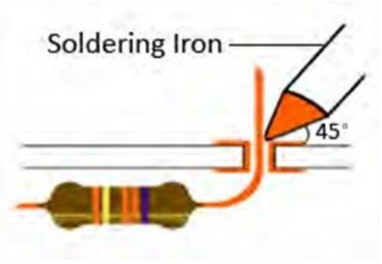
Step 2: Clean the soldering iron with a damp sponge, if it is dirty. If a soldering station is used, adjust its temperature.

Step 3: Apply suitable flux to remove any type of oxide when soldering.

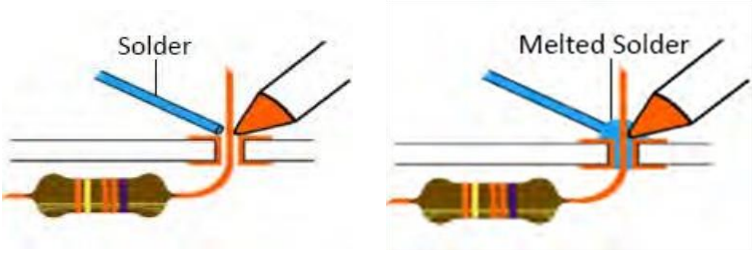
Step 4: Coat the soldering iron's tip with a thin layer of solder. This process of tinning helps in transferring heat between tip and the component to be soldered.

Step 5: Use pliers for bending the lead of the component being soldered so that it can easily be embedded on the board, as shown in the following image:

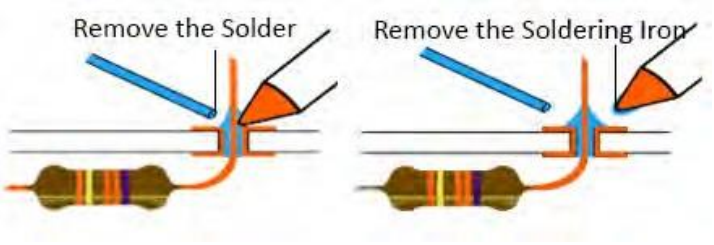
Step 6: Hold the soldering iron and place the iron tip in such a way that it touches both the surface and the lead of the component. The following figure shows how to hold the soldering iron:



Step 7: Touch the solder to the iron tip and move that around the joint by keeping the iron tip fixed. Let the solder melt and flow till the joint is covered, as shown in the following figure:



Step 8: Remove the iron after removing the solder and make sure the joint is kept stationary till it cools down.



Tips

- When the soldering iron gets hot, it becomes dirty because of oxidization. Clean the tip with a wet sponge until the tip shines.
- While soldering, iron tip should not be touched.
- Soldering iron should be placed at an angle of 45 degree.
- Clean the tip using a damp, clean and sulphur-free sponge or de-ionized water.

UNIT 1.4: LED Basics

Unit Objectives

At the end of this unit, you will be able to:

- Explain the evolution of High Power LED.
- Demonstrate LED working principle.
- List the parameter which affect the overall life of LED.
- Identify various types of LED.
- List the advantages of LED light product.

1.4.1 LED Basics

On completion of the session, the trainee will be able to explain:

- What light emitting diode(LED) is and what its characteristics are
- the history of LED

Introduction

An LED is a light emitting semiconductor electronic component. LEDs serve as a suitable replacement for halogen or standard light because they consume less energy, have longer life, are more bright, are smaller in size, are capable of faster switching and are more durable and reliable.

History of LED

LEDs have been used for many years in various areas of application which includes industrial systems, advertising fields, light devices and car lights. LED technical development continues to stride ahead. In recent years, the luminous efficacy of white LEDs has risen to 130 lumens per watt and even more. The technical development of LEDs will continue in the future.

A short glance at the history of LED:

In 1907, Englishman Henry Joseph Round found out that inorganic materials can light up when an electric current is applied. In 1921, Russian physicist Oleg observed the "Round effect" of light emission. In 1935, French physicist, Georges Destriau discovered emission of light in zinc sulfide. He is the inventor of electroluminescence. American Nick Holonyak, developed the first red luminescence diode (type GaAsP). This first LED in the visible wavelength area was the beginning of the ndustrially -produced LED. With development of new semiconductor materials, LEDs began to be produced in new colours such as green, orange, and yellow. In 1993, Shuji Nakamura developed the first brilliant blue LED and later the white LED. The first light-emitting diodes with 100 lumens per watt were manufactured in 2006.

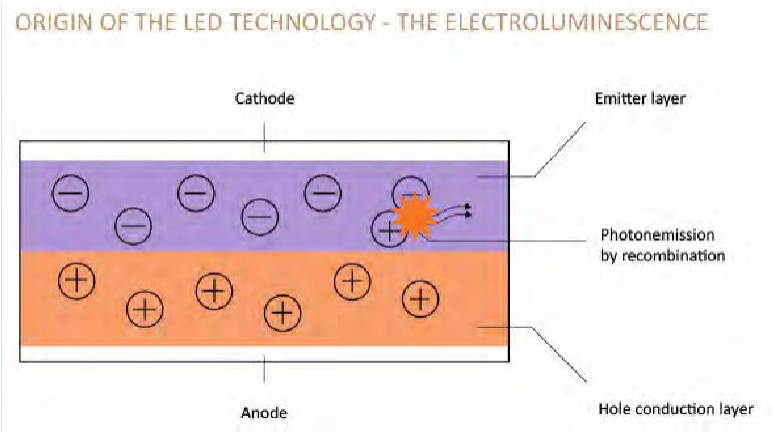
Since 2010, LEDs with a luminous efficacy of 250 lumens per watt, are being produced under laboratory conditions. OLED (organic light-emitting diode) is seen as the future technology.

1.4.2 Working of LED

On completion of the session, the trainee will be able to explain:

- the working principle of LED
- the advantage of LED in lighting

An LED comprises of several layers of semi-conducting material. When the diode is being utilized with DC, the active layer produces light. The light is decoupled directly or through reflections. The LED emits light in a particular colour and this colour is dependent on the type of semiconductor material used in it. LEDs with a high degree of brightness, in all colours, can be produced by two material systems. Different voltages are needed to use the diode in forward bias.



In LED chips, on application of certain voltage, electromagnetic radiation in the form of light is given out.

LEDs are made of semiconductor crystals and when current flows through them, they emit light in the colours of red, green, yellow, or blue, depending on the composition of the crystal compounds. Blue LEDs also emit white light by using a yellowish fluorescent layer or by creating a mix of red, green, and blue LEDs (RGB). The latter method is used for giving a decorative effects to lighting.

1.4.3 Advantages of LED technology

LEDs have many advantages over other lighting technologies. The consumers' profit from various possibilities of design due to a wide choice of colour and dimensions. They have high economic benefits due to consumption of less energy, long life and better service intervals. LEDs are reliable even in adverse environmental conditions. Its advantages are as follows:

1. Involves low consumption of power
2. Exhibits high level of efficiency
3. Has long life
4. Shows continuous dimming along with an ECG

5. Has small dimensions
6. Shows High resistance to switching cycles
7. Provides immediate light when switched on
8. Has a wide range of operating temperature
9. Exhibits high resistance to impact and vibration
10. Gives out no UV or IR radiation
11. Possesses high colour saturation level without filtering
12. Has no mercury

1.4.4 Types of LEDs

On completion of the session, the trainee will be able to explain:

- types of LED

There are basically three type of LED's.

- Indicator Type or Low Power LED's, also called PTH LED
- Illuminator Type LED or Power LED's also called SMD LED
- Chip on Board (COB) LED

Indicator type: These LEDs are generally available in 5 mm size, but also come in 3 mm and 8 mm sizes. They typically possess two “legs” and a narrow beam spread of 15˚ to 30˚. These LEDs have low power and function on currents from 20 mA to 100 mA. The heat produced is dissipated within the LEDs.

Illuminator type: These LEDs were first available in the market as effective packages of 1W and operated at 350 mA. Later, 3W and 5W high power LEDs were manufactured. These LEDs are soldered on a PCB directly. They provide a path which is thermally conductive for extracting heat and benefit from much better heat extraction. High power LEDs are available in various shapes and sizes.

Chip on board (COB): These LEDs are utilized for closely packed high-power LED modules. COB technology is used to place the LED chips directly onto the PCB. The beam spread can be narrow- or wide angle.

1.4.5 Factors affecting life of LED

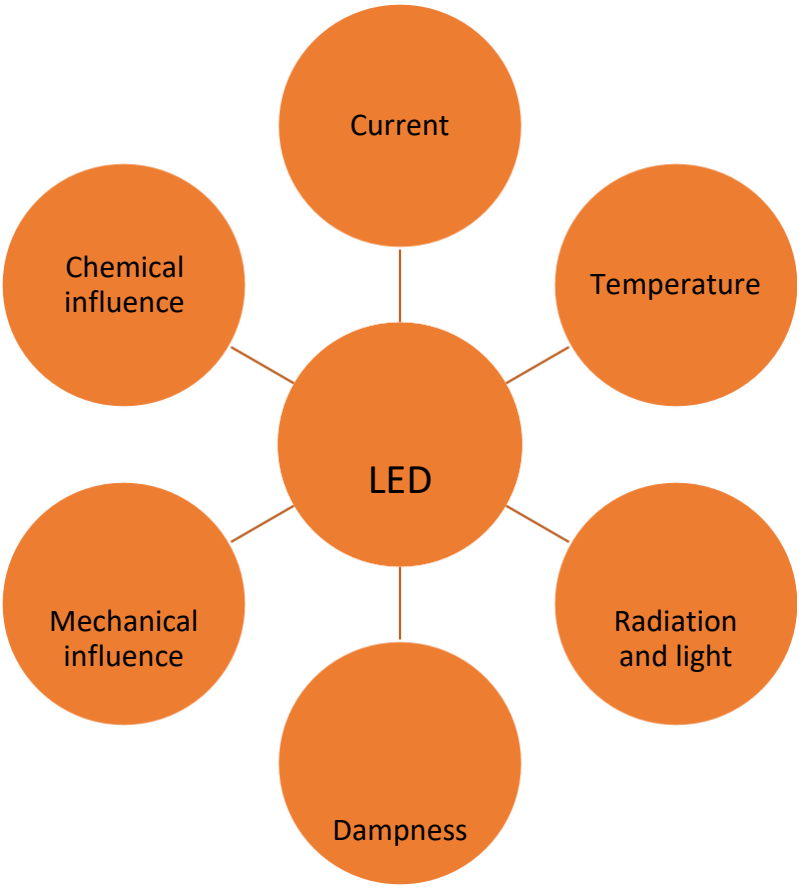
On completion of the session, the trainee will be able to explain:

- the factor affecting the life of LED
- the basic definition of current, voltage, power, and energy

LEDs can have an operating life of more than 50,000 hours. As compared to other light sources, LEDs seldom fail and are generally service free. The exception is the luminous flux

whose life slightly decreases over the operating period. The following are the factors that can affect the entire LED module.

1.4.6 Factors influencing an LED module: in detail



Temperature

When light is produced, heat too will be generated. This affects both the life cycle of an LED and its luminous flux and is applicable to an individual LED as well as the entire LED module. Thus, installation methods or suitable heat sinks should be used to diffuse the heat. The lower the temperature at which an LED works, the better will be its performance and life.

Mechanical influence

Mechanical forces can influence an LED at various stages. This can happen when the LED is being manufactured, assembled or handled otherwise. It can also occur due to the use of certain materials which develop these forces during big temperature fluctuations. These forces can have a negative effect on the operating life of an LED or even damage it.

Current

There is a specific current range within which an LED module should be operated. Even within the range, the lower the current is, lesser will be the energy released and lower will be the heat produced. The current, thus, has a direct effect on the operating life of an LED.

Radiation and Light

An LED's housing design plays a vital role in the aging process of the components, which are influenced by the light given out by the chip. The built-in reflector ages faster within the first few hundred operating hours in some housing designs due to the high intensity and luminance of the light given out by the chip.

Dampness

An LED by itself is strong and non-sensitive. It is unaffected by vibrations and is unbreakable. However, many metal components, connections and electronic parts inside it are sensitive and may get corroded due to dampness, thus, causing the module to fail. An appropriate choice of materials for the LED protects it from corrosion. If high operating life of the LED modules is desired than protection from dampness is a must.

Chemical influences

Chemical influences can have varying influences on an LED, depending on the location of the application. Hence, while setting up an LED lighting system, the environmental conditions must be kept in mind.

The following conditions of the environment have a negative effect on the operating life of an LED:

- If the atmosphere is corrosive (the air has high sulphur dioxide content)
- If the climate is coastal with medium salt content
- If there is a chemical industry nearby
- If it is in a swimming pool with medium chloride content

UNIT 1.5: Basic Parameter of LED

Unit Objectives

At the end of this unit, you will be able to:

- List the basic parameters of LEDs
- Describe the importance of CCT and CRI in LED products

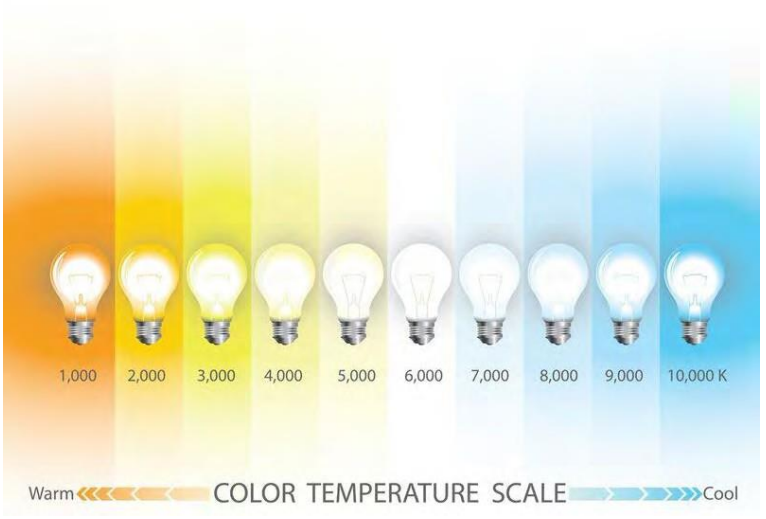
1.5.1 Colour Rendering Index

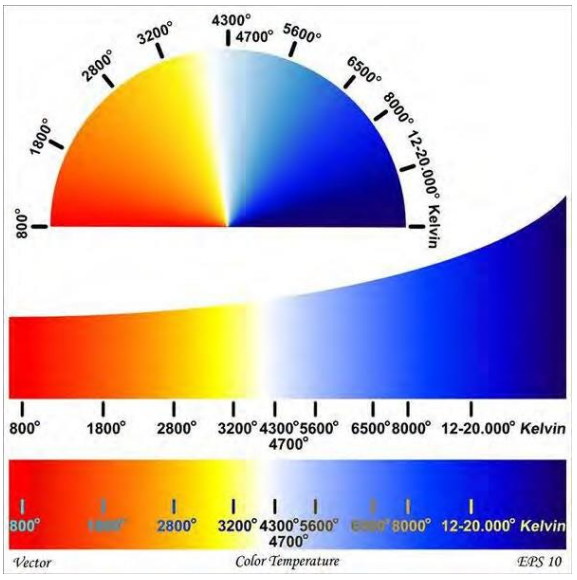
On completion of the session, the trainee will be able to explain:

- What CRI is
- The importance of CRI in an LED lighting product

Colour Rendering Index (CRI) is used to know how well the colours of the objects are rendered by the light sources. The CRI has a scale from 0 to 100. It has a reference light source with which the light source rendering colour is compared and its performance is judged. Incandescent lamp, having a CRI of 100, is taken as the reference light source. The more the CRI, the better will be the colour rendering ability of the LED. CRI is, therefore, an important parameter to evaluate the quality of light.

However, the CRI measure of light sources can only be compared if they have the same colour temperature (CCT).





LED products with CRI greater than 80 are considered best for indoor application. Products with a CRI less than 80 are suitable for outdoor application.

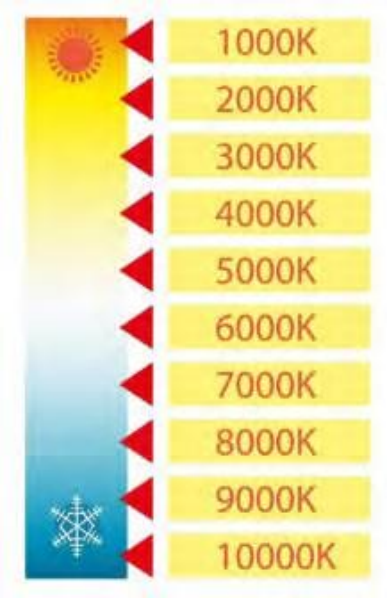
1.5.2 Correlated Colour Temperature (CCT)

On completion of the session, the trainee will be able to explain:

- What CCT is
- The importance of CCT in general lighting

The colour characteristics of light warm (yellowish) or cool (bluish) can be described by determining its colour temperature. It is measured in degrees of Kelvin (°K).

In case of an LED light, there are primarily three types of white colours: warm white, natural white and cool white. The colours below 3000°K will seem yellow or orange, while those at 4000°K will appear almost neutral. When the colour temperature falls, the light seems warmer, and as it rises, it is cooler. Generally, most LED lights make CCT from 2700°K–6700°K. The exceptions are a few special applications, such as decorative lights, aquarium lights or glow lighting.



Different colour temperature LED lighting for different places:

Public applications: People mostly use warm white LEDs of 2800–3500°K to promote relaxation.

Hotel LED lighting: Hotel lobbies go for cool white LEDs of 5500–6500°K, while rooms generally have warm white lights of 2700–3200°K.

Office lighting: Offices usually have natural white LED of 4000–5000°K to cool white with CCT of 5500-6500°K to enhance concentration.

Warehouse lighting: Warehouse mostly use natural white light of 4000–5000°K or cool white light of 5500–6500°K.

Shopping mall LED lighting: Malls generally go for warm white lights with CCT OF 2700–3200°K. Within the mall, different areas use different lighting—natural white with 4000–5000°K and cool white with 5000–6500°K.

UNIT 1.6: LED Power Sources

Unit Objectives

At the end of this unit, you will be able to:

- Identify the LED power sources
- List components used in power supply
- Describe series and parallel connection of LED

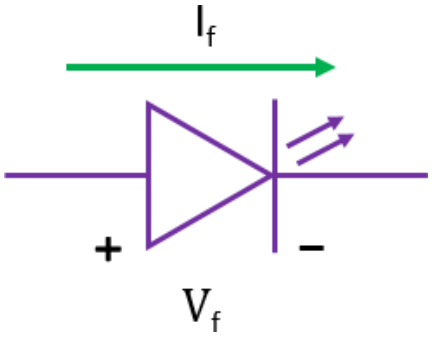
1.6.1 Introduction

On completion of the session, the trainee will be able to explain:

- how LED are powered
- the importance of Voltage and current in LED operation
- the basic parameters of LED

The difference between powering an LED and other electronics product lies in the source of power since a constant current source is required by an LED while most others need a constant voltage source. Hence, a dedicated power supply requires to be implemented to power the LEDs in a circuit.

The power supply must be able to provide a high voltage known as the forward voltage (V_f) that is enough to illuminate the LED and must also provide controlled constant current known as forward current (I_f). Current above the value of I_f may damage the LED and the light output depends on the forward current.



LEDs can be categorised as:

- LEDs used as indicators: These use low power and are used to light a small indicator such as the one on a laptop that shines when the hard drive is on. The I_f requirements are generally 10 mA to 20 mA.
- LEDs used for lighting: The power required for these is greater than that used for the indicator ones. Inefficient methods for powering LEDs result in huge power losses that

are counterproductive, because LEDs are chosen to maximize the efficiency of lighting systems over others. LEDs in may require hundreds of mAs (typically 350mA) to provide the light output that they are able to produce.

The light output is measured in:

- Candelas: It is the power of a light source that is emitted in a particular direction.
- Lumens: It is the amount of light that is produced from a source of 1 Candela in a solid angle of 1 steradian (SI unit of solid angle).

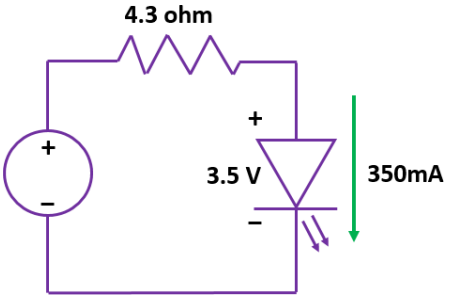
The LED applications specify high luminous intensity and therefore, the supply of power should be efficient, and output current must be controlled with accuracy.

1.6.2 LED Power Sources

On completion of the session, the trainee will be able to explain:

- How LED drivers works
- The types of LED drivers
- The main characteristics of LED drivers

The easiest method of supplying power to an LED is to utilize a DC constant voltage source that is already giving power to the other electronics within the circuit. Current can be typically regulated using a series resistor. This method proves to be cost-effective and useful, especially if other components already have power.



Indicator LEDs are generally powered by this method. For lighting applications, there are some drawbacks of this method and one of them is inefficiency. There is loss of power across the resistor in the form of heat. For example, if a 10V source is used to provide power

to an LED with a Vf of 4.5V and an If of 450 mA, it results in a 1V drop across the resistor. This will lead to power wastage.

P = VI

P = (1V) (0.45A) = 0.450W

That means that there is 450 mW wastage in powering just one LED. One more drawback of this method is lack of control over the current. Vf can vary from one LED to another and, consequently, the voltage drop across the resistor too can vary. As a result, the current can vary across the various LEDs and so will the light output. In the case of multiple LEDs being powered, these drawbacks become even more prominent. If there is a 10V supply, the LEDs would have to be supplied power in parallel. Power would be dissipated across many resistors and the light output could vary from one LED to another. Thus, instead of using a current limiting resistor having a constant voltage source, it would be more suitable to arrange a constant current power supply. Many simple linear constant current supplies exist but the most efficient is a switching mode power supply (SMPS).

This can be explained with the help of the following example:

There is power loss in the linear supply due to voltage conversion. If a linear regulator is being utilized for the conversion of 12V to 3.5V and the load is 350 mA, the total power consumed can be given as:

P (total) = (12V) (0.350A) = 4.2W

The power utilized by the LED is: PLED = (3.5V) (0.35A) = 1.23W

The power wasted in the regulator is: PLINEAR = P (total) – PLED = 2.98W

Most SMPs are around 90 percent efficient. In the above example, the power consumption is: Ptot = (Vout) (Iout)/90%

P (total) = (3.5V) (0.35A)/ (0.90) = 1.36W PLED = (3.5V) (0.35) = 1.23W PSMPS = P (total) – PLED = 0.13W

Thus, if a switching regulator is being used, 0.13W is lost in power conversion. On the other hand, 2.98W is lost if a linear regulator is being used.

The designs of switching power supply controllers are complex as compared to those of linear regulators. They have the following components:

1. A controller IC
2. A high side MOSFET
3. A low side MOSFET/ catch diode
4. An Inductor
5. Resistors and capacitors

The choice of a low side MOSFET or a catch diode depends on the kind of SMPS.

1.6.3 Series or Parallel

On completion of the session, the trainee will be able to explain:

- how LEDs are connected in a circuit
- the purpose of LED connection in series
- the purpose of LED connection in parallel
- LED is connected in both series and parallel

It is very important to figure out whether to power the LEDs in applications having multiple LEDs in series or in parallel. The available supply voltage is often too low that it cannot meet the V_f of multiple LEDs. It may seem that powering the LEDs in parallel configuration would be the preferred method. A few disadvantages of parallel configuration of the LEDs include:

1. There is a variation of light output from one LED to the other.

The variation of forward voltage from LED to LED results in varying I_f, which causes the light output to vary. Because of negative temperature coefficient, the hotter the LED gets, the more current it uses and thus gets even hotter. However, grouping of the LEDs considering the light output characteristics, is performed by the manufacturers of LED.

2. The LEDs may be damaged if there is failure in opening an LED.

More current could also flow to the other LEDs, which could possibly burn them out. If there is a short, too little current would flow to the other LEDs. Faults would have to be monitored and the available current would have to be adjusted to other LEDs. Additional circuitry would be required to operate under these circumstances.

3. The required amount of current increases with each LED.

If multiple LEDs are powered in parallel, it could affect the power supply design. If N is the number of LEDs, it needs N* amount of current output. This implies that the inductor, catch diode and MOSFET need to be rated at a greater current. This would make them more expensive and larger in size.

If multiple LEDs are powered in series, these issues are eliminated, but some other problems come up. In series, the total Vf of the LEDs is cumulative. For example, if a series of five LEDs with a Vf max of 4V has to be turned on, the power supply voltage would require an output voltage of 20V. Instead of needing a larger maximum current rating, the output capacitors would need a larger voltage rating. The increase in the size and expense of a capacitor with a voltage rating of 6V verses 50V is less as compared to a 500 mA inductor verses a 5A inductor.

For example, for lower current, the difference in the size of the inductor could be 5 mm^2 in comparison with 12 mm^2 for higher current. The package size of a high voltage rated capacitor and a low voltage rated one could be same. The other drawback in series configuration is that if one LED fails, all other LEDs connected in the series are turned off.

If the LEDs are secured with appropriate mechanical design for being protected and a thermal design for preventing it from being overheated, they have a greater lifespan. The

advantage of LEDs connected in series is that each of them receives the same current which results in same output light of each LED.

Summary

Designing efficient power supplies is very important for the LED assemblies since they require high power. SMPS provide efficiencies more than 90 percent. Connecting LEDs in series configuration removes the current variations from one LED to the other. It also eliminates the need for high current components and minimizes the requirement of fault-monitoring individual LEDs. For high power LED lighting applications, connecting the LEDs in series in conjunction with an efficient constant current SMPS must be the first consideration.

UNIT 1.7: Thermal Management of LEDs

Unit Objectives

At the end of this unit, you will be able to:

- Explain the heat transfer procedure in an LED
- Describe the passive thermal design
- Identify the use of heat sink

1.7.1 Introduction

On completion of the session, the trainee will be able to explain:

- How heat is transferred from LED to atmosphere
- What junction temperature is and why junction temperature should be kept low

Heat transfer procedure in a LED Luminary

For better performance of LED it is required to keep the junction temperature low. Heat is transferred by three means:

- Conduction
- Convection
- Radiation

The encapsulation of LEDs is typically made up of transparent resin, a poor thermal conductor. The electrical energy that was not converted in to light, generated heat and is conducted via back of the chip. The conduction of heat to outside ambience takes a long path:

junction →solder point→ board→ the heat sink -→atmosphere.

If the thermal impedance is low, the temperature of the junction will be lower and hence, lower will be the temperature of the ambience. Hence, the thermal resistance within the path of heat conduction must be minimized in order to maximize the range of ambient temperature for a specific power dissipation.

The thermal resistance values vary depending on the manufacturer of the LED. For example, it ranges from 2.6 °C/W to 18 °C/W. The thermal resistance of the thermal interface material (commonly thermal grease, solder and pressure-sensitive adhesive) also varies according to the type of material. Power LEDs are mounted on MCPCB, which will be then attached to a heat sink. In the package design, the important parameters are:

- flatness of the surface and contact area
- quality of each component
- applied mounting pressure
- the type of interface material and its thickness

1.7.2 Passive Thermal Designs

On completion of the session, the trainee will be able to explain:

- how to maintain low junction temperature
- heat transfer medium used for better heat transfer
- what heat sink is and its purpose
- metal Core PCB versus FR4 PCB

Adhesive and heat sinks are considered for passive thermal designs for ensuring efficient thermal management of high power LED application.

Adhesive

Adhesive is used to attach LED to board, and board to the heat sinks. Thermal performance can be optimized by using a thermal conducive adhesive.

Heat Sink

Heat sinks play as medium for the travelling of heat from a LED source to outside. Power can be dissipated by the heat sinks in three ways:

- Conduction: It is the mechanism of heat transfer from one solid to another
- Convection: It is the mechanism of heat transfer from a solid to a moving fluid (air, for most LED application)
- Radiation: It is the mechanism of heat transfer through thermal radiation from two bodies having different surface temperatures.

Material — The efficiency of dissipation through conduction is affected by the thermal conductivity of the heat sink material (usually aluminium, but copper is also used). The new materials of a heat sink may include thermoplastics to be used for the applications with lower heat dissipation requirements. The heat sink made up of natural graphite solutions offer thermal transfer better than copper but it has a high production cost. Heat pipes can be used with aluminium or copper heat sinks for reducing the spreading resistance.

Shape — Heat sinks should have a large surface area as the heat transfer takes place at the surface. For this, the size of the heat sink can be increased or many fine fins can be used.

Surface Finish — Thermal radiation of heat sinks depends on its surface finish. For example, a painted surface offers emissivity greater than the unpainted one. About one-third of the heat, in flat-plate heat sinks is dissipated by radiation. A perfectly flat surface area allows reducing the thermal resistance between the LED source and the heat sink by using a thinner layer of thermal compound. Anodizing the surface of a heat sink also helps in decreasing the thermal resistance.

Method of Mounting— Heat-sink mountings using screws and springs provide better performance than thermal conducive glue, clips or sticky tape.

1.7.3 Heat Pipes and Vapour Chambers

They are passive devices used in LED thermal management, and offer effective thermal conductivity in the range of 10,000 to 100,000 W/m K. The benefits are as follow:

- They transfer heat to a heat sink that is in a remote location offering minimum drop in temperature
- A natural convection heat sink can be isothermalized, by reducing size and increasing the efficiency. For example, adding five heat pipes may reduce the mass of the heat sink from 4.4 kg to 2.9 kg that is by 34%.
- They directly transform the high heat flux under an LED to a lower one efficiently that can easily be removed.

1.7.4 PCB (Printed Circuit Board)

MCPCBs (Metal Core PCB) are the circuit boards which have a base metal (aluminium alloy) to dissipate heat. To lower the thermal resistance, MCPCBs have dielectric polymer layer. One advantage of PCBs is the reduction in errors of routing and assembly.

To prevent raising of the temperature of the LED junction by the heat produced by the driver, the LED drive circuitry must be separated from the LED board.

UNIT 1.8: LED Configurations

Unit Objectives

At the end of this unit, you will be able to:

- Describe constant current of LED Driver
- Identify the needs of LED Driver parameters

The number of customers who use LEDs increases with the increase in cost efficiency and brightness of the LEDS and decrease in their costs. Some common applications of LEDs, such as traffic lights, car lamps, LCD back lighting, and architectural lighting, prove to be advantageous considering the high efficiency and long operational lifetime of LEDs.

1.8.1 Constant Current LED Driver

On completion of the session, the trainee will be able to explain:

- Working of constant current LED Driver

Colour and brightness of an LED can be controlled using a constant current driver. It continuously maintains the level of current through the LED, regardless of the operating conditions and the external factors, such as power supply drift and variations in V_f. There is an internal feedback network which keeps track of the flow of current in a string of LEDs and regulates the output in order to maintain the desired level of current.

The driver offers a flexible power solution for a wide range of LED products. The same current driver may be used for the super-bright LEDs that require forward voltage in the range of 3 V to 3.5 V and.

1.8.2 LED Configuration Options

On completion of the session, the trainee will be able to explain:

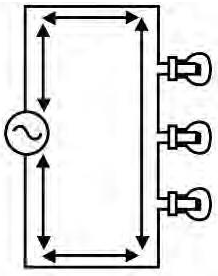
- the type of LED connection on LED light engine
- how to connect LED in series and its advantage and disadvantages

LED lighting applications generally utilize many LEDs operating in the range of 1W to 3W together.

Multiple LEDs can be connected either in parallel or in series. Both configuration have advantages regarding:

- efficiency
- brightness matching
- LED failure immunity.

Another option of configuration known as a matrix is hybrid of the series and parallel connection.



The total string voltage is a function of the number of LEDs in the string, and the forward voltage (Vf) of each LED. If 30 LEDs with a Vf of 4.5VDC are used, the total string voltage would be 135VDC. One constant current driver provides power the LEDs and hence, in this configuration all LEDs receive the same current.

Advantages

- The configuration is simple consisting of only a single circuit.
- Since each LED gets the same amount of current, there is no current imbalance.
- Since there is no resistor to limit the current, the efficiency of this configuration is high.

If an LED fails to work then the remaining LEDs continue to operate normally and the string voltage will decrease by the Vf of the failed LED and consequently the power consumption will also decrease. The overall brightness of the string will dim by only one LED.

Disadvantages

- This configuration poses a safety risk as the output voltage may become high if large numbers of LEDs are used.

For instance, to calculate the maximum number of LEDs that can be safely connected in a series configuration, to a constant current LED driver use the maximum output voltage of the driver divided by the forward voltage of each LED.

If Vout max = 40VDC, and the Vforward = 3.5V, then the maximum number of LEDs is 40/3.5=11.43. A total of 11 LEDs can be connected in series with the constant current LED driver. To select the required output current of the driver, refer to the specification sheet for the LED used for the optimal current and then select an LED driver with the same optimum.

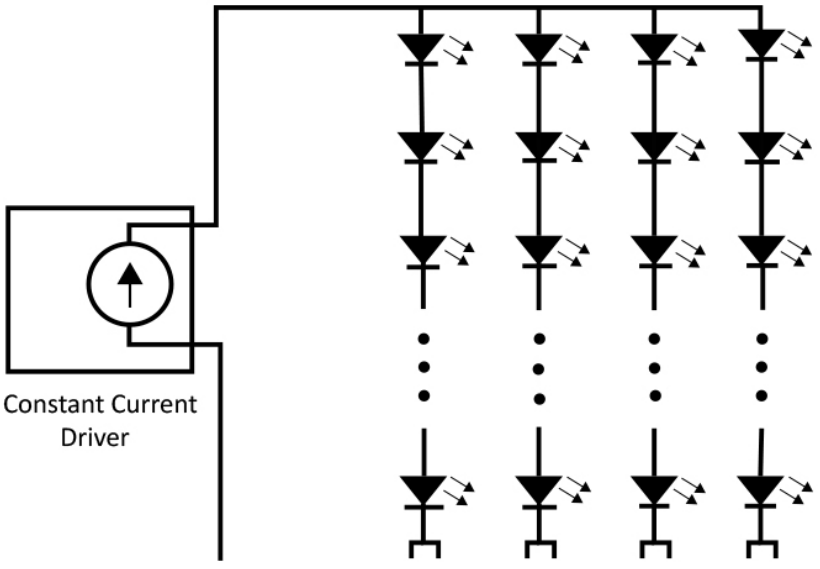
1.8.3 Parallel String Configuration

On completion of the session, the trainee will be able to explain:

- how to connect LED in parallel and its advantages and disadvantages.

Joining LED strings in parallel will decrease the maximum string voltage and also add to the fault immunity.

Consider the following example where 10 LEDs are being used to light a lamp. The LEDs could be organised in 2 strings parallel to each other, with 5 LEDs in each.



The combined string voltage of the entire setup decreases as compared to the series connection of the same by a factor. This factor is equal to the number of strings of the bulbs laid parallel to each other. There is division of the current between the strings, depending upon how perfectly the limiting resistor of each string has been matched. The Vf of the LEDs could also vary and result in major imbalances in the current of the various strings. Generally, a resistor is used in each string to balance the current.

Advantages: -

- A parallel configuration needs only a single driver.
- The combined output voltage is comparably low.
- An approximate equal sharing of current can be obtained amidst the various LED strings by selecting the resistance value properly.

Disadvantages: -

- Although there is improvement in current sharing in this type of configuration, the power consumption rises and the system efficiency decreases.
- In a situation where one of the LEDs fail short, the rest of the LEDs face a higher level of stress since they are compelled to handle a larger amount of current. This might result in

other LED failures in the string. The LEDs in the rest of the strings will become dimmer as the total current is decided by the driver's current rating.

- In a situation where one of the LEDs fails open, all the LEDs in that string will stop working. The current in the rest of the strings will rise as per the number of strings. The effect of the open failed LED can be reduced by connecting a by-pass circuit in parallel with each LED This measure will short out the failed LED.

Calculating the maximum output voltage of an LED Driver

In a parallel connection, the product of V forward and the number of LEDs in each string is the total forward voltage. If the value of V forward is 3.5V and there are 2 strings of LEDs connected in parallel, the total forward voltage will be 5 x 3.5 = 17.5Vdc.

The output of a constant current LED driver is calculated by multiplying the optimal current for the LED being used with the number of strings. If there are 2 strings of LEDs and 350mA is the optimal current for the LEDs, then the LED drive must have a current rating of 350 x 2 = 700Ma.

1.8.4 Matrix Configuration

On completion of the session, the trainee will be able to explain:

- how to connect LED's series and parallel and its advantages and disadvantages

The matrix configuration tries to eradicate a few of the issues linked with parallel configuration by including more connections between the LEDs. Both matrix and parallel configuration have similar topology with the difference in there being a connection between each of the strings in the matrix configuration. The first LED of each string has a parallel connection with the first LEDs of all the rest of the strings. Thus successive LEDs are in parallel with their neighbouring LEDs. Thus the LEDs are organised in a matrix of rows and columns.

Advantages

- A single output driver is required in this configuration. The output voltage as compared to a parallel configuration is relatively low
- Usually, this configuration possesses greater fault-tolerance.
- The efficiency is more as current sharing resistors are generally not utilized.

Disadvantages

- Current imbalances are a problem. Including resistors to help in current sharing is the simple solution as in the case of a parallel configuration.
- Unequal current sharing results in irregular light and thermal distribution.
- In a situation where an LED fails short, the rest of the LEDs of the same row will also stop functioning. The LEDs of the other rows will function normally except that the lamps will become less bright.
- In a situation where an LED fails open, the rest of the LEDs of the same row will have to face higher current. This raises the chance of another LED of that row also failing. The rest of the LEDs will function normally.

  The effect of the open failed LED can be reduced by connecting a by-pass circuit in parallel with each LED. This measure will short out the failed LED.

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2. LED Luminary Assembly

Unit 2.1 – LED Luminary Assembly

Unit 2.2 – Selection of LED Drivers

Unit 2.3 – Diagnose and Repair LED Light

Key learning Outcomes

At the end of this module, you will be able to:

- Demonstrate basic knowledge of product assembly
- Identify the tools required for LED product assembly
- Explain different types of drivers
- Demonstrate driver selection according to the LED

UNIT 2.1: LED luminary Assembly

Unit Objectives

At the end of the session, the participant will be able to:

- Demonstrate basic knowledge of product assembly.
- Identify the tools required for LED product assembly.
- List the materials used in LED product assembly.

2.1.1 LED Luminary Assembly

Led luminary assembly means to assemble light, engine, and driver into the mechanical.

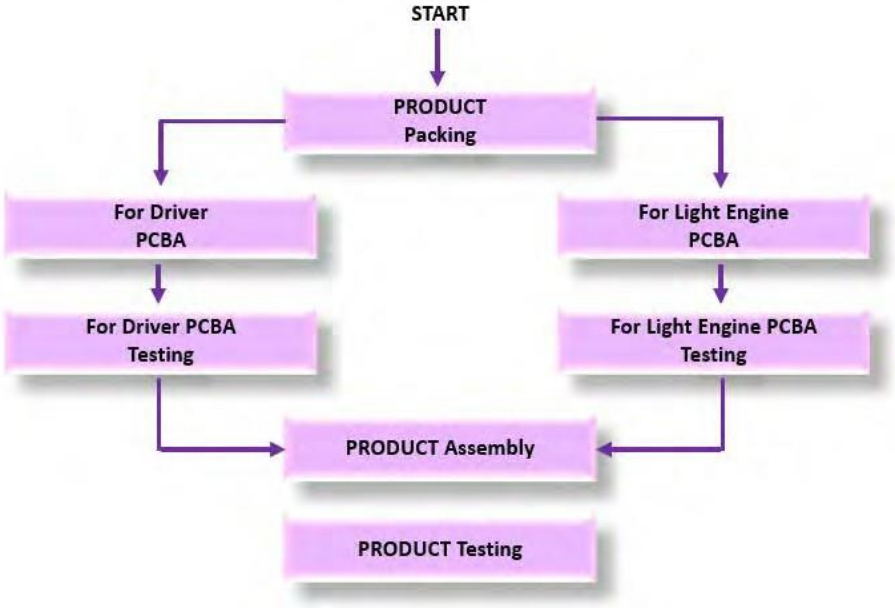
Mainly three things are required for production of LED lights.

1. Name of the product.
2. Quantity of the product.
3. The target date of production.

Learning Outcome:

- Understanding of the process of LED product assembly.
- Identification of the production requirement and the target date.

Process Flow Chart for LED Luminary Assembly



2.1.2 Components of an LED Luminary

On completion of the session, the trainee will be able to explain:

- The Major Components of LED Products:
    - Led Light Engines
    - LED Drives
    - LED Heat Sinks

An LED Luminary has the following major components/ parts:

1. An LED Light Engine
2. An LED Driver
3. An LED Heat Sink
4. An LED Luminaire Diffuser / Lens
5. Mechanical Housing
6. Thermal Compounds/ Thermal Tapes/ Thermal Pads
7. Connecting Wires

LED Light Engine: It is the source of light of a luminaire. A light engine is simply, a PC board mounted with LEDs. The following images are some examples of LED light engines/modules:

COB based light engine module

LED based light engine module

Flexible based light engine module

2.1.3 Heat Sink

On completion of the session, the trainee will be able to explain:

- What a heat sink is and its purpose in an LED luminary.

Heat sink of a thermal system allows conduction of heat away from various sensitive components.

2.1.4 Thermal Interface Materials

The types of thermal interface materials used for LED products:

- Thermal Grease.
- Thermal Pad
- Thermal Tape

Thermal Grease:

Thermal Tapes:

Thermal Pads:

2.1.5 Tools Used in a Luminaire Assembly

On completion of the session, the trainee will be able to explain:

- How to use different mechanical tools in an assembly of LED products.
- The types of mechanical tools used in an LED light assembly.

The following tools are commonly used in an LED luminary assembly:

1. An Automatic Screw Driver.
2. A Manual Screw Driver.
3. A Wire Cutter.
4. A Wire Stripper.
5. Nose pliers.
6. An Allen Key Set.
7. A Spanner Set.

2.1.6 LED Product Assembly

In LED light production there are basically three steps:

- Base assembly
- Assembly of heat sink
  - Joining of base assembly and heat sink assembly.
  - In a base assembly, we place the driver into the enclosure. There are various options available in a base assembly such as shrinking the driver by a PVC tube and inserting the driver inside the cavity.
  - In a heat sink assembly, we place the LED module onto the heat sink either by using a thermal tape or a heat sink compound, according to our requirement.
  - Joining the base assembly with the heat sink assembly means connecting the LED driver to the LED module by a manual solder or a connector.

2.1. 7 MR-16/Spot Light Assembly

On completion of the session, the trainee will be able to explain:

1. The assembly of an LED spot light

MR16 Assembly Parts:

Driver PCBA:

2.1.8 Product Assembly Instruction

1. Place double sided adhesive thermal tape on the bottom side of the light engine printed circuit board assembly (PCBA) and ensure that there are no wrinkles while pasting the tape.
2. Place the taped light engine PCBA on the aluminium profile. Ensure that there are no dust or foreign particles on the profile surface.

3. Press the PCBA gently to get proper bonding between the light engine PCBA & the aluminium profile. Ensure that there are no gaps in between.

4. Take the required driver PCBA and place it into the plastic enclosure. Ensure that there are no damages to the input and output end wires of the driver.

5. Later, place the lens on the mechanical.

6. Fit the LENS placed with the spring ring.

7. Then, draw the wires of the spotlight out of the plastic.

8. Connect the spotlight output wires to the input wires by soldering.

9. Apply 220V AC and observe that the LED should be lit and the required wattage should be achieved.
10. Keep the spot light in ON position for minimum 4 hrs for burn-in test.
11. Power -up and ensure that there is correct wattage and intensity.

2.1.9 LED Bulb Assembly

On completion of the session, the trainee will be able to explain:

1. The assembly of an LED bulb

Manufacturing Process of a 7W COB Bulb EMI/EMC PCBA:

Electromagnetic Interference (EMI)/Electromagnetic Compatibility (EMC) Driver PCB Assembly:

1. Place all the components required for an EMI/EMC board manually and solder them
2. Cut-off the leads, if extended
3. Solder input and output wires
4. Clean the boards.

2.1.10 Product Assembly Instructions

On completion of the session, the trainee will be able to explain:

The procedure of LED bulb assembly

1. Placement of the EMI/EMC driver assembly inside the fireproof plastic holder.
2. Draw out the input and output wires from the plastic holder and fix the EMI/EMC PCB to the plastic holder by tightening the screws.
3. Apply thermal paste on the back side of the COB module. Spread the thermal paste homogenously.


4. Place the COB module on the aluminium surface of the heat sink. Ensure, there are no dust or foreign particles on the aluminium surface.
5. Then, solder the output wires of the EMI assembly to the AC points on the COB module.
6. After soldering on the COB module, fix the COB module on the heat sink by tightening the screws.
7. Solder the input wire of the EMI assembly to the base B22/or E27 depending upon the type of bulb required. If a pin type bulb is required, use B22 base and if a screw type bulb is required, use E27 base. After soldering the AC input wire, crimp the base to the heat sink.
8. Later, place the PC diffuser on the heat sink and lock it.

Product Testing

Driver PCBA Testing:

1. Apply 200Vac to 260Vac, 50Hz to the Input wires for testing.
2. Observe that LED lumens are according to those mentioned in the datasheet.
3. Power Factor is >0.95 and the Efficiency>80%.
4. Keep the COB light bulb in ON position for 4hrs-BURN-IN TEST.
5. Lastly, after testing is done and the product is given as PASS, pack the bulb in the required packing

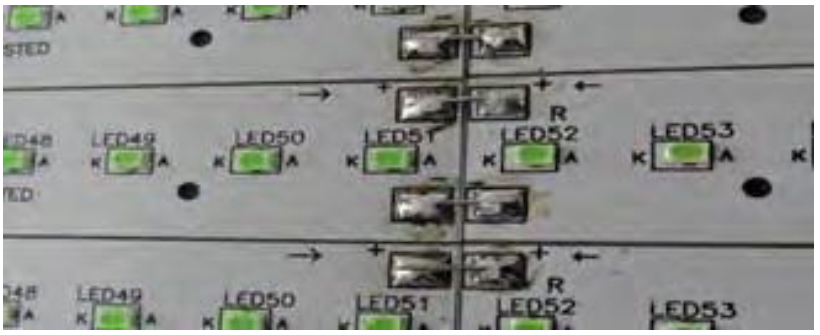
2.1.11 LED Tube Light Assembly

On completion of the session, the trainee will be able to explain:

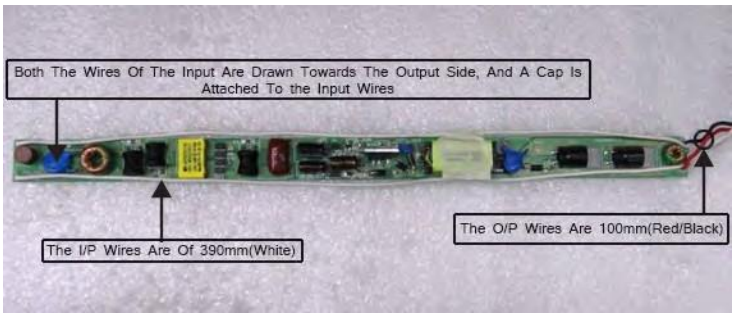
- The assembly of LED tube light

Follow the given process for the assembly of a 4 feet LED tube light:

1. For 4 feet, we have to solder two light engines with jumper wire.



2. For a custom designed heat sink, apply thermal compound over the heat sink surface for heat transfer prior to fitting the light engine PCBA in the aluminium heat sink.
3. Place the light engine PCB after applying the thermal compound on the aluminium heat sink.
4. Ensure that there are no gaps between the profile and the PCBA.
5. Place the tube light driver into the oven with the sleeve for protection.



6. Take the tested driver and insert into the sleeve. Pass the sleeved driver through the reflow oven at conveyor speed 0.70 m/min, for heat shrinking of heat sink sleeve at reflow temperature of 110 degree C.

7. Place the sleeved driver inside the aluminium extrusion, and solder the input wires to the end caps and the output wires to the light engine input points.

The wire colours: input-White, output- Red (+) / Black (-)
The input points of the light engine are connected to the output of the driver, while the inputs points on the other side of the light engine are shorted.

8. Mount the end caps over the LED tube light profile as shown above and tighten it with screws on tested and passed lights.

9. Apply the required voltages and current and ensure that all LEDs must be lit with the same intensity.
10. Solder the Inputs wires on the end caps and the output wires on the light engine PCBA. Ensure that no solder splashes and balls remain during manual soldering.
11. Apply 90-265Vac and ensure that all LEDs must be lit and the required wattage is achieved.
12. Insert the required printed PC covers onto the aluminium profile; ensure that there are no scratches and the lamination sheets must be on the cover.
13. Keep the tube light in ON position at least for 4 hours on Burn-In Test aging line.

14. Tested and passed lights must be screwed with end caps.
15. Power up and ensure correct wattage and intensity.
16. Pack the light in their covers.

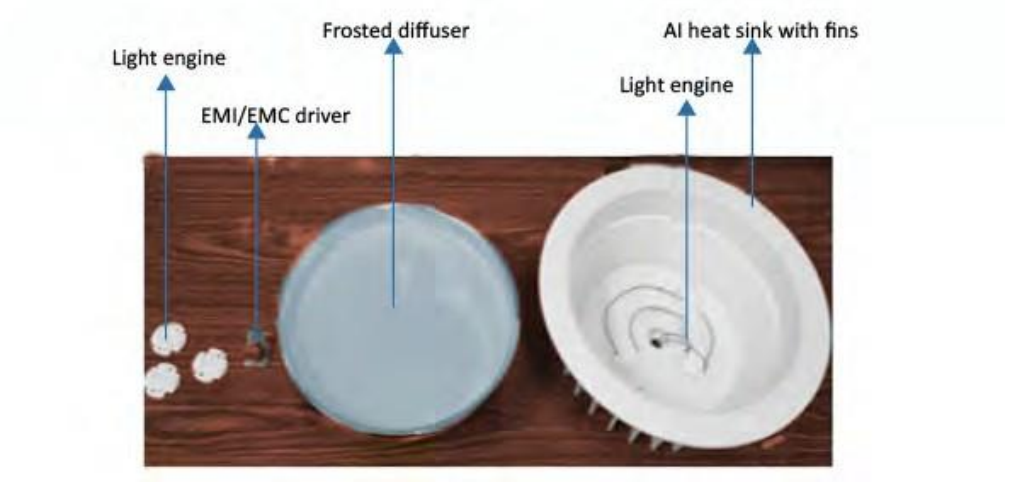
The thermocol box shown above is used for packing a set of 5 LED tube lights.

2.1.12 LED Down Light Assembly

On completion of the session, the trainee will be able to explain:

- The assembly of an LED Down light

Down lighter assembly parts:



Product assembly instructions:

1. Ensure that there is correct PCB usage per production order, which means size and number of the LEDs' board.
2. Clean the surface at the bottom of the COB with IPA (Isopropyl alcohol), and then place the thermal adhesive tape.
3. Place the COB on the aluminium profile. Ensure that no dust or foreign particles are there on the profile surface. Press it against the aluminium heat sink for proper contact.

4. Place these light engines in an orientation of 120 degree (if 3 COB's are used for 18W), and 90 degree with each other (if 4 COB's are used for 24W).
5. After placing the light engines, connect the COB with the output wires of the EMI/EMC PCB.
6. Ensure that there is no continuity between the input wires.
7. Apply 220Vac, 50Hz to the Input wires.
8. Observe. The LED's must be illuminated with the same intensity.
9. Measure the PF and the efficiency. The PF must be >0.9 and the efficiency must be >80%. When P1 represents input power and P2 represents output power

   Efficiency (Ƞ) = P2/P1

10. Solder the AC supply points with wires
11. While soldering does not place more than the required solder on the pads otherwise the wires may get disconnected or the pads may come out.
12. Solder the EMI/EMC PCB with the output wires of the COB.
13. Later place the reflector and the frosted cover over the heat sink.
14. Lock the product with screws.

15. Apply 220VAC, 50Hz and check whether the COB's are having correct illumination.
16. The following image is a testing report on a power analyser at 220VAC of 18W Down lighter.
17. Keep the COB light in ON position for minimum 4 hrs.
18. Ensure that there is correct wattage and intensity.
19. Pack the light.

20. Keep the colour of wires as:
21. Input=Red (Both line and neutral)
22. Output=Red (Line), Black (Neutral)

EMI/EMC PCB inside an enclosure

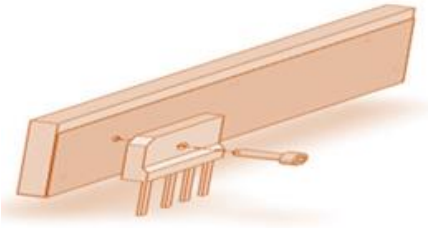
2.1.13 LED Street Light Assembly

On completion of the session, the trainee will be able to explain:

- The assembly of an LED street light

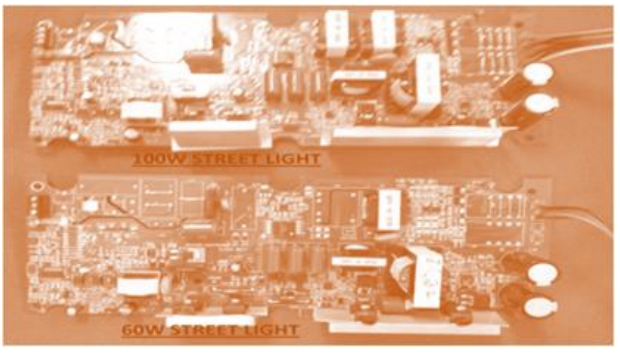
Before starting the LED street light assembly, first complete the heat sink assembly.

Heat Sink Assembly Insulation Sheet:



Note:

This heat sink is made of Aluminium (Al) and covered with thermal tape. It is used to mount on a metal–oxide–semiconductor field-effect transistor (MOSFET) for heat management. The MOSFET after being mounted is screw fitted. Also, ensure there is no air bubble in between the insulation sheet and the heat sink.



1. The driver PCB is placed properly inside the PSU cover and its screw is tightened with the help of washers.

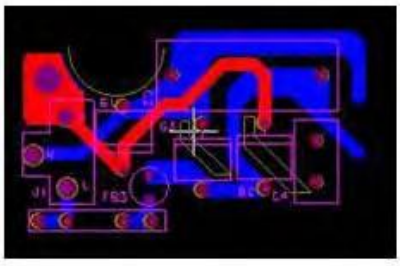
2. The thermal tape is used for heat management through LEDs. It is made in such a way that it has two window openings to fit the lens and the light engine PCBs.

1. It is placed below the metal sheet.
2. Later, the wires are drawn through the holes and the connectors. LEDs are placed, and then rapid repair(RR) powder is added to fill the holes.
3. Gasket is used for air tight fittings.
4. For 60W we will use a 24 LED light engine.
5. This is used for 100W, 48 LED light engine.

The flexible arm is later screwed to the street light fixture to enable it to move to an angle.

Burn in Test:

	WIRE COLOR
Phase/Live (L)	Red
Neutral (N)	White
Earth (E)	Green with yellow tracer



- Each and every assembled PSU must power up on resistive loads at least for 8 hrs.
- Ensure that the wire colour combination and polarity is according to the given table.
- The same polarity has to be followed in a light engine, while connecting with a wire.

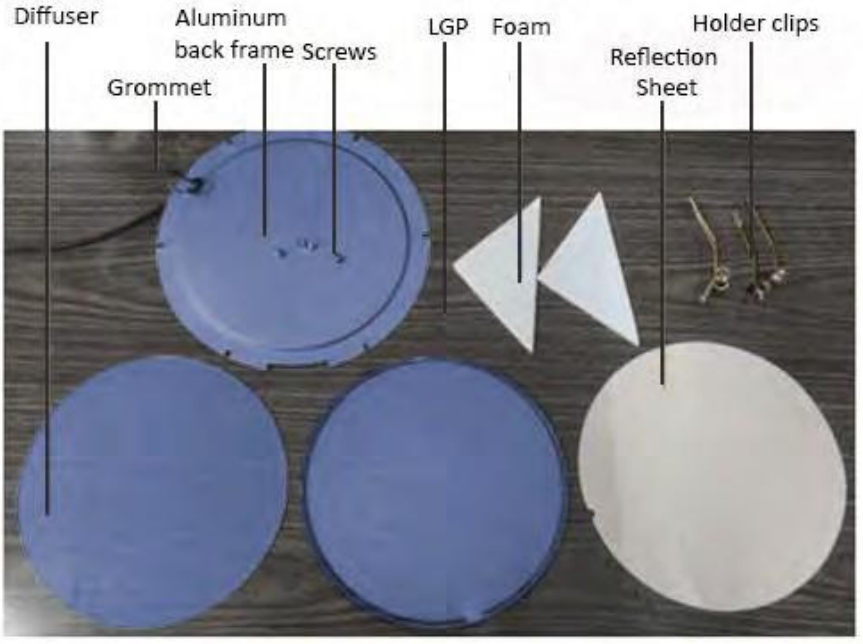
2.1.14 LED Round Panel Light Assembly

On completion of the session, the trainee will be able to explain:

- Assembly of a 6” Round panel light

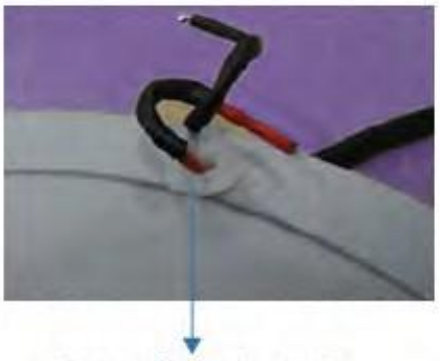
6” Round Panel Light Assembly

6 inches Round panel light parts are shown in the following image:



Product Assembly:

1. Clean the aluminium die cast and the LED light engine with IPA.
2. Take the LED strip and paste the double sided thermal tape behind it.
3. Paste the thermal tape around the die cast.
4. Draw out the wires.
5. Now place the diffuser.
6. Place the LGP over the diffuser.
7. Then, place the reflection sheet.
8. Place the foam sheet before covering it with the aluminium back plate.
9. Finally, place the screws and tighten up, drawing the output wires out of the hole in the aluminium back panel.
10. A grommet is placed in the aluminium back plate to keep the wires stiff.
11. A connector is placed in the output wires.



Grommet for drawing out wires

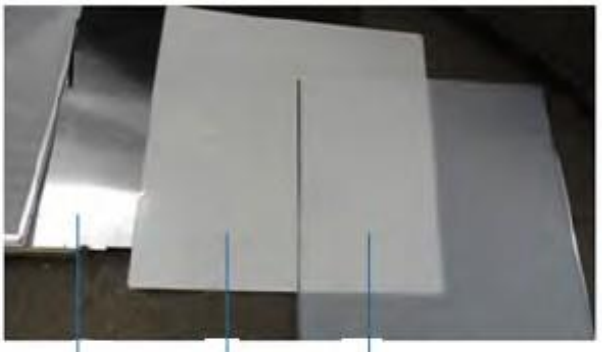
6 inches round panel light

2.1.15 1x1 and 2x2 Square Panel Light

On completion of the session, the trainee will be able to explain:

- Assembly of a 1x1 and 2x2 Square panel light

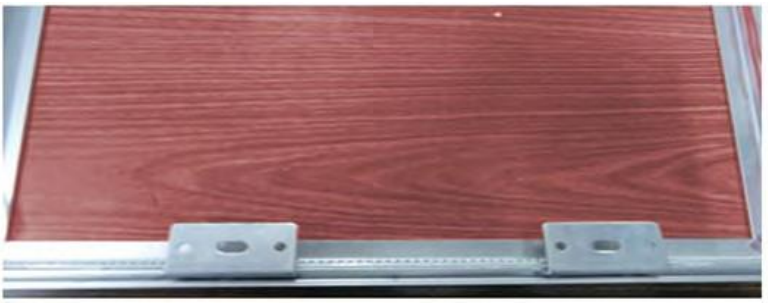
1x1 LED Panel Light



2x2 Panel Light Assembly Steps:

1. The four aluminium extrusions are taken and cleaned with IPA.

2. The extrusions are placed together to form a frame.
3. Then, the LED strips are pasted behind them with the thermal tape
4. The diffuser is placed initially on the thermal tape over frame.
5. Then, the LGP is placed over the diffuser.
6. he LGP has a reflection sheet below it.
7. Lastly, the foam sheet is provided and covered by an aluminium sheet and screwed tight.
8. The reflector sheet has an aluminium reflection tape pasted on the two sides to cover the light coming out from the LED strip to prevent losses.
9. Grooves are made in the extrusion and the reflection sheet to provide for holding of clips and to fasten them with screws.



10. A grommet is provided to draw out the output wires through the aluminium back panel.

Product Assembly:

A panel light has many parts included in its mechanicals:

- Extrusion/Die Cast
- Diffuser
- Light Guide Plate
- Reflection Sheet
- Foam Sheet
- Aluminum Back Plate
- Thermal Tape, Reflection Tape

Steps for Product Assembly:

1. For 2x2 and 1x1 panel light, use a 599mmx599mm and 299mmx299mm aluminium frame
2. Use two light engines at opposite sides in a 2x2 and 1x1 Panel light.
3. The output wires (Red, Black) are soldered onto the light engine polarities.
4. Clean the light engine and the Al extrusion with IPA to remove the dust particles and to place the thermal tape properly without any gap.
5. Then, for 2x2 panel light, the thermal tape of 570mm length and 8mm width is used beneath the light engine and for1x1 panel light, 282mmx8mm thermal tape is used.
6. The frame with a light engine is ready.
7. Place the diffuser inside the frame and the LGP on top of it.
8. Then, place the reflection sheet on top of the LGP and cover from all sides using an aluminium reflection tape to avoid any light dissipation or losses.
9. Lastly, place the foam sheet to provide stability to the mechanicals of the panel light.
10. Finally, place the aluminium back plate.
11. Driver PCBA +Light Engine Testing:
12. Connect the driver output with the light engine.
13. Place the driver into its enclosure and draw out its input and output wires. Ensure that there is no continuity between the input wires.
14. Connect the light engine at the output wires.
15. Apply 220Vac, 50Hz to the input wires; take extreme care against electric shock. Observe that all LEDs must be illuminated with the same intensity.
16. Measure the PF and the efficiency. PF must be > 80 % and the efficiency must be >.

$$\eta = P2/P1$$

P1= Input Power and P2= Output Power

17. Power up the driver and ensure that it is working.

18. Check that there is no damage to the driver and its input and output wires are not shorted or torn out while closing in the enclosure.

For Panel Light	No. of Screws	No. of Screws for V Angle	No. of Screws for Hanging Clips
2 Feet by 2 Feet	18 pcs (As per sample)	16 pcs as per sample	8 pcs as per sample
1 Feet by 1 Feet	13 pcs (As per sample)	16 pcs as per sample	4 pcs as per sample
6 Inches round	6 pcs (As per sample)	NA	NA

2.1.16 Burn in Test for LED Luminaire

On completion of the session, the trainee will be able to explain:

- Burn in test of LED Luminary

Burn-in is the process of exercising the components of a system before they are placed in service.

The purpose is to detect the components that may fail due to the initial, high- failure rate of the reliability of the component. Longer and stressful burn-in period ensures that the system is free from further early failures after the process is complete.

One of the efficient and reliable ways is to do burn in test of the product on an aging line with a conveyer having different voltage zones and a high temperature zone.

Inspection of the Completed Assembly

After the burn in test, the next step is visual inspection. In visual inspection, check for the following:

- Assembly faults
- Soldering faults
- Wire color incompatibility

2.1.17 IP (Ingress Protection) Rating

On completion of the session, the trainee will be able to explain:

- What IP testing is
- Importance of IP rating in Led products
- IP rating requirement for different products based on the product area of use

The Ingress Protection Marking referred to as IP Code, is also known as International Protection Marking. It falls under IEC standard 60529, published by International Electromechanical Commission (IEC) and defines the ratings and categorization of the degree of protection provided against the followings:

- accidental contact by electrical enclosures and mechanical casings
- intrusion by hands and fingers
- water
- dust

The rating is denoted as IP (characteristic numerals). For example, an electrical socket of rating IP22. The first and second digits denote protection against solid particles and liquid ingress respectively.

The digits indicate the conformity of the component with some specified conditions. The numerals are replaced with 'X' such as IPX7 when there is no protection rating available with regard to any one of the criteria. Level of protection against solid particles are listed in the following table:

Level	Object size protected against	Effective against
0	—	No protection provided against contact and entrance of objects.
1	>50 mm	Protection provided against any large surface of the body part (back of hand). No protection provided against intentional contact with body.
2	>12.5 mm	Protection provided against fingers or objects of the same type.
3	>2.5 mm	Protection provided against thick wires and tools.
4	>1 mm	Protection against screws, wires and so on
5	Dust protected	Complete protection provided against dust contact. It can be said as dust proof. Entry of dust is not totally prevented, however, it is restricted to a tolerable level that it does not limit the operation.
6	Dust tight	Provides complete protection from dust (it is considered to be tightly packed to allow dust.)

UNIT 2.2: Selection of LED Drivers

Unit Objectives

At the end of the session, the participant will be able to:

- Explain different types of drivers.
- Demonstrate driver selection according to the LED.

2.2.1 LED Drivers

On completion of the session, the trainee will be able to explain:

- The purpose of a driver in an LED product
- Types of LED drivers
- How a constant current driver operates an LED product

An LED driver is the source of power for LEDs. Whenever you are building LED luminaries, you will always need a driver or possibly even multiple drivers. There are different types of LED drivers, as there are different types of LEDs.
LED drivers can be categorized into:

- constant current (CC)
- constant voltage (CV) drivers.

LED driver is usually an AC/DC converter. In another words, it converts AC voltage from main 220V, 230V or 240V power supply to DC supply, suitable for the LED component.

2.2.2 Selection of an LED Driver

On completion of the session, the trainee will be able to explain:

- How to select power rating of an LED driver for a given light engine
- Decide specification of an LED driver for an LED product

2.2.2.1 Steps

Step 1: What forward current does your LED need?
We should find the forward current your LED needs, from the datasheet. If your LED needs a current of 350mA, you should try to find a driver with 350mA output current.

Step 2: How powerful should your driver be?
The power consumption of the LED can also be found from the datasheet or at least it can be calculated with the data in the datasheet. The power consumption can be calculated by multiplying the typical driving current value with the typical forward voltage value. Both are present in the LED data sheet. Sometimes you can even find the power consumption directly from the datasheet. If you are using multiple LED components, you have to find a driver that can feed all the LED components in the luminaires.

Step 3: What output voltage range do you need from the driver?

Take a look at the datasheet and check the voltage of the LED. If you have multiple LEDs, you should add the voltages together. Then, you should find a driver with a voltage range that your LEDs fit into.

Step 4: Do you need dimming? If you do, then what type of dimming do you need?

A need for dimming is mainly dependent on the specification of your luminaire. If you do not need dimming, a normal on/off driver is enough for you. If you need dimming, there are many different types available.

Step 5: What are the physical dimensions within which the driver has to fit in?

You should also consider whether there are some limitations for the physical dimensions of the driver. These will obviously have an impact on your driver selection. You will generally find the physical dimensions of the driver from its datasheet.

Step 6: What kind of environment is the luminaire used in?

Where is your luminaire designed to be used? If it is designed for indoor use, then you probably would not need to think about IP-classification much. If the luminaire is used in a room with a lot of dust or moisture, this has to be taken into account. IP20 class drivers can be used in indoor lighting applications but hardly stand harsh conditions in outdoor lighting, unless the luminaire itself is waterproof, thus protecting the driver.

When a luminaire is designed for outdoor use, then you should check that the driver has good IP-class. Usually IP67 drivers are heavier in weight, the driver electronics is molded with plastic (such as potted) and the electrical throughputs of the wires, both on the primary voltage and the secondary voltage side, are sealed with the required protection against moisture.

Step 7: Is the driver suited for European standards or American standards?

Does the driver have any approvals? Are the approvals for Europe (ENEC) or America (UL). This can generally be found from the datasheet of the driver. With these steps you should be able to find a suitable LED driver for the application.

2.2.3 Constant Current LED Driver

Constant current drivers always feed relatively constant current. Voltage range may vary. Many times the output voltage range is related to the physical dimensions of the driver. This restriction may set some selection challenge, if the luminaries are compact and there is limited space for the driver. One of the important functions of a constant current driver is the capability to maintain constant current. The characteristics of a constant current LED driver are:

- efficiency: It indicates what part of the input power can actually be used by the driver to power the LED
- power factor: The power factor indicates how much load the driver puts on the electrical network. The maximum value of power factor can be 1.

2.2.4 Constant Voltage LED Driver

A constant voltage driver keeps the voltage constant. The feeding current varies according to the load. The higher the load is, the bigger the current is. Constant voltage drivers are usually used in applications where all LED components are in series. These with high powers can be used as electrical energy suppliers for many smaller power constant current drivers. In larger lighting systems, they are storages that feed stable current into the LED loads they have .In some cases, constant voltage drivers are the only suitable solution, such as when replacing halogen lamps. Replacements require 12V or 24V voltage. If used in a parallel mode, electrical load variation can result into brightness variation due to current variation.

UNIT 2.3: Diagnose and Repair LED Light

Unit Objectives

At the end of the session, the participant will be able to:

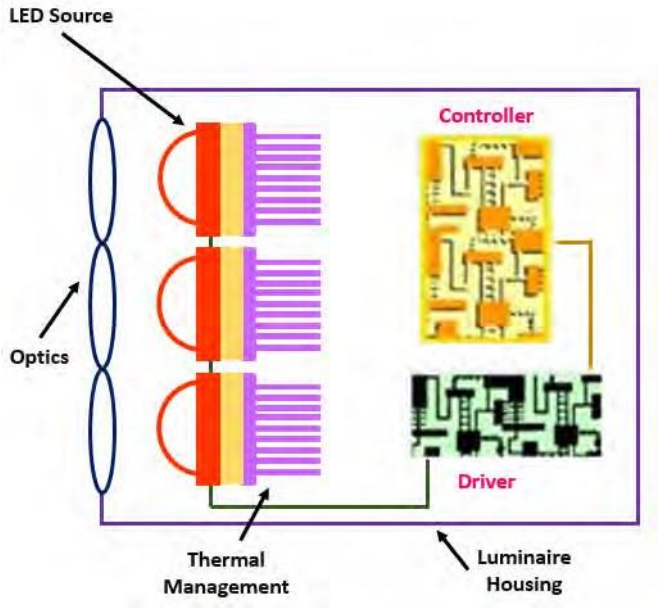
- Explain different types of drivers.

On completion of the session, the trainee will be able to explain:

- How to find component level fault and repair it
- How to find Led strip level fault and repair it
- How to achieve productivity and maintain quality standards.

Major Components of an LED Light:

1. Every component is critical in the functioning of an LED luminaire
2. Failure of any one of them would cause the entire system to stop functioning.



2.3.1 Reasons for LED Failure

LED Lighting, one of the efficient sources of lighting available in the market, offers several benefits, including lifespan up to 50,000 hours. However, there may be failure of LED lights before their lifetime, if they are not properly maintained. For preventing the premature failure of LEDs, one must be aware of the reasons behind the failure of LEDs.

Different reasons for LED failure are as follows:

1. Hot Environment:

The light emitted by LEDs reduces exponentially, depending on time and temperature. The higher the temperature of the environment, the earlier the degradation of the LED light,

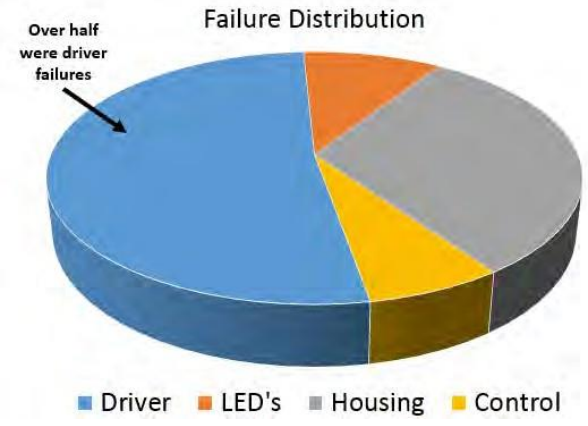
leading to a shorter lifespan. Hence, thermal management is vital for ensuring longer duration for the LEDs lifetime.

2. Incorrect LED Driver:
LED must be powered from a DC source, while incandescent lighting can be operated by using either AC or DC. LEDs can be driven by an AC power supply by using LED power supply or an LED driver. High voltage or current from the driver or the power supply results in failure of an LED, as it will suffer overdrive.

3. Incorrect Polarity:
LEDs must be connected according to their polarity; as being diodes, they are polar sensitive. Hence, the positive terminal (anode) and the negative terminal (cathode) are connected to the positive and negative terminal of the supply respectively. If LED terminals are connected in reverse, there may be catastrophic failure, leading to open-circuit failure along with no light emanation.

2.3.2 LED Luminaire Failure Analysis

90% of the luminaire failures are due to something other than the LEDs.



LED Luminaire Failure Types:

1. LED Failure Modes
2. Secondary Optics Failure Modes
3. Thermal Management System Failure
4. LED Driver Failure

LED Failure Modes:

Different LED failure modes are listed as follows:

1.1 Packaging Related Failure

Epoxy degradation: Some components of the plastic package material turn yellow when they are subjected to heat. It causes partial absorption of the affected wavelengths and thus results in loss of efficiency.

Thermal stress: Epoxy resin package starts expanding rapidly when the glass transition temperature is reached. The expansion causes mechanical stresses on the bonded contacts and the semiconductor, leading to the weakening of the bonded contacts and even tearing off. Very low temperatures also can lead to cracking of the packaging.

Degeneration of differentiated phosphor: The degradation of different phosphors in white LEDs at different rates due to heat and age causes changes in the light color produced by the LEDs. For example, organic phosphor formulation is used in purple and pink LEDs, that may degrade after a few hours of lighting and it may lead to a major shift in the light color.

1.2 Metal and Semiconductor Related Failure

A common mechanism for degradation of the location of radiative recombination (known as active region) is nucleation and growth of dislocations. This is caused due to the presence of a defect in the crystal and the rate is accelerated by high current density, heat and the light emitted from the LED. Elements such as aluminum gallium arsenide are more vulnerable to it. Metal atoms are moved to the active region from the electrodes as a result of metal diffusion, which happens due to high voltage or currents at elevated temperatures.

1.3 Stress-related

- Thermal runaway: This is caused by loss of thermal conductivity due to presence of non-homogeneities in the substrate. In this case, damage caused by heat results in more heat generation. Most common voids are the ones which are caused by incomplete soldering.
- Electrostatic discharge: It may cause:
  - a permanent shift of the parameters of the semiconductor junction
  - immediate failure
  - latent damage that leads to enhanced rate of degradation.

Secondary Optics Failure Modes

Secondary optics ensures that the output beam of the LED lamp meets the photometric specifications by modifying it.

Secondary optics in LED may be any of the following:

- Diffuser
- Lens
- Specular or diffused reflector
- Lens and reflector combination; for example, total internal reflection lens or TIR

Smooth diffusing

Small detailed texture features on the lens surface

Diffusing on TIR lens

The secondary optic, in case of outdoor applications, is exposed to ionizing radiation emitted from the sun.

Thermal Management System Failure

These include the following:

- Heat sink failure
- Thermally conductive adhesives wear
- Thermally conductive gap filling materials degradation
- Thermal tape wear
- Thermal grease dry up

Driver Failure

Most of the high-power LED drivers, especially using power greater than 15W, use electrolytic capacitors. There can be two cases. The capacitors can be placed either on the input AC stage for allowing noise filtering or on the driver's output DC stage.

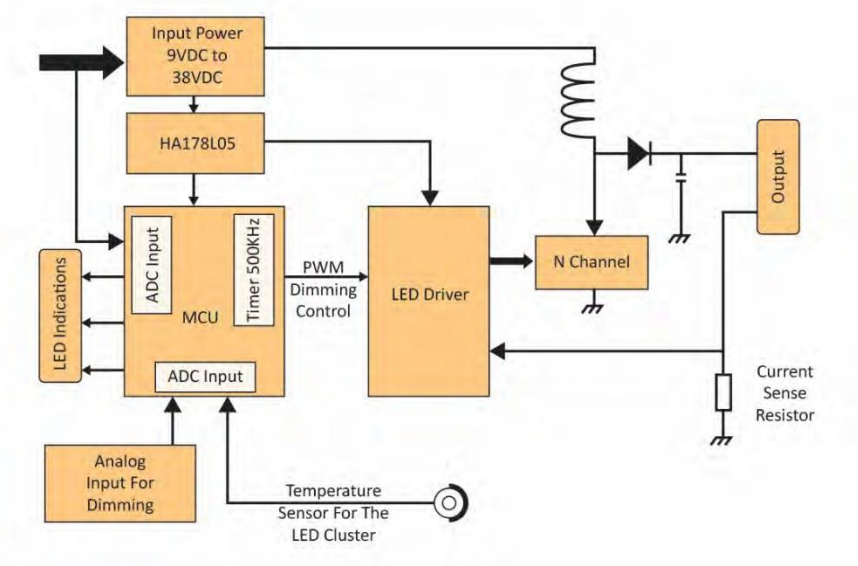
In a driver circuit, the electrolytic capacitors are weak elements and fail frequently at high temperatures.

Other prominent components that can fail:

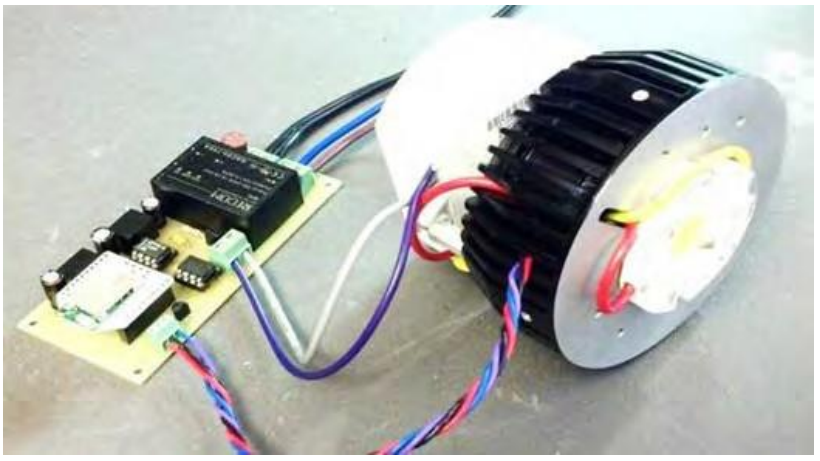
- Isolated-
  - Input- fuse/ MOV
  - Output- transistor/ transformer/ IC

2.3.3 LED Driver

The main function of an LED driver is to restrict the current, regardless of various operating conditions.



2.3.4 Diagnose and Repair Fault in LED Light



Types of LED faults:

- Finding and repairing component level faults
- Connection/soldering faults

2.3.4.1 Steps for Diagnosing LED Fault

Step 1: Connect the LED light that is not functioning with the AC source.
Step 2: If the light does not switch on, look for loose or de-soldered wires and connections.
Step 3: Solder the wire and check for any loose connections so that the light can be operational again.

Light Engine Fault:

Step 1: Disassemble the parts of the LED light, if there are no faults in the connections.

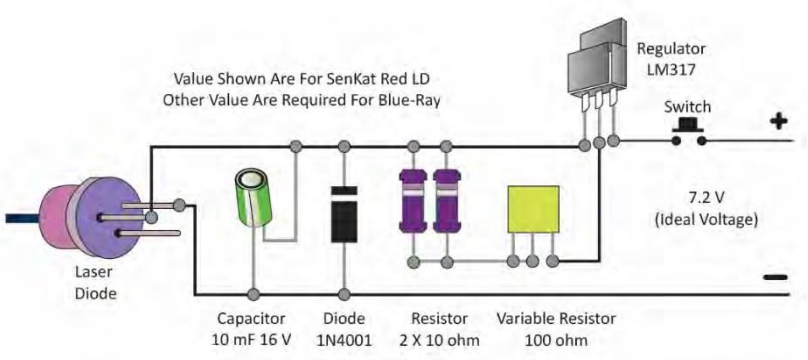
Step 2: Ensure that the light engine as well as the DC supply complies with the voltage/current requirements of the LED product.

Step 3: If the LED light engine is found to be faulty, replace it.

LED Driver Fault:

Step 1: Check the driver with an AC supply or a multi meter to measure the voltage and the current output, in case the LED light engine is functioning properly.
Step 2: Measure the output voltage and the current of each section of the supply unit to identify the faulty section.
Step 3: Check every component of the section that either shows no output or has output voltage less than the desired one, by using a multi meter.
Step 4: Repair /replace the damaged component, primarily the electrolytic capacitors.
Step 5: Check the output voltage/current again with the multimeter and reassemble, if the repaired driver is found okay.

Components of a Typical LED Driver:



LED Strip Level Fault:

Step 1: Connect the LED light that is not functional with the AC supply.
Step 2: Look for the damaged or non-functional LED strips or LEDs from the LED strips array in the light.
Step 3: Replace the damaged LED strips by removing the glass shell.
Step 4: Connect the LED array with the AC source and check it.
Step 5: Replace the glass shell if all the LED strips are working.

Achieving Productivity and Quality Standard:

- Identify the root cause for the non-functionality of an LED light correctly and repair it effectively as soon as possible.
- Document the steps of fault diagnosis and process of repairing as per standard operating procedures (SOP).
- Effectively communicate with the colleagues and the supervisor about the fault diagnosing and the repairing method.
- Report faults found in the LED lights.

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3. Safety Standards

Unit 3.1 – Electro Static Discharge (ESD)

Unit 3.2 – Safety Standards

Unit 3.3 – Importance of 5S on Productivity & Management

Key learning Outcomes

At the end of this module, you will be able to:

- Interpret basic knowledge of ESD
- How to prevent ESD Damage
- Balancing an ESD Control Plan

UNIT 3.1: Electro Static Discharge (ESD)

Unit Objectives

At the end of the session, the participant will be able:

- Interpret basic knowledge of ESD
- Explain how to prevent ESD Damage
- Describe balancing of an ESD Control Plan

3.1.1 ESD Prevention

On completion of the session, the trainee will be able to explain:

- What ESD is
- The importance of ESD safety in LED product assembly

3.1.2 Introduction

1. ESD occurs every day, everywhere
2. Humans are usually the biggest cause of ESD
3. Bare LEDs are sensitive to ESD from a certain discharge level
4. In lighting industry, no standards are known for level 2 LED light engines
5. Take ESD seriously; total cost of latent ESD damage in product life cycle experiencing ESD is very high.

3.1.3 What is ESD?

ESD is the sudden flow of static electricity when two objects come into contact and one gets positively charged while the other gets negatively charged. ESD can build up on humans, tools and various other non-conductors or semiconductors. These ESD events can pose serious problems in industrial environments as they can damage electronic devices and components. There can be a latent effect on the devices where they continue to function but their life is shortened.

Some electrostatic-sensitive devices are as follows:

- MOSFET transistors, used to manufacture ICs
- Complementary metal–oxide–semiconductor (CMOS), ICs made with MOSFETs; such as computer CPUs, graphics ICs.
- Expansion cards
- Transistor-transistor logic(TTL) chips
- Laser diodes
- Blue LEDs
- Resistors with high accuracy

3.1.4 ESD Safe Working

ESD protection is essential for sensitive components such as microchips, during and after production, while shipping, during assembly of the device and in the finished device. Grounding is imperative for ESD prevention. An ESD Simulator having special output circuit called human body model (HBM), is generally utilized to test the vulnerability of electronic devices to ESD from human contact. Generally, an ESD-safe foam or an ESD-safe bag is needed for carrying ESD sensitive components. A technician should use a grounding mat or some other grounding equipment to safeguard the equipment from ESD. The person may also use safety gear such as a wrist strap, safety clothes or rubber gloves.

There are many types of ESD protective materials:

- Conductive: Materials having a resistance ranging from 1kΩ and 1MΩ

- Dissipative: Materials having a resistance ranging from 1MΩ and 1TΩ
- Shielding: Materials that abate current and electrical fields

Anti-static materials: These materials control the build-up of charge by hampering triboelectric effects. This can be done by physical separation or by choosing materials that resist charge build-up. Humans have electrical sources in their body by nature and hence if they touch an ESD sensitive device unequipped with a safety gear, they can damage the device.

3.1.5 ESD Sensation Level for Human Beings

- ~3.5 kV = feeling
- ~4.5 kV = hearing
- ~5 kV = seeing
- Often these sparks are so small that we cannot experience them, but they still damage electronic components like LEDs
- ESD is a natural phenomenon. Normal movement of a person around a work bench can generate up to 6 kV
- An exceptionally high 15 kV was measured on an assembly-line personnel in a factory on a dry winters day

3.1.6 ESD in Our Daily Lives

- Most clothing causes charging due to friction and rubbing
- Tearing foils like tape or packaging also causes charging

Key parameters for charge level are:

- Material (charging/insulating)
- Relative air humidity (circumstance)

Control Variables to Limit ESD Levels:

- Avoid charge build-up / slow discharge
- Monitor and/or regulate humidity

3.1.7 ESD Damage

- ESD is a form of electrical overstress
- Most exposed electronic devices, like LEDs, can be damaged or ruined by ESD sparks

ESD damage failure modes of lighting products are:

1. Catastrophic: device is non-functional
2. Parametric: device functions and works but not according to specifications
3. Latent: device performs within tolerance limits but fails prematurely. Where are OEMs (Original Equipment Manufacturer) confronted with ESD risk?

Three Main Categories of ESD Sensitivity:

1. ESD sensitive LED products (up to 100V HBM); typically Level 0 & level 1 standards for ESD process control are IEC 61340-5-1 & ANSI/ESD S20.20
2. ESD moderately robust LED products; typically Level 2 for ESD control in lighting industry. No standards are known for moderately ESD-robust modules. Nowadays, lighting component manufacturers bring exposed LEDs into the OEM factory
3. ESD robust LED products; typically Level 3 & Level 4

For these products, generally, no ESD control measures are required

Note: discharge test level for luminaires (IEC61547) is 4kv contact and 8kv air.

ESD needs to be addressed early in the chain. Further down the chain, ESD damage will have a larger impact such as:

1. Catastrophic : visible in manufacturing environment
2. Parametric : visible in manufacturing environment

3.1.8 How to prevent ESD damage?

On completion of the session, the trainee will be able to explain:

1. How to minimize ESD risk.
2. How to control ESD in the work place

3.1.9 Find the Balance

ESD robustness can be increased by either the supplier at component level or the OEM in the assembly process.

3.1.10 Quality Approach for LED Modules

What measures to take to minimize ESD risk for OEMs?

- ESD is a crucial aspect of supplier selection, contracting and supplier quality management.
- This requires suppliers to manufacture and deliver ESD-safe components
- Verified via supplier ESD control plan tests, supplied products are tested on ESD performance
- LED products are characterized on ESD in the specification offer ranges, with high ESD resilient features built-in – such as Forimo LED Line with built-in Zener diode
- LED light engines are delivered to OEMs in appropriate packaging:
    - It provides adequate protection against mechanical damage and ESD
    - To warrant this the product can only be ordered at a minimum order quantity (MOQ)

3.1.11 Contact versus Air Discharge

How to specify contact versus air discharge

Complementary tests for Equipment under Test (EUT) are prescribed:

1. Contact discharge direct: Test electrode is kept in contact with the EUT indirect. Then test electrode is kept in contact with a metal plate, simulating ESD to adjacent objects
2. Air discharge; charged test electrode is moved towards the EUT until it touches the EUT

3.1.12 ESD Process Control in Assembly Environment

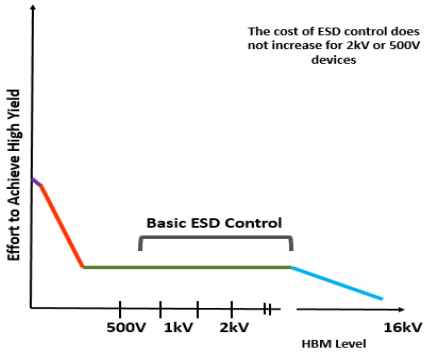
What should OEMs be considering?

- Avoid charging
- Careful selection of materials to be used
- Controlled continuous discharging (resistive conduction or ionic air flow)
- Careful selection of plastics and foils; besides humans, well known source of charge buildup are plastics and foils like optics used in lighting fixtures (lenses, diffuser plates)
- Protective foils which are removed during assembly
- Time for charges to decay to acceptable levels into the ambient atmosphere may take hours
- Air humidifiers and/or ionizers can reduce this decay time to less than minutes
- Cost due to ESD damage can be prevented with control actions and proper products

3.1.13 Balancing an ESD Control Plan

On completion of the session, the trainee will be able to explain:

1. ESD control plans
2. How to do an ESD audit



3.1.14 Requirement for an OEM

An OEM to consult an ESD expert for audit and equipment to ensure the requirement is met.

An ESD control plan could contain:

1. An ESD Way of working, auditing, sensitivity analysis, ESD control plan, work instructions and personnel training
2. Access control ionizers while handling high risk insulators and humidity monitors
3. If lower specified (4 kV/8 kV) products are used, extra measures could involve protective clothing, anti-static or low-charging static-dissipative bags, sensitivity marking seats, ESD- safe storage requirements and work mats

3.1.15 Conclusion: Commitment is Key

1. Check the specification (the requirement)
2. Verify if the assembly and the installation process meet the spec (such as by asking the ESD consultant)
3. Incorporate the proposed working order and tools (and commit to these) in an ESD control plan
4. Ensure management commitment to provide safe and ESD friendly facilities and prevention tools
5. Ensure effective implementation plan that reflects measurable and realistic requirements
6. Maintain consistent and frequent communication about the importance of ESD prevention
7. Perform regular audits of ESD testing and control processes

The indicated preventative measures are easy to implement, do not restrict worker activity and will quickly pay for themselves through higher yield. Committing to these strategies will increase the success of an ESD program.

UNIT 3.2: Safety Standards

Unit Objectives

At the end of the session, the participant will be able to:

- Identify ESD causes and safety gear
- Identify company rules on PPE
- Explain precautions for ESD product testing

3.2.1 ESD Safety

On completion of the session, the trainee will be able to explain:

- ESD causes
- ESD safety gear

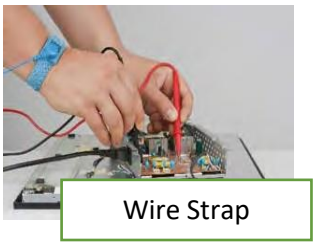
Causes of ESD:

- Static electricity.
- Electrostatic induction

Safety gear for ESD:

- Apron: An apron is used to protect the assembly from static charge generated in our clothes.
- ESD Shoe: ESD shoes are used to ground our body's static charge.
- Wrist Band: ESD wrist bands are used to ground our body's static charge

Some safety gear are shown in the following images:



Wire Strap

Rubbern Gloves

Safety Clothes

3.2.2 PPE Company Policy

On completion of the session, the trainee will be able to explain:

1. Safety rules at workplace
2. The company policy on the use of PPE

Personal Protective Equipment (PPE) is essential to avoid any electrical, heat or physical hazard. A PPE may not eliminate a particular hazard from occurring but it avoids the situation of an employee getting exposed to it. All attire and accessories used to protect against workplace hazards can be considered as PPE. Sometimes, the only close at hand protection for employees might be the use of PPE and usually in emergencies, PPE will be needed for worker's safety.

Safety Rules:

- Injuries must be done reported immediately.
- There should be no horseplay, alcohol or drugs within the premises.
- There should be no usage of alcohol during lunch break.
- PPE must be worn as directed by the management.
- There should be good maintenance of all tools/equipment.
- Care should be taken that appropriate tools are used for specific jobs.
- All guards should be in right place.
- Spliced electrical cords/wiring should not be used.
- Forklift vehicles should be operated by only authorized personnel.

Company Policy & Rules:

1. Workers to be provided with a safe work place
2. Routine/regular workplace inspections to be done
3. PPE to be provided
4. Safe work procedures and rules to be formed and implemented
5. On-going safety training to be given
6. Safety rules and discipline to be enforced
7. Property conservation practices to be given

3.2.3 PPE

On completion of the session, the trainee will be able to explain:

1. What precautions should be taken while doing ESD product testing

Environment

The work environment should not have static more than 100V. A humidifier should be used to avoid low levels of humidity. Materials that produce static should not be used. There should be a periodic review of the effects of measures taken to decrease static.

Working

In the work area, conductive materials should replace insulating materials as much as possible. Materials such as synthetic fibers and plastics are susceptible to charge build-up. Use of work clothes for controlling static and air ionizers should be encouraged.

Equipment

To keep static at bay, earthing must be done for all equipment. This includes the various instruments and testing devices, conveyors, mats, tools, workbenches, soldering irons and solder baths. A conductive mat should be used to cover the workbench and one should be spread on the floor. Both of them should be earthed.

Human body

Workers must wear wrist straps or ankle straps to earth their body. They should also wear gloves to avoid direct contact with the devices. They should not wear nylon gloves or work clothes, which are prone to building up a charge. They must wear footwear with a resistance between 100kΩ to 100MΩ. Dirt and humidity could, however, change the resistance.

Methods of working

A soldering iron made especially for use with semiconductors (with low voltage of 12V to 24V) should be utilized. Earthing of the tip should be done. Handling of the device should be kept to the minimum while mounting the device.

UNIT 3.3: Importance of 5S on Productivity & Management

Unit Objectives

At the end of the session, the participant will be able to:

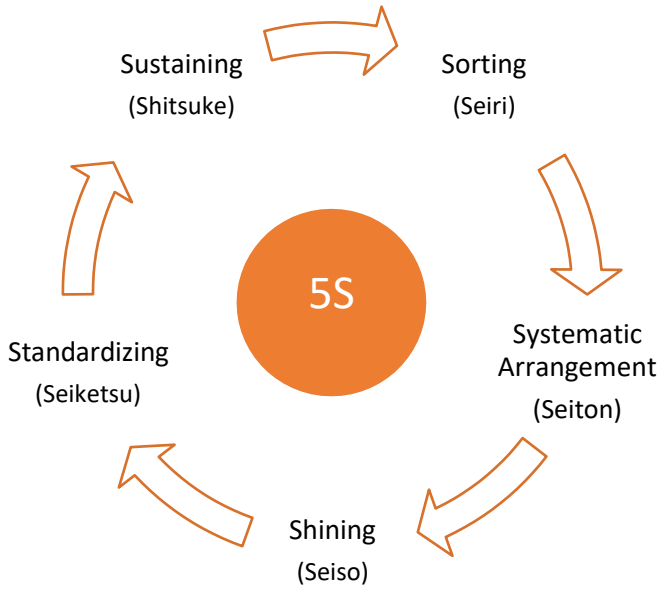
- Recognize 5S work standards

3.3.1 5S

A work standard describes the right way of doing a task. It documents the existing best practice and ensures that it is implemented in every sphere of the organization to improve the work process. 5S is a workplace organization method which ensures or enables improvement of the work process.

5S

5S describes how to efficiently and effectively organize a workplace by maintaining the area, identifying the items used and storing them in their proper place, ensuring sustainability to the order. 5S uses a list of Japanese words that start with "S". The following figure represents the elements of 5S:



3.3.2 Seiri (Sort)

- Keep all the items, necessary for the work, in the work area.
- Dispose off or keep the items which are not frequently used, in a distant storage place.
- Discard the extra and unneeded items.

3.3.3 Seiton (Set in Order)

- Also means "set in order" or "streamline"
- Arrange all items systematically as it promotes efficient workflow and easy retrieval
- Prevent loss and waste of time
- Facilitate picking up necessary items
- Ensure first-come-first-served basis
- There must be a clearly labelled place for each item and every item should be in its place.

3.3.4 Seiso (shine)

- Also means "sweep" or "sanitize"
- Keep the workplace and equipment clean
- Make cleaning a part of inspection
- Prevent deterioration of machinery and equipment
- Make workplace comfortable and safe to work

3.3.5 Seiketsu (Standardize)

- Maintain high standards at workplace for housekeeping and organization
- Maintain high level of cleanliness and orderliness
- Keep all equipment and tools in their proper place
- Display a picture or a diagram illustrating the right layout of the working area
- Arrange identical workstation for a particular job so that the employees can work in any station with the tools kept at the identical location in that station

3.3.6 Shitsuke (Sustain)

- Also means "do without being told"
- To keep everything in working order
- Carry out regular audits
- Sustaining involves maintaining focus on a new way of operation and gradual improvement. The impact of continuous improvement leads to: less waste, better quality and faster lead times.

3.3.7 Additional 5s

Sometimes, additional phases are included such as safety, security, and satisfaction. These are not traditional "phases" but just extra steps to clarify the advantages of 5S.

3.3.8 Safety

The phase "Safety" is sometimes included. It is debatable whether including this sixth "S" promotes safety. A comprehensive safety program could lose its value when it is dealt as a single item in an business methodology focused on efficiency.

3.3.9 Security

The phase "Security" can be included in the 5s. The seventh "S" points out risks to main business categories, such as fixed assets and information technology, to leverage security as an investment and not an expense.

3.3.10 Improving Workplace

An organization is supposed to provide protection to its employees. The primary responsibility of an organization is to ensure health and safety of the employees. However, it cannot guarantee an accident free arena to work in. Hence, it is the responsibility of both the employer and the employee to follow the safety norms. The following figure explains how an employee must contribute towards maintaining health and safety in an organization:

Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

N·S·D·C
National
Skill Development
Corporation
Transforming the skill landscape

ESSCI

4. Soft Skill

Unit 4.1 – Interaction with Superior, Company Policies and Safety Procedures

Key learning Outcomes

At the end of this module, you will be able to:

- Interact with supervisor
- Interact with colleagues
- Know safety procedures and safety measures of an organization
- Know reporting structure of an organization
- Understand organizational safety policies
- Understand organizational work policies

UNIT 4.1: Interaction with Superior, Company Policies and Safety Procedures

Unit Objectives

At the end of the session, the participant will be able to perform the following:

- Interact with supervisor
- Interact with colleagues
- Know safety procedures and safety measures of an organization
- Know reporting structure of an organization
- Understand organizational safety policies
- Understand organizational work policies

4.1.1 Interact with Superior

On completion of the session, the trainee will be able to explain:

1. Understanding Work Requirement
2. Standard Operating Procedure
3. Problem Reporting
4. How to resolve personal issues

Understanding Work Requirement

- Job priorities / schedule
- Special instruction related to a particular job about quality, delivery, material change, safety and so on
- Material handling
- Raw material issue
- Work station cleaning requirement
- Daily maintenance
- Preventive maintenance
- Calibration
- Corrective / prevention action
- Traceability
- Failure Mode /defects reporting
- Company objectives related to productivity, quality, safety, environmental pollution, organizational culture
- Behavior, work place ethics

Standard Operating Procedure

1. Work Instructions
2. Formats
3. Company procedures on
    - Productivity
    - Delivery
    - Quality
    - Safety
    - Environmental Safety
    - Corrective / Preventive Action
    - Product / Service Conformities
    - Rejection Control
    - Machine Operating Procedure
    - Process Control
    - Process Flow
    - Calibration

4.1.2 Interact with Superior

On completion of the session, the trainee will be able to explain:

- Internal communication
- Archiving Information

Internal Communications

- It is important for information to be shared openly in the organization
- People must be informed about the ongoing things in organization
- Appropriate and accurate information is essential for people to enable productivity in work
- Lack of internal communication brings the organization to a halt

Archiving Information

Have an efficient filing system for:

- Hard copy of documents
- Soft copy

Provide following documents to the web admin for updating the website:

- Documents open for the public (everyone)
- Documents confidential and strictly not to be shared

Email and the Internet:

- Impart computer knowledge/skills to the employees
- Provide internet access to employees

- Encourage using internet and emails
- Encourage the use of organizational email address

How to encourage internal communication?

- Sharing information is an integral part of employee's job description
- Defining responsibilities related to reporting and sharing information
- Avoiding procedures that are rigid
- Holding regular meetings keeping them short and effective
- Providing physical bulletin boards
- Communicating actively

4.1.3 Organizational Work Policies and Its Processes

On completion of the session, the trainee will be able to explain:

1. How to work in an organization
2. Different types of policies of an organization

Work Policies: -

1. Setting up the equipment and supplies before carrying out the job orders.
2. Operating equipment safely and effectively.
3. Ensuring that the tools and equipment are maintained.
4. Inspecting the equipment to identify any replacements, malfunctions and repairs required.
5. Performing timely equipment maintenance for better production capacity and quality.
6. Helping junior technicians with their assigned responsibilities.
7. Repairing and cleaning the tools and equipment when needed.
8. Working under the guidance of the superiors to perform and complete task timely and efficiently.
9. Evaluating tools and equipment and recommend improvements.
10. Operating required industrial vehicles to transfer the equipment between warehouse and working area.
11. Following safety procedures, guidelines and company policies for equipment operation.
12. Recommending process improvements for enhancing operational efficiency and safety.
13. Contributing to waste management programs.
14. Identifying and reporting risks and unsafe operations to the Supervisor immediately.
15. Maintaining clean and safe work area clean.

4.1.4 Core Skills- Team Work and Multi-Tasking

On completion of the session, the trainee will be able to explain:

- How to work in a team
- How to handle different types of work at a time

1. Be Liberal with Praise

People like others to recognize them for a job well done. Pay attention to what other people are doing and congratulate them on hard work and successes. Simple politeness goes a long way too. People appreciate smiling, saying please and thank you, and even saying hello and goodbye. These things are particularly important if you have people to manage. Employees expect politeness and praise from their boss or superior, and they will like you a lot better for it.

2. Pick Your Moments

When you work in a shared office space, it is important to recognize when people are available to talk. Be aware of what others are doing, and you will avoid interjecting when they're trying to get something done. They will not thank you for interrupting them when they are rushing around, trying to meet a deadline. Be careful with what you say, as well as when you say it.

3. Take an Interest Outside of Work

If you are thinking of starting to meet colleagues outside of work, first you should take an interest in their personal life at work. Ask about their families and hobbies, and discuss your weekends or evenings when you arrive in the morning. Pay attention to their moods while they are working and sympathize with them when they are said and share their joy when they are happy or sad. Make sure you balance what you ask them to reveal and what you are willing to talk to them about. It is strange if one of you is doing all the talking.

4. Be Willing to Socialize on Your Breaks

When its lunchtime, or time to go home, do not rush off immediately. Doing so will make it look like you cannot wait to get out of there and away from everyone else. Although, sometimes, it is perfectly acceptable to want time for yourself, make sure you do not go off on your own all the time. If other people spend their breaks together, you will look like the antisocial one if you do not want to join in.

5. Treat Your Co-workers as You Would Want Them to Treat You

When you leave school, you hope that you have left bullying behind. But, often, that is not the case, and many people find themselves feeling victimized at work. Treating your colleagues as you want them to treat you will get you far. Even if you do not like them and they do not like you, take the higher ground and be polite for the sake of your working relationship.

6. Do Not Gossip

One thing you probably do not want people to do is talk about you behind your back. It may be difficult not to join in, especially when you are dying to agree with someone about a colleague's behavior. But there is always a risk that gossip will get back to the person it is

about. If you do have a problem with someone, you can choose to keep silent or to confront them. Which one is most appropriate will depend on the situation, but if all you want to do is avoid it then wait until you get home. It is better that whoever you live with gets fed up with your work complaints rather than you create a bad atmosphere in the office.

7. Face Problems Head On

Sometimes when there is just no chance of getting along with a colleague, you need to do something about it. In particular, if a colleague is doing something that makes you feel uncomfortable or upset, you should follow the company procedure for reporting it. It can be difficult to work up the courage to do this, and you should weigh up the possibilities of where it might lead. It could end in the problem getting resolved or it could escalate and get worse. In the best case, your company has a supportive system that resolves these issues appropriately. You can also attempt to deal with problems informally, by approaching your colleague face-to-face. This may help to resolve the issue but you should remain calm and prepare yourself for them to be unresponsive.

8. Do not Push Too Hard to Make Friends

Never put making friends over being a professional. Remember that you are there to do your job first of all. By being nice at work and during breaks, you can increase your chances of socializing with your colleagues outside of work. However, people do not need to see everything of who you are while you are working. The worst case scenario, when you are polite and professional, is that you have not made good friends. If you get on with your work you are unlikely to clash with anyone or make any enemies.

9. Offer Help When It is Needed

Make yourself stand out as the friendly and helpful one by offering help when others need it. Do not be so enthusiastic that it gets annoying, but be willing to lend a hand when someone asks. Even when no one is asking, you might want to volunteer to help someone occasionally, if you have the time. However, do not slack off on your own work to help others.

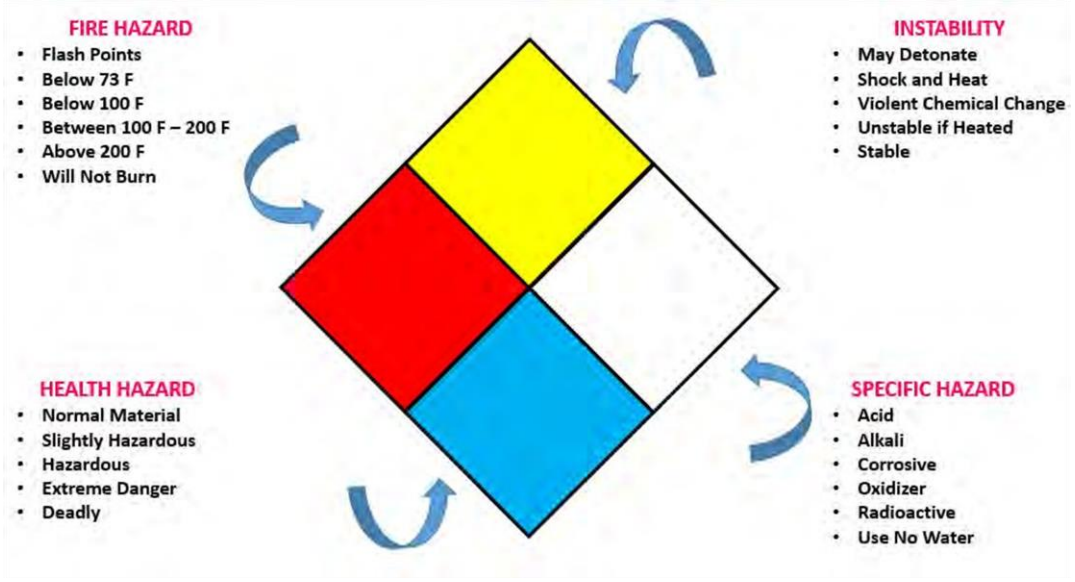
4.1.5 Professional Skill

On completion of the session, the trainee will be able to explain:

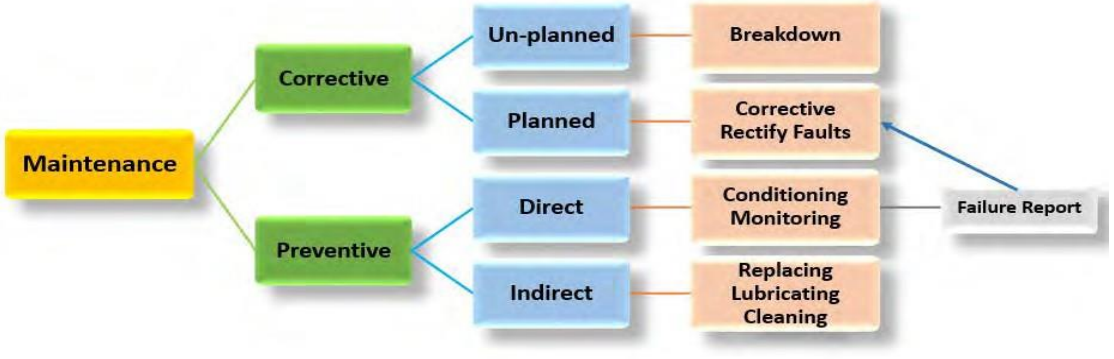
- Problem Reporting
- Potential Hazard

Problem Reporting:

1. Repetitive Defects
2. Machine Failure
3. Potential Hazards
4. Process Disruptions
5. Repair & Maintenance of Machine



Process Involved in Plant Maintenance:



4.1.6 Potential Source of Accident

On completion of the session, the trainee will be able to explain:

1. Types of Hazards

2. Emergency Response

Follow Procedures:

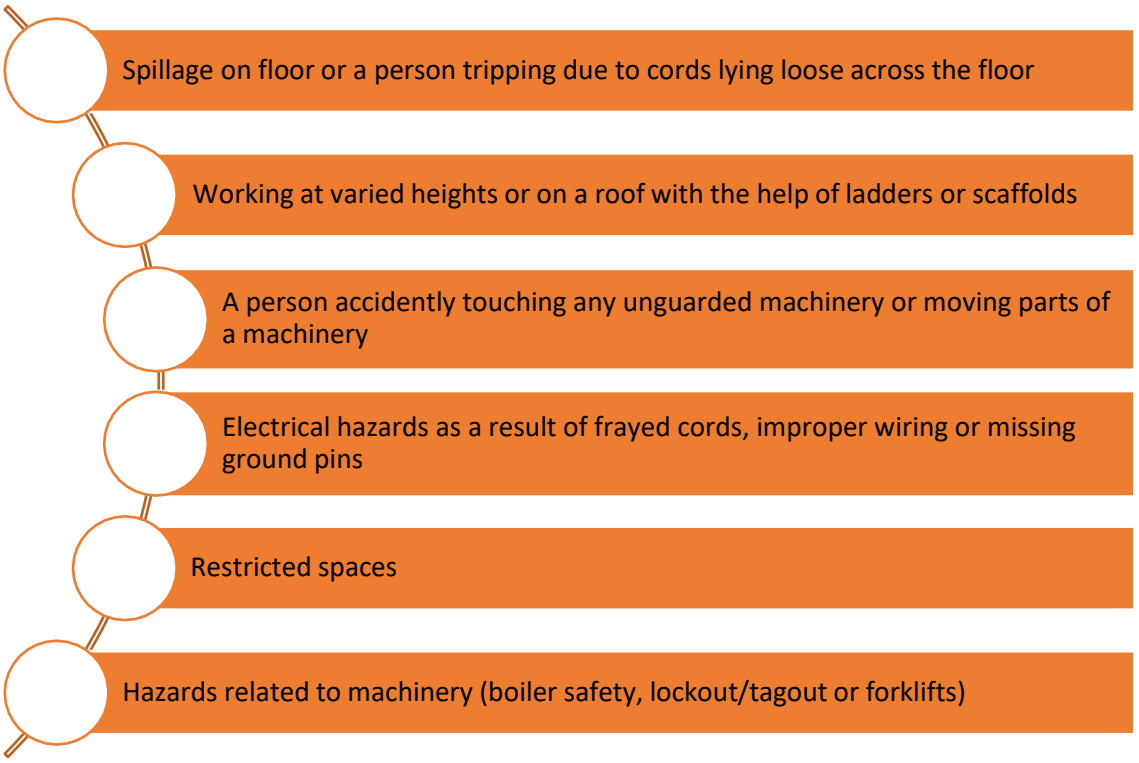
- Identifying and reporting potential hazards on time.
- Following company guidelines, policies and rules regarding hazard materials.
- Handling equipment and tools with care.
- Avoiding accidents while using dangerous chemicals, gases and sharp tools and hazards from machines involving exposure to possible injuries such as cuts, bites, stings, minor burns and so on.

Types of Hazards:

1. Safety Hazards
2. Biological Hazards
3. Physical Hazards
4. Ergonomics Hazards
5. Chemical Hazards

Safety Hazards

Death or any type of illness or injury caused due to unsafe conditions are categorized under safety hazards. The following figure lists some instances of safety hazards:



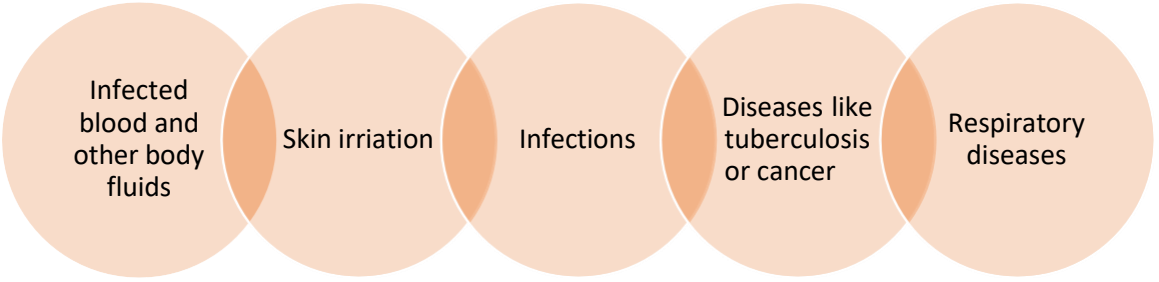
Biological Hazards

Any biological substance that may threaten health of humans as a result of toxins or viruses are known as biological hazards.

A person may be exposed to biological hazards in the following cases:

- Schools, colleges and universities
- Day care facilities,
- Hospitals, laboratories and nursing homes
- Outdoor occupations

The following figure lists the types of ill- health effects caused by biological hazards:



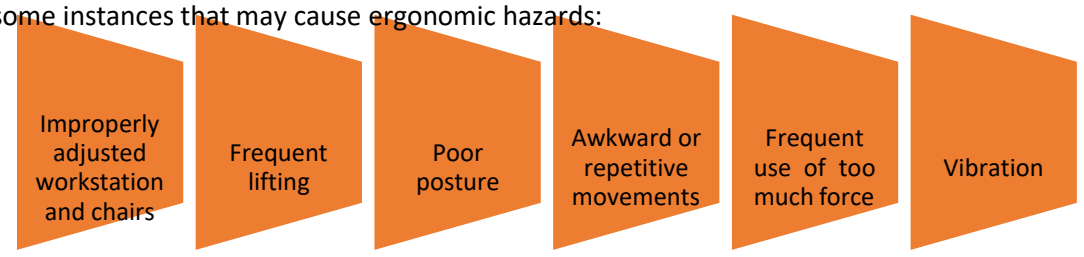
Physical Hazards

An occupational hazard caused by environmental factors is termed as a physical hazard. It includes hazards such as:

- Radiation caused by radio waves, microwaves or EMFs
- Sunlight/ultraviolet rays exposure
- Extreme temperatures, be it hot or cold
- Noise pollution

Ergonomic Hazards

Ergonomic hazards occur due to single/multiple factors within the working environment that pose a threat to the musculoskeletal system of an individual. An uncomfortable workstation leading to wrong sitting postures, repetitive movement of a body part causing sprain or strain, muscle sores, etc., are categorized under ergonomic hazards. The following figure lists some instances that may cause ergonomic hazards:

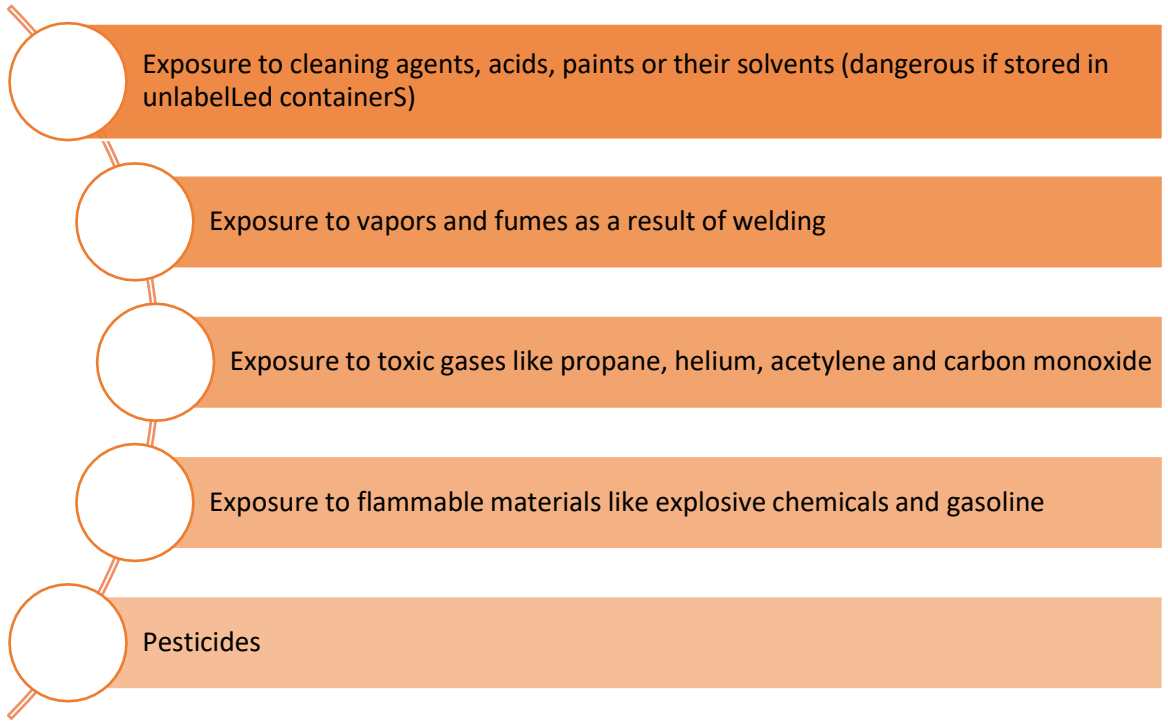


Chemical Hazards

Exposure to chemicals at a workplace is the main cause of chemical hazards. Exposure to chemicals can be due to working around items that involve chemical preparations in any

state solid, liquid or gas. Not all chemicals pose a threat, but there may be workers who are sensitive to even the mildest or non-toxic forms of chemical that is termed healthy. A person can be exposed to chemicals by inhalation of fumes, ingestion or poisoning.

The following figure lists some chemicals that one should be aware of:



4.1.7 Use of Safety Gears

On completion of the session, the trainee will be able to explain:

1. Safety Procedure
2. PPE

PPE are specially made to protect workers from:

- Injuries caused by impacts of electricity
- Electrical hazards
- Heat and chemicals
- Other occupational safety hazards

The following figure lists the PPE used at workplace:

PPE is the last measure of control when worker exposure to the safety hazards cannot be eliminated by feasible work practices or engineering control.

The following figure lists some responsibilities of employer and the employee regarding use of PPE:

Responsibilities of employer	Responsibilities of employee
• Assess hazards at the workplace • Provide PPE • Determine the use the PPE • Ensure protective helmet for employees at all times to avoid head injuries	• Use PPE as per the instructions received in the training • Inspect condition of PPE regularly • Maintain PPE and keep it in a clean/reliable condition

Protective clothes refer to clothing designed especially to protect workers from potential hazards. Lab coats and ballistic vests worn by electricians, scientists and law enforcement officials respectively fall under this category. The different items of the PPE can either be worn individually or in complete sets.

The following figure highlights different types of protections:

Skin protection

- The most common type of occupational diseases are related to skin and their treatment is expensive.
- Skin damage may be due to severe cuts, punctures, burns, abraisions or extreme temperatures.
- Any form of PPE acting as a barrier between the skin and agent of exposure is considered a skin protector.
- Gloves are an essential PPE for skin protection. For example: heat resistant gloves, cut-resistant gloves and chainsaw gloves.

Eye protection

- Example of eye injury is when solid particles such as wood chips, cement, metal slivers, or sand get into the eye.
- Smaller and larger particles in smoke, such as broken glass, also account for particulate matter causing eye injuries.
- Goggles provide better protection than safety glasses and are effective in preventing eye injury from a dusty environment, chemical splashes, and welding.

Hearing protection

- Industrial noise is an occupational hazard, though it is not visible to the eye.
- About 82% of occupational hearing loss cases occurred to workers in the manufacturing sector.
- Hearing protection must be used whenever an employee's noise exposure exceeds an 8-hour time-weighted average (TWA) sound level of 90 dBA. Noise levels above 115 dBA require control measures for any duration.
- PPE for hearing protection consists of earplugs and earmuffs.

Foot protection

- It may be due to exposure of foot to heavy objects such as barrels or tools that might roll onto or fall on employees' feet, sharp objects such as nails or spikes that might pierce ordinary shoes and molten metal that might splash on feet; it may be due to hot, wet or slippery surfaces.
- Safety shoes have impact-resistant toes and heat-resistant soles and may be electrically conductive for use in explosive atmosphere or nonconductive for protection from electrical hazards.

4.1.8 Safety Procedure

On completion of the session, the trainee will be able to explain:

- Safety Procedure
- Fire Safety
- Electrical Safety

Safety Policies

A health and safety policy is a written declaration made by an employer. It states the company's commitment for safeguarding the health and safety of the workers and also is an assurance to the public. It is a signed document made by the management related to the health and safety of the employees. A workplace requires a health and safety policy for the following reasons:

- To show complete commitment towards their health and safety of employees
- To prove to the employees that safety performance and work performance are in harmony with each other
- To give a clear statement of the company's objectives, principles, plans, ideas and procedures
- To increase buy-in through all divisions of the company
- To provide a definite outline of the accountability of the organization for the health and safety of the workers and also give a clear idea of the responsibility of the employer and the employees.
- To abide by the Occupational Health and Safety Act
- To define practices and processes to be adhered at the workplace to avoid injuries and diseases

Responsibilities towards Safety Policies

All the members in an organization have their own responsibilities to ensure workplace safety. There is a safety committee in an organization. All the workers and managers as well as the safety committee members need to carry out their responsibilities related to safety.

The following figure highlights the responsibilities towards safety policies:

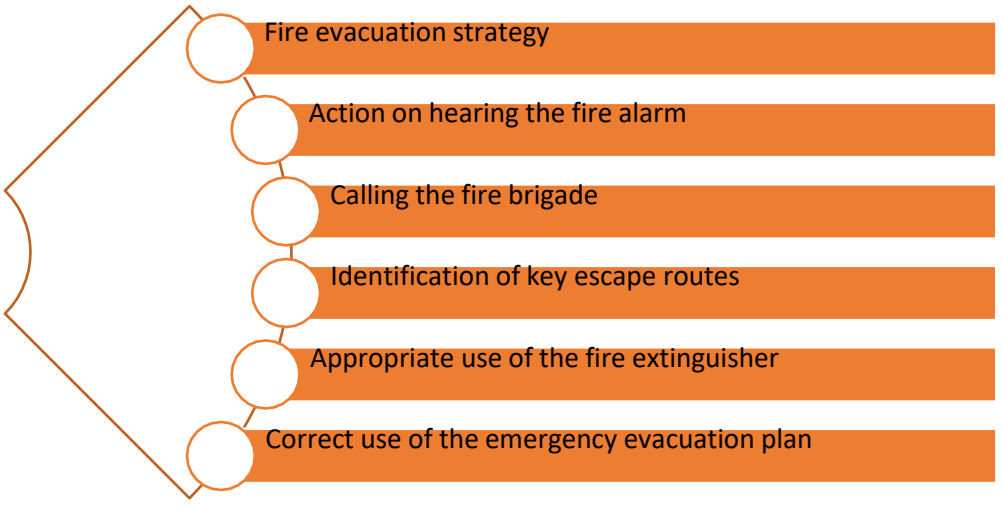
Safety Committee Responsibilities	• Detect unsafe conditions and work practices by inspecting the facility regularly • Participate actively in health and safety training programmes and evaluate the programme's effectiveness • Plan improvements to existing procedures, health and safety rules, and plan safety promotions/incentives • Assessing personal protective equipment (PPE) needs • Overseeing emergency response preparedness and tests • Performing job safety analysis and serving as a resource for questions on safety • Immediately investigate workplace accidents
Responsibilities of Managers	• Familiarize employees with the OHS program, ensuring its effective implementation in the plant and enforce all company safety rules consistently and fairly • Beware of all safety considerations on introduction of a new process/procedure, machine/material to the workplace and providing safety training to employees before assigning duties • Give maximum support to programmes and committees that promote health and safety • Review and complete all reports related to an accident/incident, when required, to ensure fulfilment of all requirements so that appropriate action is taken to prevent recurrence • See that all injuries, even minor ones, are treated immediately and referred to a medical facility, if necessary • Inspect the work area regularly to look out for unsafe conditions and work practices and ensuring that unsafe or harmful conditions found in the course of inspections or incident investigations are remedied without delay • Conduct risk assessments for potential hazards from ergonomic hazards, violence at the workplace or emergencies to minimizing risks. • Conduct a safety orientation for all new employees, as well as for existing employees who are learning a new role and including the risks associated with the role • Ensure that all employees are healthy at work
Responsibilities of Workers	• Work with care and attention at all times and wear protective equipment as needed or required • Operate equipment/machinery after receiving the proper instructions • Report minor/major injuries/symptoms to the manager to enable action towards prevention and take possible remedy action to ensure that no one gets hurt • Encourge co-workers to work safely and assist them to have a safe working environment by suggesting actions to improve the effectiveness of the programme on health and safety • Maintain equipment in good, safe working order and check the usage of guards and safety devices on equipment as per the standards • Adhere to all safety rules and regulations • Take necessary steps to improve health and attendance as every employee has an obligation to meet the attendance requirements of the job; When an employee shows extraordinarily long absences, the rest of the team can be placed in a compromising position and conditions could become unsafe

Fire Safety

It is essential to ensure safety from fire whether a professional is working onsite or offsite. To ensure fire safety, the panel installer should do the following:

- In case of fire, break the glass of the nearest manual call point and try to alert persons in the immediate area of danger.
- Dial the emergency phone number and inform other persons about the location of the fire and/or use the fire bell.
- Attempt to extinguish the fire using the nearest suitable fire fighting equipment, without exposing yourself to undue risk.
- If you are familiar with the plant machinery or equipment affected by fire, isolate it for containment and to avoid further spread of the fire.
- If the fire is from electrical power, do not use water until the main supply is switched off.
- Nobody is allowed to get water from hose reel and hydrants except to put off fire.
- Strictly obey "No Smoking" instructions.
- A fire drill is normally carried out every six months. Educate and expertise every person in fire fighting by nominating them in these drills.

A fire drill is a practice of the procedure of evacuating a building in case of an emergency. The following points should be kept in focus while conducting a fire drill:



After completion of the drill, one should:

- Record the total evacuation time.
- Silence the alarms.
- Bring the fire alarm system back to its normal operating condition.
- Re-evaluate and discuss concerns arising during the fire drill.
- Keep records and notes of the fire drill and update the evacuation checklist report.

Electrical Safety:

This involves ensuring the following:

The wiring is adequate.	The electrical equipment is appropriate for the environment, with the correct capacity and labeling.	The equipment is in good condition and not damaged before installation.	The current will break at the listed rating for the circuit breaker.
Electrical parts are not exposed.	The overhead power-lines are not within contact range of the work area.	The wires do not have poor insulation.	Electrical systems and tools are grounded or double-insulated.
Circuits are not overloaded.	Damaged power tools and equipment are removed from the site.	Appropriate PPE is used by the employees.	Appropriate tools are used by the employees.
Chemicals are labeled and used correctly.	The ladders do not conduct electricity.	The area is dry with no standing water.	The equipment is installed securely.

4.1.9 Safety Measures

On completion of the session, the trainee will be able to explain:

1. Safety measures before starting of work
2. Safety measures during work
3. Safety measures after completion of work

Safety procedures and measures are dependent on the type of work. There may be a need for electrical safety, fire safety or mechanical safety for a panel installer. The following figure lists the general measures an employee should be aware of to ensure safety:

Daily safety instructions

- Take safety measures to prevent accidents.
- Ensure zero accidents while at work.
- Avoid damaging components caused by negligence in electrostatic discharge (ESD) procedure.
- Ensure no loss for company due to safety negligence.
- Ensure proper maintainance of machine and work process for achieving quality output as per the company standards.

Before starting work

- Plan and discuss requirement of work to be done.
- Consider potential hazards and measures to be taken.
- Confirm permission to isolate (use a permit system if relevant).
- Isolate the electrical equipment or circuit.
- Place a "DANGER, DO NOT OPERATE" tag.
- Put up safety barriers when required.
- Use the correct earthing equipment.
- Cover and insulate a nearby live apparatus.
- Check test instruments and get authorization to do the work.

When working

- Use safety observers when required.
- Always wear PPE.
- Never rely on memory.
- Connect the earth and neutral conductors first.
- Check the isolation points before resuming work after a break.
- Check and clean the tools that are used regularly.
- Use non-conducting tape measures.

After completion of work

- Check if tools are left after work completion.
- Remove own earthing equipment.
- Notify all personnel involved that the equipment will be energized.
- Hand in the work permit (if relevant).
- Remove "DANGER, DO NOT OPERATE" tags.
- Switch off all machineries.
- Remove and store all PPE properly.

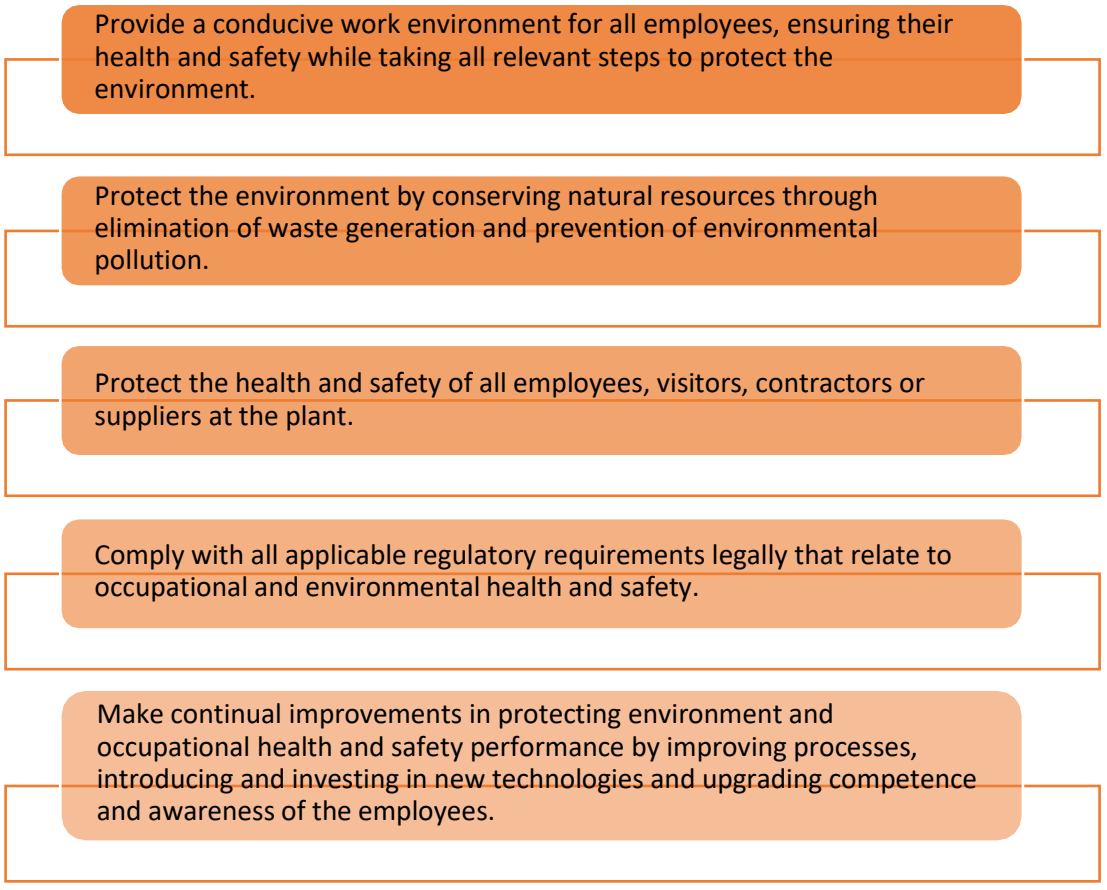
4.1.10 Organizational Safety Policies

On completion of the session, the trainee will be able to explain:

1. Environmental Health and Safety(EHS)
2. Management System

EHS Policy

The following figure highlights some important points from EHS policy guidelines:



EMS Policy

To minimize the risk of 'environmental impacts', some objectives and targets are set. The following points to the list of the primary objectives and goals set at ISO14001- certified plants.

- Minimization of wastes and enhancement of recycling rate
- Advancement of energy and resource conservation
- Adequate supervision of chemical substances
- Promotion of environmentally friendly products

The following table lists some other objectives and targets of EMS policy:

Aspect	Objectives	Targets
Use of paper	Reduction in use of paper	Reduction in use of paper by 25% within a year
Consumption of electricity	Reduction in the consumption of electricity	Reduction in the consumption of electricity by 20% within 1 year (based on current year consumption)
Use of cleaning material	Reduction in the use of hazardous cleaning material	Reduction in the usage of cleaning material by 25% within a year
Use of hazardous chemicals such as solder paste, epoxy potting and tin-lead solder	Increased use of environmental friendly alternative chemicals	Reduction in the usage of these chemicals by 5% within a year

H&S Policy

The following figure lists some of the objectives and key measures of health and safety policy:

Priority Actions	Measures/Key Performance Indicators
Make workplace free from injuries and illnesses	
• Improve workstation ergonomics • Reduce manual handling slips, trips and falls • Provide EHS training, safety audits and participation	• Number of incidents/accidents and near misses • First aid incidents • Number of days lost
Improve Occupational Health and Safety Assessment Series (OHSAS) knowledge throughout the organization	
• Provide EHS training, as per defined needs, of at least 6 hours to each employee • Improve OHSAS knowledge by employee participation	• Number of hours of training given to each employee in a year • Number of suggestions received from workers to improve workplace safety besides internal audit findings and safety audit findings

Health and Safety Objectives:

Priority actions	Measures / KPI(key performance indicator)
Make workplace free from injuries and illnesses	
1. Make workplace free from injuries and illnesses by: • Improving workstation ergonomics • Reducing manual handling • Reducing slips, trips and falls • EHS training, safety audits & participation	• Number of incidents/ accidents & near misses • First Aid incidents • No of days lost • Near misses
Improve OHSAS(Occupational Health and Safety Assessment Series) knowledge throughout the organization	
2. Provide EHS Training as per defined needs of at least 6 hour to each employee 3. Improve OHSAS knowledge by employee participation	• Number of hours training given to each employee in a year • Number of suggestion received from workers to improve work place safety besides internal audit finding and safety audits findings

Safety Committee Responsibilities:

Responsibilities of the committee shall include:

- Inspecting the facility at regular intervals to spot insecure conditions and unsafe work procedures.
- Participating earnestly in programs related to health and safety training and assessing the result of such programs.
- Planning enhancement of the existing health and safety norms, practices and regulations.
- Determining PPE requirements
- Supervising emergency response readiness and tests.
- Acting as a resource for answers to safety questions.
- Devising safety campaigns and incentives.
- Investigating promptly all workplace accidents and carrying out analysis of job safety.

EHS Responsibilities of Managers:

- Get acquainted with the OHS program and make certain that it is effectively implemented in the plant.
- Ensure awareness of all safety concerns when presenting a new method, process, gadget or material at workplace.
- Make provision for safety training of the employees prior to giving them duties. Ensure that the employees sign off during the training program.
- Implement all company safety rules and regulations consistently and justly.

- Give encouragement to programs and councils that work for the promotion of health and safety.
- Analyze all mishaps and the entire investigation reports of all the incidents/accidents to make certain that the documentation is complete and the required precaution has been taken to rule out recurrence.
- Ensure reporting of all important work related mishaps by filling up the Incident/ Accident Reporting Form # FMT-H&S-001-00 within 24 hours of the occurrence.
- Ensure that all injuries have been given prompt treatment and have been referred for medical care, if required.
- Examine the work place regularly to find out insecure conditions and unsafe work procedures.
- Make certain that if insecure and harmful conditions were detected during inspection or investigation process, they are corrected immediately.
- Carry out analysis of potential risks from violence in the work area.
- Plan a safety orientation program for new workers as well as the existing ones who are preparing themselves for a new role.
- Remove or reduce all conditions that endanger the employees by enforcing control measures, guiding and training the workers and assessing the effectiveness of the control measures.
- Make certain that all employees are physically fit and competent for the work they have been assigned. An employee must not be given a task where a disability, handicap or injury may pose a risk to own self or others.

EHS Responsibilities of Workers

- Refrain from deliberately putting oneself or others in danger.
- Take part in inspections and inquiries, whenever required.
- Perform jobs with utmost care and concentration
- Use protective gear whenever it is needed.
- Refrain from operating machines or tools in the absence of appropriate instructions.
- Ensure prompt reporting of all mishaps, injuries and illnesses to the manager for implementation of preventive measures
- Motivate the coworkers to do their duties cautiously.
- Report dangerous actions or situations to the manager and try to rectify the conditions so that no one gets injured.
- Ensure guards and safety gadgets on the equipment are utilized as per instructions.
- Keep the equipment in a sound and secure working condition.
- Follow all the safety norms and regulations.
- Ensure that if there is a mishap and one gets injured, the doctor's instructions must be followed and the management team's advice too should be heeded for a fast recovery.
- Adhere to the attendance specification of the job. If an employee is absent for a long duration, the rest of the team gets effected and unsafe conditions could arise. Hence, proper care of health is important to maintain the required attendance.

- Help in creating a secure work environment by suggesting measures that will facilitate the health and safety programs.

Housekeeping

Good housekeeping is an observable proof of management and their concerned for health and safety of an employee on a daily basis. A workplace well in order adds to the safe working environment and minimizes obstacles that are a threat to health and safety.

The following figure lists the purpose of housekeeping:

4.1.11 Communicational Skill

On completion of the session, the trainee will be able to explain:

- Effective communication at Workplace
- Skillful Learning
- Impact of Emotions

Introduction:

- The ability to effectively communicate with others is one of the most powerful tools for personal and/or professional success.
- Most people are challenged by the daily interactions with co-workers, family and friends.
- Emotion communication and conflict are present in all human interactions and affect each of us in different ways.
- Maximum number of problems at workplace are communication related.

- Effective communication helps employees influence others people.
- The capacity to communicate effectively is often an indicator of a person's capability and intelligence.

Past Experiences Shape the Communication Style:

- The cycle is perpetual. Your thoughts are influenced by your experiences. These thoughts shape your attitude. These attitudes act as a blueprint for fresh experiences that forms behavioral patterns.
- You should be aware of your personal style to be able to change your negative attitude into a positive one.
- This awareness will enable you to become personally responsible and accountable for all steps taken to change your behavior.

Acknowledgement:

- Listen carefully to the speaker and give your acknowledgement, even though you might disagree. Avoid expressing your view point at this juncture.
- Acknowledgement of the speaker's words and feelings does not imply that you agree with those viewpoints or acts.
- Your keen listening abilities and acknowledgement of the speaker's words assures the latter of being understood.

Reflecting Back:

- Before replying to the speaker, analyze and reflect on what you have heard.
- Pausing to reflect serves as encouragement and allows the speaker to explain the topic.
- The feedback determines how meaningful the exchanges between you and the speaker are going to be.
- You will be able give apt and precise feedbacks to a speaker's emotions and thoughts, if you are actively involved in the process of listening.
- You should try to put yourself in the speaker's place and try to experience what the latter is trying to convey. You must try to understand the speaker's feelings by using your own experience.

Communicating Long or Emotional Messages:

- Explain the motive of your conversation briefly.
- The listeners will pay more heed to your words if they realize the time and effort they be giving to the conversation.
- Make use of statements with "I" to communicate your emotions, expectations or incidents you have personally seen or heard.
- Refrain from involving yourself in verbal fights. If there is need for criticism, focus on the behavior and not the person.
- State the requirements or expectations in a positive tone.

Five Components of Your Message

Communication should comprise of five essential components as mentioned below:

- What is being seen- have seen earlier
- What is being heard- have heard earlier
- What is being felt-have felt regarding the issue
- What the positive effect will be after your request or expectation has been acted upon/received

Emotional Obstacles

Emotional obstacles to effective communication include:

- People may refrain from expressing their true feelings as they are hesitant to reveal themselves to others.
- People may evade expressing their thoughts because they are afraid of hurting the other person's feelings.
- The norms of the society, profession or culture may come in the way of the expression of certain feelings.
- People desire the support and acceptance of others. The fear of rejection might prohibit them from saying what they really mean.

Manage Your Emotions

- Identify your true feelings, whether you are annoyed, hurt or contrite.
- Describe your feelings in a simple and specific manner.
- Restrain yourself from taking an immediate action or a decision , based on your feelings. Avoid discussions or communication when angry or frustrated.
- Select a proper time and situation to communicate.
- Acknowledge that you are responsible for your feelings. While communicating use" I" statements. "I feel angry" should be said and not" You make me angry".

Managing a Conflict

- Try to be calm by regulating your breathing. Keep in mind that the present moment is only temporary and shall pass.
- Focus on what can be done to move ahead rather than thinking about the other person's errors.
- Sum up the main points of the other person's feelings to comprehend what they are trying to communicate.
- Obtain confirmation from the other person regarding their feelings.
- Never hesitate to accept and apologize for your mistakes.
- Concentrate on positive results and make all efforts which are required for the achievement of these targets.

4.1.12 Reporting Structure

On completion of the session, the trainee will be able to explain:

1. Organizational Structure

Importance of having a Structure

- All organizations need to organize what they do.
- A definite structure makes it easier to perceive the functions of the different parts of the business.
- A business can be structured in different ways.

Ways to Structure a Business

- According to the function: The business is organized according to what is being done by each department or section.
- According to the product or activity: The business is arranged as per the product or activity.
- According to the area: The business is organized as per the geographical or regional area.
- According to the customer: The business is structured based on the fact that different customer categories have different requirements.
- According to the process: The business is organized as per the stages that the products have to go through as they are being made.

Pros and Cons of Different Structures

- There are certain merits/demerits of the various types of business structures.
- These depend on the type, size and structure of the business.

Let us look at a functional structure:

Functional Structure

Advantages

- A major advantage is that there is specialization. Each department concentrates on its own activities.
- There is accountability in this type of structure. Each section is managed by a responsible person.
- There is clarity as everyone knows their own roles as well as that of the others.

Disadvantages

- Since the communication is closed, it could decrease the focus.
- The departments could become averse to changes.
- Coordination could become a lengthy process.
- The top and bottom tier of the structure has a big gap in between them.

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