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Participant Handbook

Sector
Telecom

Sub-Sector
Handset

Occupation
Communication Electronics

Reference ID: **TEL/Q2501, Version 4.0**

NSQF Level 4

Telecom Surface Mount Technology (SMT) Technician

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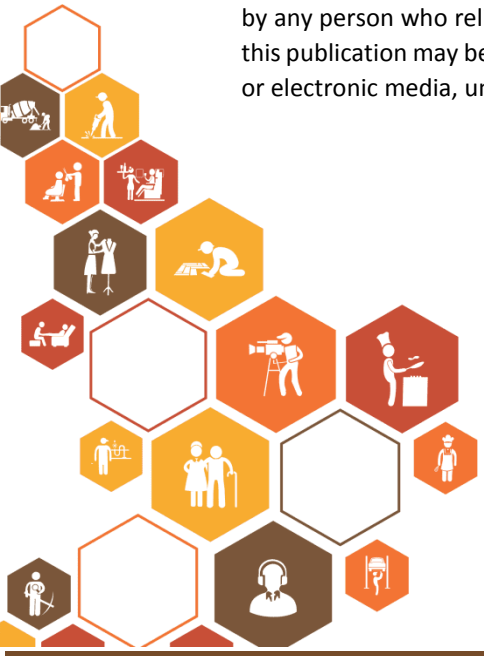

Skilling is building a better India. If we have to move India towards development then Skill Development should be our mission.

Shri Narendra Modi
Prime Minister of India


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The preparation of this Participant Handbook would not have been possible without the Telecom Industry's support. Industry feedback has been extremely encouraging from inception to conclusion and it is with their input that we have tried to bridge the skill gaps existing today in the Industry.

This Participant Handbook is dedicated to the aspiring youth who desire to achieve special skills which will be a lifelong asset for their future endeavours.

About this Book

In the last five years, the growth of the Indian telecommunications sector has outpaced the overall economic growth. This sector is poised for strong growth of about 15 percent in short term during 2017–22, driven by growth in organized retail, technological advancements, changing consumer preferences and government support. With over 1000 million subscribers, India is the second largest telecom market in the world.

The sector currently employs over 2.08 million employees and is slated to employ more than 4.16 million employees by 2022. This implies additional creation of ~2.1 million jobs in the nine-year period.

This Participant Handbook is designed to impart theoretical and practical skill training to students for becoming a Telecom Surface Mount Technology (SMT) Technician.

This Participant Handbook is based on Telecom Surface Mount Technology (SMT) Technician Qualification Pack (TEL/Q2501) & includes the following National Occupational Standards (NOSs):

1. Screen Printing of Telecom Boards (TEL/N2503)
2. Component Placement on Telecom Boards (TEL/N2504)
3. Reflow Soldering on Telecom Boards (TEL/N2505)
4. Cleaning and Inspection of Telecom Boards (TEL/N2502)
5. Organize work and resources as per health and safety standards (TEL/N9101)
6. Interact effectively with team members and customers(TEL/N9102)

The Key Learning Outcomes and the skills gained by the participant are defined in their respective units.

We hope that this Participant Handbook will provide a sound learning support to our young friends to build an attractive career in the telecom industry.

Symbols Used

Key Learning Outcomes

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1. Introduction to role and responsibilities of Telecom Surface Mount Technology (SMT) Technician

Unit 1.1 – Fundamentals of Electronics

Unit 1.2 – Basic Functionality of Common Electronic Components

Unit 1.3 – Introduction to Printed Circuit Boards (PCB)

Unit 1.4 – PCB Designing Concepts

Key Learning Outcomes

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

1. Identify the basic electrical quantities
2. List the factors affecting the resistance of an element
3. Define Ohm's law
4. Differentiate between series connection and parallel connection
5. List the types of electronic components
6. Identify the applications of diodes and transistors
7. Demonstrate the functions of different logic gates
8. Assess the applications of transmitters and receivers
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UNIT 1.1: Fundamentals of Electronics

Unit Objectives

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

1. Identify the basic electrical quantities
2. List the factors affecting the resistance of an element
3. Define Ohm's law
4. Differentiate between series connection and parallel connection

1.1.1 Charge

An electric charge is the property of matter where, in its atoms, the number of electrons is either more or less than the number of protons. Electrons bear a negative charge while the protons bear a positive charge. If the matter has more protons than electrons, it is positively charged and if the number of electrons exceeds the number of protons, it is negatively charged.

The electric charge is represented by Q and is measured in Coulomb (C).

1 C of charge = $1/ 1.6x10^{-19}$ or $6.24x10^{18}$ electrons.

1.1.2 Electric Current

Electric current can be defined as the flow of electric charge in the form of free electrons. The number of free electrons that passes a particular point of a circuit per second is the measure of the electric current in it. Hence, the amount of current in a circuit is defined by the flow of charge per unit second.

The current is measured in Amperes in International System of Units (SI) and is denoted with the symbol A. Constant current is denoted by the symbol I. The value of the current is 1 A when the electric charge flows at the rate of 1 coulomb per second, that is 6.24×10^{18} electrons passing a given point per second.

Mathematically, the relationship between electric current (I) and charge (Q) is defined as:

I (amperes) = Q (coulombs) / t (seconds)

Where, I denotes average current flowing; Q denotes total charge flowing across a fixed point and t denotes the time that is taken for passing the fixed point.

Conventionally, the current flows from the positive end to the negative end and in the direction of the movement of the positive charge. Electrons flow from the negative end to the positive end, in the opposite direction of the current flow. The direction of the positive current flow in a circuit is represented by an arrow.

1.1.3 Voltage or Potential Difference

Voltage or potential difference is the difference between the electric potential or charge of two points. Thus, the potential difference between two points is determined by the work done in joules to move charge of 1 C from one point to the other. Voltage is measured in volts (V) in SI system and is given as:

$$V \text{ (volts)} = W \text{ (joules)} / Q \text{ (coulombs)}$$

Where, V is the voltage in volts; W is the work done and Q is the total charge across a fixed point.

A constant voltage is referred as DC voltage and is sourced by a solar cell or a battery. The voltage varying sinusoidally with time is referred as an AC voltage and is sourced by an alternator or generator. DC voltage is denoted as VDC; for example, 12 VDC. AC voltage is denoted as VAC; for example, 240 VAC. The following images show batteries and a generator:

Fig. 1.1.1: Batteries (left) and a generator (right)

1.1.4 Resistance

Besides being influenced by the voltage that propels it around, the current in an electrical circuit also depends on the resistance of the components, wires and connections of the circuit. Resistance (R) refers to the ability of the circuit components to oppose the electron flow (flow of current) in the circuit, thereby necessitating the supply of a greater voltage to the circuit so that current can flow again. Resistance opposes the flow of current.

The amount of resistance that different circuit elements put up against the current flow varies. The circuit elements with low resistance are termed as 'good conductors', the ones with high resistance are termed as 'bad conductors' or 'insulators' and the rest are in between these two categories. The unit of resistance is Ohm. The resistance of any material which has a uniform cross-sectional area, A and length, l, can be represented in a mathematical form as:

$$R = \rho * l/A$$

where, ρ is the resistivity of the material in ohm-meters.

The following figure lists some factors affecting the resistance of an element:

Length of Material	• The resistance of a material is directly proportional to its length. • The longer the material the more resistance it has.
Cross-sectional Area	• The resistance of a material is indirectly proportional to its width. • The wider or thicker the material is the less resistance it has, allowing more free electrons to flow.
Type of Material	• The type of material affects the number of free electrons able to flow through it. • A material which is a conductor has less resistance while a material which is an insulator has more resistance.
Temperature	• The temperature of the material affects its resistance. • Some materials such as thermocouples and thermistors are designed to change their resistance with temperature.

Fig. 1.1.2: Some factors affecting the resistance of an element

The following diagram shows different resistor symbols:

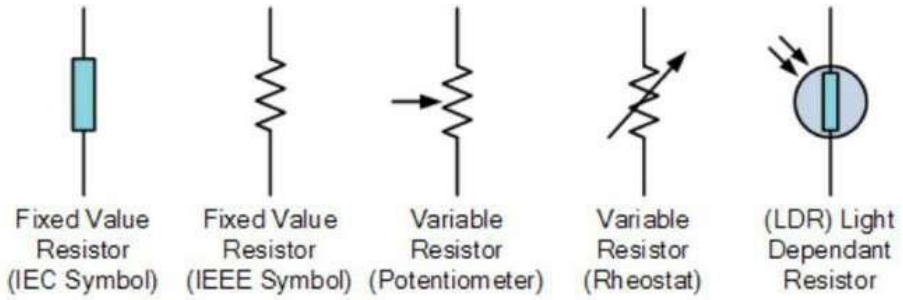


Fig. 1.1.3: Different resistor symbols

1.1.5 Ohm's Law

Ohm's law delineates the relationship that exists between the current, voltage and resistance of a circuit. The following image shows the concept of Ohm's law:

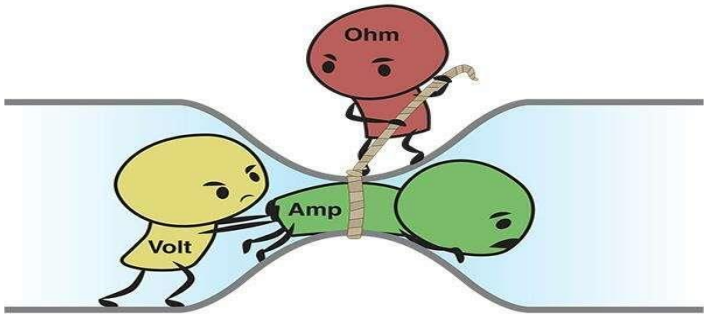


Fig. 1.1.4: Concept of Ohm's law

Ohm's law states that a voltage V, across a resistor R, is directly proportional to the current I flowing through the resistor. The following figure represents the mathematical expression of Ohm's law:

$$\text{Current (I)} = \frac{\text{Voltage (V)}}{\text{Resistance (R)}} \text{ in Amperes (A)}$$

Fig. 1.1.5: Mathematical expression of Ohm's law

When any two values among the V, I and R are known, the value for the third one can be calculated using Ohm's law.

1.1.6 Power

Electrical power is measured in Watt (W). 1 W of power is equal to the work done by 1 V of voltage in one second, in moving 1 C of charge through a circuit. As an ampere is equal to 1 C per second, hence, the power will be denoted as volts times amperes. It is shown as:

$$P = V \times I$$

A resistor may be used in any combination of current and voltage until its 'dissipating power rating' is exceeded. Power rating of a resistor, known as wattage, indicates the amount of heat the resistor can dissipate safely before getting damaged. If more heat is produced by a resistor than that it can dissipate, it will be overheated and damaged. The following figure shows the calculation of power:

$$\text{Power, (P)} = V \times I = I^2 \times R = \frac{V^2}{R} \text{ Watts}$$

Fig. 1.1.6: Calculation of power

1.1.7 Inductance

A magnetic field is built up around a length of wire when electric current flows through it. The relation between the direction of current flow and direction of the lines of force of the magnetic field can be understood by taking the example of a wooden screw being tightened into the conductor. The direction in which it would be tightened would represent the direction of current flow and the direction in which the head of the screw would be turned would represent the direction of the lines of force.

The magnetic flux of a single straight length of a wire can be increased manifold by forming a coil of N turns with it. Also, the value of the magnetic flux around the coil can be increased by increasing the magnitude of the current flowing through the coil's conductor.

However, when the strength of the magnetic flux increases, a secondary voltage known as the back electro-motive force (emf) is induced in the coil. In a coil of wire, when there is a change in the current flowing through the coil, a self-induced voltage is developed across the coil. The polarity of the self-induced voltage results in a secondary current within the coil, which generates another magnetic flux. This flux resists any alterations to the original flux.

This means the moment there is a rise (or fall) in the value of the main current, an opposing effect will attempt to control this change. However, since the coil of wire is long, there will be no instantaneous change in the current flowing through the coil. The current will take some time to change because of the resistance of the wire and the self-induced impacts of the wire coil.

The self-inductance of a coil, denoted by L, capacitates the coil to oppose any changes in the current that is flowing through it. The unit of self-inductance value (inductance value) of an inductor is Henries (H). Milli-henry (mh) and micro-henry (µH), which are smaller units, are used more than Henry. For a given source voltage, the more the inductance value of a coil, the slower will be the rate of change of the current.

The following figure shows the mathematical representation of inductance of a coil which has a uniform cross-sectional area denoted by A, length denoted by l and coil turns denoted by N:

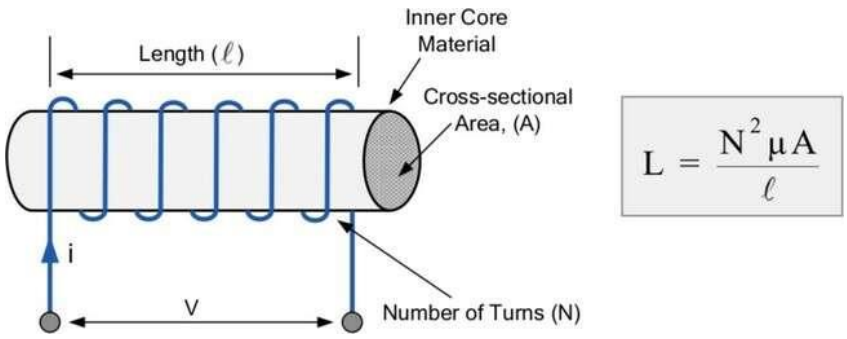


Fig. 1.1.7: Mathematical form of inductance of a coil

In the above figure, N represents the number of coil turns, µ represents the permeability of the central core, A represents the area in m2 and l represents the core's mean length in meters.

An inductor, also called a choke, is a device which stores energy within itself as a magnetic field. The inductor is a coil of wire that is designed in such a way that it can benefit from the relationship given in the above formula. It induces a magnetic field within the core or within itself because of the current passing through the coil. This could induce a magnetic field that is stronger than that produced by an ordinary coil of wire. An Inductor can be of both fixed or variable type.

Inductors are constructed with a wire wrapped tightly around a solid core. This is done to concentrate their magnetic flux. The core can be either a continuous loop or a ring or a straight cylindrical rod.

The magnetic properties of the central core of a coil has a direct influence on the core's inductance. The core is generally made up of powdered iron materials and ferrite to raise the flux around the coil and thereby, increase the inductance.

The following figure shows different inductor symbols:

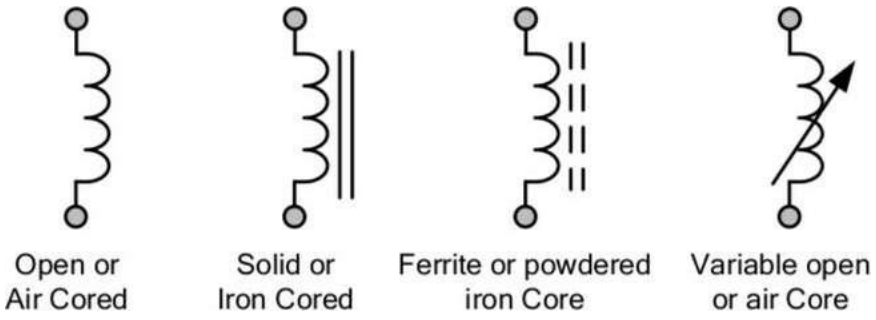


Fig. 1.1.8: Different inductor symbols

1.1.8 Capacitance

A capacitor is a device that can store energy in the form of electrical charge. It thereby generates a potential difference across its multiple conductive plates. These plates can be of metal or foil and are parallel to each other. There is no connection between the plates. They are electrically separated either by air or some insulating material. Paper, ceramic, mica and plastic are examples of the insulating material used for this purpose. The plates are commonly known as capacitor's dielectric.

The unit of capacitance is Farad (F). The different types of capacitors are named according to the dielectric materials used in their construction. This is because the performance of a capacitor depends on the kind of material used for its dielectric.

The different kinds of capacitors include disc and tubular ceramics. These can be made from titanium oxide or aluminium oxide, silvered mica or metallised film. These films are made by using strips of oiled or waxed paper and aluminium foil or with plastic dielectrics like mylar, polyester, polyethylene, polycarbonate and polypropylene.

The types of capacitors also include large electrolytic capacitors in the form of polarised or non-polarised tantalum electrolytic capacitors and aluminium electrolytic capacitors. The following figure shows different capacitor symbols:

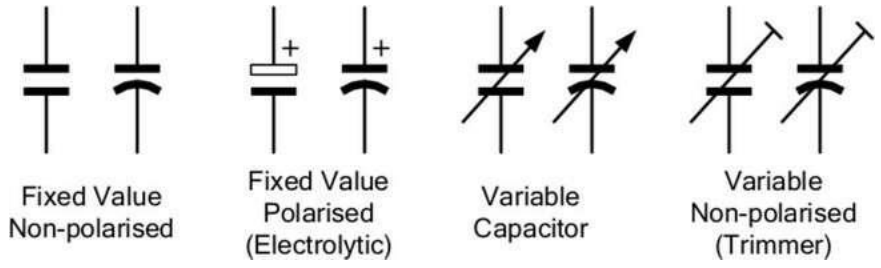


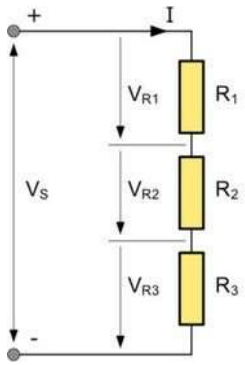
Fig. 1.1.9: Different capacitor symbols

1.1.9 Series Connection

When the resistors are connected together in a single line, a series connection is formed. A common current flow through all the resistors connected in series as there is only one path for the current to flow. In a series connection:

IR1 = IR2 = IR3 = IR4

The following figure shows a series connection and the formulae for calculation of different parameters:



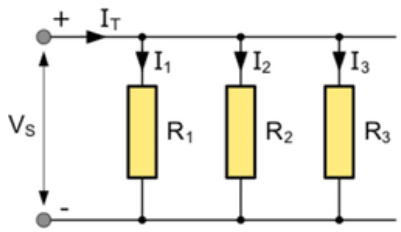
$$R_T = R_1 + R_2 + R_3 + \dots$$
$$V_S = V_{R1} + V_{R2} + V_{R3} + \dots$$
$$I = \frac{V_S}{R_T} = \frac{V_{R1}}{R_1} = \frac{V_{R2}}{R_2} = \frac{V_{R3}}{R_3}$$

Fig. 1.1.10: A series connection and formulae for different parameters calculation

1.1.10 Parallel Connection

A parallel connection is formed when the terminals of the resistors are connected respectively to each terminal of other resistors. Unlike a series connection, in a parallel connection the current can flow through multiple paths.

The current flowing through the parallel circuit is not same at all points, since there is more than one path for the current to flow through. However, the voltage drop across all resistors connected in parallel is same. There is a common voltage across all elements in parallel connection in a circuit. The following figure shows a parallel connection and the formulae for calculation of different parameters:



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$
$$I_T = I_1 + I_2 + I_3 + \dots$$
$$V_S = I_{R1} = I_{R2} = I_{R3} = \dots$$

Fig. 1.1.11: A parallel connection and formulae for different parameters calculation

Notes

UNIT 1.2: Basic Functionality of Common Electronic Components

Unit Objectives

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

1. List the types of electronic components
2. Identify the applications of diodes and transistors
3. Demonstrate the functions of different logic gates
4. Assess the applications of transmitters and receivers
5. Distinguish between different types of switches
6. Identify different power supplies
7. Classify different types of amplifiers
8. List the applications of multiplexers and demultiplexers

1.2.1 Types of Electronic Components

Basically, there are two types of electronic components; active components and passive components.

Active Components

Active components refer to those components which require external power supply to operate them such as diode, transistor, integrated circuits, mosfets and so on.

Passive Components

As their name suggests, passive components do not require any electrical power to operate, unlike the active devices that need to be powered to make them work.

Passive devices do not offer amplification, gain or directionality to a circuit. But they provide attenuation to the circuit as they have a gain less than unity. Hence, the passive devices cannot generate, amplify or oscillate an electrical signal.

Passive devices can be used individually. They are used to control complex circuits or signals by getting connected together in series or in parallel combination. They are also used for generating a phase shift to signal or providing some form of feedback. But, since these devices have no power gain, they cannot multiply a signal by more than one.

Passive devices consume power in a circuit. They act like attenuators, whereas the active devices provide power to a circuit.

Passive devices are bi-directional components. Thus, in a circuit, they can be connected either way if they don't have a polarity marking; for example, electrolytic capacitors. The flow of the current from the positive to negative terminal determines the polarity of the voltage across the passive devices.

Some basic passive elements are resistor, capacitor and inductor.

1.2.2 Diode

A diode is an electrical semiconductor device. It works as a one-way switch to permit the current to flow through it in one direction only. A diode shows an exponential I-V relationship and hence, it does not have a linear relationship with the applied voltage. Therefore, its operation cannot be explained using equations such as Ohm's law. The following figure shows the I-V characteristics of a diode:

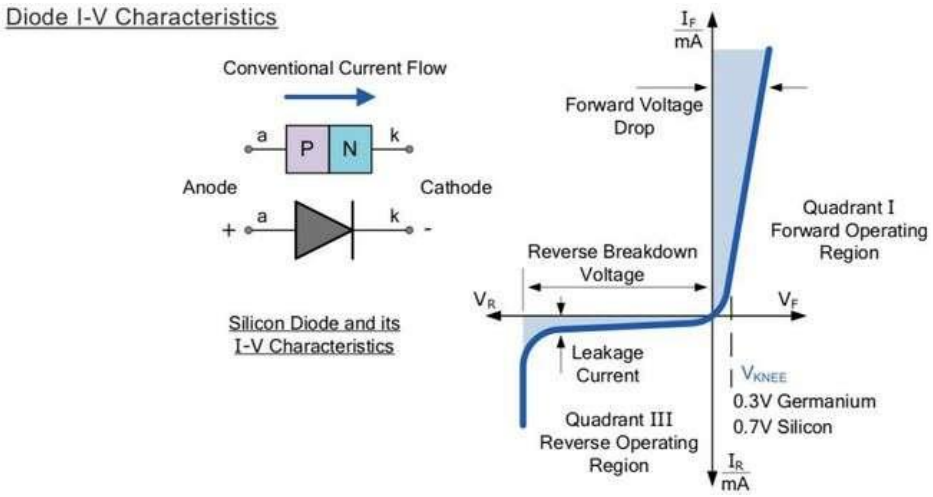


Fig. 1.2.1: I-V characteristics of a diode

The arrow in the above figure points in the direction in which current flows. Anode (A) and cathode (K) are the two terminals of the diode in which the cathode is the negative end and can be identified by the band marked on it.

A diode can be either 'forward biased' or 'reversed biased' and can be explained as follows:

Forward biased	The anode terminal of the diode is more positive than the cathode terminal; minimum 0.7 volts in case of a silicon device.
	It permits the current to flow through the device.
Reversed biased	The anode terminal of the diode is more negative than the cathode.
	It resists the flow of the current till its reverse breakdown voltage is reached.
	The diode becomes unstable at this point.

Fig. 1.2.2: Forward biased or reversed biased condition of diode

Diodes are made of semiconductor materials which include silicon and germanium. Unlike in silicon diodes, the conduction in germanium diodes occurs if the forward biasing voltage is 0.2 volts or more. Diodes can be classified as follows:

- **Small signal diodes:** Utilised in multiple low voltage applications
- **Power diodes:** Utilised in mains powered circuits and in rectifying

Since diodes are devices in which current flows in one direction only, they cannot be haphazardly connected in series.

The following figure shows the combination of diodes in series connection:

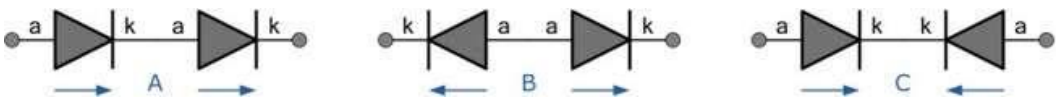


Fig. 1.2.3: Combination of diodes in series connection

In the above combination, only circuit A will conduct current.

Applications of Diode

Diodes can be used in many ways. They can work as a half wave rectifier, a full wave rectifier, a switch and so on.

Diode as a Switch

In case of forward bias, if the voltage of the diode exceeds the threshold level, generally 0.6V, then the diode performs as a short circuit and permits the current to pass. In case of reverse bias, that is if the polarity of voltage is changed, the diode performs as an open circuit and does not permit the current to flow. The following figure shows a diode as a switch:

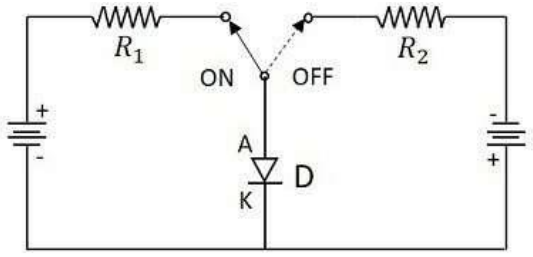


Fig. 1.2.4: A diode as a switch

Diode as a Half Wave Rectifier

The following figure shows a diode as a half wave rectifier:

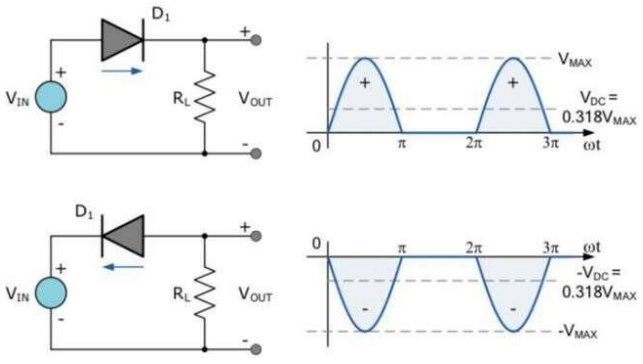


Fig. 1.2.5: A diode as half wave rectifier

The following figure explains the working of a diode as a half-wave rectifier (from above figure):

During the positive half cycle of the input supply (sinusoidal wave):	During the negative half cycle of the input supply (sinusoidal wave):
• Anode is made positive with respect to cathode so the diode gets forward biased. These results in flow of a current to the load. • Since the load is resistive, the voltage across the load resistor will be same as the supply voltage; that means, the input sinusoidal voltage will appear at the load. • The load current flow is proportional to the voltage applied.	• Anode is made negative with respect to cathode so the diode gets reverse-biased. • No current flows to the load. The circuit becomes open circuit and no voltage appears across the load.

Fig. 1.2.6: Working of diode as a half wave rectifier

The polarity of the current at the load is identical to the polarity of the voltage of the load. The output voltage is hence a periodic current, that is, pulsating DC. A capacitor is used in the rectification circuit. It is connected across the load so that a stable, continuous DC current devoid of ripples is produced.

Diode as a Full Wave Rectifier

The following figure shows a diode as a full wave rectifier:

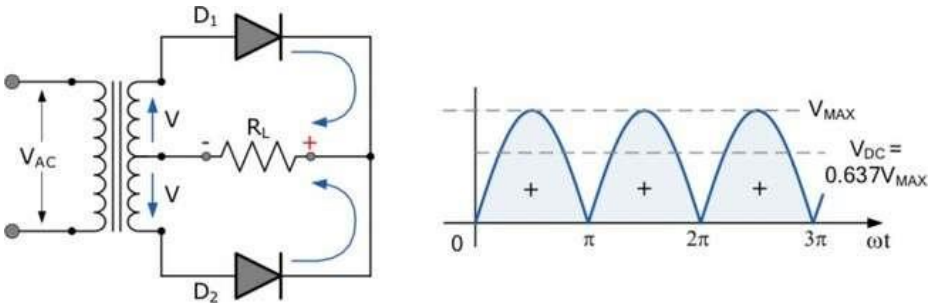


Fig. 1.2.7: Working of diode as a full wave rectifier

Diode as a Full Wave Bridge Rectifier

The following figure shows a diode as a full wave bridge rectifier:

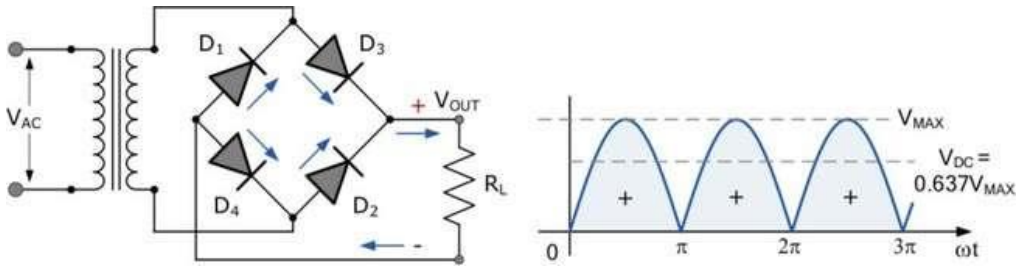


Fig. 1.2.8: Working of diode as a full wave bridge rectifier

Zener Diode

A zener diode is a specialised diode that can be used in place of a semiconductor junction diode. The latter is used to block current flow in reverse direction. At times, when the voltage in this type of diode exceeds a limit, the PN-junction of the diode breaks down and it gets damaged. The current begins to flow in the circuit at this breakdown voltage which is also called peak reverse voltage. In such cases a zener diode can be used instead. Th following figure shows the characteristics of Zener diode:

It is designed to operate in the reverse biased mode in such a way that at a certain breakdown voltage point, the reverse voltage causes the diode to conduct in a controlled way, thereby allowing a reverse current to flow through a series limiting resistor (Rz). This breakdown voltage is called the zener voltage (Vz).

The breakdown voltage point of a zener diode, Vz, is determined by the doping technique used during its manufacture. Zener breakdown voltages range from 2.7V to about 200V.

The voltage, Vz, across the zener diode remains reasonably constant over a wide range of reverse currents passing through the diode.

Fig. 1.2.9: Characteristics of Zener diode

The following figure shows the working of a zener diode:

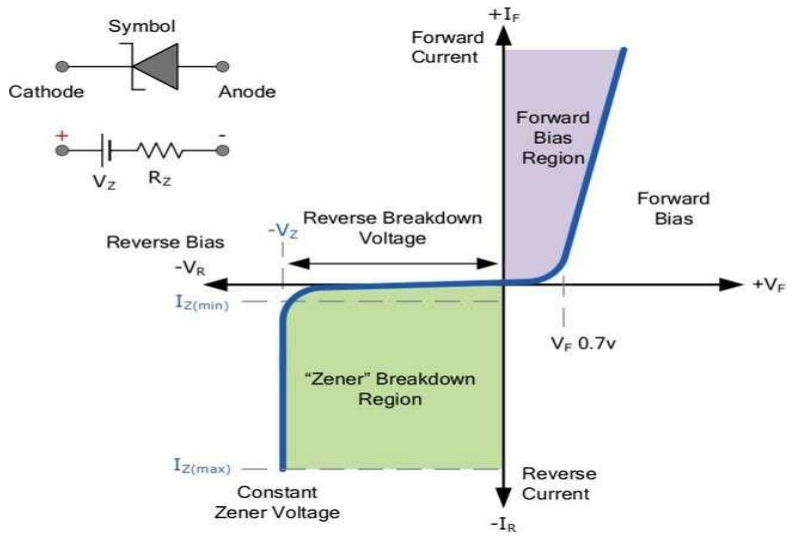


Fig. 1.2.10: Working of zener diode

In the above figure, a zener diode is shown with its reverse bias characteristics. A region can be observed where nearly constant negative voltage has been depicted. The region is unaffected by the magnitude of the current flowing across it. The changes in the magnitude of the load current does not affect the voltage of this region.

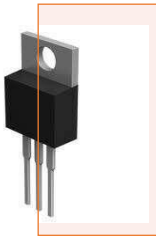
This special characteristic of a zener diode to remain in control at all times can be employed to keep a voltage source stabilised against the variations in the load or supply magnitude.

1.2.3 Transistor

A transistor is an electronic semiconductor device. It is made by including a semiconductor layer in a PN-junction diode. Whenever there a minute change in the current flowing in one lead, the transistor functions as a conductor or an insulator. It produces a considerable change in the current, voltage and power with its other two leads. The two fundamental functions of a transistor within an electrical circuit are as follows:

- Amplification (in analog circuits)
- Switching (in digital circuits)

The following figure shows the basic construction of a bipolar transistor:



A bipolar transistor consists of two PN-junctions producing three connecting terminals, which are:

- Emitter (E)
- Base (B) and
- Collector

Fig. 1.2.11: Basic construction of a bipolar transistor

Bipolar transistors are used as current regulating devices. They act like current-controlled switches by controlling the amount of current across them in proportion to the amount of biasing voltage employed to their base terminal. There are basically two types of transistors; NPN and PNP. Their operations are based on the same principle but the difference lies in their biasing as well as the polarity of the power supply applied to them. The following figure shows the symbols and circuit diagram of NPN and PNP transistors:

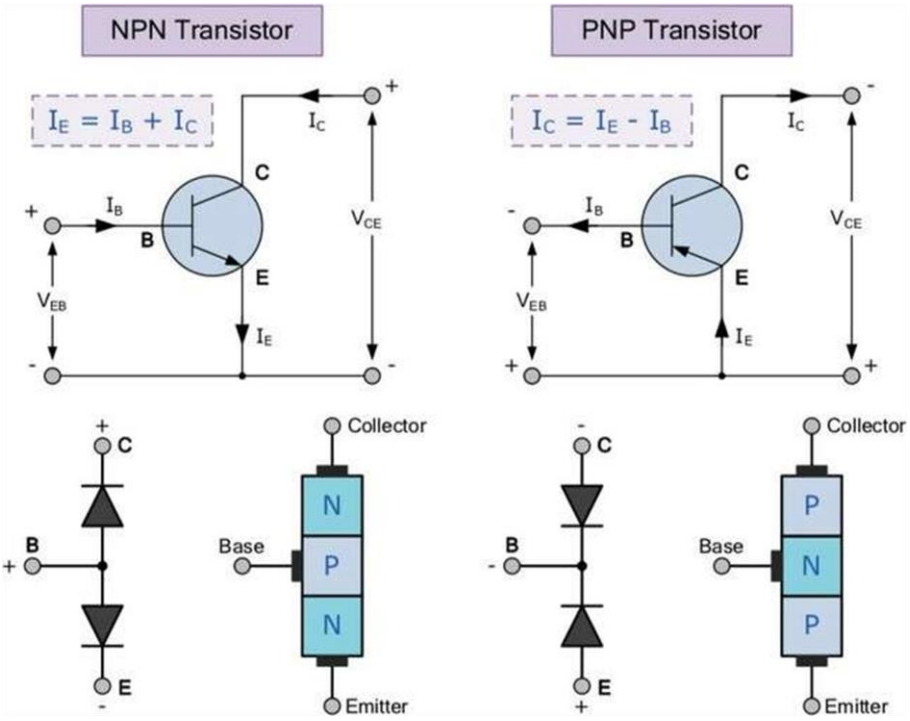


Fig. 1.2.12: Symbols and circuit diagram of NPN and PNP transistors

The following figure shows the interpretation of the circuit diagrams of two type transistors:

The arrows in the circuit in the above diagram represent the direction of the conventional current flow between the base and the emitter terminal.

For both transistor types, the direction of the arrow points from positive P-type region to negative N-type region, which is same as for a standard diode symbol.

Fig. 1.2.13: Interpretation of the circuit diagrams of two type transistors

Bipolar transistors can operate within three different regions. The following figure lists the three regions:

Active Region

Saturation Region

- Transistor is 'Fully-ON', operating as a switch and Ic = I (saturation).

Cut-off Region

- Transistor operates as an amplifier and $I_c = \beta.I_b$.
- It is 'Fully-OFF', operating as a switch and Ic = 0.

Fig. 1.2.14: Three regions of a bipolar transistor

Transistor as an Amplifier

The following figure shows working of a transistor as an amplifier:

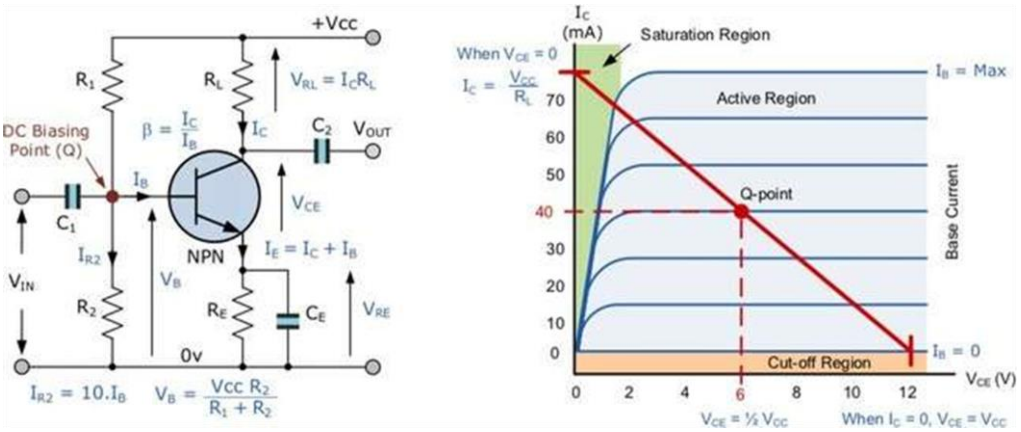


Fig. 1.2.15: Working of a transistor as an amplifier

In the above figure, a change of 0.1 V in the input voltage produces a change of 1 mA in the emitter current. This emitter current then produces a change of 1 mA in the collector current.

If a load resistance of 5 kΩ is placed at collector, it will produce a voltage of 5 V (calculated as 5 kΩ × 1 mA). Therefore, a change of 0.1 V in input produces a change of 5v in output, amplifying the voltage level of the signal.

The following figure explains the current gain and voltage gain:

Current Gain

- The gain in terms of current when changes in input and output currents are observed, is called as Current gain.
- By definition, it is the ratio of the change in collector current (ΔIC) to the change in base current (ΔIB).

  Current gain, $\beta = \Delta IC / \Delta IB$
- The value of β ranges from 20 to 500. The current gain indicates that input current becomes β times in the collector current.

Voltage Gain

- The gain in terms of voltage when changes in input and output currents are observed, is called as Voltage gain.
- By definition, it is the ratio of change in output voltage (ΔVCE) to the change in input voltage (ΔVBE).

  Voltage gain, $AV = \Delta VCE / \Delta VBE = \frac{\text{Change in output current} \times \text{effective load}}{\text{Change in input current} \times \text{input resistance}}$

Fig. 1.2.16: Current gain and voltage gain

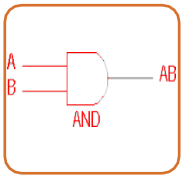
1.2.4 Logic Gates

Logic gates are electronic circuits that are used to process signals which represent true or false. Normally, the positive supply voltage (typically +5 V) is represented true and 0 V is represented as false. The following figure lists the terms related to logic states:

Logic States	
True	False
1	0
High	Low
On	Off
+5V	0V

Fig. 1.2.17: Terms related to logic states

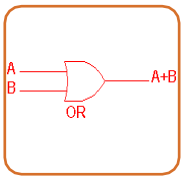
The following figure lists the basic logic gates, their symbols and truth tables:



AND Gate

The AND gate generates a high output (1) only if all its inputs are high. The AND operation is represented by a dot (.); for example, A.B. Sometimes, the dot is omitted and AND operation is represented as AB.

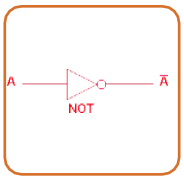
2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1



OR Gate

The OR gate generates a high output (1) if at least one input is high. A plus (+) is used to represent the OR operation.

2 Input OR gate		
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1



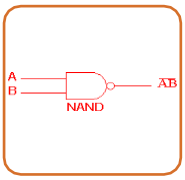
NOT gate

The NOT gate, also known as an inverter, produces an inverted version of the input at its output. If the input variable is A, the inverted output is known as NOT A, shown as A', or A with a bar over the top.

NOT gate	
A	$\overline{A}$
0	1
1	0

Fig. 1.2.18: Basic logic gates, their symbols and truth tables

The following figure lists the universal gates, their symbols and truth tables:

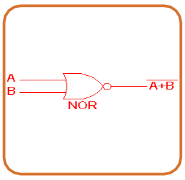


NAND Gate

This is a combination of an AND gate and a NOT gate. NAND gates produce high outputs if any of the inputs is low.

It is represented by the symbol of an AND gate with a small circle at the output representing inversion.

2 Input NAND gate		
A	B	$\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0



NOR Gate

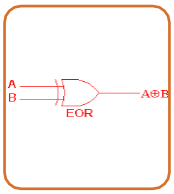
The NOT-OR gate is a combination of an OR gate and a NOT gate. NOR gates produce low outputs if any of the inputs is high.

It is represented by the symbol of an OR gate with a small circle at the output representing inversion.

2 Input NOR gate		
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

Fig. 1.2.19: Universal logic gates, their symbols and truth tables

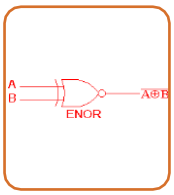
The following figure lists the combinational gates, their symbols and truth tables:



X-OR Gate

The 'Exclusive-OR' gate produces a high output when either of its two inputs, but not both, are high. The X-OR operation is represented as an encircled plus sign (⊕).

2 Input EXOR gate		
A	B	A⊕B
0	0	0
0	1	1
1	0	1
1	1	0



X-NOR Gate

The 'Exclusive-NOR' gate circuit does the opposite to the X-OR gate. It generates a low output when either of its two inputs, but not both, are high. It is represented as an X-OR gate with a small circle on the output representing inversion.

2 Input EXNOR gate		
A	B	$\overline{A \oplus B}$
0	0	1
0	1	0
1	0	0
1	1	1

Fig. 1.2.20: Combinational logic gates, their symbols and truth tables

1.2.5 Transmitter

A Transmitter is defined as a combination of one or multiple electronic circuits or devices which converts the source information, also called as baseband signal, to a form suitable for transmission. Transmitters are used in the system where the sender encodes the information. AM radio transmitters and mobile phones are some of the examples. The following figure lists some characteristics of transmitters:

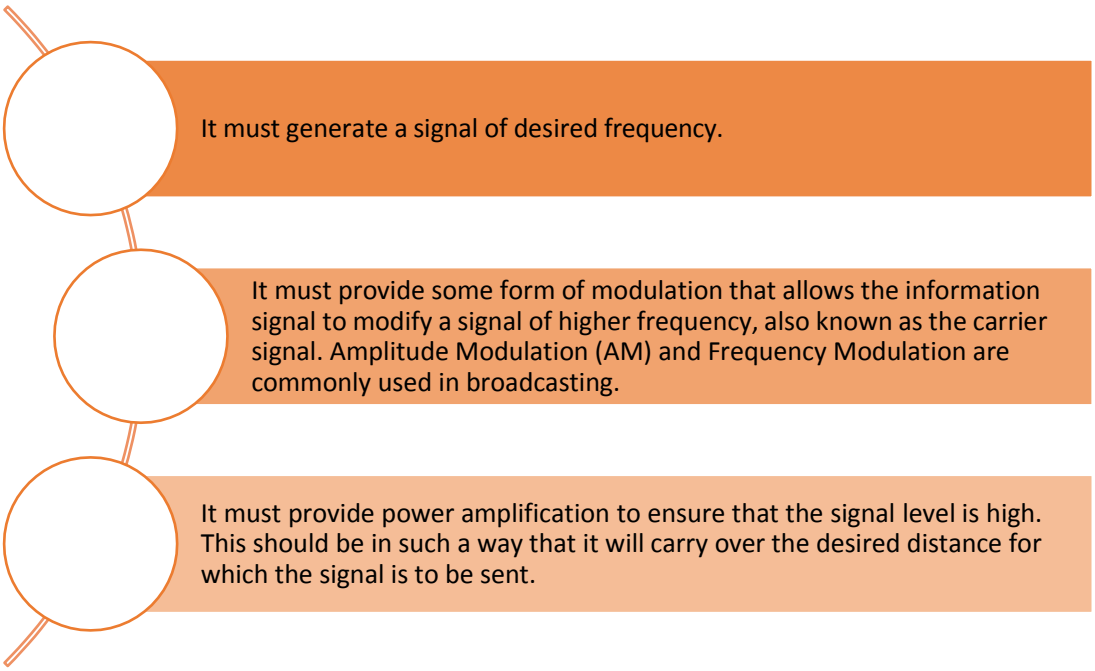


Fig. 1.2.21: Some characteristics of transmitters

1.2.6 Receiver

A receiver is a collection of various electronic circuits and devices which accepts the signals transmitted from the transmission medium and then converts them back to their original form understandable by humans. Television is a good example of a receiver. The following figure lists the primary requirements for a communication receiver:

Selectivity

- It is the ability of a receiver to select a signal of a desired frequency while rejecting those on closely adjacent frequencies.
- With good selectivity, the receiver can select the desired signal and eliminate all other RF signals.
- Tuned circuits or LC circuits are used to obtain selectivity.

Sensitivity

- It is the ability of a receiver to pick up weak signals.
- Sensitivity is directly related to receiver's gain. Gain is the factor by which an input signal is multiplied to produce the output.
- This gain can be increased by having a series of amplifications.
- Better sensitivity is attained with higher gain.

Fig. 1.2.22: Primary requirements for a communication receiver

The following figure shows an overall communication system:

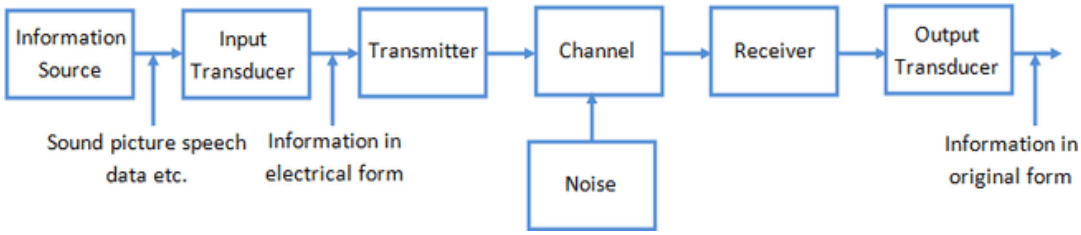


Fig. 1.2.23: An overall communication system

1.2.7 Switches

A switch can automatically or manually connect or break an electrical circuit. It mainly works with an ON (open) and OFF (closed) mechanism. The following figure lists the basic types of switches:

Single Pole Single Throw (SPST)	Single Pole Double Throw (SPDT)	Double Pole Single Throw (DPST)	Double Pole Double Throw (DPDT)

Fig. 1.2.24: Basic types of switches

SPST Switch

An SPST, also known as toggle switch, is a basic on/off switch. It just breaks or connects the connection between two terminals. It is used for switching the power supply to a circuit. The following figure shows a simple SPST switch:

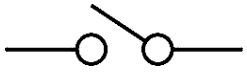
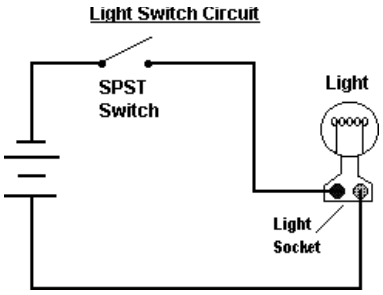


Fig. 1.2.25: A simple SPST switch

The following figure shows an SPST circuit diagram and its working:



This switch has two contacts; one is input and the other, output.

In the circuit, the SPST switch controls the wire (pole) and makes a connection (throw).

When the switch is on (in closed state), current flows across the terminals allowing the bulb to glow.

When the switch is off (in open state), no current flows in the circuit.

Fig. 1.2.26: SPST circuit diagram and its working

SPDT Switch

It is a three-terminal switch, with one input terminal that is common to one or both of the two output terminals.

To use an SPDT as an SPST switch, COM terminal needs to be used instead of other terminals. For example, COM with A or COM with B is used. The following figure shows an SPDT switch:

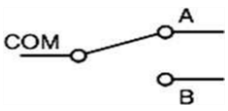
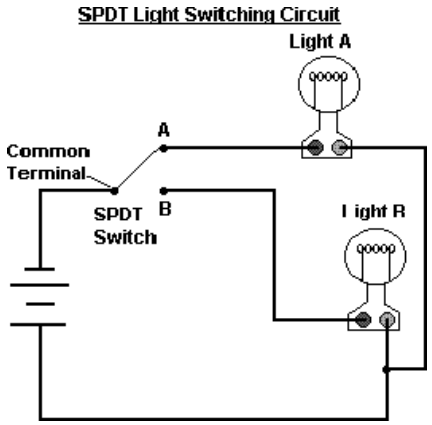


Fig. 1.2.27: SPDT switch

The following figure shows an SPDT circuit diagram and its explanation:



The above circuit demonstrates what happens when the SPDT switch is moved back and forth.

These switches are used in a three-way circuit, where it is required to switch on/off a light from two locations; for example, from the bottom as well as top of a stairway.

When switch A is closed only light A will be in ON position and the light B will in OFF position. Only light B will be in ON position, when the switch B is closed.

Here, two circuits or paths can be controlled via one way or one source.

Fig. 1.2.28: SPDT circuit diagram and its explanation

DPST Switch

The double pole in a DPDT switch means that it has two identical switches controlled by a single toggle or lever. The following figure shows a DPST switch and its characteristics:

DPST switch has four terminals with two for inputs and two for outputs.

A DPST switch is used to control a 240-volt appliance, where it is essential to switch both supply lines, keeping the neutral wire permanently connected.

When this switch is in ON position, current flows through two circuits and when it is in OFF position, the flow is interrupted.

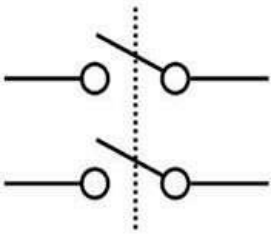


Fig. 1.2.29: DPST switch

DPDT Switch

A DPDT switch is equivalent to two SPDT switches operated by the same actuator. Two separate circuits are controlled by connecting each of the two inputs to one of the two outputs. At a time, only two loads can be in ON position. The number of ways each of the two contacts can be contacted depends on the position of the switch. The following figure shows a DPDT switch:

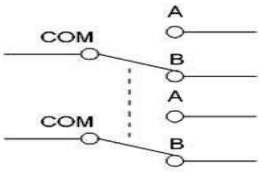


Fig. 1.2.30: DPDT switch

This can be used in an application requiring an open and closed wiring system.

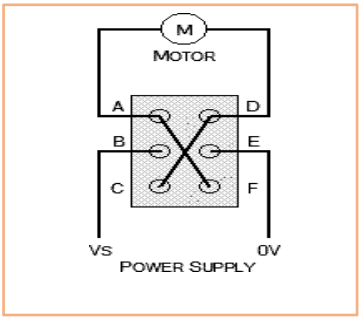
The following figure shows an example of such application:

DPDT switch is used in railroad modeling that makes use of small scaled bridges, trains and railways as well as cars.

The closed state allows the system to be continuously in ON position while the open state allows the other piece to be activated or turned into ON position through the relay.

Fig. 1.2.31: Example of an application requiring an open and closed wiring system

The following figure explains the working of a DPDT circuit:



In the circuit, connections A, B and C form one pole of the switch and connections D, E and F form the other pole. Connections B and E are common in each of the poles.

If the positive power supply (Vs) enters at connection B and the switch is set to the top most position, connection A becomes positive and the motor will rotate in one direction.

If the switch is set to the lower most position, the power supply is reversed, connection D becomes positive and the motor will rotate in the opposite direction.

In the centre position, the power supply is not connected to the motor and it does not rotate.

Fig. 1.2.32: Working of a DPDT circuit

These circuits are used in motor controllers.

1.2.8 Power Supply

A power supply supplies electric power to electrical loads by converting the current from a source to the correct voltage, current and frequency. There are two types of power supplies: AC and DC power supply. The following figure lists the specifications of various electrical devices to use AC power or DC power:

	OUTPUT = DC	OUTPUT = AC
INPUT = AC	• Wall wart • Bench power supplies • Battery charger	• Isolation transformer • Variable AC supply • Frequency changer
INPUT = DC	• DC-DC converter	• Inverter • Generator • UPS

Fig. 1.2.33: Specifications of various electrical devices to use AC power or DC power

Variable AC Power Supply

The following figure lists the characteristics of variable AC power supply:

- AC voltages are produced by using a transformer. It may have multiple windings and allows the switches to select different voltage levels.
- A variable transformer, also known as an adjustable autotransformer, may be used to vary the voltages continuously.
- Some variable AC supplies include meters that allows the monitoring of the voltage, power and/or current.

Fig. 1.2.34: Characteristics of variable AC power supply

Unregulated Linear Power Supply

The following figure lists the components of unregulated linear power supply:

Input Transformer

- The input transformer is used to convert the incoming line voltage down to the required level of the power supply.
- It also isolates the output circuit from the line supply. Here a step-down transformer is being used.

Rectifier

- The rectifier used to convert the incoming signal from an AC format into raw DC.

Filter Capacitor

- The pulsated DC from the rectifier is fed to the smoothing capacitor.
- It will remove the unwanted ripples in the pulsated DC.

Bleeder Resistor

- Bleeder Resistor is also known as a power supply drain resistor.
- It is connected across the filter capacitors to drain their stored charge so that the power system supply does not become dangerous.

Fig. 1.2.35: Components of unregulated linear power supply

This type is very simple and the most reliable source when low power is required. It is the least costly power source but the output voltage varies with the load current and input voltage. It is one of its disadvantages. Also, the ripple is not acceptable for electronic applications. If the filter capacitor is replaced by a resonance circuit (inductor-capacitor or LC), the ripple can be reduced, but it increases the cost. The following figure shows the circuit diagram of an unregulated linear power supply:

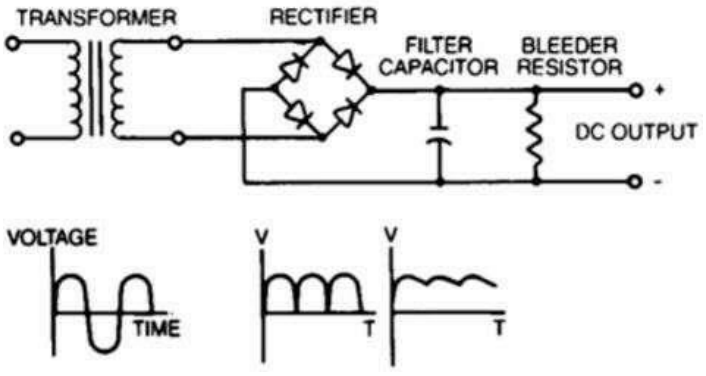


Fig. 1.2.36: A circuit diagram of an unregulated linear power supply

Regulated Linear Power Supply

Regulated linear power supplies include three-terminal regulators in place of the bleeder resistor which is used in unregulated supplies. This supply is intended to provide the required level of DC power to the load. Varying DC voltage when converted to a constant low DC voltage by a linear voltage regulator, the function of the regulator prevents the power supply or an overcurrent load from limiting the current.

Most power supply applications require an output voltage that is constant but the energy sources providing voltage vary with load impedance changes. Moreover, the output voltage varies with changes in input voltage when a DC power supply as the source of energy is unregulated. To avoid this, linear voltage regulator is used by a few power supplies for maintenance of output value at a constant value, free from any variance in load impedance and input voltage. Ripple's magnitude and output voltage noise can be reduced by linear regulators. The following figure shows the block diagram of regulated linear power supplies:

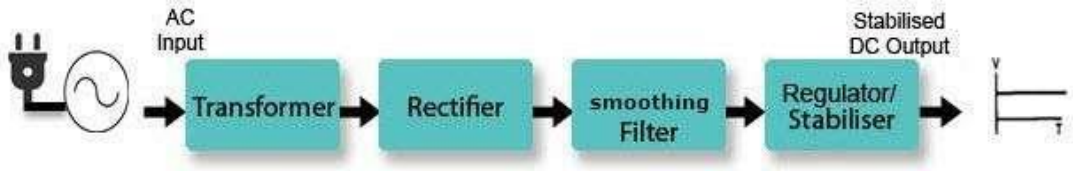


Fig. 1.2.37: A block diagram of regulated linear power supplies

The following figure shows the basic circuit diagram of regulated linear power supply:

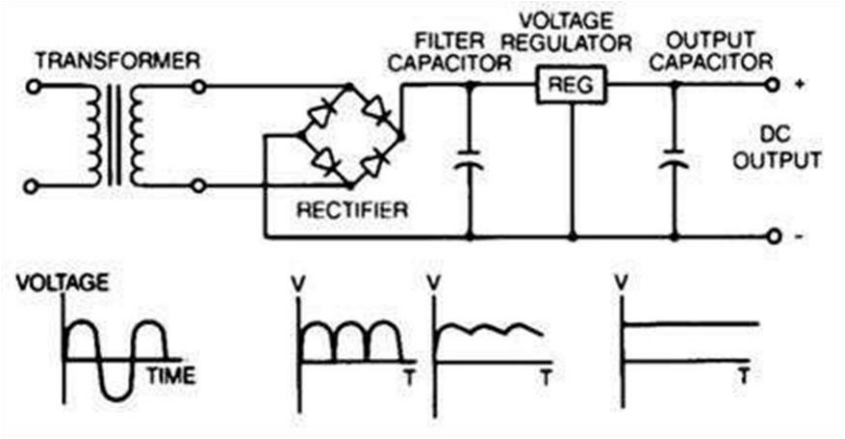


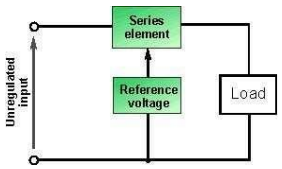
Fig. 1.2.38: A circuit diagram of regulated linear power supply

The following figure explains the working of smoothing filter and voltage regulator:

Smoothing	Once rectified from an AC signal, the DC needs to be smoothed to remove the varying voltage level.
	Large value capacitors are generally used for this purpose.
Voltage Regulator	A linear regulator has an active (BJT or MOSFET) pass device (series or shunt) controlled by a high gain differential amplifier.
	It compares the output voltage with a precise reference voltage and adjusts the pass device to maintain a constant level output voltage.

Fig. 1.2.39: Working of smoothing filter and voltage regulator

The following figure lists two types of voltage regulators:



Series regulator

- This is the most widely used regulators for linear power supplies.
- A series element is placed in the circuit and its resistance is varied via the control electronics to ensure that the correct output voltage is generated for the current taken.

Shunt regulator

- The shunt regulator is less widely used as the main element within a voltage regulator.
- In this, a variable element is placed across the load as shown in the figure.
- A source resistor is placed in series with the input and the shunt regulator is varied to make sure that the voltage across the load remains constant.

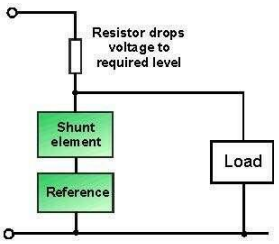


Fig. 1.2.40: Two types of voltage regulators

Switch Mode Power Supply (SMPS)

An SMPS includes filter capacitor, regulator, rectifier, series transistor and transformer. The following figure shows the block diagram of an SMPS and its working:

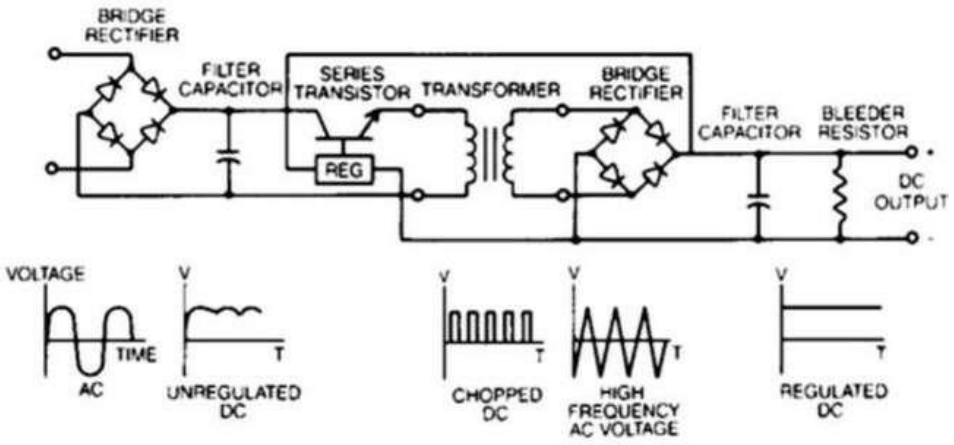


Fig. 1.2.41(a): Block diagram of SMPS

The AC voltage is converted to an unregulated DC voltage by passing it through a rectifier, a series transistor and a regulator.

This DC is then chopped to a constant voltage of high frequency that enables the size of the transformer to be reduced dramatically, thereby allowing a smaller power supply.

Fig. 1.2.41(b): Working of an SMPS

The disadvantages of SMPS are listed in the following figure:

It requires all the transformers to be custom-made.

The complexity of the power supply could lead to low production.

Fig. 1.2.42: Disadvantages of SMPS

The following image shows an SMPS:

Fig. 1.2.43: SMPS

Uninterruptible Power Supply (UPS)

UPS is known as a backup power source. It allows sufficient time for a standby generator or any system to shut down in an orderly manner in the case of a power fluctuation or a failure. A UPS comprises of power sensing and conditioning circuitry and a set of rechargeable batteries. The following image shows a UPS:

Fig. 1.2.44: UPS

1.2.9 Amplifier

An amplifier is used for increasing the magnitude of the signal that is applied to its input. The following figure shows the concept of an amplifier circuit:

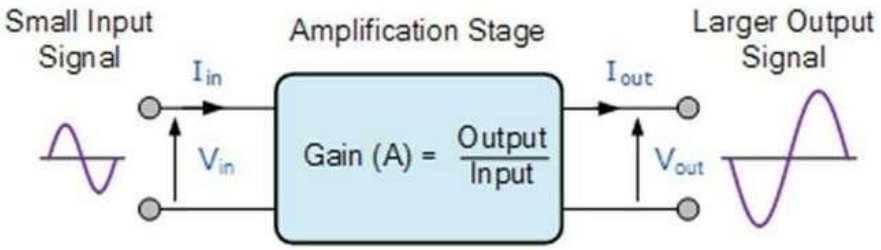


Fig. 1.2.45: Concept of an amplifier circuit

The following figure shows the concept amplifier gain:

The difference between the magnitude of the input and output signal is referred to as the amplifier's gain.

The gain measures the extent to which the input signal is amplified.

For example, an amplifier is provided input signal of 1 volt and it generates an output of 50 volts. The gain of the amplifier is 50. It means, the input signal has been amplified by a factor of 50.

Fig. 1.2.46: Concept amplifier gain

Amplifier gain is basically the ratio of output to input. The following figure lists three types of amplifier gains:

Voltage Amplifier Gain

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

Current Amplifier Gain

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

Power Amplifier Gain

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

Fig. 1.2.47: Types of amplifier gain

Amplifier Class

The various mode of operations of an amplifier are better known as Amplifier Class.

- **Class A Amplifier Operation:** In this form, a signal waveform identical with that of the input signal is reproduced by the amplifier. It can be done because the transistor within its active region is perfectly biased and hence it does not reach either the cut-off or the saturation region. This allows the AC input signal to be 'centred' within the upper and lower limits of the amplifier. The following figure shows Class A amplifier output waveform:

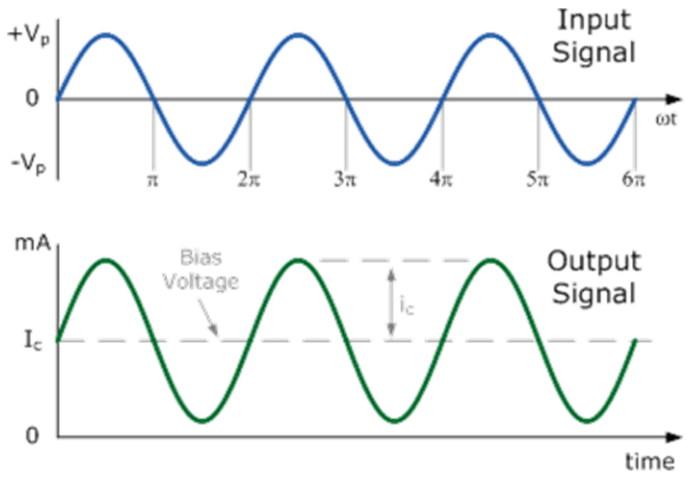


Fig. 1.2.48: Class A amplifier output waveform

The following figure lists the working of Class A amplifier:

Class A amplifiers use the same transistor for each half of the output waveform.

The output transistor has current flowing through it constantly even when there is no input signal.

- It is because of its biasing arrangement.
- The nature of the output transistor of always being in ON position makes the Class A operation very inefficient.
- This is because the conversion of DC power to AC power delivered to the load is very low.

The output transistor gets very hot even if input signal is present.

- Hence, heat sinking is required. The DC flowing through the output transistor in absence of any output signal is equal to the current passing through the load.
- Thus, Class A amplifier is inefficient because most of the DC power gets converted to heat.

Fig. 1.2.49: Working of Class A amplifier

- **Class B Amplifier Operation:** The following figure lists the characteristics of Class B amplifier:

The Class B Amplifier uses two different set of transistors, either an NMOS and a PMOS or an NPN and a PNP for each half of the output waveform.

- One of the two transistors conducts for one-half of the signal waveform while the other one conducts for its opposite half.
- Each transistor amplifies only 50% of the input signal as it remains half of its time in active region and the other half in the cut-off region.

The transistor conducts only when the input signal voltage is greater than the base-emitter voltage (VBE).

For the silicon devices the VBE is about 0.7 V. Hence, only half of the input signal gets amplified, thereby giving a greater amount of amplifier efficiency.

Fig. 1.2.50: Characteristics of Class B amplifier

The following figure shows output waveform of Class B amplifier:

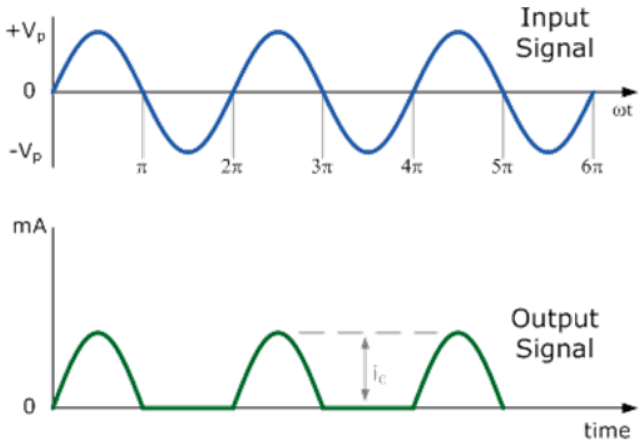


Fig. 1.2.51: Output waveform of Class B amplifier

In a Class B amplifier, to bias the transistors, no DC voltage is used. For the output transistors, to start conducting in both the halves (positive and negative) of the waveform, the VBE needs to be more than 0.7 V. This is a must for the bipolar transistor for conducting.

The lower part of the output waveform below 0.7 V is not accurately reproduced as one transistor is in OFF position and is waiting for the other one to come back to ON state. Hence, it results in a deformed area of the output waveform with a small part of it distorted at the zero-voltage cross over point. This is known as Crossover Distortion.

- **Class AB Amplifier Operation:** The following figure lists the working of class AB amplifier:

Two complementary transistors are used in their output stage and a small biasing voltage is applied to bias the transistor at its base.
This is done so that the cut-off region is reached even in the absence of any input signal.
Any crossover distortion is eliminated because an input signal causes the transistor to operate normally as it operates in its active region.
In absence of any input signal, a small Collector current flows.
The transistor remains in 'ON' position for more than half a cycle of the waveform.
This configuration improves the efficiency and linearity of the amplifier circuit as compared to the configuration of Class A.

Fig. 1.2.52: Working of class AB amplifier

The following figure shows the output waveform of Class AB amplifier:

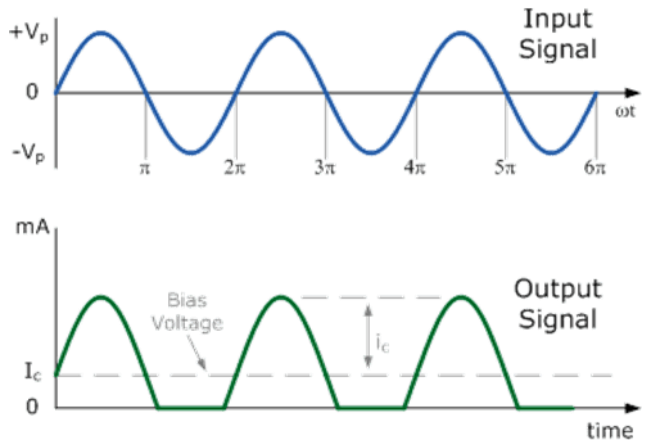


Fig. 1.2.53: Output waveform of Class AB amplifier

The class of operation depends on the amplitude required for input signal and the amount of transistor bias needed for the operation. The classification of the amplifier considers the following points:

- Segment of the input signal in which the transistor conducts
- Efficiency
- Amount of power that is consumed and dissipated in terms of heat by the switching transistor

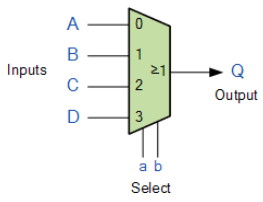
The following figure shows a table of comparison between the common classes of a power amplifier:

Class	A	B	C	AB
Conduction Angle	360°	180°	Less than 90°	180 to 360°
Position of the Q-point	Centre Point of the Load Line	Exactly on the X-axis	Below the X-axis	In between the X-axis and the Centre Load Line
Overall Efficiency	Poor 25 to 30%	Better 70 to 80%	Higher than 80%	Better than A but less than B 50 to 70%
Signal Distortion	None if Correctly Biased	At the X-axis Crossover Point	Large Amounts	Small Amounts

Fig. 1.2.54: Table of comparison between the common classes of power amplifier

1.2.10 Multiplexer (MUX) and Demultiplexer (Demux)

The following figure explains the multiplexer and demultiplexer:



The multiplexer is a combinational logic circuit designed to switch one of several input lines to a single common output line by the application of a control logic.

Multiplexers can be either digital circuits made from high speed logic gates used to switch digital or binary data.

They can be analogue types using transistors, MOSFET's or relays to switch one of the voltage or current inputs to a single output.

The demultiplexer is a combinational logic circuit designed to switch one common input line to one of several output lines by the application of a control signal.

The data distributor, known more commonly as a Demultiplexer, is the exact opposite of the Multiplexer.

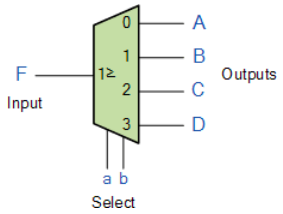


Fig. 1.2.55: Multiplexer and demultiplexer

1.2.11 Coupler

Coupler is used to transfer electrical energy from a part of a circuit to another part. For example, conductive coupling transfers the energy from a power source to a load. The following figure lists the types of coupling:

Direct Coupling

- Direct coupling is essential for very low frequency applications Such as photoelectric current.
- It has got advantages of having simple and cheap circuit arrangement and outstanding ability to amplify low frequency signals.
- The drawbacks include poor temperature stability and unsuitability for amplification of high frequency signals. Direct coupled amplifiers are used when the load is directly in series with the output terminal of the active circuit element.

Impedence Coupling or Transformer Coupling

- Impedence coupling results in more efficient amplification because no signal power is wasted in Inductor L.
- Such coupling has the drawback of being larger, heavier and costlier than the RC coupling. Impedence coupling is rarely used beyond audio range.

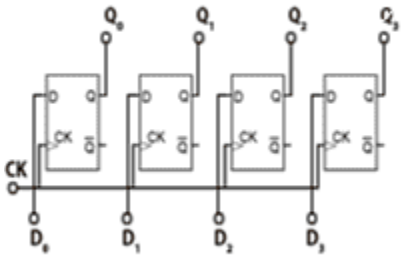
RC Coupling

- RC coupling is the most commonly used coupling between the two stages of a cascaded or multistage amplifier because it is cheaper in cost, has very compact circuit and provides excellent frequency response.

Fig. 1.2.56: Types of coupling

1.2.12 Registers and Memories

The following figure shows a 4-bit register and its characteristics:



An electronic register is a form of memory which uses several flip-flops in series for storing individual bits of a binary word, for example, as a byte of data.

The length of the binary word to be stored is determined by the number of flip-flops making up the register.

Fig. 1.2.57: A 4-bit register and its characteristics

The following figure explains the working of a 4-bit register shown in the above figure:

- The above 4-bit register is comprised of four D-type flip-flops sharing a common clock input and providing synchronous operation to ensure that all the bits are stored promptly.
- The binary word is applied to the D inputs. The word is remembered by the flip-flops at the rising edge of the next clock (CK) pulse.
- At any time, the stored data can be read from Q outputs as long as the power is maintained, or until there is a change of data on the inputs stored by a further clock pulse, overwriting the previous data.

Fig. 1.2.58: Working of a 4-bit register

The registers are typically classified according to the storage method and the readout used. The basic form of register is Parallel In/Parallel Out (PIPO) register. The following figure lists the type of registers:

Serial In Serial Out (SISO)	Data bits are entered serially and output is also taken serially.
Serial In Parallel Out (SIPO)	Data bits are loaded serially but output is taken parallelly.
Parallel In Parallel Out (PIPO)	Data bits are loaded parallelly and output is also taken parallelly.
Parallel in Serial out (PISO)	Data bits are loaded parallelly and the output is taken serially.

Fig. 1.2.59: Types of registers

The following figure shows the configuration of SISO registers:

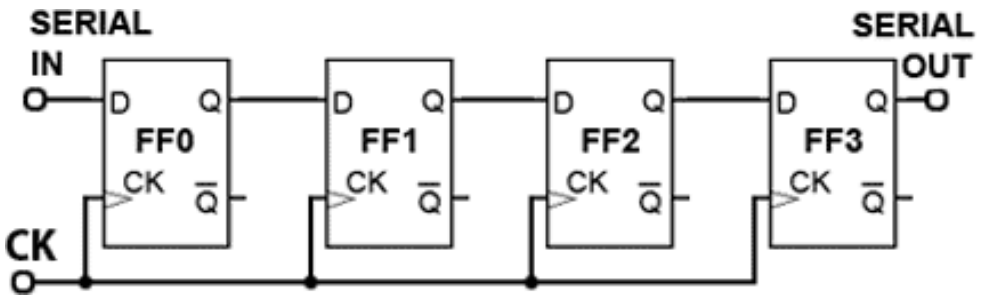


Fig. 1.2.60: Configuration of SISO registers

The following figure shows the configuration of SIPO registers:

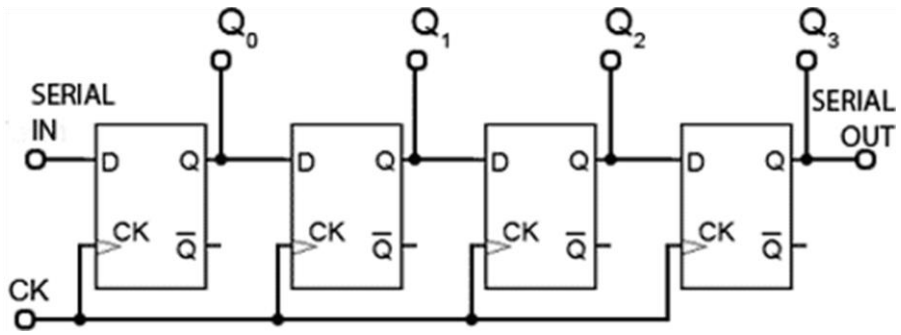


Fig. 1.2.61: Configuration of SIPO registers

Shift Registers

The structure of shift registers is similar to that of the PIPO registers but they have the ability to perform shifting of the stored word, one bit at a time, to right or left. These registers are used as a necessary component in communication systems to handle serial data. They are used to convert the data to parallel form and then to convert it back again to serial form. The following figure shows the application of shift registers:

Shift registers are also important for arithmetic circuits to shift the binary numbers to right (by dividing by two) or to left (by multiplying by two) as part of a calculation.

These can also be used for delaying the passage of data at a specific point in a circuit.

- At a time, one bit of data is shifted from the input towards the output.
- The amount of delay depends on the number of flip-flops and the frequency of the clock pulses driving the shift register.
- The action of storing several bits of data after they are inputted and then recovering them from the output at a later time is known as a digital delay line.

Fig. 1.2.62: Application of shift registers

1.2.13 Radio Frequency (RF) Circuits in Telecom

RF range is used in radio. The frequency ranges between audio frequencies (with the upper limit of 20 kHz) and infrared frequencies (with lower limit of around 300 GHz).

The following figure shows the building blocks of a typical RF communication system:

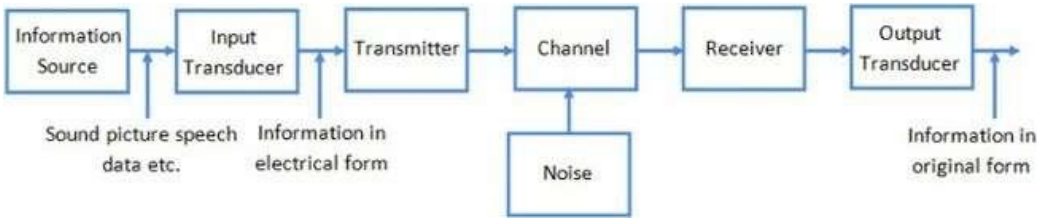


Fig. 1.2.63: Building blocks of a typical RF communication system

Notes

UNIT 1.3: Introduction to Printed Circuit Boards (PCB)

Unit Objectives

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

1. Identify the various parts of a PCB
2. Differentiate between the different layers of a PCB
3. List the three types of PCB
4. Analyse the performance requirements of a PCB

1.3.1 What is PCB?

A PCB helps to connect electronic components with tracks, lines and pads which are incorporated on a laminated copper sheet. It allows the power and the signal to be routed between the components. The copper sheet is divided by chemical etching process into different parts. The following figure shows the parts of PCB:

Separate conducting lines referred as tracks or circuit traces

- The tracks that serve as wires fixed in specific places are insulated from each other by board substrate material and air.

Pads for connections

Vias for passing the connections between the layers of copper

Different features such as solid conductive areas for EM shielding or other purposes

- The PCB surface may have a coating for protecting the copper from corrosion and for reducing the chances of unintentional electrical contact with stray bare wires or solder shorts between the traces.

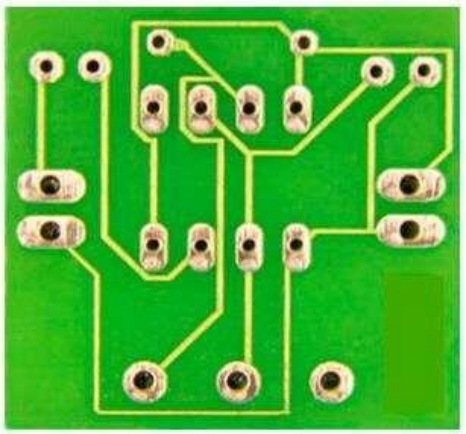


Fig. 1.3.1: Parts of a PCB

Click/Scan the QR Code to know about PCB

1.3.2 Composition of PCB

A PCB contains different layers that are joined together by using heat and adhesive, providing it a compact shape of a single object. The following figures show the layers of a PCB:

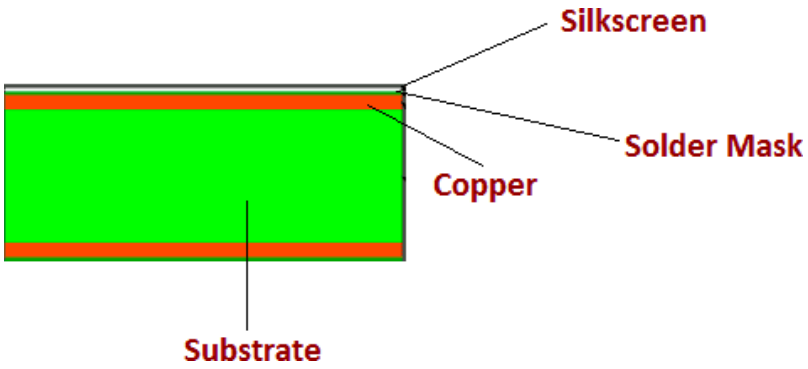


Fig. 1.3.2a: Layers of a PCB

Substrate Layer

- It is the base layer that is composed of fibre glass. Nature of substrate material defines whether board will be Flexible PCB or Rigid PCB.
- The FR4 is the most common fiber glass used today. It is like a solid core that provides rigidity and thickness to the PCB board.
- Some PCB boards are composed of phenolics and epoxies which are not as durable as FR4 and come with unique bad smell but they are less expensive. Low end consumer electronics mostly use these types of substrates.
- Phenolics come with low decomposition temperature which allows these substrates to erupt and delaminate if solder is placed on the board for longer duration of time.

Copper Layer

- It is a thin layer of copper foil that is laminated on the board using heat and adhesive.
- Commonly, both sides of substrate are laminated with copper, especially in double sided PCB, except in cheap electronics where only one side of the board is laminated with copper.
- The copper thickness varies from board to board and can be defined in ounces per square foot. One ounce per square foot is suitable for most of the PCBs, but applications which require more power come with 2 or 3 ounce per square foot.
- Each inch per square encompasses 35 micrometres of thickness.

Solder Mask Layer

- This layer is applied on the copper layer to insulate the copper layer. This is done to avoid conduction in case direct contact happens with some metal or conductive material.
- Most commonly used solder-mask comes in green colour; however, it is also available in other various colours like red, blue, brown and white.

Silkscreen Layer	•This layer allows the user to add symbols and number for better understanding of the board. •Silkscreen labels provide clear indication of function of each pin and component soldered in the board. •Silkscreen mostly comes in white colour but there are also other colours available including red, grey, black and yellow. •Common practice is using silkscreen in one colour as combination of different colours of silkscreen makes it difficult for the user to read the board properly.

Fig. 1.3.2b: Layers of PCB

1.3.3 Types of PCB

PCBs are classified according to the nature and number of layers. The following figure lists the types of PCBs:

Single-sided PCB

- Copper tracks are found on one side of the PCB board.
- Pins of the components are inserted from one side of the board to the other side that comes with copper tracks and lines. These pins are soldered on the copper side to provide the conducting path to the components.
- These are commonly used in many electronic devices including printers, coffee machines, basic electronics circuits and calculators.

Double-layer PCB

- Copper tracks are applied on both sides of the boards.
- Holes are drilled through the board to connect the circuits on one side of the board to the circuits on the other side.
- The components on these boards are connected electrically using two techniques: through hole or through surface mount technology.
- In through hole technology, leads (wires) are inserted in the hole and then connected to the component, thereby building a smooth conducting path throughout the board surface.
- In surface mount technology, small leads of the components are directly connected to the board.
- These PCBs are used in many applications including amplifiers, vending machines, LED lightening, HVAC systems and general power supplies.

Multi-layer PCB

- Multi-layer PCBs consist of a series of three or more double-layered PCBs.
- Specialised glue is used to secure these boards together. The boards are then sandwiched between pieces of insulation to ensure that excess heat does not melt any of the components.
- Multi-layer PCBs can be as small as four layers or as large as ten or twelve layers. The many layers of PCBs enable the designers to make complex designs that are suitable for a broad range of complicated electrical tasks.
- The thickest multi-layer PCB developed was 50 layers thick.
- These boards help in initialising faster operations than that done by standard PCB boards and are very similar to microchip composition.
- These are used in wide range of applications including satellite system, weather equipment, X-ray equipment, data storage, GPS technology and many more.

Fig. 1.3.3: Types of PCB

1.3.4 Copper Clad Laminates (CCL)

Copper Clad Laminate is a type of base material for the PCBs. It contains wood pulp paper or glass fibre as the reinforcing material, which is laminated with copper clad on either one or both sides after being soaked in resin. The following figure shows a set of CCL boards and the construction of a CCL board:

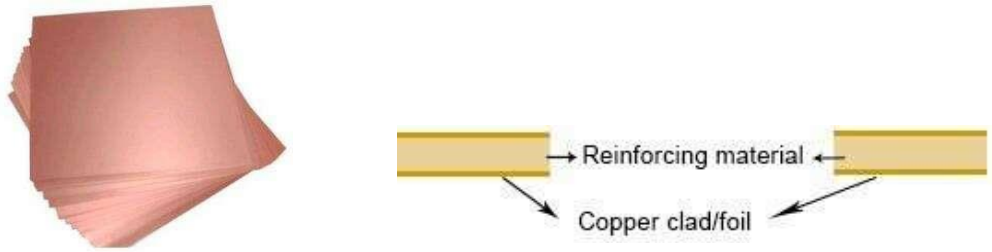


Fig. 1.3.4: A set of CCL boards and the construction of a CCL board

The following figure lists the performance requirements for CCLs:

Appearance

- Issues may be caused on copper foil due to unexpected elements in manufacturing process such as dent, scratch, resin point, wrinkle, pinhole, bubble and so on.
- All these problems will lead to low performance of the CCL and consequently, the PCB. Therefore, an excellent CCL should be flat and smooth in appearance.

Size

- Since CCLs are base material of PCBs, they have to conform to size requirements corresponding to the PCBs.
- Parameters concerning the size of CCLs include length, width, diagonal deviation and warpage, each of which has to meet specific requirement.

Electric Performance

- The factors affecting electric performance of PCBs which are to be carefully designed include dielectric constant (Dk), dielectric breakdown voltage, dielectric loss tangent (Df), surface resistance, arc resistance, volume resistance, insulation resistance, electric strength, Comparative Tracking Index (CTI) and so on.

Physical Performance

- Parameters concerning physical performance of a CCL include dimensional stability, peel strength (PS), bending strength, heat resistance (including thermal stress, Td, T260, T288, T300), punching quality and so on.

Chemical Performance

- Chemical performance of a CCL has to meet the requirements of flammability, chemical reagents resistance, Tg, Z-axis coefficient of thermal expansion (Z-CTE), dimensional stability and so on.

Environmental Performance

- It has to cater to the requirements in terms of water absorption amongst others.

Fig. 1.3.5: Performance requirements for CCLs

Notes

UNIT 1.4: PCB Designing Concepts

Unit Objectives

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

1. List the steps of designing a PCB
2. Identify the inspection checks to be performed
3. Execute the cleaning of boards before pattern transfer
4. List the standards published by IPC

1.4.1 Steps of PCB Designing

The following figure lists the steps of designing a PCB:

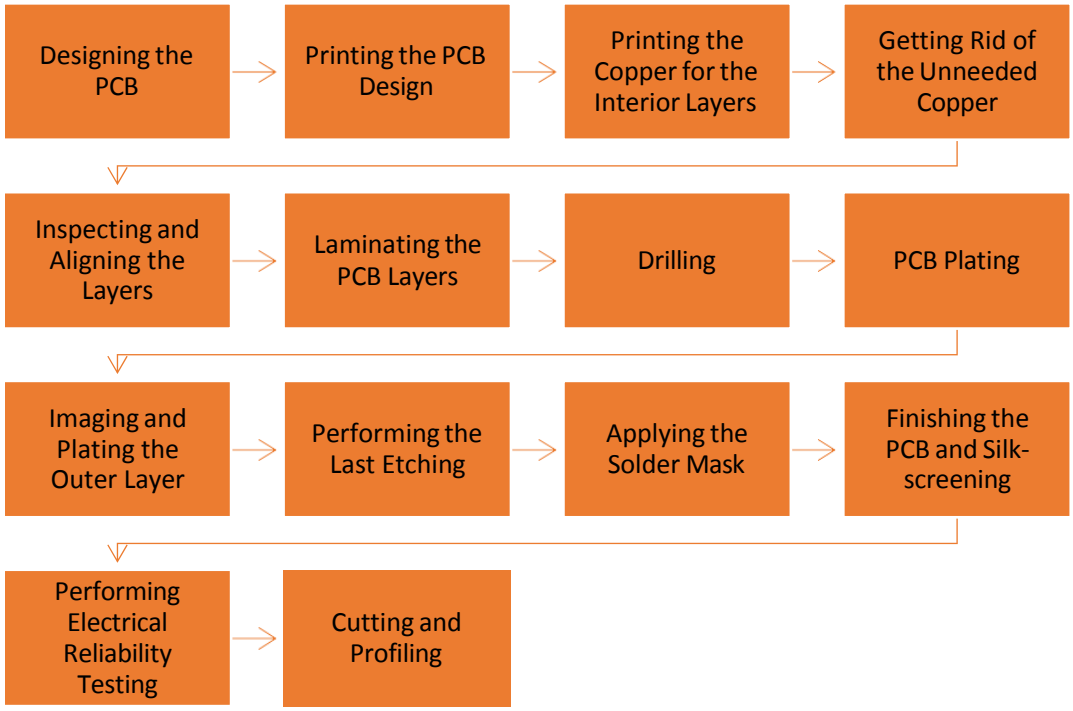


Fig. 1.4.1: Steps of designing a PCB

Designing the PCB

A blueprint is prepared by the designer for the PCB, considering all the specifications.

The following figure lists the steps of designing the PCB using software:

The software encodes all information required by the designer, such as the amount of solder masks required, the number of copper layers needed and the pieces of component notation required. The design software most widely used by the PCB designers is Extended Gerber, also known as IX274X.

Once the design blueprint gets encoded by the software, the design is checked, considering all aspects, to ensure that there are no errors.

When the checking is done, the design is sent out to a PCB fabrication house to be built.

The fabricator checks the PCB design plan, known as a Design for Manufacture (DFM) check, to verify that the design meets the tolerances required for the manufacturing process.

Fig. 1.4.2: Steps of designing the PCB using software

Printing the Design on PCB Layers

When all required checks are complete, a plotter printer prints the design on the PCB layers by making a "film" of the PCB which looks similar to a photo negative of the board itself.

The layers are represented in two different ink colours. The following figure lists the colours to represent the layers of the PCB:

Inner Layers	
Black ink denotes the copper traces and circuits of the PCB.	Clear Ink denotes the non-conductive areas of the PCB such as the fibreglass base.

Outer Layers	
Clear ink denotes the line of copper pathways.	Black ink denotes the areas from where copper would be removed.

Fig. 1.4.3: Colours used to represent the layers of the PCB

There are separate films for each PCB layer and its solder mask. The following figure lists the sheets required for a two-layer PCB:

For a two-layer PCB, there will be four sheets:

- One for each layer
- One for the solder mask of each layer

Fig. 1.4.4: Sheets required for a two-layer PCB

The films are lined up after being printed. A hole is punched through the films. It is referred as registration hole and it helps in aligning the films in later process.

Printing Copper for the Inner Layers

Once the design gets printed on the laminate, copper is pre-bonded to it which acts as the structure for the PCB. The following figure lists the steps of the printing process:

The copper is etched away so that the earlier blueprint is revealed.

The laminate panel is then covered with a photo-sensitive film called resist, which consists of a layer of photo-reactive chemicals.

- These chemicals harden when they are exposed to ultraviolet light.
- Resist helps to obtain a perfect match between the photos of the blueprint and what gets printed to the photo resist.

Once the resist, along with the laminate, is lined up, ultraviolet light is passed through it.

- The photo resist gets hardened when the ultraviolet light passes through the translucent parts of the film, thereby indicating the areas of copper meant for the pathways.
- The black ink prevents the light from reaching the areas which are not meant to harden and they are removed later.

The board is then washed with an alkaline solution so that any leftover from the photo resist can be removed.

After that, the board is pressure-washed for removing any leftover from the surface and is left to dry.

When the PCB is dried, the resist should only be left on top of the copper, which remains as part of the PCB.

Fig. 1.4.5: Steps of the printing process

A technician needs to check the PCB to ensure that there are no errors.

Getting Rid of the Unwanted Copper

The unwanted copper (not protected by the photo resist) is removed using another powerful chemical like an alkaline solution. After this the hardened photo resist should be removed using another solvent, leaving the copper necessary for the PCB.

Inspection and Alignment of the Layers

After cleaning the layers of the PCB, they are aligned using the holes. The layers are placed on an optical punch. The punch aligns the holes by driving a pin down through them.

The layers are then passed through an optical inspection to ensure that they are free of defects. The PCB is inspected by automated optical inspection (AOI) machine and the design on it is compared with the specified design received from Extended Gerber software. After the PCB passes the inspection, it is moved on to the lamination process.

Laminating the layers of the PCB

Once the layers pass the AOI inspection, they are ready to be joined together. The following figure explains the two-step process of laminating:

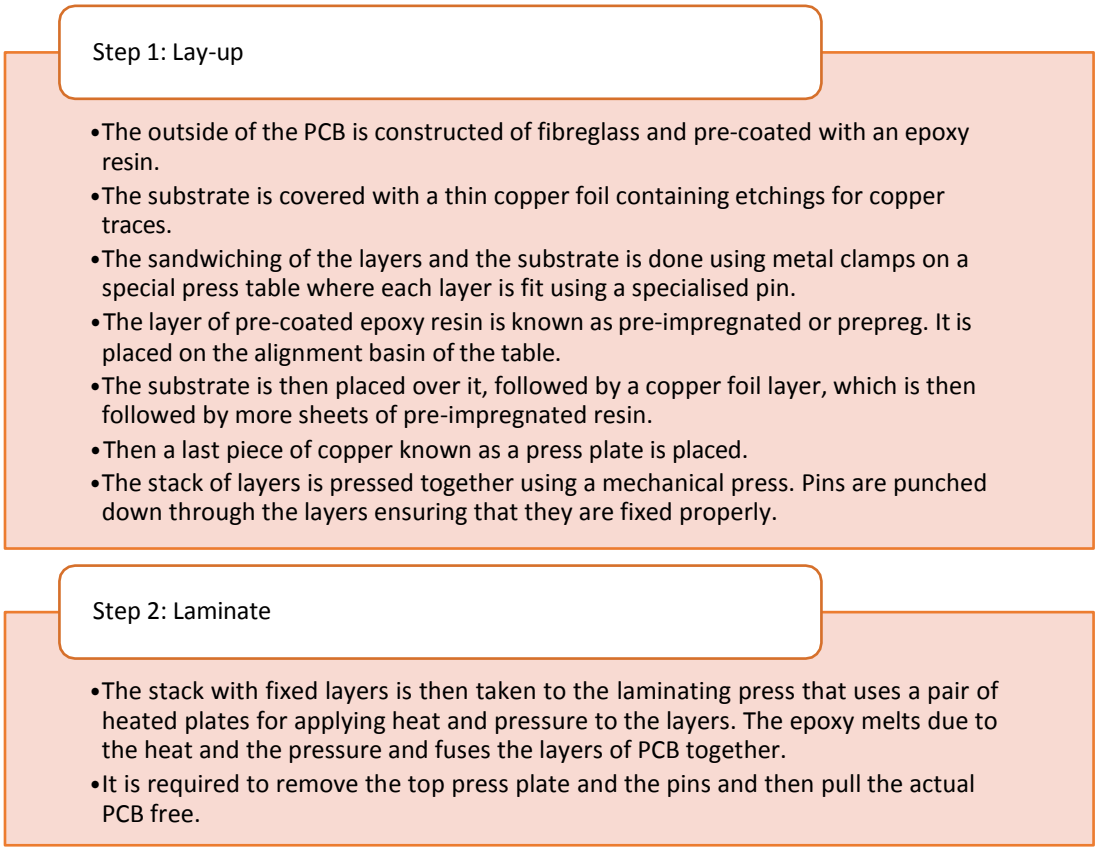


Fig. 1.4.6: Two-step process of laminating

Drilling

The following figure lists the steps of drilling holes on the PCB:

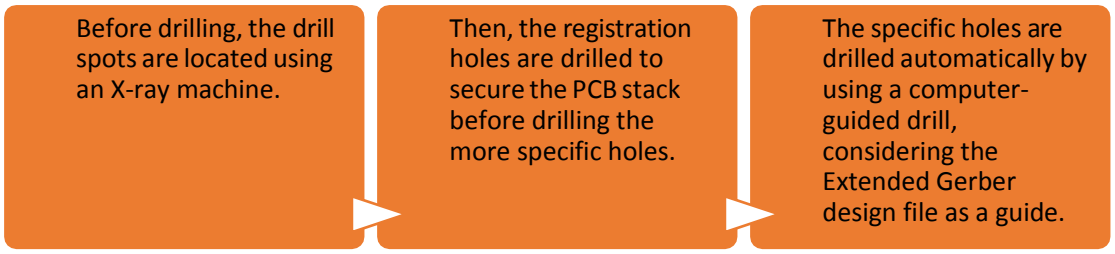


Fig. 1.4.7: Steps of drilling holes on the PCB

The additional copper, left at the edges, needs to be scraped off after drilling is completed.

PCB Plating

The plating process fuses the layers of the PCB together through bathing process in which it is passed through various chemicals. A micron-thick copper layer is used to coat the panel. The copper layer is deposited into the just-drilled holes and over the top most layer. The fibre glass substrates inside the panel are exposed through the holes before they are filled with copper. The walls of the holes get covered after being bathed in copper.

Imaging and Plating Outer Layer

The outside layers then need to be imaged.

The following figure shows the process of plating the outer layers:

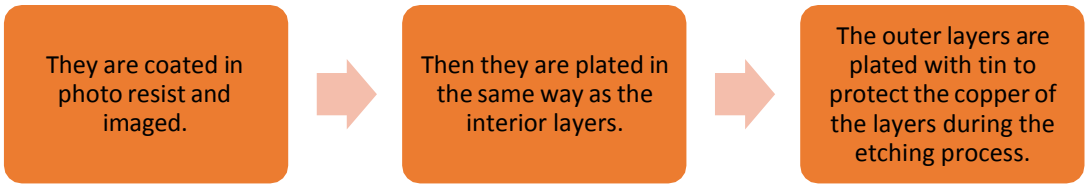


Fig. 1.4.8: Process of plating the outer layers

The Last Etching

In this process, the unwanted copper is removed using copper solvent. The tin plating protects the required copper of the etching area.

The PCB panels are sent for solder masking when the removal of unwanted copper and the establishment of connections are done properly.

Application of Solder Mask

Before the panels are masked, they are cleaned. The following figure shows the steps of applying solder mask:

An ink epoxy in combination with solder mask film is then applied to the cleaned PCB panels.

↓

The boards are passed through ultraviolet light and certain portions of the solder mask are marked for removal.

↓

After the unwanted solder mask is removed, the PCB is kept inside an oven and baked to allow the solder mask to be cured.

Fig. 1.4.9: Steps of applying solder mask

Finishing the PCB and Silk-screening

In the finishing process, in order to protect the copper, the board is plated with hot air solder levelling (HASL), gold or silver. The plating is also done to enable the soldering of the components to pads.

Once the plating is done, all the important information, for example, company ID numbers manufacturer marks and warning labels, are printed on the boards using the silk-screening process. After silk-screening the PCB appropriately, it is passed through final curing stage.

Electrical Reliability Testing

Once the board has been cured, the technician needs to ensure the functionality of the PCB by conducting electrical tests such as circuit continuity and isolation tests, on different areas of the PCB. The following figure lists the purpose of the electrical tests:

Circuit continuity test:	Circuit isolation test:
• It checks for any disconnections in the PCB, known as “opens.”	• It checks the isolation values of various parts of the PCB to check if there are any shorts.

Fig. 1.4.10: Purpose of the electrical tests

The electrical tests also check how well the initial PCB design will perform and react to the manufacturing process.

Besides the basic electrical reliability testing, some other tests are performed to determine whether a PCB is functional. The following figure shows an example of such functionality test:

The “bed of nails” test is done to check the PCB’s performance under high-pressure contact. Several spring fixtures are attached to the test points on the board and then the test points are subjected to up to 200g of pressure.

Fig. 1.4.11: An example of such PCB functionality test

If the PCB passes all the tests, it can be moved for cutting.

Cutting and Profiling

Cutting and scoring is the last stage that involves cutting out PCBs from the original panel. The following figure lists the two ways of cutting the PCBs from their original panels:

- Using a CNC machine or router, which cuts out small tabs around the edges of the PCB
- Using a V-groove, which cuts a diagonal channel along the sides of the board

Fig. 1.4.12: Two ways of cutting the PCBs from their original panels

Usually, the individual boards from the PCB panels are routed out and scored. This process enables the separation of the panels from the construction board when they are assembled. Once the boards are separated, a final inspection is performed. The following figure lists the inspection checks to be performed:

- The boards are checked for general cleanliness to ensure that there are no sharp edges, burrs or other manufacturing hazards.
- Slots, chamfers, bevels and countersinks are added during the routing and fabrication process, as necessary.
- If any shorts are repaired, the shorted boards are re-tested using the electrical reliability tests.
- A visual inspection can be conducted, if necessary, to ensure that boards meet industry specifications and match up to the details laid out in Gerber data.
- The visual inspection can also be done to verify the hole sizes and the physical dimensions of the PCB.

Fig. 1.4.13: Inspection checks to be performed

1.4.2 Cleaning of Boards before Pattern Transfer

It is usually assumed that the boards are clean enough to start the printing process and often paper rolls are used to clean the boards. However, this should not be done as the boards get microfibres or lint due to cleaning with cheap wipes. These microfibers cause various defects in the boards, thus increasing the cost of production. Hence, it is highly recommended that the boards are properly cleaned before the printing process.

The boards can be cleaned in a dip-tank cleaner that has a special ultrasonic cleaning capability. If the volumes of the boards are high, then it is recommended to use the vapour degreaser as it has a high throughput and uses less electricity compared to the aqueous system.

1.4.3 IPC Standards

IPC, a standard developing organisation by the American National Standards Institute (ANSI), is globally recognised for its standards. The acceptability standards, widely used in the electronics manufacturing industry are published by IPC.

IPC-A-610, Acceptability of Electronic Assemblies, is used by EMS companies and the original equipment manufacturers across the world.

The following figure lists the standards published by IPC:

General documents	•IPC-T-50 Terms and Definitions •IPC-2615 Printed Board Dimensions and Tolerances •IPC-D-325 Documentation Requirements for Printed Boards •IPC-A-31 Flexible Raw Material Test Pattern •IPC-ET-652 Guidelines and Requirements for Electrical Testing of Unpopulated Printed Boards
Design specifications	•IPC-2612 Sectional Requirements for Electronic Diagramming Documentation (Schematic and Logic Descriptions) •IPC-2221 Generic Standard on Printed Board Design •IPC-2223 Sectional Design Standard for Flexible Printed Boards •IPC-7351B Generic Requirements for Surface Mount Design and Land Pattern Standards
Material specifications	•IPC-FC-234 Pressure Sensitive Adhesives Assembly Guidelines for Single-Sided and Double-Sided Flexible Printed Circuits •IPC-4562 Metal Foil for Printed Wiring Applications •IPC-4101 Laminate Prepreg Materials Standard for Printed Boards •IPC-4202 Flexible Base Dielectrics for Use in Flexible Printed Circuitry •IPC-4203 Adhesive Coated Dielectric Films for Use as Cover Sheets for Flexible Printed Circuitry and Flexible Adhesive Bonding Films •IPC-4204 Flexible Metal-Clad Dielectrics for Use in Fabrication of Flexible Printed Circuitry
Performance and inspection documents	•IPC-A-600 Acceptability of Printed Boards •IPC-A-610 Acceptability of Electronic Assemblies •IPC-6011 Generic Performance Specification for Printed Boards •IPC-6012 Qualification and Performance Specification for Rigid Printed Boards •IPC-6013 Specification for Printed Wiring, Flexible and Rigid-Flex •IPC-6018 Qualification and Performance Specification for High Frequency (Microwave) Printed Boards •IPC- 6202 IPC/JPCA Performance Guide Manual for Single and Double Sided Flexible Printed Wiring Boards •PAS-62123 Performance Guide Manual for Single & Double Sided Flexible Printed Wiring Boards •IPC-TF-870 Qualification and Performance of Polymer Thick Film Printed Boards

Flex assembly and materials standards	• IPC-FA-251 Assembly Guidelines for Single and Double Sided Flexible Printed Circuits • IPC-3406 Guidelines for Electrically Conductive Surface Mount Adhesives • IPC-3408 General Requirements for Anisotropically Conductive Adhesives Films

Fig. 1.4.14: Standards published by IPC

Source: https://en.wikipedia.org/wiki/IPC_(electronics)

The following image shows the IPC standards related to PCB design and manufacturing flow:

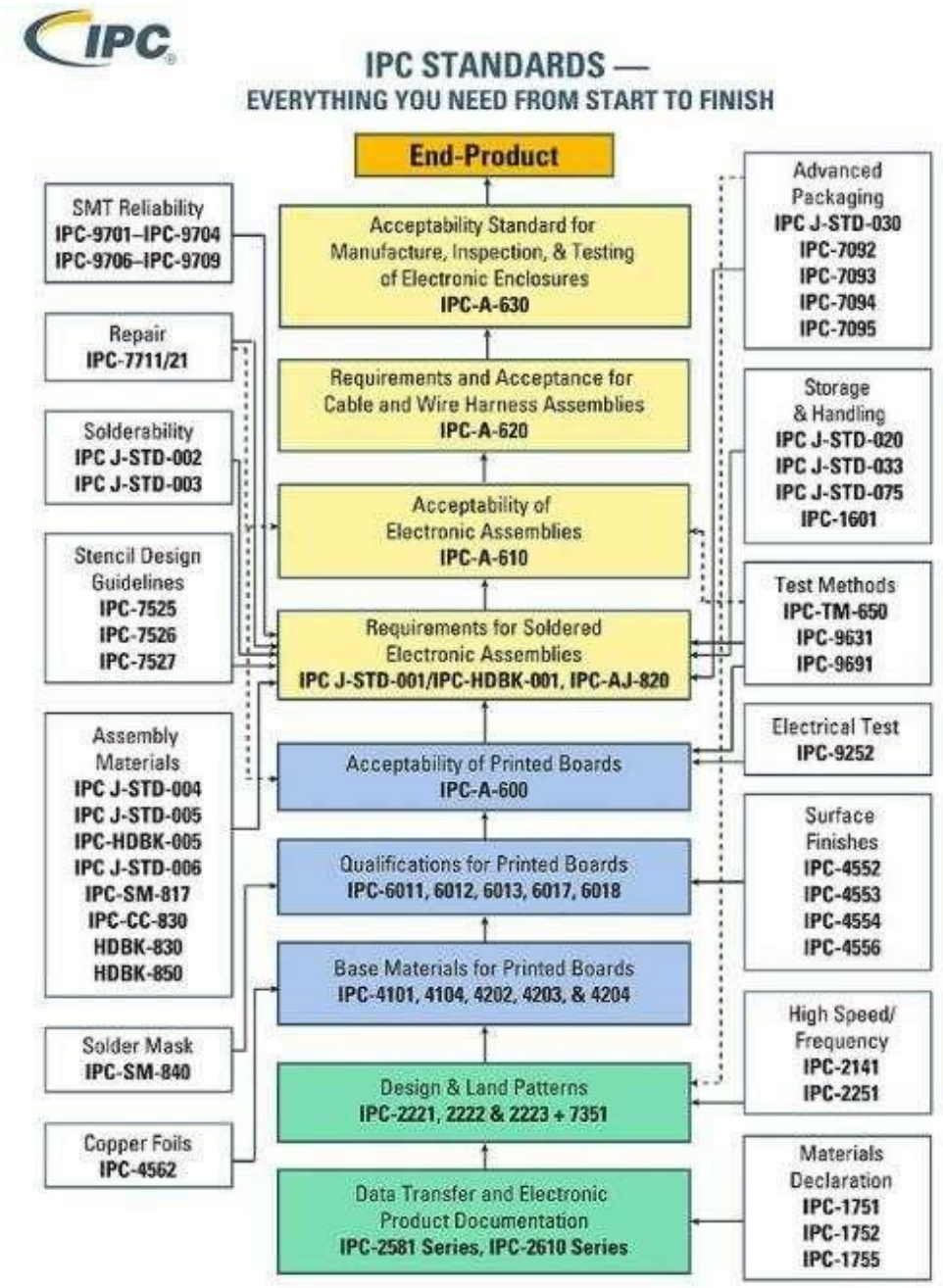


Fig. 1.4.15: IPC standards related to PCB design and manufacturing flow

Exercise

1. List the different types of PCBs.

2. What are the steps of PCB designing?

Notes

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

Telecom Sector Skill Council

1. Screen Printing of Telecom Boards

Unit 2.1 – Screen Printing Process

Unit 2.2 – Pre-baking of Board

Unit 2.3 – Screen-Printing Machines

Unit 2.4 – Inspection of Solder Paste Printing

TEL/N2503

Key Learning Outcomes

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

1. Demonstrate the process of applying solder paste on a PCB
2. List the tools and accessories used in screen printing
3. List the parameters of the printing process
4. Demonstrate the stencil cleaning process
5. Analyse the need of baking process
6. Identify the oven requirements to perform baking
7. List the factors that affect the time and temperature required for effective baking
8. Differentiate between the different types of screen-printing machines
9. List the key features of equipment used for identifying solder paste printing defects
10. Differentiate between the types of inspection available
11. Analyse the causes of some possible solder paste print inspection results
12. List the solder paste printing defects and their criteria

UNIT 2.1: Screen Printing Process

Unit Objectives

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

1. Demonstrate the process of applying solder paste on a PCB
2. List the tools and accessories used in screen printing
3. List the parameters of the printing process
4. Demonstrate the stencil cleaning process

2.1.1 Applying Solder Paste

When a bare PCB is entered in the SMT assembly line, the first task is to apply the solder paste on the PCB. Screen printing is the process which is widely used to accomplish this task. In this process, solder paste is applied on the PCB using a metal mesh or stencil. The solder paste is partly rolled and pressed through the stencil aperture onto the copper pads of the PCB by an angled squeegee. The angle for the squeegee must be within 45 to 60 degree. The following image shows the way of applying the solder paste on the board:

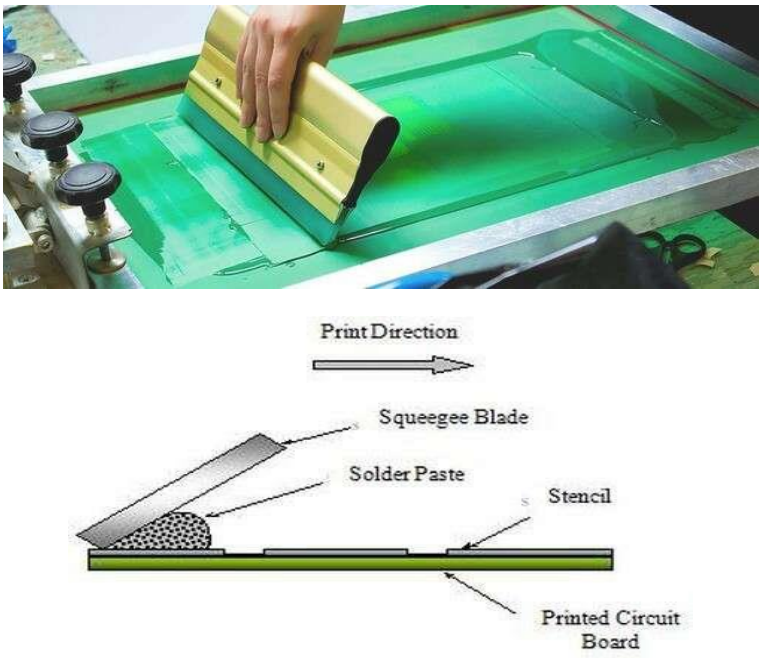


Fig. 2.1.1: The way of applying the solder paste on the board

Click/Scan the QR Code to understand screen printing process

2.1.2 Tools and Accessories Used in Screen Printing

The following figure shows the process of solder paste printing:

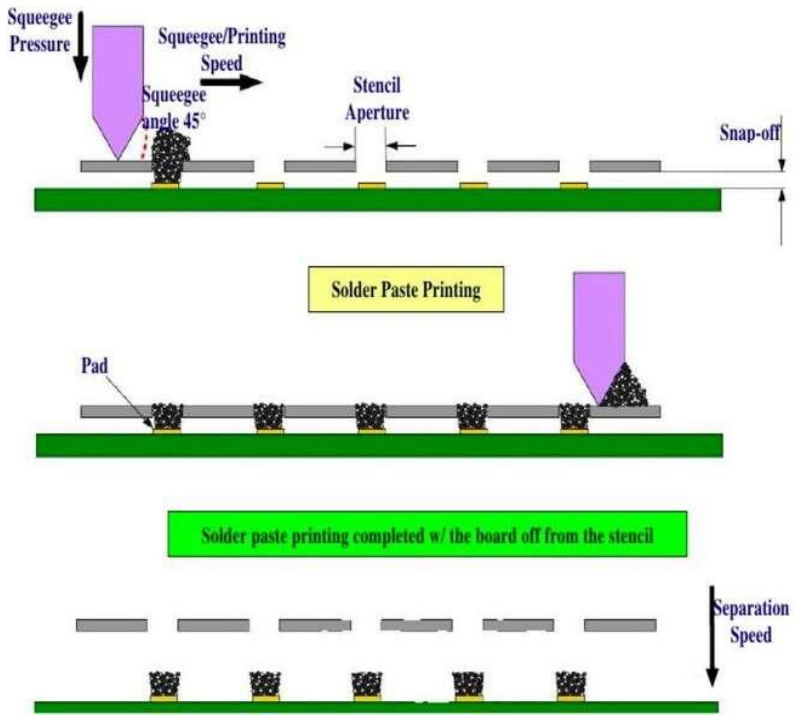


Fig. 2.1.2: Solder paste printing

Solder

It is a grey, putty-like material containing metal solder that is powdered and suspended in flux. Flux is a thick medium that is used to act as a temporary adhesive. The flux helps in keeping the components where they are placed, until the solder melts and joins them to the pads and board. A container of solder paste is shown in the following image:

Fig. 2.1.3: A container of solder paste

Squeegee Blade

A squeegee is a tool containing a flat, smooth rubber blade used for cleaning and printing. It is used to control/remove the liquid flow on a flat surface.

The following images show squeegee blades:

Fig. 2.1.4: Squeegee blades

Stencil

It is a thin sheet of metal (usually stainless steel) on which the pattern is made through laser cutting as per the Gerber data or CAD file. Solder paste is passed through the openings in the stencil onto the solder pads on the PCB. This thin sheet is then framed in an aluminum frame so that the frame can be bolted to the stencil printing machine. This keeps the sheet and the frame intact during the process. The aperture in the stencil includes slightly conic and sharp edges. This allows the paste to slip off the aperture edges securing a uniform print. The typical thickness of the stencil is 100 to 150 microns (4 to 6 mils). The top surface of the stencil top is slightly roughened so that a perfect solder paste rolling can be achieved during the printing. The following figure shows the types of stencils:

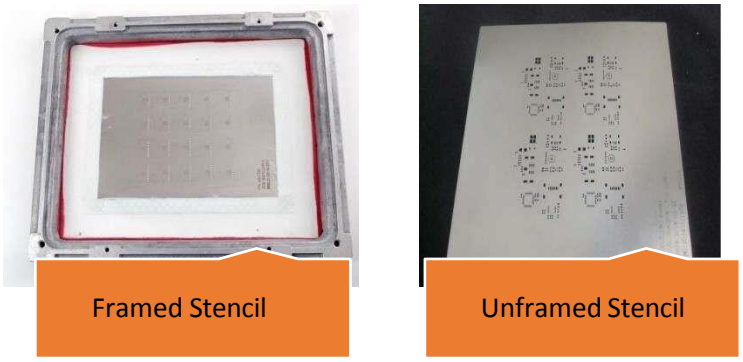


Fig. 2.1.5: Types of stencils

The following image shows a framed stencil bolted on a screen-printing machine:

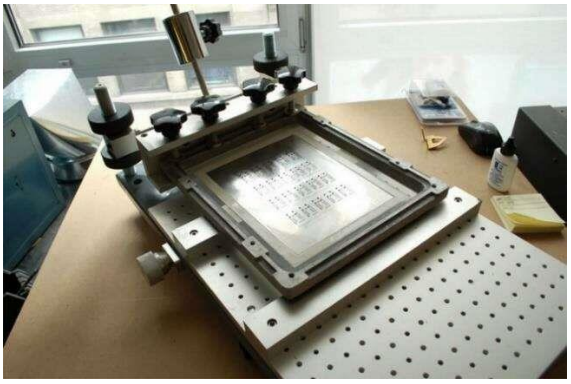


Fig. 2.1.6: A framed stencil bolted on a screen-printing machine

2.1.2 Parameters of Printing Process

The following figure lists the key parameters of an effective solder paste printing:

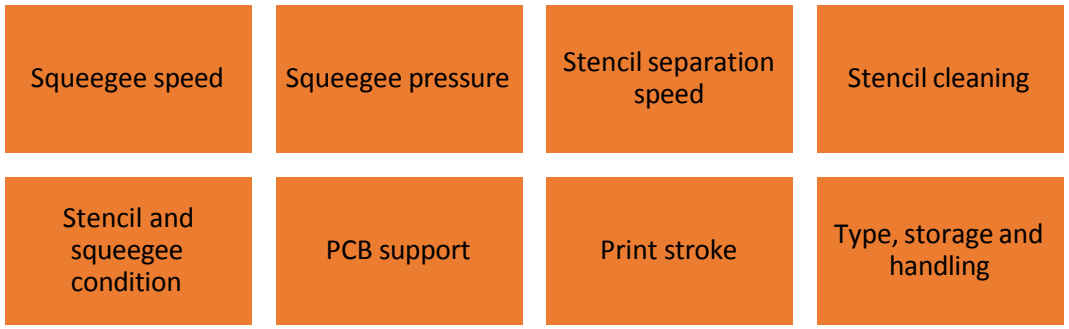


Fig. 2.1.7: Key parameters of an effective solder paste printing

Squeegee Speed

The available time for the solder paste to get rolled into the stencil apertures and then onto the PCB pads depends on the speed of the squeegee. Typically, squeegee speed is set at 25mm per second but this may vary on the basis of the aperture's size and the type of solder paste used.

Squeegee Pressure

Sufficient pressure is required to be applied along the length of the squeegee blade during the print cycle to achieve a clean wipe of the stencil. The following figure lists the effect of insufficient squeegee pressure on the PCB:

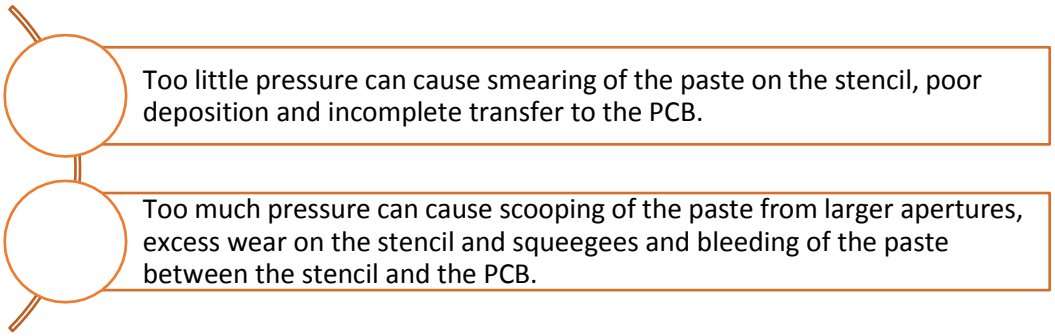


Fig. 2.1.8: Effect of insufficient squeegee pressure on the PCB

Typically, the pressure is set at 0.5Kg per 25mm of squeegee blade.

Stencil Separation Speed

It is the speed at which the PCB gets separated from the stencil after printing. The aperture size governs the speed. Typically, the speed of up to 3mm per second needs to be used. If separation is too fast, it will not allow the solder paste to be fully released from the apertures. Also, high speed will cause dog-ears, which is the formation of high edges around the deposits.

The following image shows dog-ears formation in solder paste printing:

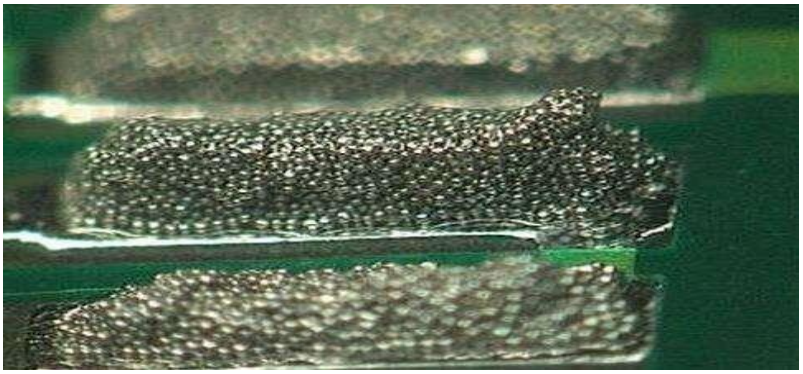


Fig. 2.1.9: Dog-ears formation in solder paste printing

Condition of Stencil and Squeegee

Squeegees and stencils need appropriate storage facilities and need to be maintained carefully. If any mechanical damage occurs to them it may cause undesired results. Before they are used, they need to be checked properly. After being used, they should be thoroughly cleaned to eliminate any solder paste residue. An automated cleaning system is ideally used to clean them. If any damage to the squeegees or stencils is detected, they should be promptly replaced. This is required to ensure that the process is reliable and repeatable.

PCB support

During the printing process, the PCB is required to be held flat against the stencil. It needs to be well supported and secured otherwise printing defects can occur such as smudging and improper paste deposit. The PCB supports that come with the printing machines generally permit a certain fixed height. These supports have the provision for programmable positions to ensure a consistent process. These adaptable PCB supports are available in different designs. These are useful for the double-sided assemblies and can mould themselves as per the PCB. The following image shows an adaptable PCB support in use:

Fig. 2.1.10: An adaptable PCB support in use

Print Stroke

The distance that is travelled by a squeegee across a stencil is known as a print stroke. The distance recommended for a stroke past the furthest aperture is at least 20mm. This distance is essential as it gives the required space to the paste to roll on its return stroke. The downward force that is generated due to the rolling of the solder paste bead propels the paste inside the apertures.

Type of Solder Paste, its Storage and Handling

The solder paste of correct type should be selected depending on the size of the aperture. The particle size within the solder paste affects the release from the apertures. The following table lists the available particle sizes:

Particle size in microns	Particle type
75-45	2
45-25	3
38-20	4
25-15	5
15-5	6

Table 2.1.1: Available particle sizes

There is a '5 ball rule' stating that at least 5 solder particles should span across the width of the smallest aperture. The following figure shows the 5-solder ball rule:

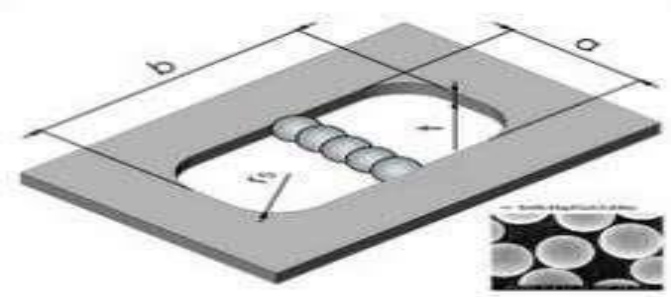


Fig. 2.1.11: 5 solder ball rule

Both types of solder paste, Tin-Lead and Lead-Free, need to be stored in a refrigerated place to maintain their shelf-life. But before using the paste, it must be brought to room temperature for at least eight hours for maintaining the quality. The paste should be mixed well manually or automatically for one to three minutes before being used. This needs to be done to achieve even distribution of the components throughout the paste. The following figure explains the expiry of solder paste:

Solder paste that has been in use for more than 8 hours should be disposed off.

Solder paste which has been in use for up to 4 hrs can be stored for up to 24 hours in a sealed container at room temperature before being re-used depending upon data sheet of solder paste used

Fig. 2.1.12: Expiry of solder paste

The working environment that includes relative humidity and ambient temperature affects the performance of the paste. A basic coalescence test may be performed to check the paste condition.

2.1.4 Stencil Cleaning Process

A regular cleaning of the stencil is a must. It can be done manually or automatically. Most of the automatic printing machines provide a system that can be set up in such a way that it cleans the stencil after a pre-defined number of prints. It does this by wiping with a lint-free material along with using a cleaning chemical such as IPA. The system carries out following two functions:

- Cleaning the underside of stencil in order to stop smudging
- Cleaning the apertures using vacuum in order to stop blockages

The following images show the defects that occur when the stencil is not cleaned:

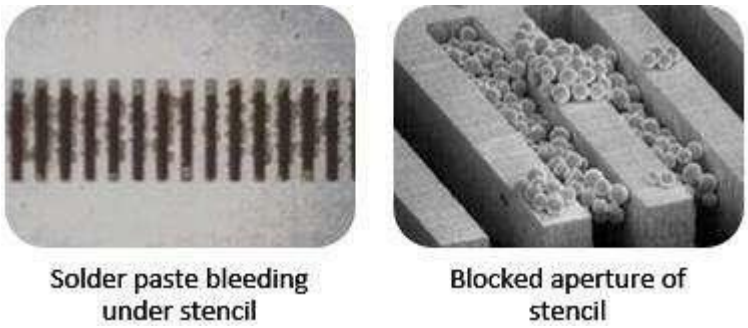


Fig. 2.1.13: Defects when the stencil is not cleaned

The following image shows the stencil cleaning rolls:

Fig. 2.1.14: Stencil cleaning rolls

Notes

UNIT 2.2: Pre-baking of Board

Unit Objectives

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

1. Analyse the need of baking process
2. Identify the oven requirements to perform baking
3. List the factors that affect the time and temperature required for effective baking

2.2.1 Need of Baking Process

Baking process may be essential for the removal of any residual moisture which may get absorbed into the PCB during the period between its fabrication completion and exposure to assembly soldering. Ideally, the PCBs should be dry packed by the manufacturers adhering to the printing board handling and storage guidelines (IPC-1601), where the moisture content is controlled as per the specifications. However, there may be chances that lead to increased moisture contents in the PCB once it is opened from the packaging for the screen-printing process. The increased moisture content in the PCB may lead to delamination of the PCB once it is put into the soldering process. The following image shows delamination and blistering defects:

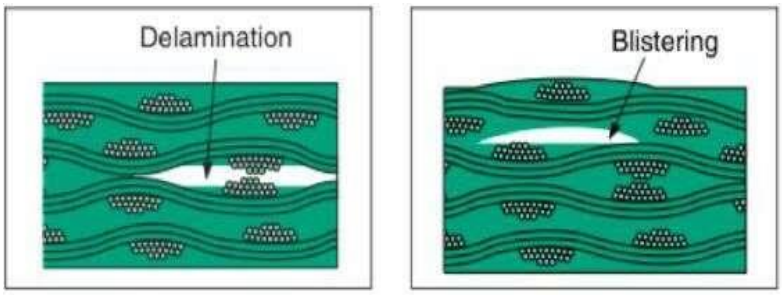


Fig. 2.2.1: Delamination and blistering defects

The moisture content can be checked with a humidity indicator card. The following image shows a humidity indicator card:

Fig. 2.2.2: Humidity indicator card

It is highly recommended that a printed board fabricator should control the moisture content of the PCB during the fabrication process before placing it in protective packaging. This is needed to avoid the baking process. The baking of board should be done only when it is required as excess baking reduces solderability. It also increases the cost as well as the cycle time.

Baking should be performed in a forced air recirculating oven, though effectiveness may be improved by reducing the relative humidity or vapour pressure in the oven, such as through baking in vacuum or nitrogen atmosphere. The oven that is used for baking, should not only be vented but also be able to maintain the required temperature along with the relative humidity (RH) as less than 5%. The oven should be free of contamination. Contaminants such as silicones can deposit on the surface of the board. Sufficient space should be maintained between the printed boards for heated air to circulate and remove the moisture.

The following figure lists the factors that affect the time and temperature required for effective baking:

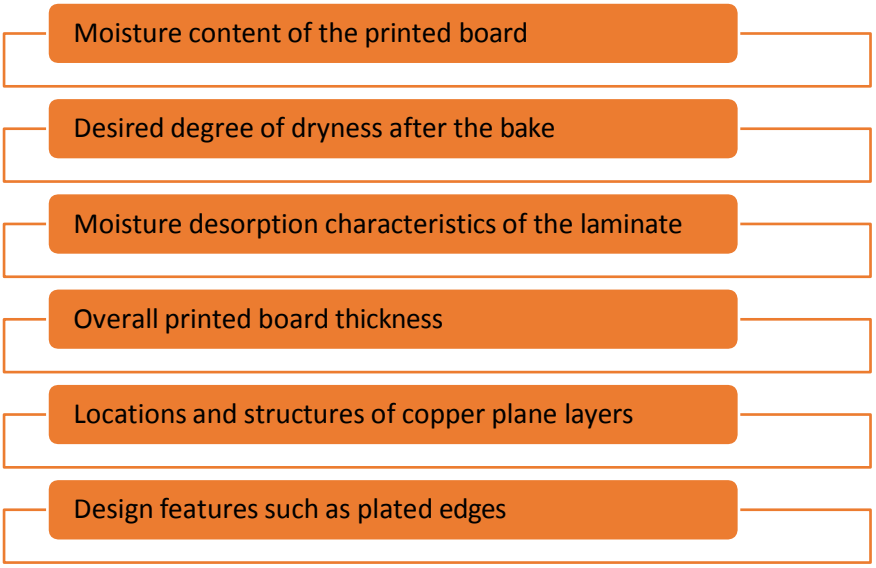


Fig. 2.2.3: Factors that affect the time and temperature required for effective baking

The following table shows the typical recommendations for oven settings:

Final Finish	Temperature	Time	Comments
Tin	105 – 125 °C	4-6 Hours	Higher temperature may reduce solderability
Silver	105 – 125 °C	4-6 Hours	Silver may tarnish, but solderability should not be affected
Nickel/Gold	105 – 125 °C	4-6 Hours	No issue with extended bake on Nickel/Gold finish
HASL/HAL	105 – 125 °C	4-6 Hours	Final surface thickness below 0.77 μm [30.0 μin] may turn into pure intermetallics and render the printed board unsolderable

Table 2.2.1: Typical recommendations for oven settings

If the boards are baked in stacks, the maximum recommended stack height is 25.4mm (1.0in) to ensure that heating is uniform throughout the stack. Stacks are typically baked for two hours at 105-120 ºC. The material should be cooled as fast as possible in a dry environment as hot material in a humid atmosphere will reabsorb moisture rapidly.

2.2.2 Solder Paste thawing

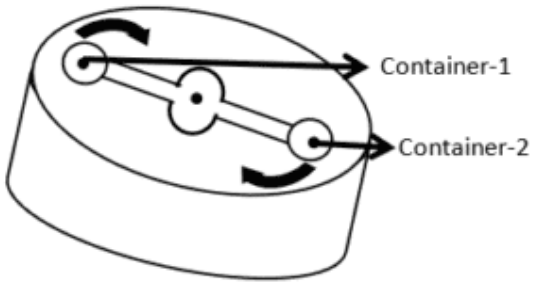
A printed circuit board (PCB) is a support framework for the traces used to transmit power and signals between different components. Additionally, PCB serves as a support structure for components with wetness on both sides.

Since some WIP PCBs must also be baked because they are already filled with components, as was already indicated, the baking equipment must be properly grounded to ensure that there are no risks for electrostatic discharge.

After baking, the PCBs go through a chilling process before being moved on to the solder paste printing step of production.

A mixture of solder balls of a particular size combined with a flux medium to create a homogeneous paste is known as solder paste. Solder paste needs to be stored at a temperature of 5°C to ensure uniformity. Additionally, the First in First out (FIFO) cycle must be followed when stocking solder paste.

Before using the solder paste printing machine, the solder paste needs to reach room temperature. To guarantee it starts reaching the shop floor ambient temperature, the solder paste is first removed from its colder storage and permitted to be kept in a cool spot.



A thawing apparatus is used to ensure that the solder paste is thawed. Two solder paste containers that can be left on the shop floor for a set amount of time depending on the cold storage temperature are put in the defrosting apparatus. After positioning the equipment, as illustrated in the Figure, it is turned on (Figure: Typical thawing the two containers and closing the transparent lid). The solder ball size in the paste and the temperature at which the solder paste was being stored in the cold storage determine the RPM and duration of the spindle's high-speed spinning.

The solder paste containers are removed from the rotating thawing apparatus and carefully examined to determine whether there are: 1) Any solid lumps. 2) Any bubbles that are present; 3) Any separation between the solder ball and flux that is still visible. The decision to either re-thaw the solder paste container or reject it is made based on the discovered problem.

According to: There are various kinds of thawing equipment available. 1) The maximum number of containers that can be accommodated by the machinery at one time. 2) The option of single versus variable speed. 3) Low upkeep options for machinery (since solder paste may come outside the container and get deposited on parts of the equipment).

Stencil

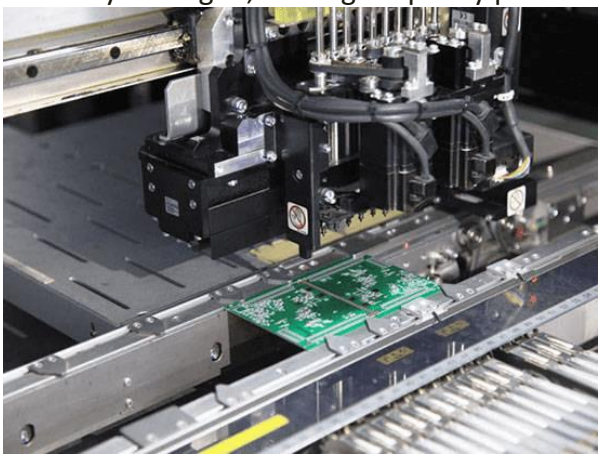
The manufacturer will create a stencil with openings or apertures that are the same size and shape as the surface mount pads on your design using the CAD data from your PCB design tools. Depending on the components to be soldered and the quantity of paste needed, these stencils can be constructed from a variety of materials and are frequently laser cut for precision. Materials that will smooth out the aperture openings and aid in the even application of the paste can be used to plate and coat the stencils. It usually takes 15 to 45 seconds per board to spread solder uniformly over the stencil and fill all of the perforations using a squeegee. To check the quality of the applied solder paste, the board is optically scanned when the printing process is finished. After cleaning the stencil, the printing procedure is then repeated for the following board.

The advantages of utilizing a solder paste stencil are as follows:

- Stencils guarantee that solder paste is applied uniformly to each SMD pad.
- Rather than taking into consideration one pad at a time, they enable the paste to be applied all at once to the entire board.
- They make sure that the solder paste is applied precisely and forms deposits that are the right size and shape on the substrate.
- Using solder paste stencils can make your work easier, quicker, and more accurate, which will cut down on the amount of time and effort needed to assemble PCBs.
- They promise printing with incredibly fine pitch accuracy.
- Even when printing designs on the board with an incredibly fine pitch, stencils can assist reduce flaws and errors.
- They provide exceptional accuracy in pad position.

2.2.2 SMT Temperature and Humidity

Controlling the atmosphere in the manufacturing is one of the most crucial steps in preventing PCB faults. Very expensive components, and perhaps entire assemblies, may be jeopardised if the humidity and temperature levels on the production floor are not correctly managed, leading to quality problems and needless expenses.



The location of the facility or even the kind of machinery being utilised to make the boards might have an impact on the environmental conditions on a manufacturing floor. Even in the most temperate parts of the world, manufacturers must monitor and manage the temperature and relative humidity on their floor.

Relative Humidity: Relative humidity (Rh), which is the ratio of the partial pressure of water vapour to the equilibrium vapour pressure of water at the same temperature, is used to assess humidity in a space. Rh is a measurement of the amount of water vapour in the air, to put it simply.

High Humidity: In a manufacturing setting, high humidity can lead to a number of major issues, including:

- Slumping: Too much water is absorbed by solder paste, which results in bridging during reflow.
- Solderballing (or "popcorning"): this occurs when solder paste absorbs too much water, which results in poor coalescence.
- Out-gassing: When too much water gets underneath surface mounts, particularly BGAs, it builds up pressure and causes out-gassing. Covers may occasionally be blown off.

Low Humidity: Solderpaste dries out because flux evaporates too quickly. In turn, this results in inadequate solder joint flaws and poor stencil release.

High Temperature: High temperatures cause the viscosity of solder paste to drop. This can lead to a variety of issues, chief among them paste smearing and slumping, which can also result in bridging and solderballing flaws like voiding. High temperatures may also cause the solder to oxidise more than usual, which could affect its solderability.

Low Temperature: Solder paste viscosity may increase at low temperatures. Due to the paste being too solid to print properly, this might cause printing errors including release and rolling as well as print voiding.

Acceptable Range & Conditions:
The opinions of experts on temperature ranges and Rh vary. While some advocate for a larger range (35–65%, 40–70%, 20–50%), others claim that anything above or below 60% Rh could lead to the aforementioned faults as well as lifecycle problems. Rh range, though, really comes down to personal opinion and experience—what works best for your items.

The same is true for temperature, albeit there is less disagreement among experts. The widespread view is that solder paste functions best between 68 and 78 degrees F, which is within the range of comfort for most people. However, it should be remembered that various solder pastes behave differently under certain circumstances. Allowing for some flexibility based on the product is always a smart idea.

Monitor and Control:
Some geographical areas, including those that are extremely humid or dry, might need a higher standard of environmental control. But some climate control strategies are constant regardless of where a factory situated.

- **Humidity sensors:** In addition to making a quality Rh sensor investment, it's essential to position sensors correctly for accuracy. Otherwise, unexpected changes in humidity and temperature could develop into significant, costly issues. Regular sensor inspection is also essential. Rh sensors frequently experience problems, especially in areas with high humidity.

- **Air conditioning/heating unit:** Make an investment in quality heating and cooling. The majority of the fight is this. Temperature-related faults need to be a secondary concern if the temperature can be successfully controlled. A dehumidifier is also essential, especially in areas with high humidity levels.

- **Nitrogen in ovens:** Unneeded oxidisation in the solder paste frequently results from excessive humidity. Nitrogen seems to slow down such oxidisation.

Moisture Sensitive Components:
- Another crucial factor is components that are susceptible to moisture. Depending on how delicate they are, moisture-sensitive components should stay outside of their packaging as little as possible in high humidity settings. But if the right humidity is kept, this shouldn't be a problem.

Notes

UNIT 2.3: Screen Printing Machines

Unit Objectives

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

1. Differentiate between the different types of screen-printing machines

2.3.1 Types of Screen-Printing Machines

There are 4 dimensions to consider for controlling the screen-printing process and component placements. They are X, Y, Z and Θ (Theta). Depending upon the automation required for adjustment of these variables, three types of screen printers are available.

Manual Screen-Printing Machine

All four parameters are adjusted manually. The following image shows different parts of a manual screen-printing machine:

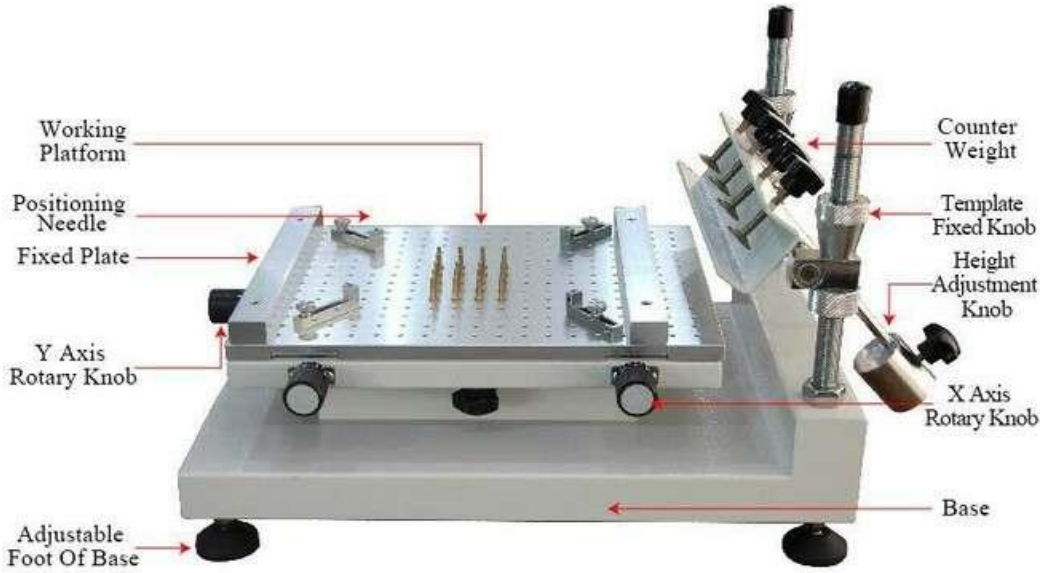


Fig. 2.3.1: Parts of a manual screen-printing machine

Semi-automatic Screen-Printing Machine

The following figure lists the features that are found in a typical semi-automatic stencil printer:

Auto open/close for board loading and unloading, reducing operator fatigue	Controlling of squeegee pressure	Controlling of movement and speed of the squeegee	Visual alignment/assist options to facilitate positioning

Fig. 2.3.2: Features of a typical semi-automatic stencil printer

The following image shows a semi-automatic screen-printing machine:

Fig. 2.3.3: A semi-automatic screen-printing machine

Automatic Screen-Printing Machine

The automatic systems may include auto fiducial alignment for the positioning of X, Y, Z and Θ and automatic board loading/unloading option. If the production requires 2,000 boards per day, more automation may be useful in terms of reduced labour costs, quality yield and more control over the production process. The following image shows an automatic screen-printing machine:

Fig. 2.3.4: An automatic screen-printing machine

The following table lists the parameters of an automatic screen-printing machine:

Printing Speed Round	4000pcs / hr Oval 5000pcs / hr
Printing Size	Round Diameter 20-100mm Length 25-270mm
Printing Length	Oval Width 25-120mm Length 25-270mm
Compressed Air	0.6MPa
Lp Gas	0.15MPa
Dimension Unit	1907×1000×1500mm
Power Unit	380VAC, 3-Phase, Unit 6.5KVA
Test Table	220VAC, 1-Phase, 0.2KVA
Packing Size	206*123*192CM
Gross Weight	800KG
Net Weight	700KG

Table 2.3.1: Parameters of an automatic screen-printing machine

2.3.2 Setting Up of Screen-Printing Machine

The following table lists the standard value of different parameters of a screen-printing machine:

Squeegee	Speed	6inch/sec(150mm/sec)
	Pressure	0.5kg, 20mm/sec
	Angle	45-75
Solder Paste	Thickness	145micrometre
	Viscosity	300,000-1600,00 centipoise
	Ratio	Sn=63% Pb=37% For Lead free solder paste; Sn=96.50% Ag=3% Cu=0.5%
Stencil	Type	According to job
	Thickness	0.02-0.16 inch
Environment	Temp.	22-25°C
	Humidity	30-60%

Table 2.3.2: Standard value of different parameters of a screen-printing machine

The following image shows the user interface of a screen-printing machine:

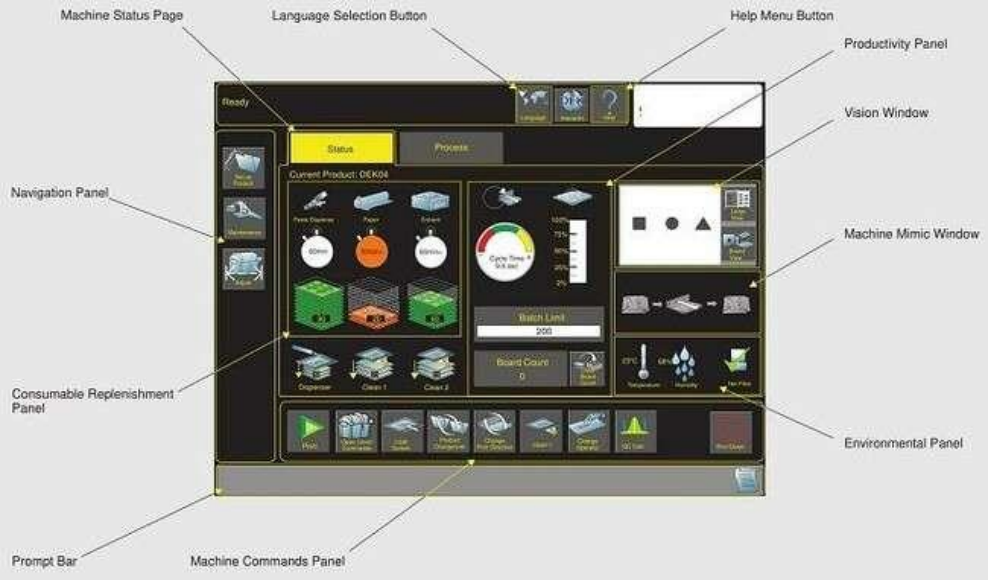


Fig. 2.3.5: User interface of a screen-printing machine

The following figure shows different operations for safety of a screen-printing machine:

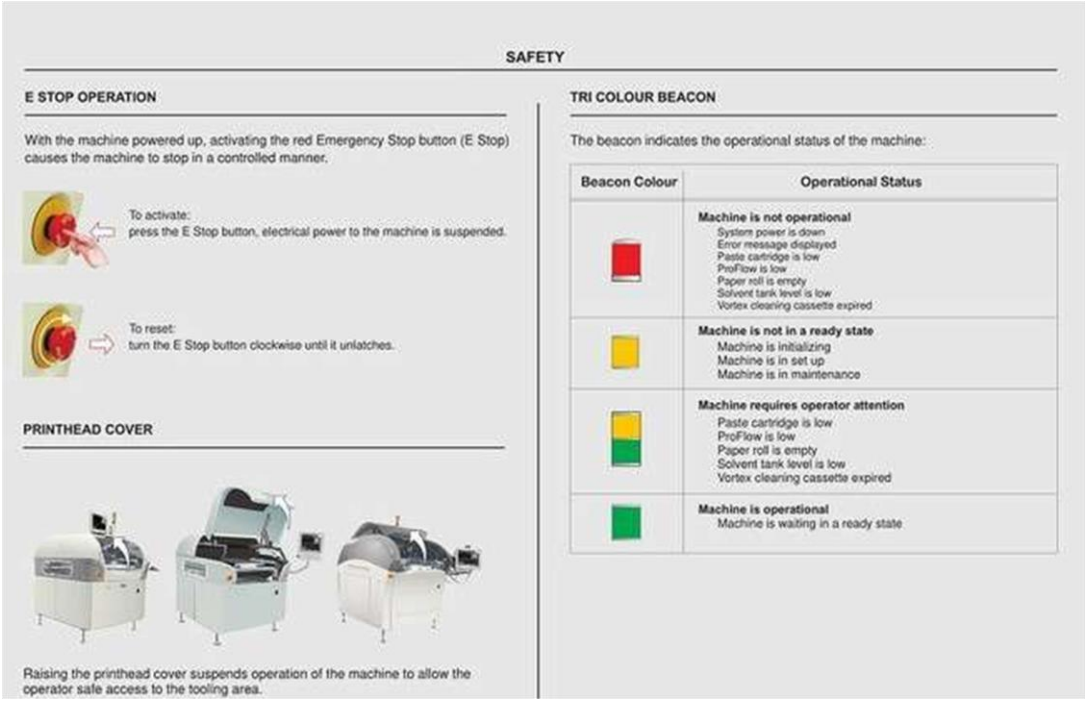


Fig. 2.3.6: Different operations for safety of a screen-printing machine

Notes

UNIT 2.4: Inspection of Solder Paste Printing

Unit Objectives

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

1. List the key features of equipment used for identifying solder paste printing defects
2. Differentiate between the types of inspection available
3. Analyse the causes of some possible solder paste print inspection results
4. List the solder paste printing defects and their criteria

2.4.1 Identification of Solder Paste Printing Defects

Solder paste inspection (SPI) equipment is used for monitoring and controlling one of the most critical steps that affects the quality of finished PCBs.

Solder paste deposition is a significant stage in board assembly operations. In modern electronics manufacturing, it is important to prevent costly repairs through improved process control.

According to research, printing errors are the cause of more than 60% of the end of line defects. Cutting off these defects before they take place, reduces the cost of rework, provides yield improvement instantly and accelerates the return on investment.

The following image shows an SPI equipment:

Fig. 2.4.1: An SPI equipment

Key Features

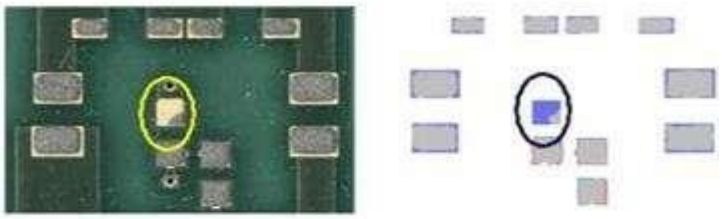
5D post-print solder paste inspection systems include the patented new sensor technology and also combine the 3D and 2D image processing methodologies simultaneously. These systems deliver defect detection much beyond what was possible earlier.

Solder paste defect detection that is done using the combination of 3D and 2D technologies provides:

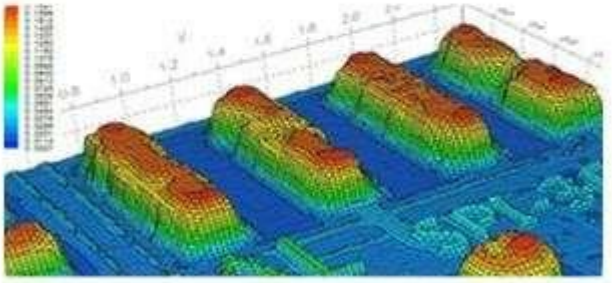
- Topographical 3D zero referencing
- Shadow free measurement with both accuracy and precision

Inspection (2D/3D)

Automatic inspection can be used to verify the process and check the accuracy of solder paste deposits. The following figure shows the types of inspection available:



2D Inspection: Checks the area of the paste deposit



3D Inspection: Checks the volume of the paste deposit

Fig. 2.4.2: Types of inspection available

The following image shows some possible solder paste print inspection results:

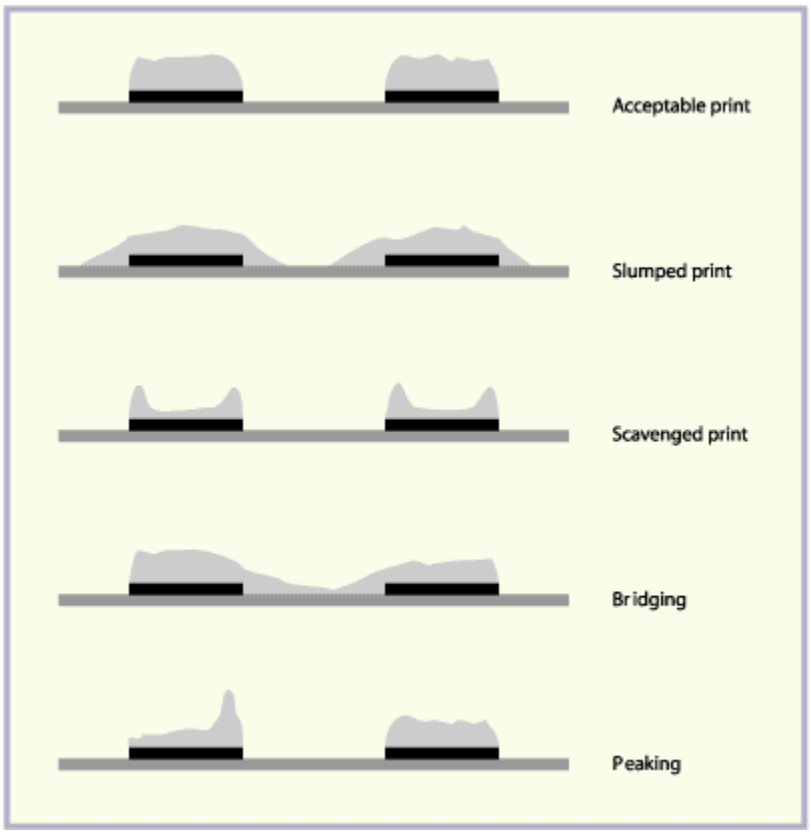


Fig. 2.4.3: Possible solder paste print inspection results

The slumped print usually occurs in a process, run at temperatures higher than the recommended level. The scavenged print takes place if squeegee pressure is too high and scooping occurs. Bridging can be caused due to improper board support or poor stencil condition and cleanliness. Peaking is usually observed if the separation speed of the stencil is too high.

The following figure lists other solder paste printing defects and their criteria in a table:

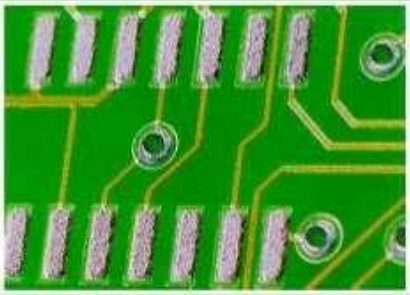
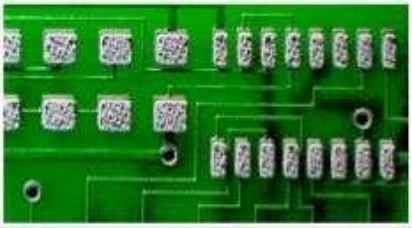
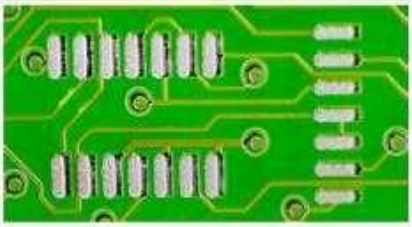
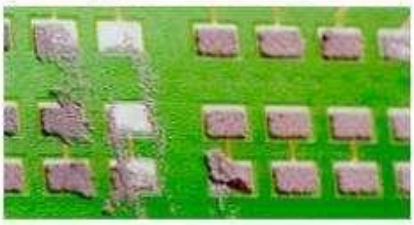
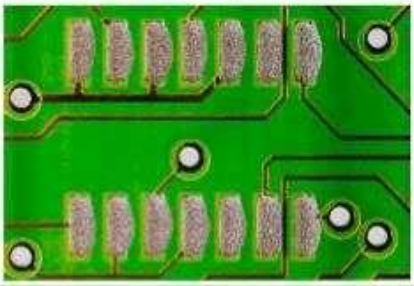
Solder paste printing shifted in x/y direction	Criteria
	**Preferred**
	**Acceptable** For Components like 0805, 1206 : Displacement ≤ 0.2 mm. For multi-lead components like array resistor with a pitch ≤ 0.8 mm : Displacement ≤ 0.1 mm.
	**Rejected** For Components like 0805, 1206 : Displacement > 0.2 mm. For multi-lead components like array resistor with a pitch ≤ 0.8 mm : Displacement >0.1 mm
	**Rejected** Contamination of paste, too little paste and no paste
	**Rejected** Paste outflow more than 0.2mm outside the solder land caused by too much solder paste or too great a placing force, (for multi-lead components with pitch ≤ 0.8 mm : outflow more than 0.1mm)

Fig. 2.4.4: Other solder paste printing defects and their criteria

Exercise

1. List the key parameters of an effective solder paste printing.

2. What do you mean by pre-baking of the board?

Notes

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3. Component Placement on Telecom Boards

Unit 3.1 – Components Pick and Place Operations

Unit 3.2 – Pick and Place Operations

Unit 3.3 – Loading of Component

TEL/N2504

Key Learning Outcomes

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

1. List the components of pick and place process
2. Define the terms used in pick and place operations
3. Identify different parts of pick and place machine
4. Demonstrate starting up and shutting down of pick and place machine
5. List the different types of feeders
6. Demonstrate the steps to use tape feeders
7. Recognise the use of trays to load chip components
8. Identify the use of chip shooter and fine pitch placer

UNIT 3.1: Components Pick and Place Operations

Unit Objectives

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

1. List the components of pick and place process
2. Define the terms used in pick and place operations

3.1.1 Component Pick and Place Process

Component placement is the heart of electronics manufacturing process that involves picking the electrical components from the feeder rolls or trays and placing them precisely on printed circuit boards (PCBs). This is done to build electrical connections between functional components and the circuitry in the PCBs through the leads-pads. The leads of the components must be immersed accurately in the solder paste deposited on the pads of the PCB. Component placement is followed by soldering.

To expedite the process, the pick and place machine uses nozzles which pick and hold the components using vacuum. They adjust the orientation of the components before placing them on the PCB precisely at defined coordinates. In mostly machines, the components are visually inspected using a camera to confirm whether the correct component has been picked up by the nozzle head. The components may temporarily be adhered to the PCB by applying a small blob of glue especially made for the SMT process.

The coordinates system is used to mark the position of components on the board. The following figure lists the movement of different axes for positioning of the components:

- The X axis moves right and left where right represents positive.
- The Y axis moves forward and back where forward represents positive.
- The Z axis moves up and down where up represents positive.
- The C or rotation axis rotates clockwise and counter-clockwise where counter-clockwise represents positive.

Fig. 3.1.1: Movement of different axes for positioning of the components

The following images show top view and side view of the positioning of the components:

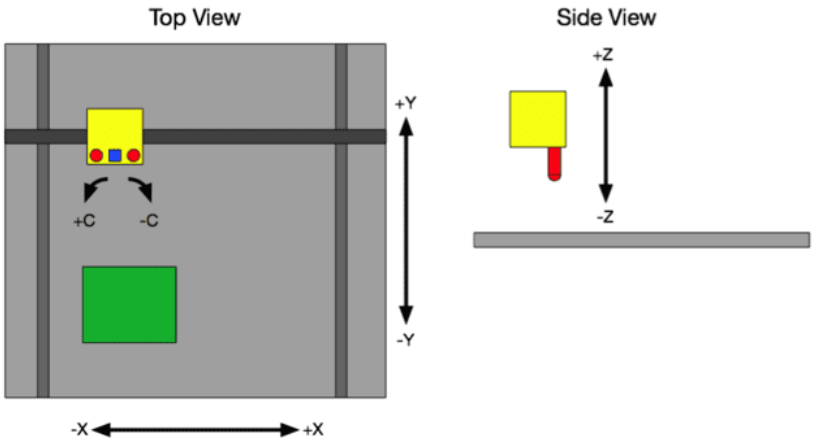


Fig. 3.1.2: Top view and side view of the positioning of the components

The units for the axes are set in the Graphic User Interface (GUI). The default unit for X, Y and Z axes is millimeters and for C axis is degree.

3.1.2 Common Terms Used in Pick and Place Operations

Board:

A board is a physical version of a PCB. Every new version of a PCB is a new board. A board includes placements that inform the software where to place parts.

Fiducial:

A fiducial is a small mark on the PCB which helps the machine to automatically locate the PCB with great accuracy. Typically, fiducials are small round pads that have a large keep out area with no solder paste applied. The following images show fiducials on a PCB:

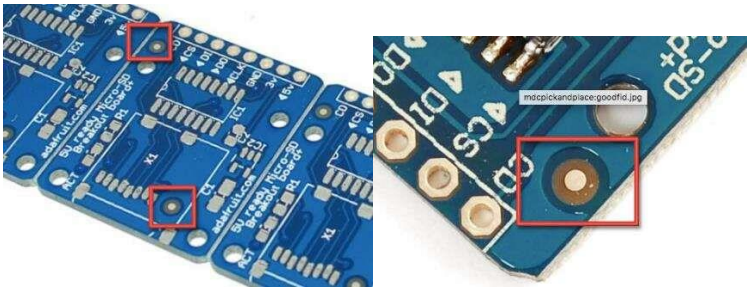


Fig. 3.1.3: Fiducials on a PCB

The following images show fiducial alignments:

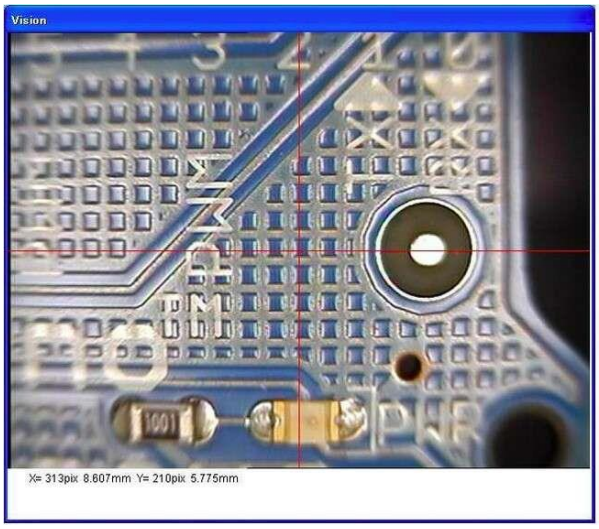


Fig. 3.1.4a: Before fiducial alignment

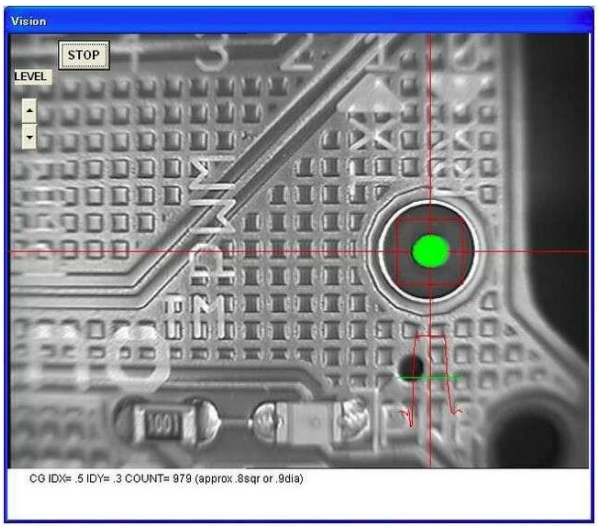
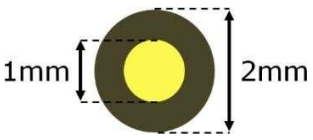


Fig. 3.1.4b: After fiducial alignment

The customers are recommended three fiducials. If three fiducials cannot be fitted, then two fiducials also suffice; however presence of fiducials must be in diagonally opposite position but using three fiducials is the best as each one serves its own purpose. The following figures shows the measurement of a fiducial and the three types of fiducials on a PCB:



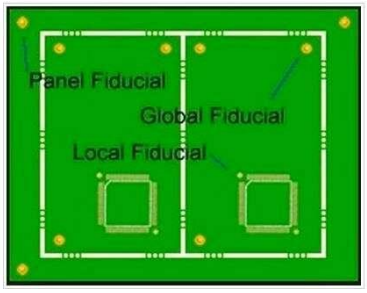


Fig. 3.1.5: Measurement of a fiducial and three types of fiducials

The following figure shows the purpose of the three fiducials:

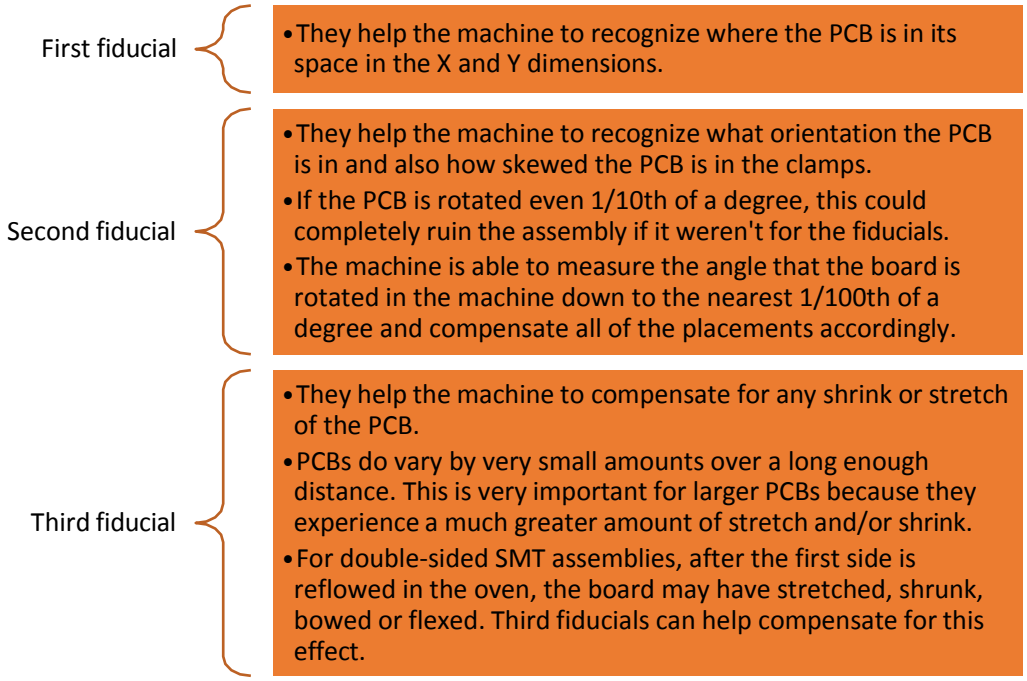


Fig. 3.1.6: Purpose of three fiducials

Part

A part is a specific element for placement of components on a board. It is similar to the manufacturer's part number. Two parts with different values represents different parts. For example, a 22k 0603 resistor and a 10k 0603 resistor are different parts. Each part is assigned a package.

Package

A package describes physical attributes of the part such as length, width and its footprint. Parts with different values may have the same package. 0603 capacitor, 0603 resistor, SOIC-8 and TQFP-32 are some of the examples of packages.

Placement

A placement is a location on the PCB where a part should be placed. It is same as the X and Y coordinates where the parts are placed at the time of designing the PCB. Each placement includes an X and Y coordinate relative to the origin on the board and a part assignment telling the software about the part that goes on that placement.

The following figure shows criteria of component placements:

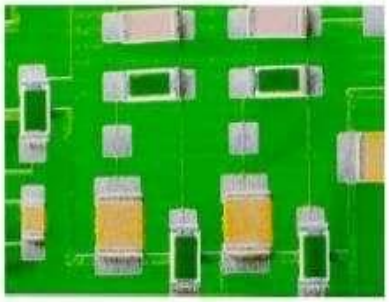
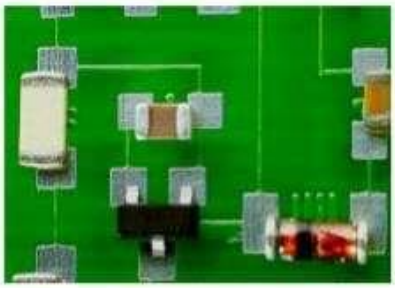
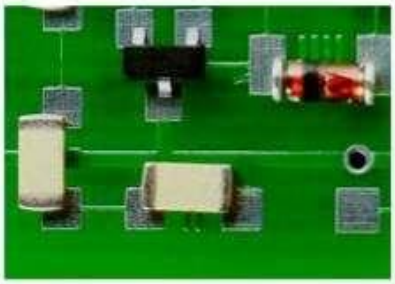
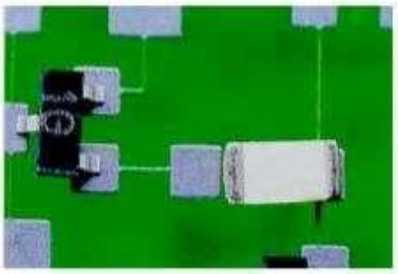
Components shifted in x/y direction	Criteria
	**Preferred**
	**Acceptable** Half or more of the width of the component is situated on the solder land. Only acceptable when the conductor is covered with insulating lacquer.
	**Rework** Less than half the width of the component is situated on the solder land.
	**Rework** The metallisation must at least be partly positioned on the solder land.

Fig. 3.1.7: Criteria of component placements

Job

A job is a file that contains a list of boards for the machine to process in a single run. A job may comprise any type of mixture of different numbers of boards, including multiples of the same board.

Footprint

A footprint defines the shapes and numbers of the pads on the part.

The following figure lists the parameters determining the footprint details:

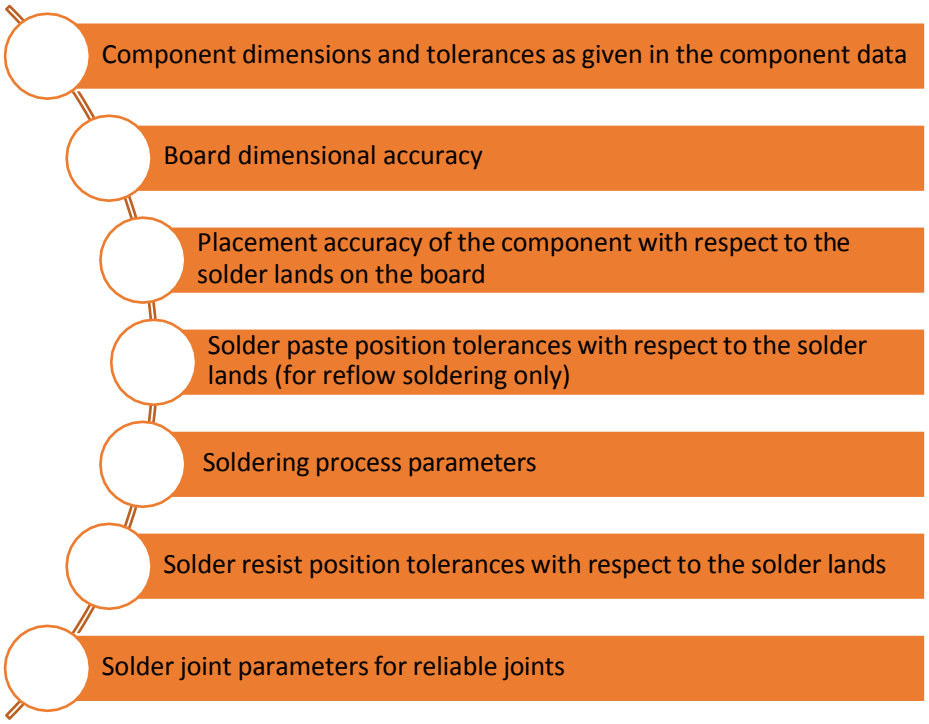


Fig. 3.1.8: Parameters determining the footprint details

The following figure shows the footprint details:

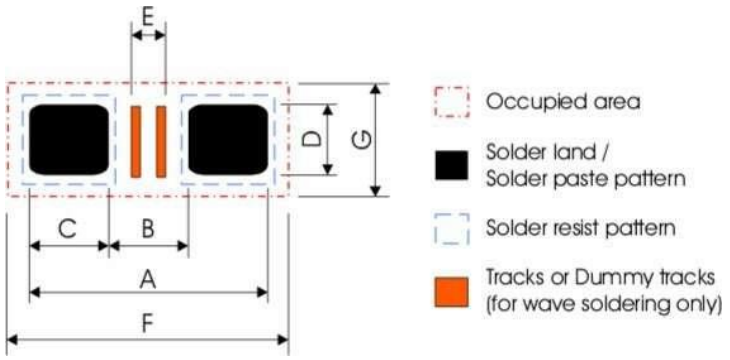


Fig. 3.1.9: Footprint details

The following figure lists the footprint design details for an array resistor:

■ Footprint design for Array Resistor :

Type	0603*4	0402*4	0402*2
Symbol / Item	WA06X / WA06T	WA04X	WA04Y, WA04P
A	2.85 +0.10/-0.05	1.80 +0.15/-0.05	1.20 ± 0.05
B	0.45 ± 0.05	0.30 ± 0.05	0.40 +0/-0.05
D	0.80 ± 0.10	0.50 ± 0.1	0.50 ± 0.05
P	0.80	0.50	0.65
F	3.10 ± 0.30	2.00 +0.40/-0.20	1.50 +0.20/-0.10

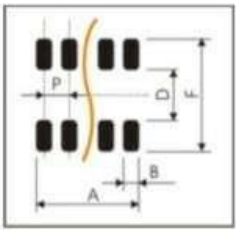


Fig. 3.1.10: Footprint design details for array resistor

The following figure lists the footprint design details for a discrete CHIP-R:

■ Footprint design for discrete CHIP-R

◆ Reflow Soldering

SIZE	Footprint dimensions in mm							Processing remarks	Placement Accuracy
	A	B	C	D	E	F	G		
0201	0.75	0.30	0.30	0.30	0.20	1.10	0.50	IR reflow soldering	± 0.05
0402	1.50	0.50	0.50	0.60	0.10	1.90	1.00	IR or hot plate soldering	± 0.15
0603	2.10	0.90	0.60	0.90	0.50	2.35	1.45		± 0.25
0805	2.60	1.20	0.70	1.30	0.75	2.85	1.90		± 0.25
1206	3.80	2.00	0.90	1.60	1.60	4.05	2.25		± 0.25
1218	3.80	2.00	0.90	4.80	1.40	4.20	5.50		± 0.25
2010	5.60	3.80	0.90	2.80	3.40	5.85	3.15		± 0.25
2512	7.00	3.80	1.60	3.50	3.40	7.25	3.85		± 0.25

◆ Wave Soldering

SIZE	Footprint dimensions in mm							Proposed number & Dimensions of dummy tracks	Placement Accuracy
	A	B	C	D	E	F	G		
0603	2.70	0.90	0.90	0.80	0.15	3.40	1.90	1x (0.15x0.80)	± 0.25
0805	3.40	1.30	1.05	1.30	0.20	4.30	2.70	1x (0.20x1.30)	± 0.25
1206	4.80	2.30	1.25	1.70	1.25	5.90	3.20	3x (0.25x1.70)	± 0.25
1218	4.80	2.30	1.25	4.80	1.30	5.90	5.60	3x (0.25x4.80)	± 0.25
2010	6.30	3.50	1.40	2.50	3.00	7.00	3.60	3x (0.75x2.50)	± 0.25
2512	8.50	4.50	2.00	3.20	3.00	9.00	4.30	3x (1.00x3.20)	± 0.25

Fig. 3.1.11: Footprint design details for discrete CHIP-R

The following figure lists the footprint design details for a discrete MLCC:

■ Footprint design for discrete MLCC :

◆ Reflow Soldering

SIZE	Footprint dimensions in mm							Processing remarks	Placement Accuracy
	A	B	C	D	E	F	G		
0402	1.50	0.50	0.50	0.50	0.10	1.75	0.95	IR or hot plate soldering	± 0.15
0508	2.50	0.50	1.00	2.00	0.15	2.90	2.40		± 0.20
0603	2.30	0.70	0.80	0.80	0.20	2.55	1.40		± 0.25
0612	2.80	0.80	1.00	3.20	0.20	3.08	3.85		± 0.25
0805	2.80	1.00	0.90	1.30	0.40	3.08	1.85		± 0.25
1206	4.00	2.20	0.90	1.60	1.60	4.25	2.25		± 0.25
1210	4.00	2.20	0.90	2.50	1.60	4.25	3.15		± 0.25
1808	5.40	3.30	1.05	2.30	2.70	5.80	2.90		± 0.25
1812	5.30	3.50	0.90	3.80	3.00	5.55	4.05		± 0.25
2220	6.50	4.70	0.90	5.60	4.20	6.75	5.85		± 0.25

◆ Wave Soldering

SIZE	Footprint dimensions in mm							Proposed number & Dimensions of dummy tracks	Placement Accuracy
	A	B	C	D	E	F	G		
0603	2.40	1.00	0.70	0.80	0.20	3.10	1.90	1x (0.20x0.80)	± 0.10
0805	3.20	1.40	0.90	1.30	0.36	4.10	2.50	1x (0.30x1.30)	± 0.15
1206	4.80	2.30	1.25	1.70	1.25	5.90	3.20	3x (0.25x1.70)	± 0.25
1210	5.30	2.30	1.50	2.60	1.25	6.30	4.20	3x (0.25x2.60)	± 0.25

Fig. 3.1.12: Footprint design details for discrete MLCC

Reticle

A reticle is a crosshair, or other shape, that is overlaid on the camera window. It helps to see the centre of an image. Rulers or arbitrary shapes can be displayed by the reticles in any physical size. The following figure shows a reticle:

Fig. 3.1.13: Reticle

Driver:

It is the part of software that converts GUI's commands into machine understandable commands. Many machines use geometric code or G-code.

G-code

It is a language that people use to instruct the computerised machine tools on how to make something. G-code instructions which are provided to a machine controller define the "how". The controller is basically the industrial computer which tells the motors where and how fast to move and what path to follow. The following figure lists the letters used in G-code:

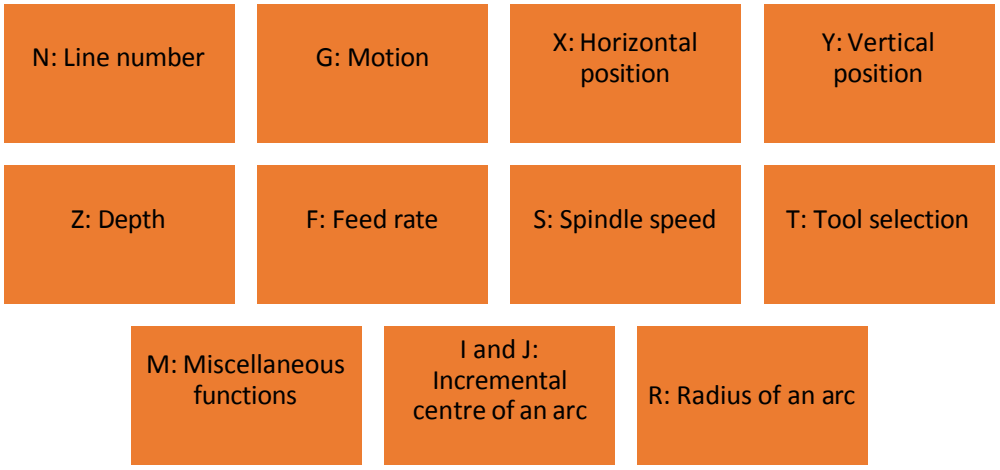


Fig. 3.1.14: Letters used in G-code

Alpha numeric codes are used for programming as they are a simple way to do the following:

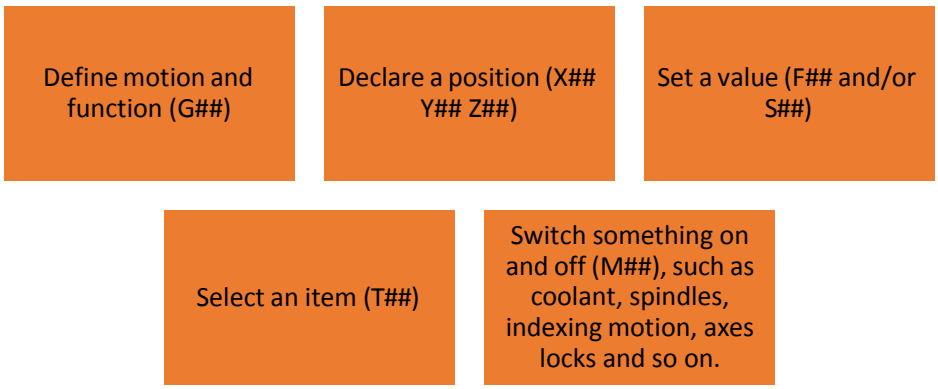


Fig. 3.1.15: Use of alphanumeric code in programming

The following figure shows an example of G-code:

G01 X1 Y1 F20 T01 M03 S500 would generally indicate:	
A linear feed move (G01) to the given XY position at feed rate of 20.	It is using Tool 1 and the spindle speed is 500.

Fig. 3.1.16: An example of G-code

The functions will be different from machine to the other. Hence, to find out what m-code means, the instruction manual of the machine will need to be referred.

Everything a machine can do is based on three basic types of motions. The following figure lists the types of motions:

Rapid move:	Feed move:	Circular move:
A linear move to an XYZ position as fast as possible	A linear move to an XYZ position at a defined feed rate	A circular move at a defined feed rate

Fig. 3.1.17: Types of motions

All G-codes instruct the machine which variation of the basic motions to execute and the way to do it. X and Y represent the Cartesian coordinates for the horizontal and vertical positions, whereas Z indicates the depth of the machine. The alpha numerals act as per the motion/function command (G) to declare the position of the machine.

S determines the spindle speed while F determines the feed rate (for feed moves or circular moves). T is used for selecting a tool. Other alpha numerals might include I, J, and R and are for arc centres and radii.

Machine Code (M-code)

M-Code relates to functions other than positioning such as speed and tool change.

The following figure lists some M-code instructions:

M00: Program stop	M01: Optional program stop	M02: End of program	M03: Spindle on clockwise
M04: Spindle on counter clockwise	M05: Spindle stop	M06: Tool change	M08: Flood coolant on
M09: Flood coolant off	M30: End of program/return to start	M41: Spindle low gear range	M42: Spindle high gear range

Fig. 3.1.18: Some M-code instructions

Bottom Vision:

Bottom vision refers to both an upwards facing camera and the process of using computer vision to automatically inspect parts before placing them. This inspection allows the SMT machine to place the part with greater accuracy than what would be achieved by going from feeder to placement directly.

The following image shows the bottom vision of a pick and place machine:

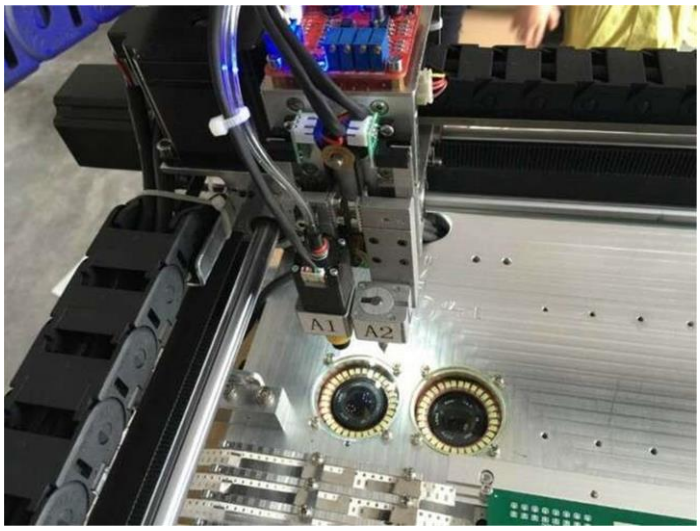


Fig. 3.1.19: Bottom vision of a pick and place machine

Top Vision

Top vision refers to the camera, facing downwards, which is mounted on the head. It is used for identifying the fiducials and for enabling computer vision on the vision assisted feeders.

Head

The head of the machine carries nozzles and often a top vision camera. It can move in both X and Y direction.

The following image shows the head of a machine:

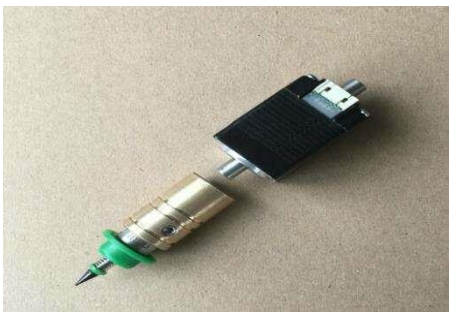


Fig. 3.1.20: Head of a machine

Nozzle:

A nozzle is a component that picks up the parts after it is lowered down. It contains a nozzle tip that touches the part that is being picked up. A machine can have multiple nozzles.

The following image shows different types of nozzles:

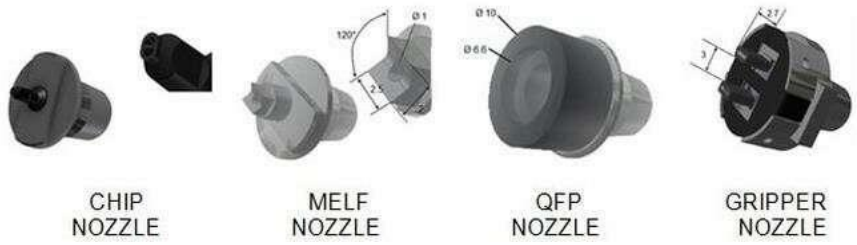


Fig. 3.1.21: Different types of nozzles

Nozzle Tip:

A nozzle tip is mounted on a nozzle. Multiple nozzle tips can be assigned to a nozzle. Generally, the tips are determined by the size of the part they are required to pick up. Many SMT machines can change nozzle tips automatically in order to pick up different parts.

Notes

UNIT 3.2: Pick and Place Operations

Unit Objectives

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

1. Identify different parts of pick and place machine
2. Demonstrate starting up of pick and place machine
3. Demonstrate how to shut down pick and place machine

3.2.1 Specifications of Pick and Place Machine

The following figure lists some specifications of a pick and place machine:

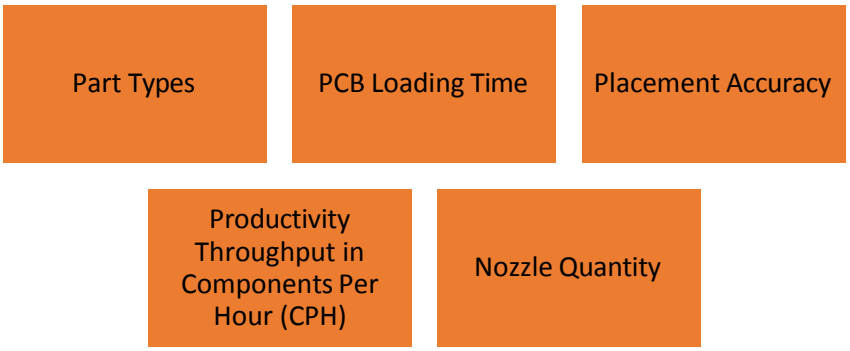


Fig. 3.2.1: Specifications of a pick and place machine

3.2.2 SMT Pick and Place Machine

The following figures show the parts of a pick and place machine:

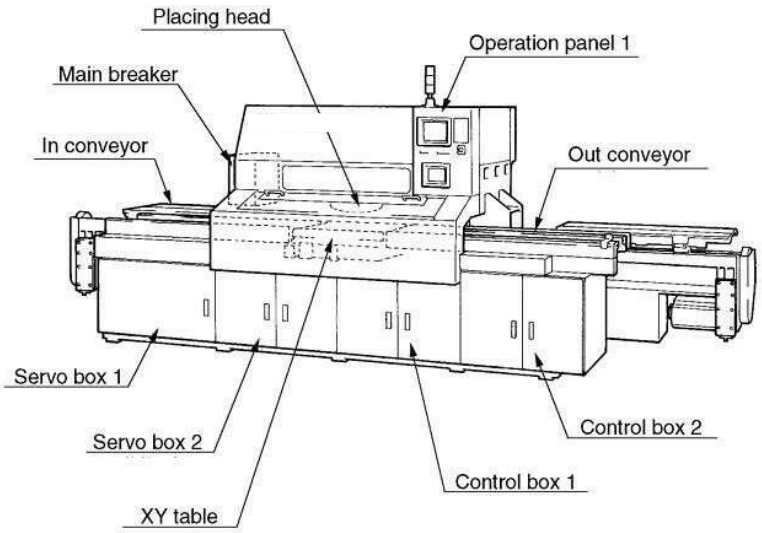


Fig. 3.2.2 (a): Parts of a pick and place machine

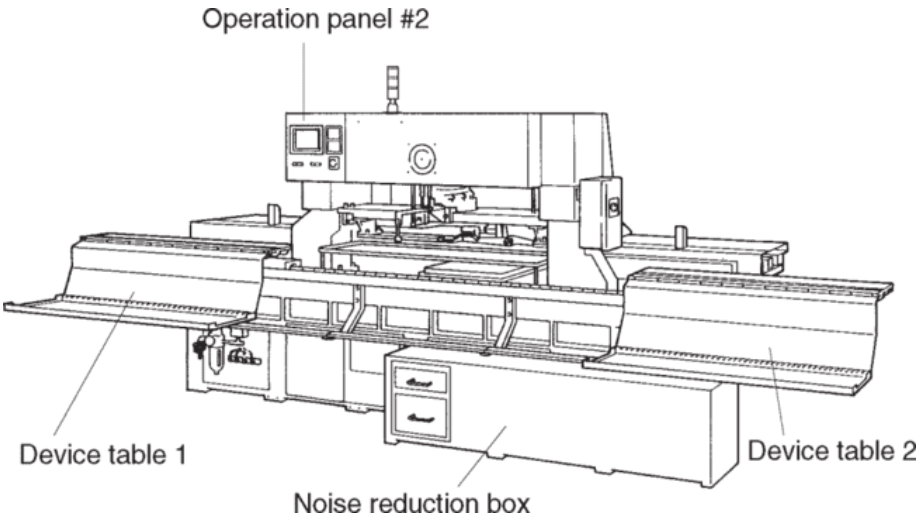


Fig. 3.2.2 (b): Parts of a pick and place machine

The following figure shows the control keys of a pick and place machine:

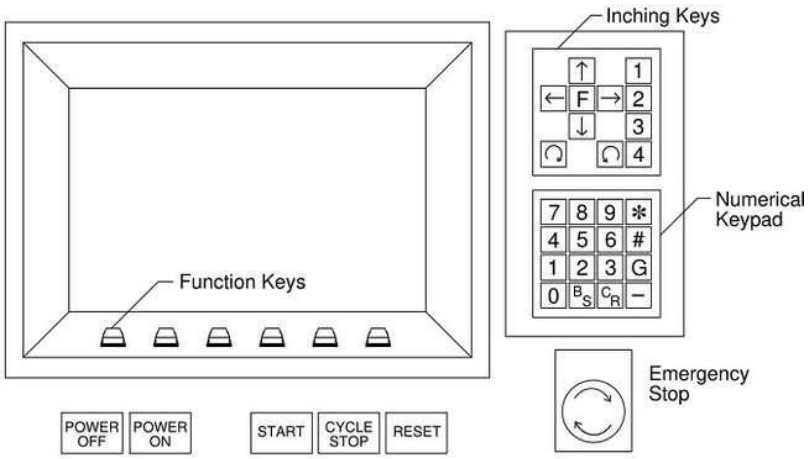


Fig. 3.2.3: Control keys of a pick and place machine

Function Keys

The function keys (F1 to F6) are pressed to select commands. Each function key corresponds to a command in the function key menu section of the MACHINE display. To execute a command, the corresponding function key is pressed.

Inching Keys

The inching keys are used to select the inching axes and to carry out inching along the selected axes.

Arrow Keys

The arrow keys are used to perform the inching operation. Some arrow keys are invalid when certain inching axes are selected.

Click/Scan the QR Code to know about PCB pick and place machine

Inching Axis Selection Keys ([1] to [4])

These keys are used to select an axis for inching.

Rapid Inching Key ([F])

This key and an inching key are pressed simultaneously to inch the axis rapidly. Inching can be carried out at any time except during machine operation or Proper data measurement. However, it is not possible to inch all of the axes at the same time. Only those axes which are currently selected by the inching axis selection keys can be inched.

Numerical Input Keys

These keys are used to input numerical values. The following figure shows the numeric input keys:

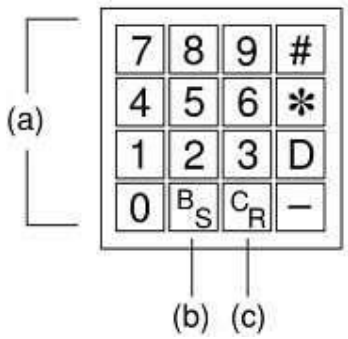


Fig. 3.2.4: Numeric input keys

The keys in the above image are as follows:

1. **Input keys (0 - 9, *, #, D, –):** The numerical keys are used to input numerical values such as camera threshold levels or I.D. codes.
2. **Backspace key (BS):** When inputting numerical values, this key is used to delete previously input values. Press this key once to move the cursor backwards by a single space.
3. **Carriage return key (CR):** This key is used to complete the entry of a numerical value. It may also be pressed to take the machine out of numerical input mode.

Buttons

The machine is equipped with several pushbutton switches. The buttons are as follows:

1. Front Panel

The following figure shows the buttons on the front panel of a pick and place machine:

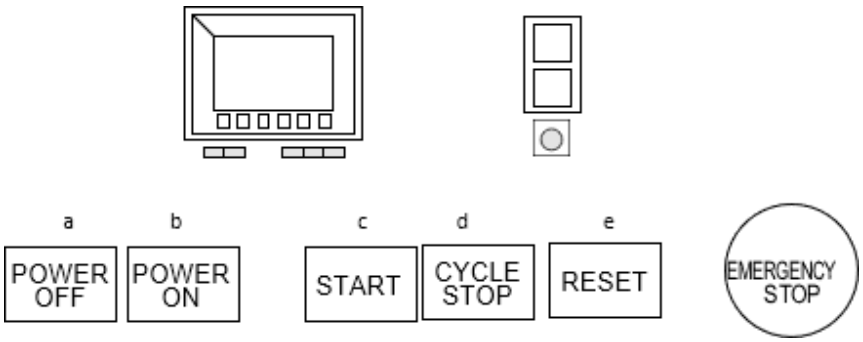


Fig. 3.2.5: Buttons on the front panel of a pick and place machine

The description of the buttons is as follows:

1. **[POWER OFF] button:** This button, when pressed after the [EMERGENCY STOP] button is pressed, turns off the power. Pressing this button alone does not turn off the power.
2. **[POWER ON] button:** This button turns on the machine. When the machine circuit breaker is turned on, this button is pressed to turn on the machine's power supply.
3. **[START] button:** This button starts the machine operation. It is pressed to start automatic operation and zero setting when the message 'Start SW' begins to blink in the second display area.
4. **[CYCLE STOP] button:** This button is for stop operation. It is pressed during automatic operation to cancel the automatic operation mode at the end of the current sequence and to return the machine to the [START] button wait mode.
5. **[RESET] button:** This button is used to reset an alarm which has occurred. When an alarm occurs, an error message is displayed and this button begins to flash. It needs to be pressed to clear the alarm.
6. **[EMERGENCY STOP] button:** This button is used to stop the machine instantly. When it is pressed, the machine's 200 V power supply is turned off. In addition, the button locks down when it is pressed. It needs to be turned in the clockwise direction of the arrow to get released.

2. Rear Operation Panel

The following figure shows the buttons on the front panel:

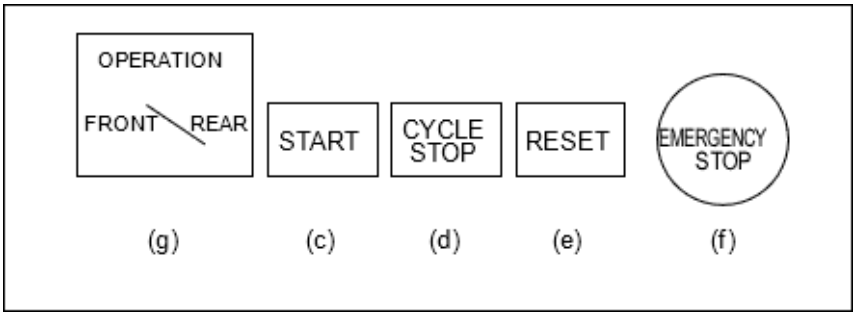


Fig. 3.2.6: Buttons on the rear panel

The description of the buttons is as follows:

1. **[POWER OFF] button:** This button, when pressed after the [EMERGENCY STOP] button is pressed, turns the power off.
2. **[POWER ON] button:** This button turns on the machine. When the machine circuit breaker is turned on, this button is pressed to turn on the machine's power supply.
3. **[START] button:** This button starts the machine operation. It is pressed to start automatic operation and zero setting when the message "Start SW" begins to blink in the second display area.
4. **[CYCLE STOP] button:** This button is used to stop operation. It is pressed during automatic operation to cancel the automatic operation mode at the end of the current sequence and to return the machine to the [START] button wait mode.
5. **[RESET] button:** This button is used to reset alarms. When an alarm occurs, an error message is displayed and this button begins to flash. It needs to be pressed to clear the alarm.
6. **[EMERGENCY STOP] button:** This button is used to stop the machine instantly. When it is pressed, the machine's 200 V power supply is turned off. In addition, the button locks down when it is pressed. It needs to be turned in the clockwise direction of the arrow to get released.
7. **Operation panel selection switch:** This selector switch is used to switch from the front operation panel to the rear operation panel. When this switch is set to a certain panel, the other panel cannot be used.

   It is to be noted that the [EMERGENCY STOP] and [CYCLE STOP] buttons on both panels are always operational.
8. **Inching keys:** It is possible to inch the X, D1, D2, C and F axes. The axes that can be inched depend on the inching axis selection keys mentioned in the previous section.

3.2.3 Operating the Pick and Place Machine

Operating the SMT pick and place machine includes its start-up, reset-start and I / O check start procedures.

Normal Operation

The following procedure is used to start the machine:

1. **Boot up the MCS 30 Supervisor Computer:** This computer compiles production information transmitted from the machine in Off Line mode.
2. **Set the Circuit Breaker:** The machine main circuit breaker must be set to ON position before the machine can be turned on.
3. **Turn on the Power:** Press the [POWER ON] button on the machine operation panel to turn the machine on. The following image shows the display that appears after pressing the [POWER ON] button:

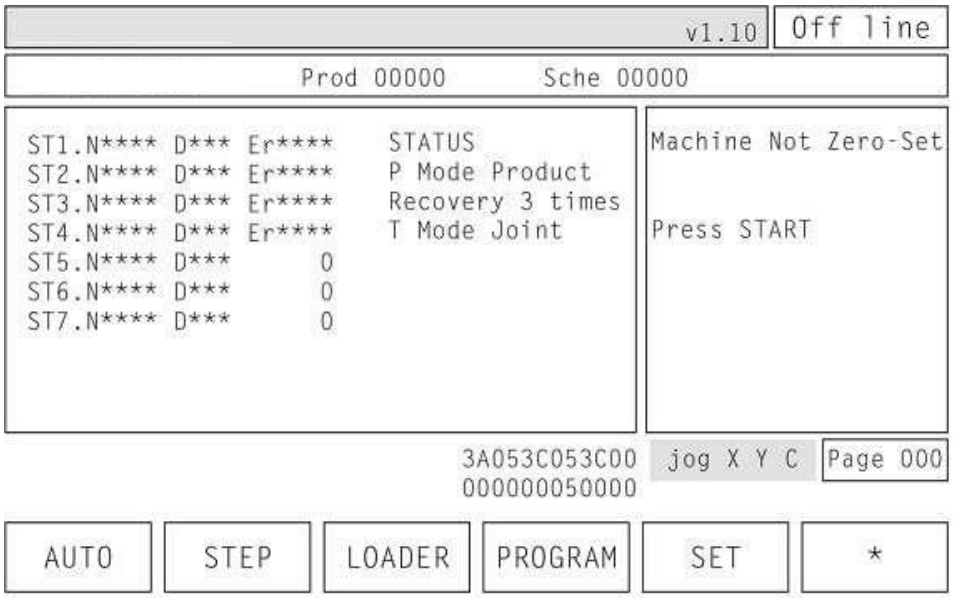


Fig. 3.2.7: Display that appears after pressing the [POWER ON] button

4. **Transmit Status Data to the Machine:** Status data is retained in the machine's memory even after the machine's power is turned off. Thus, once Status data has been transmitted to the machine, this step need not be repeated. However, it will be necessary to transmit the Status data to the machine after performing the reset-start procedure. The Status data can be modified either directly at the machine or indirectly using an MCS 30 computer. When the Status data is modified using an MCS 30 computer, it must be transmitted to the machine before operation.
5. **Transmit Proper Data to the Machine:** Proper data is retained in the machine's memory even after the machine's power is turned off. Thus, once it has been transmitted to the machine, this step need not be repeated. However, it will be necessary to transmit the Proper data to the machine after performing the reset-start procedure. When Proper data is modified at the MCS 30 computer, it must then be transmitted to the machine before operation. It is also possible to change a part of the Proper data at the machine. Once the change is made at the machine, if this data is transmitted to the MCS 30, then it will be saved on the MCS 30 computer.

6. **Transmit Programs to the Machine:** Programs are retained in the machine's memory even after the machine's power is turned off. Thus, once a program has been transmitted to the machine, this step need not be repeated. However, it will be necessary to transmit programs to the machine after performing the reset-start procedure. New programs are created using an MCS 30 computer; these must be transmitted to the machine before they can be used in production.
7. **Release the [EMERGENCY STOP] Button:** While the Machine [EMERGENCY STOP] switch is pressed, the 200V power line will be cut. If this switch is pressed, release it.
8. **Select the Production Program:** Using either MCS / 2H or the Machine [PROGRAM] command function, select the production program.
9. **Select the Quantity of the Production Run:** Press the [PROGRAM], [QTYSET] command function keys and set the number of boards to be produced. A setting of zero will make the machine run indefinitely.

   Note: Scheduled production quantity can be set in the program. Enter the production quantity into the Production_qty. field (in the Production_mode section of MCS/2H) and transmit to the MACHINE. When the production run is complete, the machine will stop automatically and the operator will be informed.
10. **Set the Operation Mode:** In either [AUTO] or [STEP], press the [MODE] command function key to change the operation mode. The operation mode changes among the three choices each time the [MODE] key is pressed. The following figure lists the three operation modes:

Product Mode	Simulate Mode	Idle Mode
Machine carries out normal production of boards.	This mode is not currently supported.	Machine carries out all functions except vision processing and fiducial mark reading. Board feed is not carried out.

Fig. 3.2.8: Three operation modes

The operation mode "Product" is automatically selected when the power is turned on.

Reset-Start

The machine memory contents have to be cleared whenever the machine's memory card and ROM chips are replaced to upgrade the software. It may also be necessary to clear the memory of erroneous data should the machine begin to operate abnormally.

All Status data, Proper data and production programs are deleted from the memory of the machine when the reset-start operation is carried out. Therefore, this data has to be transmitted from the MCS 30 to the machine again. It is important to restart the machine after transmitting the Proper data from the computer.

The following procedure explains how to reset-start the machine:

1. **Boot up the MCS 30 computer:** This computer compiles production information transmitted from the MACHINE in Off Line mode.
2. **Set the circuit breaker:** The machine's main circuit breaker must be set to ON position before the MACHINE can be turned on.
3. **Turn on the power:** While pressing the [RESET] button, the [POWER ON] button is pressed. When "Memory Backup NG" is displayed on the screen, the [RESET] button may be released.
4. **Release the [EMERGENCY STOP] button:** If the [EMERGENCY STOP] button has been pressed; the 200 V power will not come on when the operator presses [POWER ON]. It is important to release the [EMERGENCY STOP] button if it has been pressed.
5. **Transmit the Status data:** Transmit the correct Status data from the MCS 30 computer.
6. **Transmit the Proper data:** Transmit the Proper data from the MCS 30 computer to the machine. It is to be noted that the Proper data can be sent either before or after zero setting is done provided that it is transmitted before any command function keys are pressed. Valid Proper data must be transmitted to the machine. If invalid data is transmitted, the program check will not function normally and errors will occur during program transmission.
7. **Transmit the program:** Transmit the program from the MCS 30 computer to the machine.
8. **Cut the power and then restart the machine:** Even though the power has been cut, the Status data, the Proper data and the program will remain in the machine. After this, continue with normal operation.

I/O Check Start

To enter the I / O check mode, the [F1] function key is pressed and held down while pressing the [POWER ON] button. This brings the machine directly into the I / O check mode. It is to be noted that when I/O check start is used to start the machine, the 200V power does not come on. When the operator completes the I/O check and presses the [RETURN] function key, the 200V power will come on and the machine will be ready for zero setting.

3.2.4 Trace List Printout

If a problem occurs on the machine, having data from the machine that explains the conditions under which the problem occurred can help Fuji to find and eliminate the cause. A trace list is the raw data that can be obtained from the machine for this purpose.

The procedure to print out a trace list is as follows:

1. Stop the machine promptly after the trouble has occurred. Do not press the function keys or continue operating the machine as this may prevent the source of the problem from appearing in the printed trace list.
2. With the machine's power turned off, attach the printer cable from the MCS printer to the lowest of the three connectors (marked 'Parallel I / O') on the machine CPU board.

3. Press [CYCLE STOP] button along with [POWER ON] button. Release the [CYCLE STOP] button after the printer starts printing. After the printer has finished printing, the machine can be operated as normal.

3.2.5 Shutting Down the Pick and Place Machine

When shutting down the power, the following procedure should be used:

1. **Turn off the 200V power.** Press the [EMERGENCY STOP] button. When shutting down in the course of production, first press the [CYCLE STOP] button to halt automatic operation before pressing the [EMERGENCY STOP] button.
2. **Turn off the main power.** Press the [POWER OFF] button on the operation panel to turn the power supply off.
3. **Turn the circuit breaker off.** Turn off the power at the main circuit breaker if the machine is to be left idle for a longer duration or if work is to be carried out on the servo box or the control box.

It must be noted that if the power is cut while parts are being picked, the parts will drop off the nozzles and, during the next production run, vision processing will not work properly. Therefore, before shutting down the machine, press the [DUMP PARTS] command function key. The remaining parts will be placed before the board is unloaded.

Notes

UNIT 3.3: Loading of Component

Unit Objectives

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

1. List the different types of feeders
2. Demonstrate the steps to use tape feeders
3. Recognise the use of trays to load chip components
4. Identify the use of chip shooter and fine pitch placer

3.3.1 Loading of Chip Component Rolls

Feeder

A feeder is a hardware component that can supply the parts that are to be loaded into the machine. SMT machines generally support feeding from cut tape strips, trays, automatic feeders, tubes "drag" style feeders and bins of loose parts. Some common types of feeders are as follows:

- **Drag Feeders:**

  A drag feeder is a simple feeder that makes holes in SMT tapes. The head is used for dragging the tape forward to expose the next part. The following images show a drag feeder and different parts of a drag feeder:

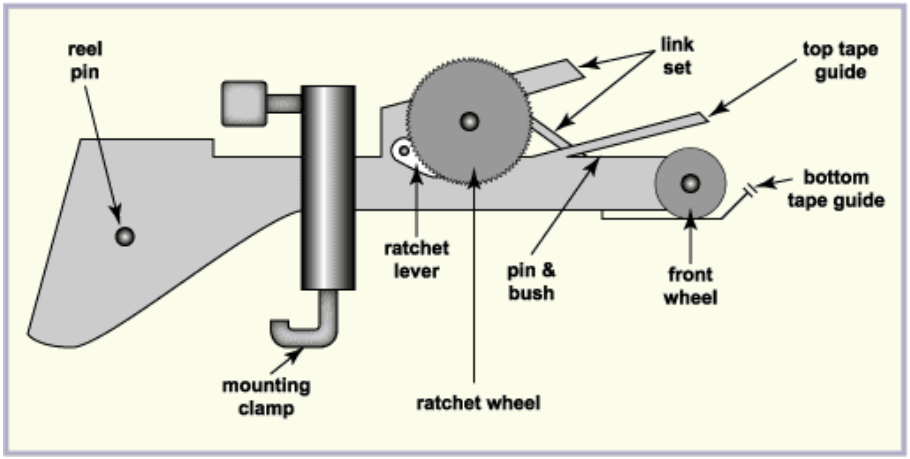


Fig. 3.3.1: Drag feeder and different parts of a drag feeder

- **Tape Feeders:**

  A tape feeder is used by performing the following two steps:

  - **Checking the feed pitch and action:** Press the manual feed lever to check that the tape is fed at a proper pitch. The following figure shows the manual feed lever of a machine:

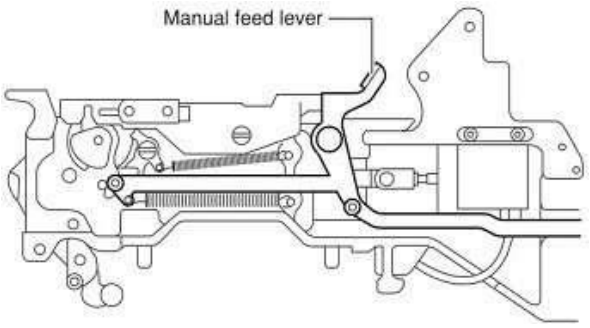


Fig. 3.3.2: Manual feed lever of a machine

  - **Setting the tape:** When fitting a new roll of tape to a tape feeder, the tape needs to be set. The procedure of using a tape feeder is as follows:

    A. **Peel off the top tape:**

    A tape consists of two layers; "carrier tape" that contains electronic components in the pockets and "top tape" that covers the upper side of components on the carrier tape. Peel off the top tape to separate these two layers.

    B. **Lift the clamping lever lock handle:**

    Lift the clamping lever lock handle to lift the tape guide.

    C. **Lift the tape guide:**

    Lift the tape guide while pressing the lock lever. After the tape guide is lifted, return the lock lever to the original position and hold the tape guide in the raised position. The following image shows a technician lifting a tape guide:

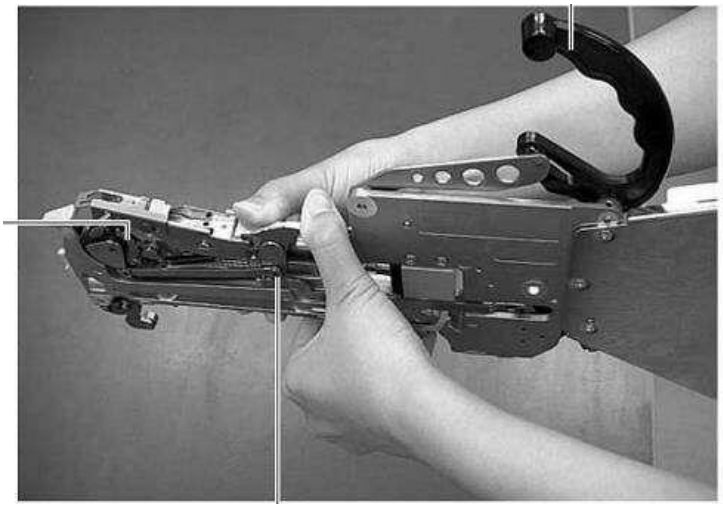
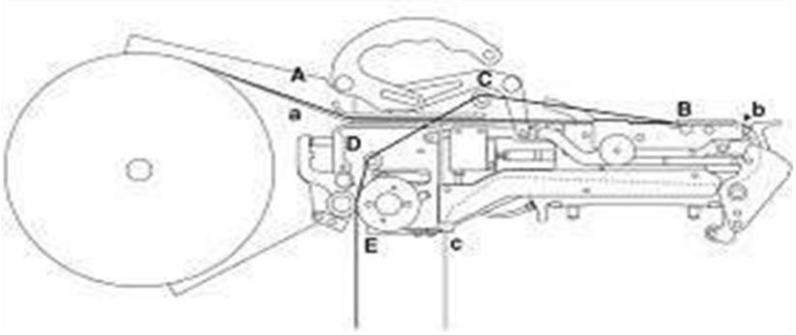


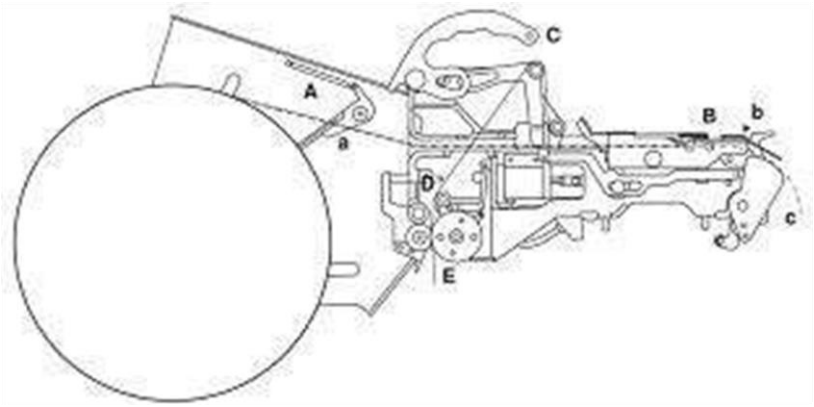
Fig. 3.3.3: A technician lifting a tape guide

D. **Set the tape in the tape feeder:**

Set the separated layers of the tape on the tape feeder through the tape paths. The following figure shows tape feeders of different measurements:



8mm tape feeder



12mm to 16mm tape feeder

Fig. 3.3.4: Tape feeders of different measurements

In the above figure, A ~ E represents the top tape and a ~ c represents the carrier tape. To turn the top tape, press the idle roller assembly lever and insert the top tape between the drive roller assembly and the idle roller assembly. The following figure shows a top tape and the notch of a tape feeder:

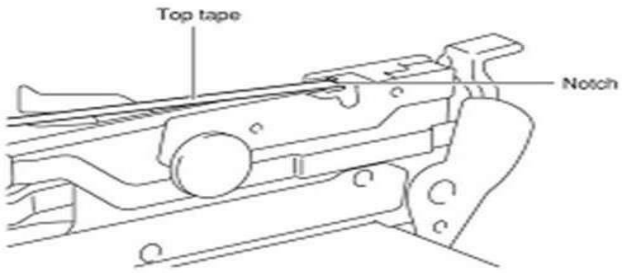


Fig. 3.3.5: Top tape and notch of a tape feeder

The following figure shows a drive roller assembly and an idle roller assembly:

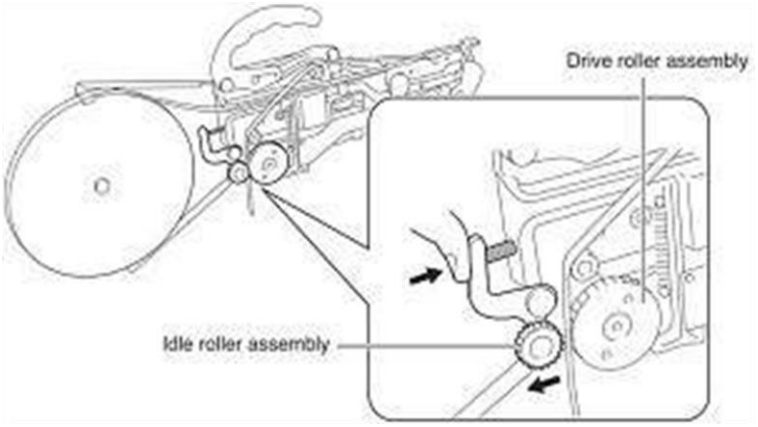


Fig. 3.3.6: Drive roller assembly and idle roller assembly

E. **Set the tape guide.**

After the tape is set, press the lock lever to lower the tape guide. The following figure shows setting the tape guide:

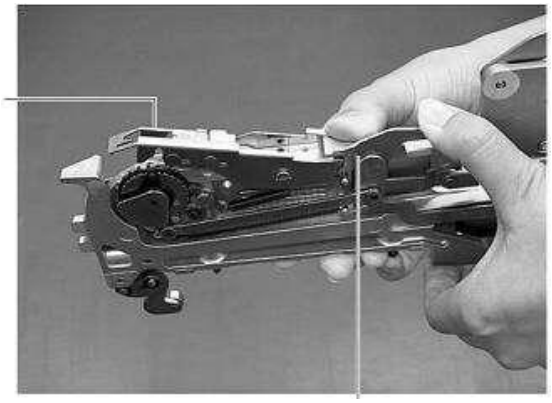


Fig. 3.3.7: Setting the tape guide

3.3.2 Loading of Chip Component Trays

Tray feeders are used to load the chip components. A tray feeder is a "virtual" feeder which picks the required parts from a uniform array of parts. The following image shows a uniform array of parts:

Fig. 3.3.8: Uniform array of parts

3.3.3 Chip Shooter and Fine Pitch Placer

A chip shooter machine in a PCB assembly has three movable mechanisms. The following figure lists the movable mechanisms:

An X-Y table carrying a PCB	A feeder carrier with several feeders holding components	A rotary turret with multiple assembly heads to pick up and place components

Fig. 3.3.9: Movable mechanisms of chip shooter

To get the minimal assembly time, all the components should be placed on the board in a perfect sequence. The components should be placed on a right feeder or feeders as two feeders can hold the components of same type. Additionally, the assembly head must pick up a component from the correct feeder. The following figure shows a chip shooter assembly:

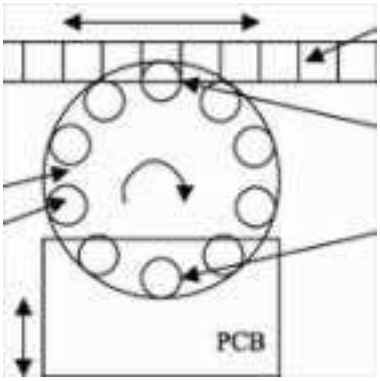


Fig. 3.3.10: Chip shooter assembly

Fine Pitch Placer

It is used when SMT components with a lead pitch of 25 mils or less are to be placed.

Exercise

1. Explain the component pick and place process.

2. List the procedure of using a tape feeder.

Notes

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4. Reflow Soldering on Telecom Boards

Unit 4.1 – Reflow Soldering

Unit 4.2 – Operation of Reflow Machine

TEL/N2505

Key Learning Outcomes

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

1. List the factors of an effective reflow soldering process
2. Identify the factors affecting the reflow profile
3. Define a footprint design
4. List different types of reflow soldering oven
5. List the stages of reflow soldering process
6. Identify the alarm messages received during reflow soldering
7. Analyse the significance of N2 conservation mode
8. Identify the defects occurred in the reflow soldering process

UNIT 4.1: Reflow Soldering

Unit Objectives

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

1. List the factors of an effective reflow soldering process
2. Identify the factors affecting the reflow profile
3. Define a footprint design
4. List different types of reflow soldering oven

4.1.1 Reflow Soldering Process

Reflow soldering is a process of using solder paste to attach one or more electrical components to their contact pads temporarily. The whole assembly is thereafter exposed to controlled heat. This, in turn, makes the joint permanent by soldering.

The reflow soldering of the surface mount electronic components to a printed circuit boards (PCB) is done by using a machine called reflow oven. The following image shows a reflow soldering oven:

Fig. 4.1.1: A reflow soldering oven

The following figure lists the key aspects that lead to an effective reflow soldering process:

- Suitable machine
- Acceptable reflow profile
- PCB/component footprint design
- Carefully printed PCB using well designed stencil
- Repeatable placement of surface mount components
- Good quality PCB, components and solder paste

Fig. 4.1.2: Key aspects of an effective reflow soldering process

Click/Scan the QR Code to understand Reflow soldering

4.1.2 Suitable Machine

Various types of reflow soldering machines are available. The type to be selected depends on the design and material of PCB assemblies and required line speed. The oven must be of a suitable size so that it can manage the production rate of the pick and place equipment. The formula to calculate line speed is as follows:

Line speed (minimum) = (Boards per minute x Length per board) / Load Factor (space between boards)

It is essential that the repeatability of the process is considered. It is for this reason that the load factor is generally specified by the manufacturer of the machine. The following figure shows the calculation of load factor:

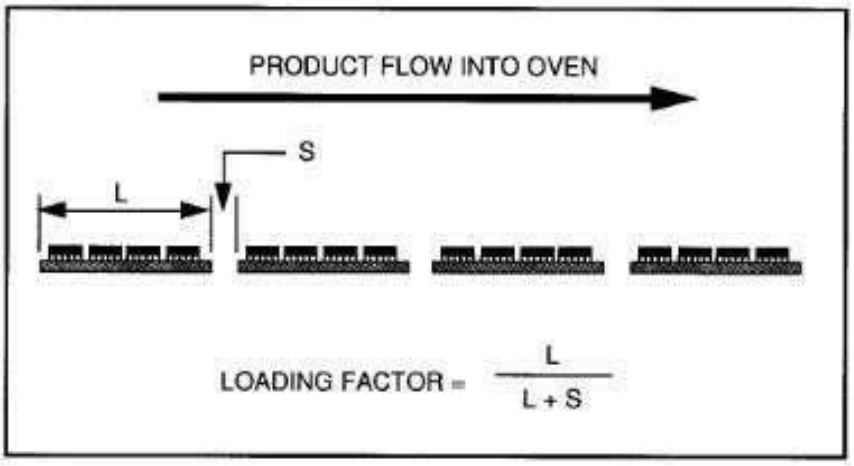


Fig. 4.1.3: Calculation of load factor

To select the reflow oven of correct size, the process speed must be more than the minimum line speed. The process speed is calculated as follows:

Process speed = Oven chamber heated length / Process dwell time

The following figure shows an example of calculating an oven size:

An SMT assembler wants to produce 8-inch boards at a rate of 180 per hour. The solder paste manufacturer recommends a 4 minute, three step profile. How long an oven do I need to process boards at this throughput?

Boards per minute = 3 (180/hour); Length per board = 8 inches; Load Factor = 0.8 (2-inch space between boards); Process Dwell Time = 4 minutes

Hence, Line Speed = [(3 boards/min) x (8 inches/board)]/0.8 = 30 inches/minute

Therefore, the reflow oven must have a process speed of at least 30 inches per minute.

Now, the oven chamber heated length is determined with process speed equation as:

30 in/min = Oven chamber heated length / 4 minutes = 120 inches (10 feet)

Fig. 4.1.4: An example of calculating the correct oven size

In the above example, the oven's overall length that includes cooling section as well as the conveyor loading section, will be greater than 10 feet. The above calculation is done for the heated length and not the overall oven length.

The selection of a machine and the additional options added to the specification is influenced by the design of the PCB assembly. The machine options which are commonly available are as follows:

- **Conveyor type –** Two types of conveyors are available—mesh conveyor and edge conveyor. Typically, edge conveyors are specified to allow the oven to work in-line and to be able to process the double-sided assemblies. A center-board-support is included in addition to edge conveyor, to prevent the PCB from sagging at the time of the reflow process. The following images show the edge conveyor with a center-board support:

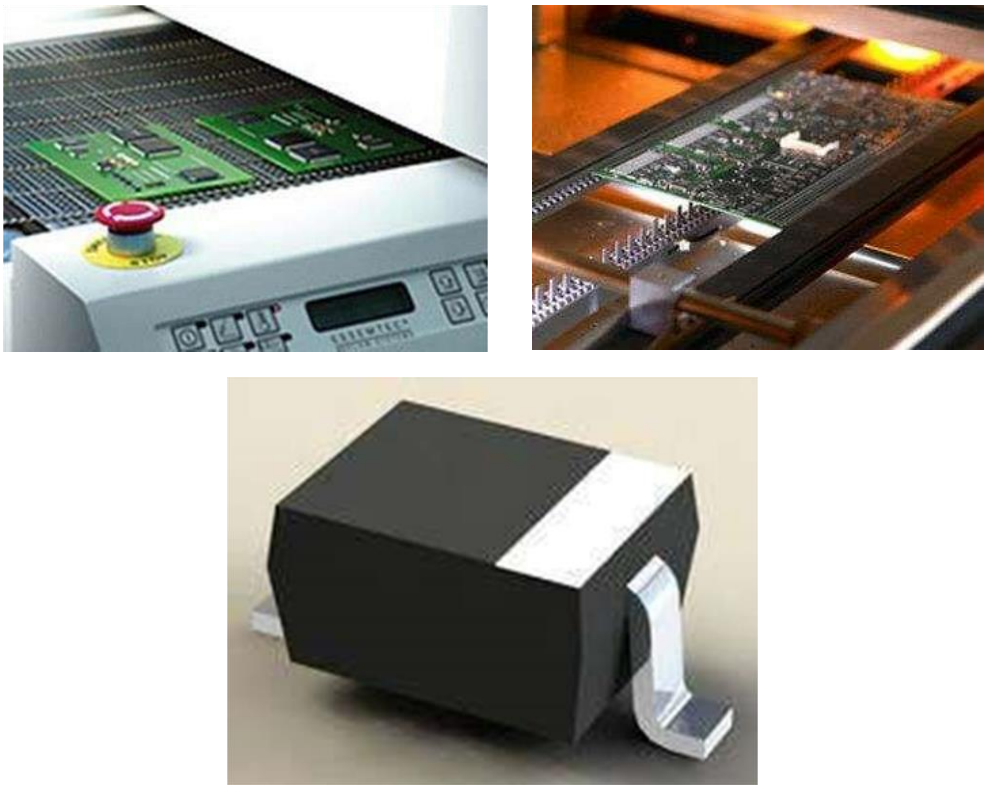


Fig. 4.1.5: Edge conveyor with a centre-board support

While using the edge conveyor system for the processing of double-sided assemblies, it must be ensured that the components on the underside are not disturbed.

- **Closed loop control of the speed of the convection fans –** During the reflow process, certain SMT packages, such as SOD323, due to having small contact area to the mass ratio, are susceptible to disturbances. Therefore, the recommended option is to use closed loop speed control of the convention fans for assemblies using such parts.
- **Automatic control of conveyor and centre-board-support widths –** This option is recommended for maintaining a consistent process in machines that have manual width adjustment and different assemblies are required to be processed with varying PCB widths.

4.1.3 Acceptable Reflow Profile

Since there are different factors affecting how a reflow oven is programmed, every assembly must be separately considered to create an acceptable reflow profile. The following figure lists the factors affecting the programming of the reflow oven:

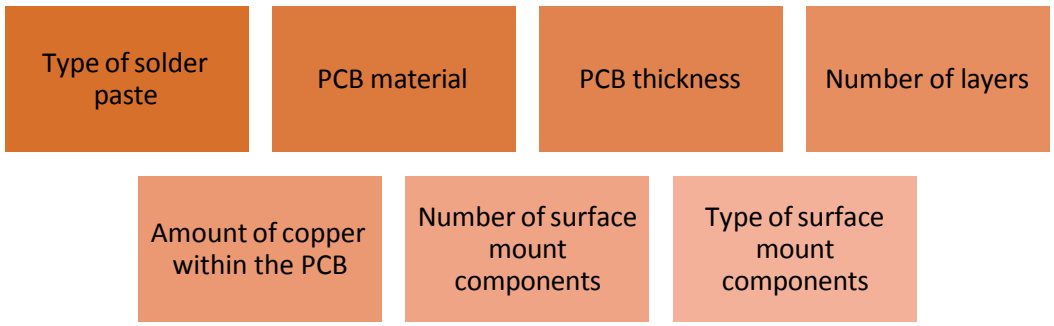


Fig. 4.1.6: Factors affecting the programming of the reflow oven

4.1.4 PCB/Component Footprint Design

A PCB design can influence the efficiency of the assembly reflow in many ways. The size of tracks that connects to a component footprint is an example. If the track that is joined to one side of a footprint is bigger than that joined to the other, a thermal imbalance can happen. This leads to 'tombstone' formation. The following images show the tombstone formation:

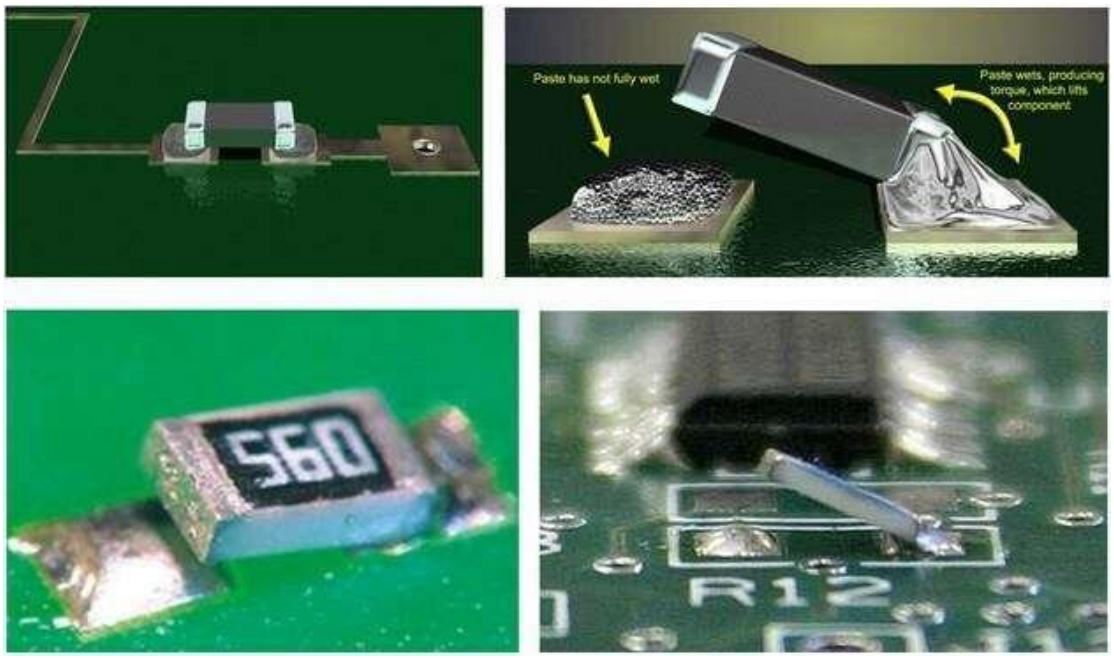


Fig. 4.1.7: Tombstone formation

Copper balancing is another example of such an aspect. Larger copper areas are used by many PCB designs, which can cause an imbalance in copper in case the PCB is put into a panel for supporting the manufacturing process. This can cause the panel to warp during reflow. Hence, the 'copper balancing' is recommended to be added to the waste areas of the panel.

The following image shows the copper balancing process:

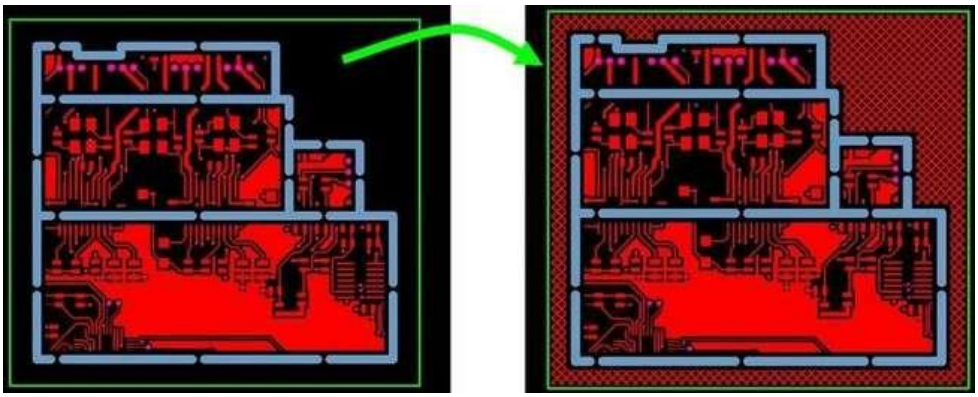


Fig. 4.1.8: Copper balancing process

4.1.5 Printed PCB using Well-designed Stencil

The process steps mentioned earlier (in Module 1 under unit PCB Design Concept) within surface mount assembly are crucial for a reflow soldering process to be effective. The solder paste printing process is the key to ensure consistency in the solder paste deposit onto the PCB. Any fault at this stage will lead to unacceptable results. Hence, effective stencil design along with complete control of the printing process is needed. The following image shows a PCB after the printing process:

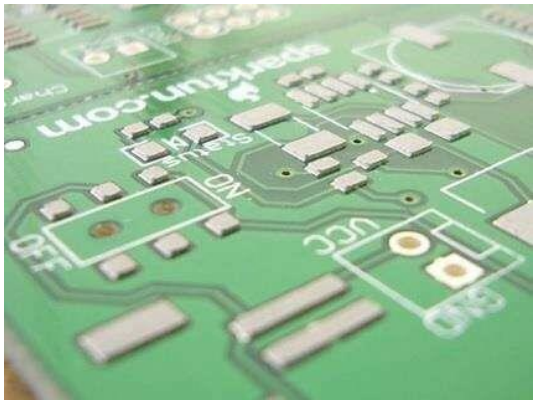


Fig. 4.1.9: A PCB after the printing process

4.1.6 Repeatable Placement of SMT Components

A well-maintained, reliable pick and place machine is essential as the placement of the SMT components is a repeatable process. In case the component packages are not identified correctly, the vision system of the machines will not perceive all the parts in the same manner. This will cause variation in the placement of the components as well as inconsistent results after the reflow process. All components placement machines should have a well-defined 'Placement Accuracy' such as, 35um (QFPs) to 60um (chips) @ 3 sigma.

The following images show component placement variation:

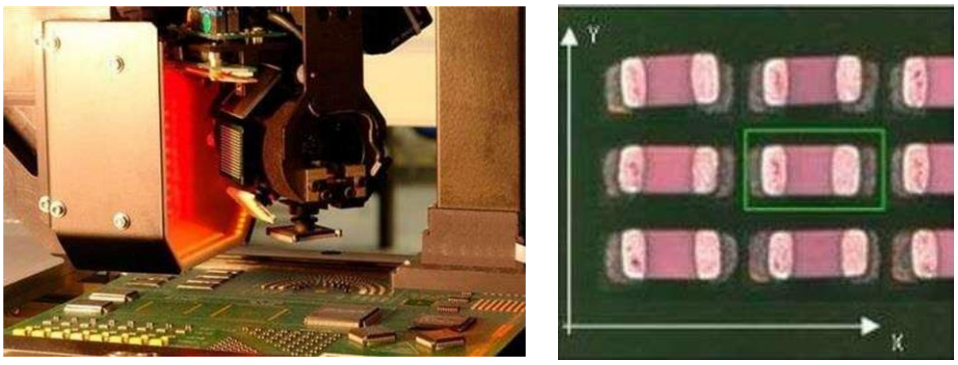


Fig. 4.1.10: component placement variation

It is also imperative to choose the appropriate nozzle for the component type. The following image shows a range of nozzles for different component placement:

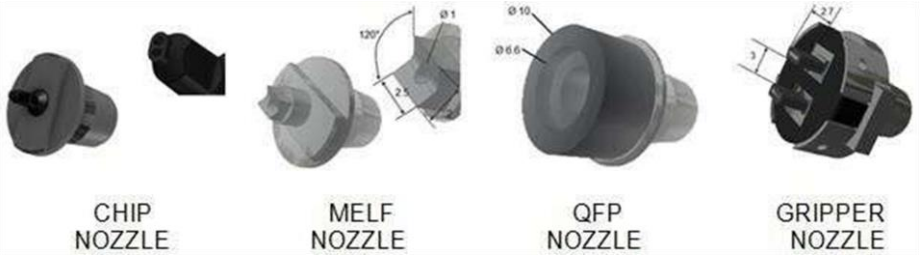
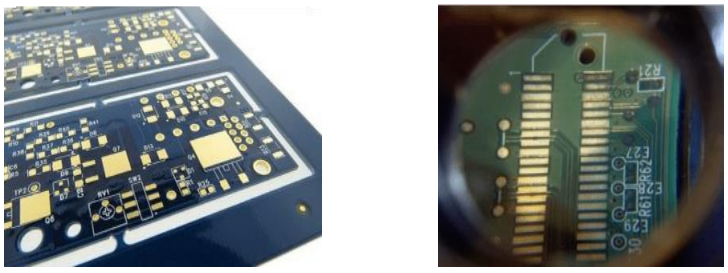


Fig. 4.1.11: A range of nozzles for different component placement

4.1.7 Good Quality PCB, Components and Solder Paste

High quality of all items should be used during the process as poor quality will lead to undesirable results. If the manufacturing process is carried out inaccurately and the PCBs are not stored properly, the low-quality surface finishing of the PCBs may lead to poor soldering during the reflow process. The following images show an example of poor surface finishing of PCB, leading to a defect 'Black Pad':



Good quality PCB finish Tarnished PCB

Fig. 4.1.12: An example of poor surface finishing of PCB

Also, depending on the manufacturing process and storage method, the quality of the leads of the surface mount component can be poor.

The following image shows poor component leads with solderability:

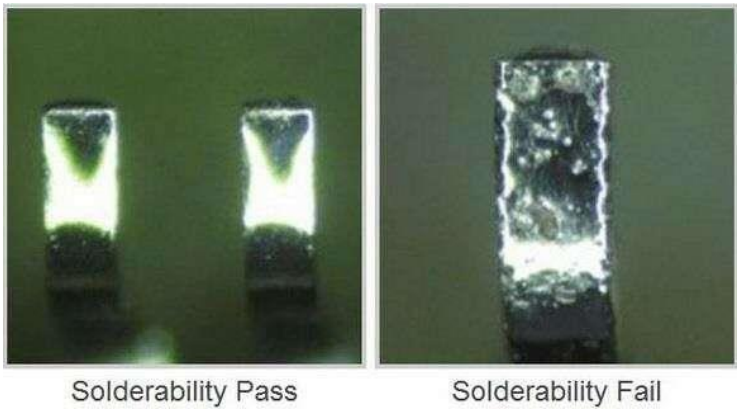


Fig. 4.1.13: Poor component leads with solderability

The storage process and the handling of the solder paste largely affect its quality.

The following images show the result of using poor quality solder paste:

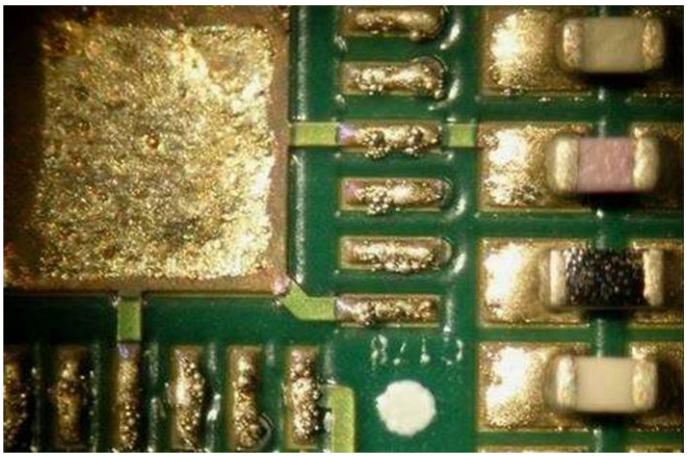


Fig. 4.1.14: Result of using poor quality solder paste

4.1.8 Types of Reflow Soldering Oven

Two types of reflow soldering oven are available. The following figure lists the types of reflow soldering oven:

Infrared & Convention Type

- A common type of reflow oven is the infrared convection oven.
- This type of oven accomplishes heat transfer to the components and solder by radiation of heat from heating elements.
- Fans provide circulation to improve heat transfer efficiency.

Vapor Phase Type

- Vapor phase ovens use the thermal energy in a layer of vapor to achieve soldering.
- A liquid perfluoropolyether is boiled to create a layer of vapor in which the PCB is immersed.

Fig. 4.1.15: Types of reflow soldering oven

The following figure shows the batch vapour phase reflow:

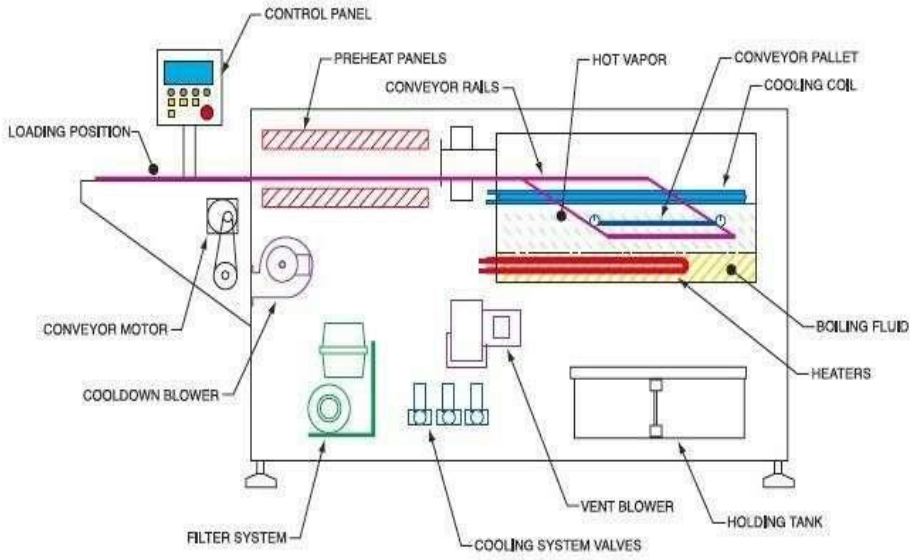
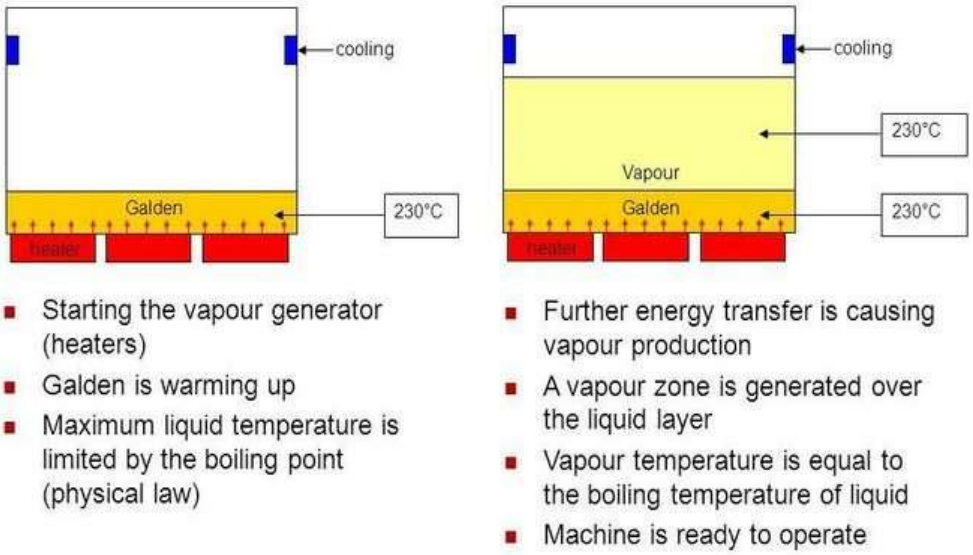


Fig. 4.1.16: Batch vapour phase reflow

The following figure shows the vapour phase soldering process:



- Starting the vapour generator (heaters)
- Galden is warming up
- Maximum liquid temperature is limited by the boiling point (physical law)

- Further energy transfer is causing vapour production
- A vapour zone is generated over the liquid layer
- Vapour temperature is equal to the boiling temperature of liquid
- Machine is ready to operate

Fig. 4.1.17: Vapour phase soldering process

Notes

UNIT 4.2: Operation of Reflow Machine

Unit Objectives

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

1. List the stages of reflow soldering process
2. Identify the alarm messages received during reflow soldering
3. Analyse the significance of N2 conservation mode
4. Identify the defects occurred in the reflow soldering process

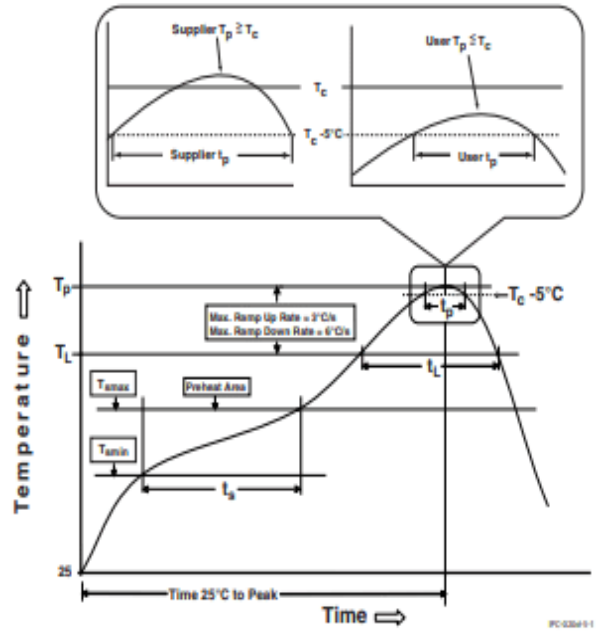
Thermocouples are attached to a sample assembly to create a reflow profile. Generally, a high temperature solder is used for this purpose at several locations so as to measure the temperature range across the entire PCB. As per recommendation, there should be minimum one thermocouple on a pad towards the edge of the PCB and one thermocouple on a pad around the middle of the PCB. Additional thermocouples would need to be used if there is a requirement to measure the range of temperatures across the PCB, which is known as 'Delta T'.

4.2.1 Stages of Reflow Soldering Profile

There are following four stages within a typical reflow soldering profile:

1. Preheat
2. Soak
3. Reflow
4. Cooling

Refer below reflow profile guidelines as per J-STD-020:



Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Preheat/Soak Temperature Min (T_{smin}) Temperature Max (T_{smax}) Time (t_s) from (T_{smin} to T_{smax})	 100°C 150°C 60-120 seconds	 150°C 200°C 60-120 seconds
Ramp-up rate (T_L to T_P)	3°C/second max.	3°C/second max.
Liquidous temperature (T_L) Time (t_L) maintained above T_L	183°C 60-150 seconds	217°C 60-150 seconds
Time (t_p)* within 5°C of the specified classification temperature (T_c)**, see Reflow Soldering Profile above.	20* seconds	30* seconds
Ramp-down rate (T_p to T_L)	6°C/second max.	6°C/second max.
Time 25°C to peak temperature	6 minutes max.	8 minutes max.

* Tolerance for peak profile temperature (T_P) is defined as a supplier minimum and a user maximum.

Fig. 4.2.1: Time-temperature profile of reflow soldering process

The primary purpose of these stages is to transfer the required heat into the assembly so that it can melt the solder and form the solder joints. However, this should be done without damaging the components or the PCB.

Preheat

During this phase, the entire assembly is ramped up towards the dwell temperature or a target soak. The main purpose of this stage is to make sure that the assembly gets to a soak or get pre-reflow temperature safely and consistently. The volatile solvents present in the solder paste get an opportunity to outgas in the preheat stage. The PCBs must be heated linearly with consistency. This enables the paste solvents to get expelled properly. The assembly can also reach the pre-reflow temperatures securely. The temperature slope rate, i.e. rise in temperature vs. time, measured in degrees Celsius per second, is an important metric for the preheat stage.

The target slope rate is dependent on many variables such as solder paste volatility, target processing time and component considerations. Though these process variables are very important, but in most cases, considerations of the sensitive components are of greater importance. If the temperature is changed too quickly, many components will crack. The maximum allowable slope will be the maximum rate of thermal change that even the most sensitive components can tolerate.

Aggressive slope rates may be tailor made to maximise the throughput and improve the processing time, if thermally sensitive components are not used. Hence, the slope rates by many manufacturers are pushed up to maximum allowable rate of 3.0°C/second. Conversely, if a solder paste which has strong solvents is being used, quick heating of the assembly can destabilise the process. The volatile solvents outgas and the solder may splatter off the pads and come onto the board.

Violent outgassing during this phase causes solder-balling. Once a board reaches the pre-set temperature of the preheat phase, it's time to enter the pre-reflow or soak phase. The following images show the impact of too fast heating of the assemblies:

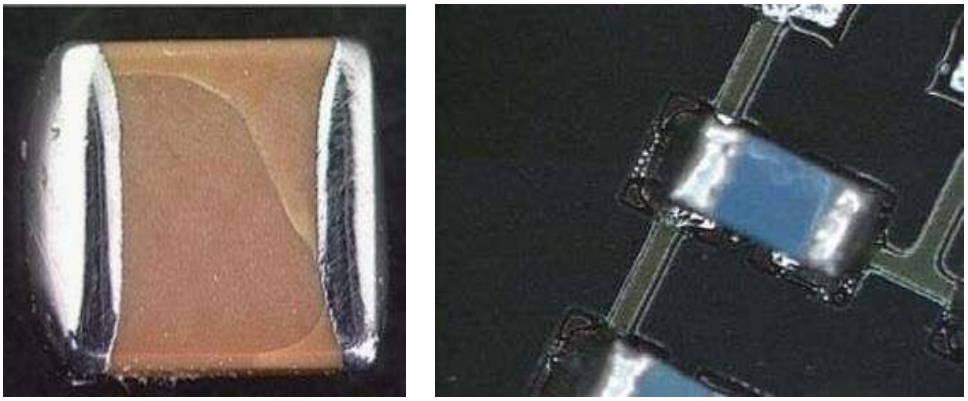


Fig. 4.2.2: Impact of too fast heating of the assemblies

Soak

The purpose of this phase is to make sure that all the components are up to the required temperature before they go into the reflow stage to remove the solder paste volatiles and activate the fluxes. The flux components then begin the oxide reduction process on the component leads and pads.

Usually, the soak lasts for 60-120 seconds depending on the types of components present in the assembly and its mass differential.

The following image shows high mass differential:

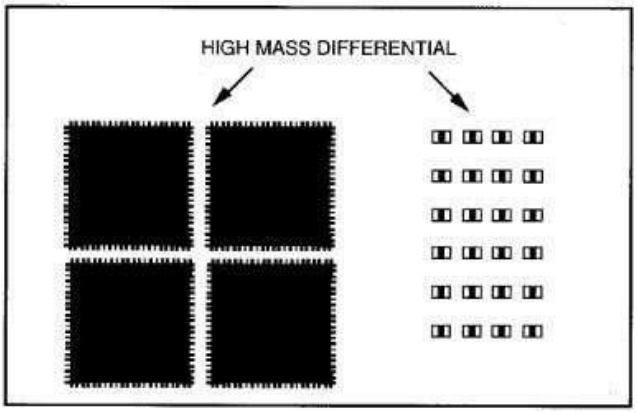


Fig. 4.2.3: High mass differential

The efficiency of heat transfer is inversely proportional to time, meaning, more is the efficiency, lesser will be the time needed to soak.

The following figure lists some characteristics of a soak profile:

Too high a temperature can lead to solder spattering or balling as well as oxidation of the paste, attachment pads and component terminations.
Fluxes may not fully activate if the temperature is too low. At the end of the soak zone a thermal equilibrium of the entire assembly is desired just before the reflow zone.
A soak profile is suggested to decrease any delta T between components of varying sizes or if the PCB assembly is very large.
A soak profile is also recommended to diminish voiding in area array type packages.

Fig. 4.2.4: Characteristics of a soak profile

Reflow

The temperature inside the reflow oven is increased so that it is more than the solder paste's melting point, causing the paste to transform into a liquid. The time the solder is kept above the melting point, termed as Time above Liquidus (TAL), is of crucial importance to ensure that appropriate 'wetting' occurs between the PCB and the components. TAL is generally set for 30 to 60 seconds for best results. It should not exceed beyond the recommended period otherwise brittle solder joints might form.

In this stage, the peak temperature or the maximum permissible temperature of the whole process is significant. Typically, the peak temperature is kept at 20–40 °C above liquidus. The component that is most susceptible to thermal damage determines this temperature; that means, the component that has the least tolerance for high temperatures.

The maximum temperature for the process is calculated by subtracting 5°C from the maximum temperature that the most vulnerable component can tolerate. The process temperature should be monitored so that it does not exceed this limit.

Additionally, high temperatures, especially if they go above 260 °C, may harm the internal dies of the SMT components. They might also stimulate intermetallic growth. On the other hand, a temperature that is not sufficiently high might hinder the proper reflow of the paste.

TAL measures the duration for which the solder is liquid. Usually, experts recommend the shortest TAL possible. A minimum TAL of 30 seconds is specified for most pastes, although there is no clear reason for the specific time. One possibility for the specific time is that there are places on the PCB which are not measured during the profiling. Therefore, if the minimum allowable time is set to 30 seconds, it reduces the chances of an unmeasured area not reflowing. The following figure lists the effects of high and low TAL:

The surface tension is reduced at the juncture of the metals by the flux to perform metallurgical bonding, allowing the individual solder powder spheres to join. The profile time higher than the manufacturer's specification, may result in premature flux consumption or, activation and drying the paste before solder joint formation.

An insufficient time-temperature relationship causes a decrease in the flux's cleaning action, resulting in poor wetting, inadequate removal of the solvent and flux, and possibly defective solder joints.

A high minimum reflow time also provides a margin of safety against oven temperature changes.

The wetting time ideally stays below 60 seconds above liquidus. Additional time above liquidus may cause excessive intermetallic growth, which can lead to joint brittleness.

The board and components may also be damaged at extended times over liquidus, and most components have a well-defined time limit for how long they may be exposed to temperatures over a given maximum.

Too little time above liquidus may trap solvents and flux and create the potential for cold or dull joints as well as solder voids.

Fig. 4.2.5: Effects of high and low TAL

Due to the trend of moving away from solder paste containing strong fluxes during the reflow process, the use of nitrogen should be considered. But in this case, the issue is not the ability to reflow in nitrogen, but the ability to reflow in lack of oxygen. Heating solder in oxygen creates oxides that are usually non-solderable surfaces.

Cooling

This is a stage in which the temperature of the processed board is brought down gradually to the room temperature so that the solder joints get solidified. If cooling is done properly, it curbs excess intermetallic formation or occurrence of thermal shock to the components. Typical temperature in this zone ranges from 30 to 100 °C (86 to 212 °F).

A fast cooling rate is selected to create a most mechanically sound and fine grain structure. Regardless of whether any component is heating up or it is cooling down, the maximum allowable slope should be considered. Commonly, a cooling rate of 4°C/s is recommended. While analysing the process results, the cooling rate is considered.

4.2.2 Alarm Messages during Reflow Soldering

The following table lists some examples of alarm messages:

ALARM	DESCRIPTION
EMERGENCY STOP	E-stop switch pushed (or electrical cabinet open)
CONVEYOR STOPPED	The conveyor is not moving
COMMUNICATIONS FAILURES -WITH CONTROLLER -PORT TO CONTROLLER COULD NOT BE OPENED -CONTROLLER GIVES ERROR	The oven controller is not functioning / communicating The oven controller is not functioning / communicating Non specific communications error
BOARD DROPPED	An expected board did not arrive at the off load sensor
OIL LEVEL LOW	The oil level is low in the Lubrication Reservoir
COOLANT FLOW	The coolant flow low or stopped. (or tank level low)
COOLANT TEMP	The enhanced cool coolant temp is too high
GAS PRESSURE LOW	The gas pressure is below switch setpoint and too low to maintain the gas atmosphere in the tunnel
CONVECTION LOW	A cell fan(s) has stopped, Inverter failure, or exhaust sensing detects low facilities exhaust flow
EXHAUST FAILURE	The facilities exhaust is below specifications
RAIL WIDTH	Rail width position is outside the acceptable tolerance
BOARD JAM	A circuit board is under the exit sensor for a time period that exceeds the jam length in the product file
IAS	The IAS Unit detected a temperature alarm condition, or a High Temperature Switch has opened
SYSTEM READY TIME OUT	The countdown timer has expired and the machine has not reached the Process Ready state
UPS BATTERY LOW	The UPS battery is low an requires charging or replacement

Fig. 4.2.6: Some examples of alarm messages

4.2.3 N_2 Conservation (Optional)

The N2 conservation mode allows the user to set a timer in order to switch off the main N2 supply beyond set timer period when there are no processing boards in the oven. The 'stand-by' N2 valve during this mode will be active. A regulator can be set to control the stand-by amount of N2. The mode has an objective to optimize the usage of N2 during the extended idle periods.

The following figure lists the settings parameters of the conservation mode:

Time out [min]	Fans [rpm]	Purge[min]
• It is the time that the machine has to be empty before the conservation mode kicks in. • If it is 0, then is is inactive.	• It is the fan speed in conservation mode.	• It is the N2 purge time when returning to normal mode.

Fig. 4.2.7: Settings parameters of the conservation mode

The settings parameters are located in the configuration under the atmosphere tab.

Principle of Operation

The following figure explains the principle of operation in the conservation mode:

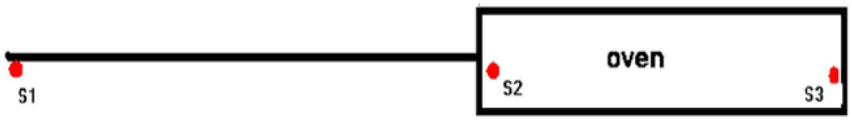


Fig. 4.2.8: Principle of operation in the conservation mode

The following figure explains the positioning of the sensors S1, S2 and S3 in the preceding figure:

S1 is the upstream sensor positioned outside the oven.

- To optimize against restricting board travel in the production line, sensor S1 should be placed far enough prior to the on load of the oven.
- This is to allow the oven sufficient time to switch from N_2 conservation mode and to re- establish the O_2 ppm level prior to a board arriving at the oven, without stopping a board prior to the oven.
- The wait time of the boards in front of the oven should be minimized to prevent blocking the line for an extended period.

S2 is the board entering sensor positioned at the entrance of the oven.

S3 is the board exiting sensor positioned at the exit of the oven.

Fig. 4.2.9: Positioning of the sensors S1, S2 and S3

The main N2 and purge valves get activated when the oven starts up with an N2 recipe. The purge time, set in the recipe, controls the duration of the purge. The oven goes into a ready status immediately after the purge is completed and all the parameters are stable.

The boards are allowed to enter the oven when it is ready. If no boards are there between the sensor S1 and the oven, the time-out timer starts. Once the time-out expires, the oven automatically switches to N2 conservation mode. The following figure lists the activities after the time-out expires:

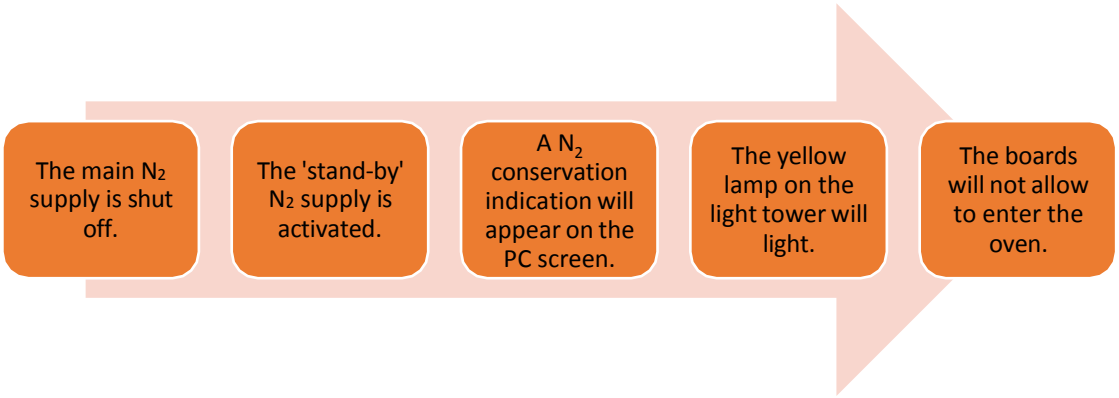


Fig. 4.2.10: Activities after the time-out expires

The following figure shows the activities when a board passes S1:

Fig. 4.2.11: Activities when a board passes S1

The event that a board is between the sensor S1 and the oven is latched. This appears on the screen as 'N2 conservation inhibited'. This latch is cleared once the oven is completely empty. The N2 conservation time-out needs to be set longer than the time a board takes to travel from S1 to S2 in the oven.

4.2.4 Common Defects during Reflow Process

Like any manufacturing process, surface mount technology is also affected by process defects. Some of the common defects during reflow process are as follows:

Solder Balling

This occurs when solder particles do not melt evenly as the oxide layer on them has not been removed completely or the surfaces are not wettable.

The following figure lists the possible reasons of solder balling:

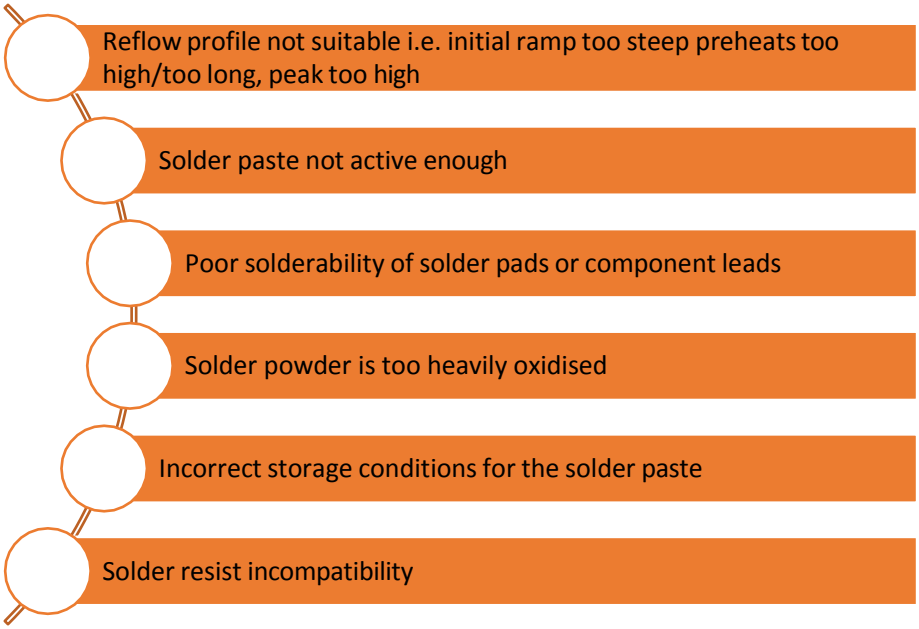


Fig. 4.2.12: Possible reasons of solder balling

Solder Beads

This is caused by the presence of the solder particles underneath the components before reflow. The following figure lists the possible reasons of solder beads:

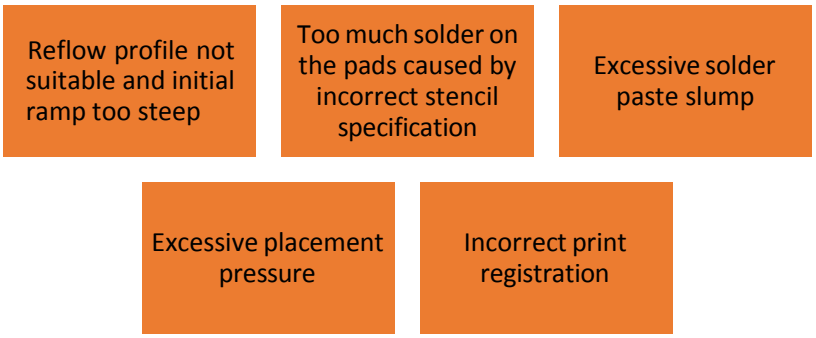


Fig. 4.2.13: Possible reasons of solder beads

Solder Balls Caused by Printing Failures

This defect occurs when the solder paste is forced onto the non-wettable surfaces, for example, solder mask. The following figure lists the possible reasons of solder balls caused by printing failures:

Bad seal between the stencil and the PCB during printing (gasketing)
Mismatch between the stencil and the PCB
Excessive squeegee pressure
Poor aperture to pad size relationships
Contaminated underside of stencil

Fig. 4.2.14: Possible reasons of solder balls caused by printing failures

Poor Wetting

Poor wetting takes place if the oxide layer has not been completely removed from the surfaces which are to be soldered. The following figure lists the possible reasons of poor wetting:

- Solder paste is not active enough.
- Solder pads or component leads are not solderable or contaminated.
- The solder powder is oxidised or is too fine for the application.
- Reflow profile is not suitable i.e. preheat too high/too long or peak too high.

Fig. 4.2.15: Possible reasons of poor wetting

Open Solder Joints

This defect occurs when the solder has only wetted one surface. The following figure lists the possible reasons of open solder joints:

Bad solderability of the component soldering surfaces due to oxide or contamination.
SOICs, PLCCs and QFPs, often coplanarity is the problem.
Solder paste not active enough.
Poor reflow profile does not allow all surfaces to come up to reflow temperature.
Not enough paste present.

Fig. 4.2.16: Possible reasons of open solder joints

Short Circuits (Bridges between Pads)

The following figure lists the possible reasons of short circuits:

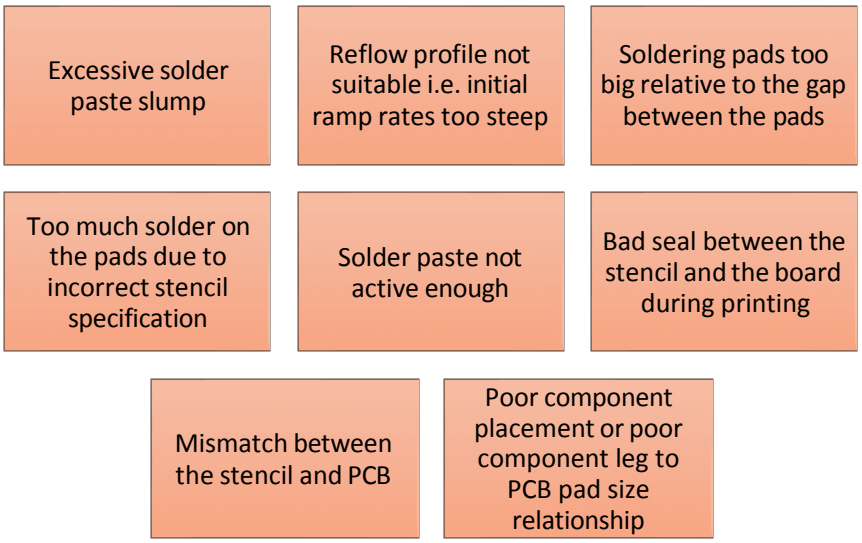


Fig. 4.2.17: Possible reasons of short circuits

Insufficient Solder on Solder Pads

The following figure lists the possible reasons of insufficient solder on solder pads:

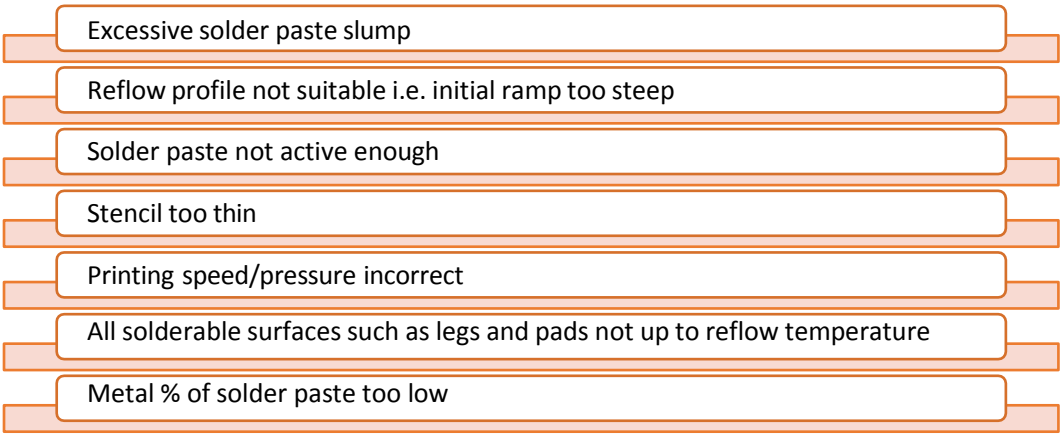


Fig. 4.2.18: Possible reasons of insufficient solder on solder pads

Component Movement or Insufficient Tackiness

The following figure lists the possible reasons of insufficient tackiness or component movement:

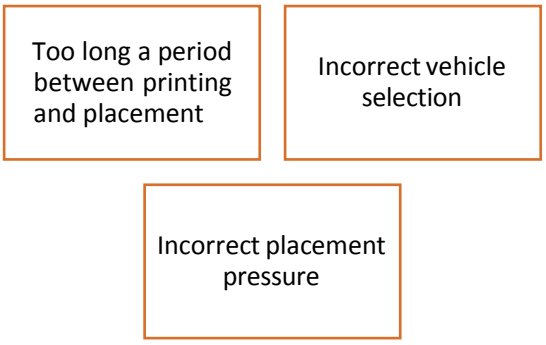


Fig. 4.2.19: Possible reasons of insufficient tackiness or component movement

Tombstoning (Manhattan) Effect

This defect takes place when one end of the component, instead of being soldered, gets displaced from the PCB surface, as a result of either mechanical displacement of the component itself or by the solder's surface tension which has wetted the component's other end properly. This issue occurs only for the chip resistors and capacitors. The following figure lists the possible reasons of tombstoning effect:

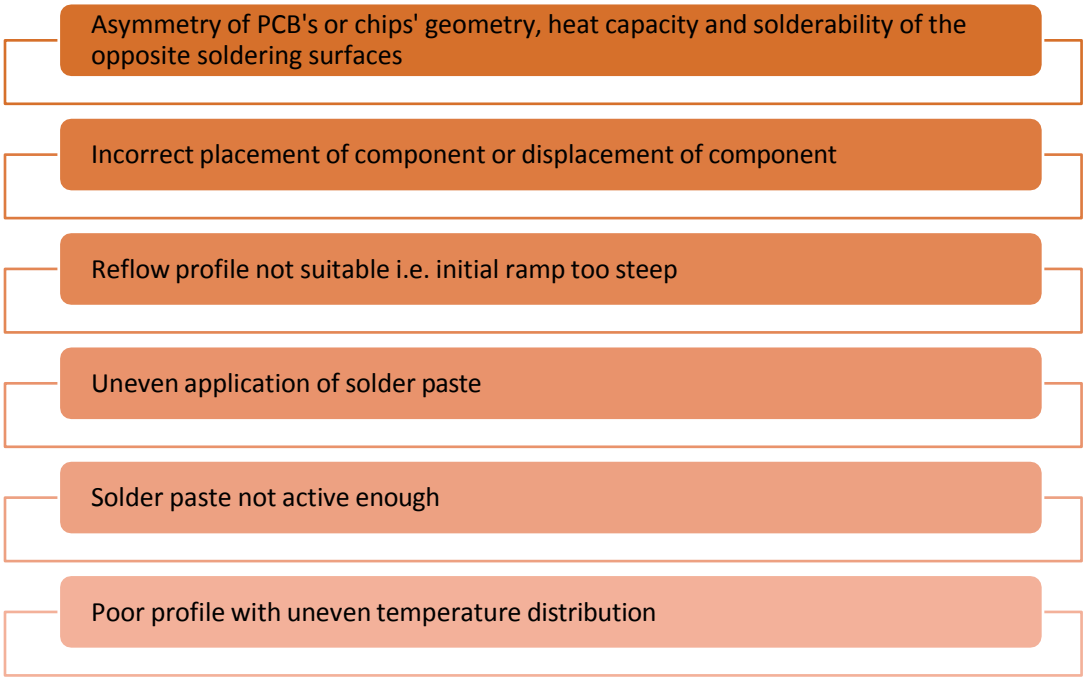


Fig. 4.2.20: Possible reasons of tombstoning effect

Wicking

The term Wicking refers to the phenomenon of the solder travelling up the component lead. The following figure lists the possible reason of wicking and the precaution to be taken for it:

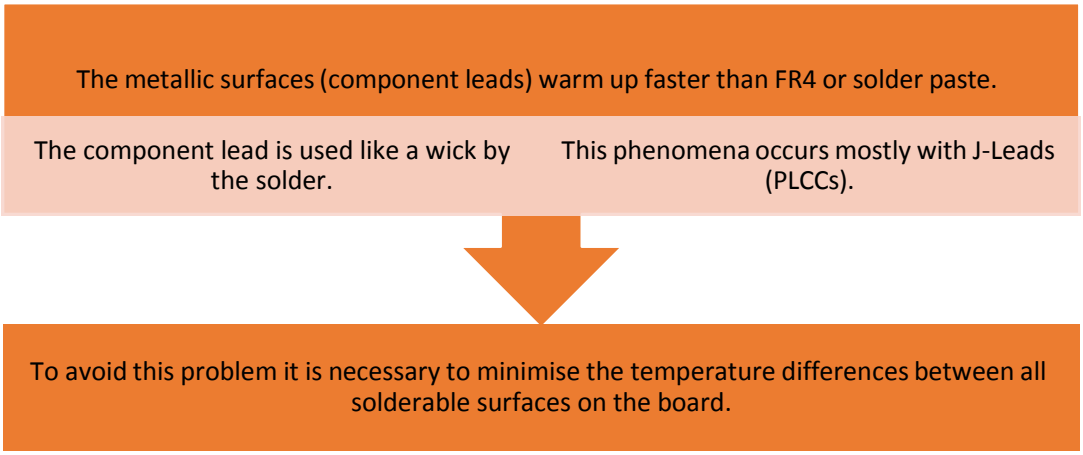


Fig. 4.2.21: Possible reasons of wicking and the precaution to be taken for it

Exercise

1. List the stages of reflow soldering profile.

2. List the common defects that may occur during reflow process.

Notes

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5. Cleaning and Inspection of Telecom Boards

Unit 5.1 – Cleaning of PCBs

Unit 5.2 – Inspection of PCBs

TEL/N2502

Key Learning Outcomes

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

1. Identify the different types of contamination in PCBs
2. List the different methods of board cleaning
3. Identify the impact of white residue on PCBs
4. Demonstrate correct methods for storage and handling of PCB after cleaning
5. List the points of importance of visual inspection
6. Identify the attributes of automated optical inspection test
7. List the applications of automated x-ray inspection method
8. Apply in-circuit tests
9. Compare different visual inspection machines

UNIT 5.1: Cleaning of PCBs

Unit Objectives

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

1. Identify the different types of contamination in PCBs
2. List the different methods of board cleaning
3. Identify the impact of white residue on PCBs
4. Demonstrate correct methods for storage and handling of PCB after cleaning

PCB cleaning refers to the process of removing solder flux residues and other contaminations from the PCB after the SMT process. The flux present in the solder paste reacts with the metal oxide at the time of the reflow process and prevents further oxidation of the solder metal. The solder flux residue, produced as a by-product of this reaction, gets trapped underneath the components as well as near the undersides of the solder balls.

This residue is flushed out during the cleaning process and is dissolved by an aqueous or a semi-aqueous solvent using external agitation. The residual flux on the board can lead to an electrochemical process called electromigration. In this process, the metal, on an insulating material, moves away from its initial location in ionic form. It re-deposits at some other location when it is provided with a humid environment and an electric field is applied. Such migration might bring down the isolation gaps and thus might be a cause of an electrical short circuit. The following figure shows the electromigration process:

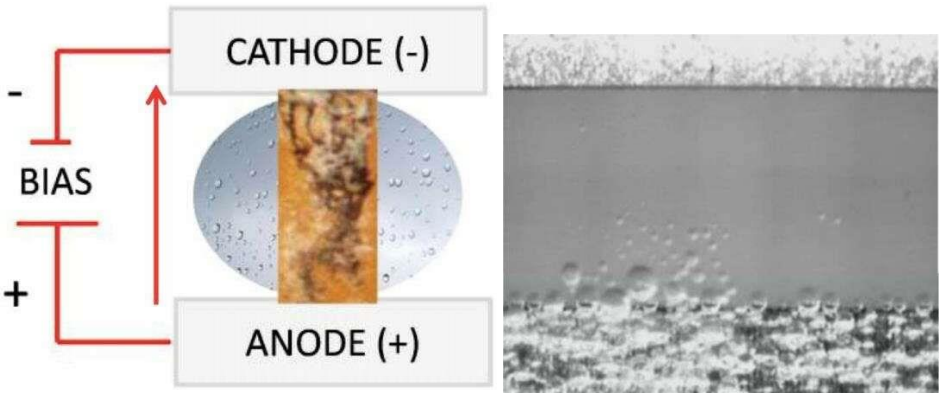


Fig. 5.1.1: Electromigration process

The process starts when a thin continuous film of water along with residue forms an oppositely charged electrode. It leads to the formation of positive metal ions at the positively biased electrode anode and their migration towards the cathode that is negatively charged. Over time, there is an accumulation of ions as metallic dendrites, as a result of which the spacing between the electrodes is reduced and eventually a metal bridge is created. The formed metal bridge would cause solder shorting when potential is applied thus inhibiting the proper functioning of the module.

5.1.1 IPC standards of soldering

Institute for Printed Circuits, or IPC, is a trading name for the electronic linking industries. IPC now officially goes by the name Association Connecting Electronics Industries and offers standards for PCBs.

IPC is referred to as an international industry with the association of more than 4000 businesses that participate in the use, specification, and design of PCBs and assemblies including advanced microelectronics, military applications, aerospace, automotive industries, computers, industrial and medical equipment, telecommunication industry, etc.

For items related to PCBs to be safe, dependable, and high performing, these are necessary. Throughout the whole production process, quality, focus, and devotion must be maintained. Many PCB production sectors employ these standards to maintain consistency, high dependability, quality, and dedication in order to meet the requirements and expectations of users and customers. These aid in many other ways in the process improvement of PCB goods.

The IPC standards in the manufacturing process of PCB required to:

- Gain control of end products with high quality and high reliability.
- Improve communication with many employees and suppliers
- Reduce cost
- Improve Reputation and a New Opportunity

The user must be familiar with the vocabulary offered by the IPC in order to apply these PCB standards, which in turn facilitates communication and the purchase of its standards. Among the terminology included in IPC specifications are:

- **Acceptance Tests:** Required to check whether the product is acceptable or not, that depends on the user or buyer or vendor.
- **Assembly:** Includes joining or assembling of various parts, and combinations together.
- **Resist:** it acts as a coating material to protect the product during the manufacturing process and testing of plating, etchant, and soldering, etc.
- **IC (Integrated Circuit):** various electronic circuits are interconnected together in one place with a single material to perform the desired function based on the application.
- **Flexible Strength:** Refers to a tensile strength of the fiber of a material that can bend in a curve or fold or turn.
- **Critical Operation:** Refers to the complete operation, process, and characteristics of the product.

For the purpose of manufacturing PCBs and PCB goods, soldering must adhere to IPC requirements. For soldering materials and processing, the IPC standard IPC - J -STD -001G is utilised in various sectors around the world. Electrical and electronic assemblies are soldered during the manufacturing process according to IPC - J - STD - 001 training and certification programmes.

When repairing broken and damaged conductors that are a part of type 2 and type 3 PCB-related electronic products without end-users, solder splices in accordance with IPC - A - 620 requirements are utilised. For the repair of conductors, four solder splicing techniques are permitted. They are

- Mesh
- Wrap
- Hook
- Lap

These solder splices are explained by the IPC standards in diagrams and words for easy understanding during the process.

In the mesh method, there are different criteria like acceptable (type 1,2,3), process indicator (type 2,3), and defect (type 1,2,3).

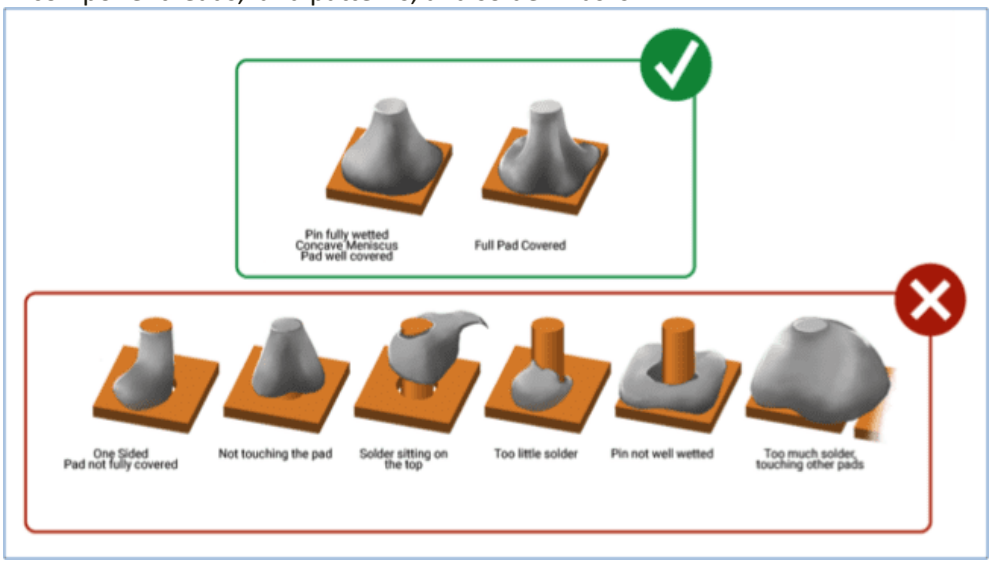
With the use of IPC standards, proper mounting of DIP pins, SIP pins and sockets can also be done easily.

Important requirements for soldering according to J-STD-001

Any standard will place focus on a few key elements as well as a few minor clauses. When discussing soldering, it is important to take into account the broad guidelines from the collaborative industry standards.

See the following points for soldering:

- To avoid contaminating materials, tools, and surfaces, cleanliness is crucial.
- In accordance with the manufacturer's recommendations, the rates of heating and cooling should be comparable. To guard against thermal excursions, stacked and multilayer chip capacitors are handled as thermal shock-sensitive.
- The wires' strands shouldn't be harmed. The wire's tinned section needs to be moistened by the solder.
- Inspections of the cleanliness and soldering should be done before applying the conformal coating and stacking.
- Defects could appear that conflict with the assembly's form, fit, and function. Then, depending on the needs of the customer, such soldering faults should be fixed or trashed.
- Automated optical inspection (AOI) and AXI should be used for visual inspection (automated X-ray inspection).
- According to the design, exposed base metal can be accommodated by conductors, component leads, land patterns, and solder masks.



There are numerous requirements for wires, strands, lead shaping, material-class-specific flaws, holes, lamination, etc. It is essential to adhere to this standard and keep accurate records of your findings and results.

5.1.2 Types of Contaminations in PCBs

The following figure lists the different types of contaminations in PCBs:

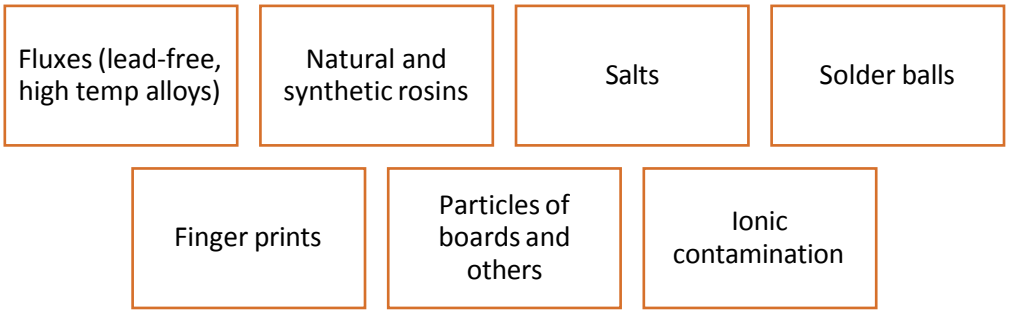


Fig. 5.1.2: Different types of contaminations in PCBs

5.1.3 Types of Cleaning Solvents

The following figure lists the different types of cleaning solvents:

Detergents, salts, surfactants, wetting agents and water
Petroleum distillates, alcohols, ketons, aII class HC
Formulated Hydrocarbons, aliphatic, cyclo, iso-paraffins, C9-C11
Terpens with additives, aII class blends
Bromated solvents, nPb blended with some alcohols
Glycols or modified alcohols, with additives and water
Fluorinated solvents, HFCs and HFEs, and azeotropes

Fig. 5.1.3: Different types of cleaning solvents

5.1.4 Board Cleaning Methods

Different methods of board cleaning are listed as follows.

Manual Cleaning Method

To clean the processed boards manually, they are soaked in cleaning solution for about 10 minutes. After that, the contaminants at solder junction are brushed off using a banister brush in ethanol solution. The board is then taken out and thoroughly washed with deionized water for three minutes. Thereafter, absolute ethyl alcohol is leveraged for dehydration.

Finally, the board's surface is dried using nitrogen gas gun until no water mark is seen. The following figure lists the steps of manual cleaning:

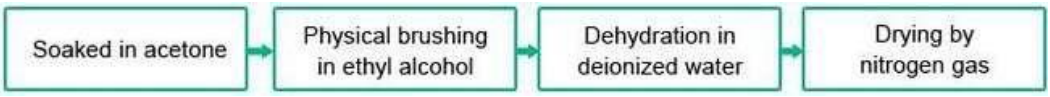


Fig. 5.1.4: Steps of manual cleaning

During this process, the following steps occur:

1. Acetone with higher solubility is used to soak the circuit boards. It makes the contaminants effectively dissolve into the solution.
2. The circuit board is placed in ethyl alcohol with detailed flux contaminants brushed off.
3. Dehydration of organic solvent takes place with the help of deionized water.
4. Finally, the board surface is dried using the nitrogen gas to complete manual cleaning after the surface mount soldering.

Ultrasonic Cleaning Method

Acetone solvent is used in ultrasonic cleaning method, using the following steps:

1. The acetone solvent is used to soak the circuit board for ten minutes.
2. Then, the board is placed and soaked into quartz container that is specialized for absolute ethyl alcohol.
3. Next, ultrasonic cleaning is implemented by placing the quartz container into an ultrasonic cleaning tank. Ultrasonic cleaning is done for five minutes using ultrasonic power of 240W.
4. The ultrasonic cleaning switch is turned off and the quartz container is taken out with a basket.
5. The board is washed using deionized water for 5 minutes and after that dehydration is carried out using absolute ethyl alcohol.
6. Finally, nitrogen gas is used to dry the surface.
7. Ultrasonic cleaning method is not recommended for PCBs with crystal oscillators.

During the process of ultrasonic cleaning, the circuit board is put into ethyl alcohol agent, which is different from manual cleaning. The following figure lists the steps of ultrasonic cleaning method:

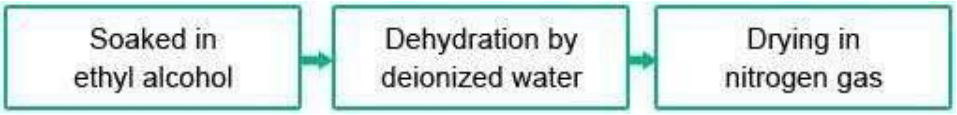


Fig. 5.1.5: Steps of ultrasonic cleaning

Vapour Degreasing

In this process, the parts are cleaned using a condensing solvent vapour put on the workpieces. Hot vapours of a fluorinated or a chlorinated solvent are used to remove soils, particularly, greases, oils and waxes.

At the bottom of a vapour degreasing unit there is a heated solvent reservoir which is also known as sump. At the top of the unit there is a steel tank and a cooling zone. The solvent is boiled to introduce sufficient heat inside the sump and generate hot solvent vapour. The hot vapour displaces the air as it is heavier and it fills the tank up to the cooling zone. Then, it gets condensed after reaching the cooling zone. Thus a fixed vapour level is maintained and a thermal balance is created. The difference in the temperature between the cool workpiece and the hot vapour causes the vapour to condense on workpiece and get dissolved the soil.

The following figure shows the vapour degreasing unit:

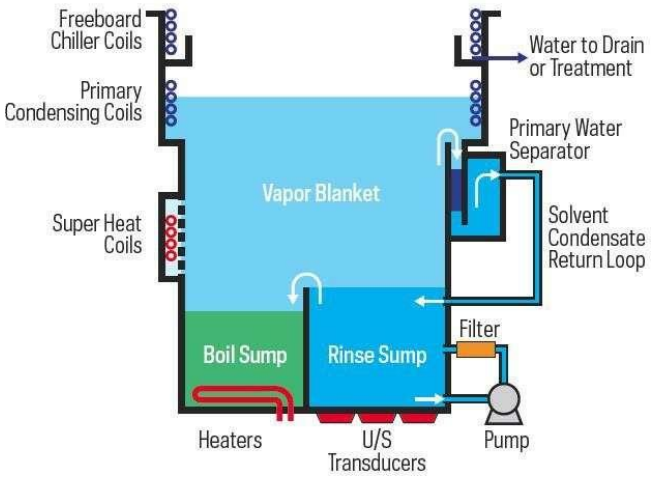


Fig. 5.1.6: Vapour degreasing unit

The soils removed from the workpieces typically boil at temperatures higher than that of the solvent. This forms essentially a pure solvent vapour, even though the boiling solvent may be contaminated with soil from earlier workpieces.

When the parts are subjected to heat, produced by the condensation of solvent vapours of the degreasing solvent, they rapidly dry when taken away from the vapours' vicinity.

The stability of the solvent is typically controlled by adding stabilizers while manufacturing the solvent. All the common chlorinated solvents require stabilizers for performing successfully in vapour degreasing.

Only condensation of solvent vapour is used in the simplest form of a degreasing unit. A spray stage may be added if any of the following two cases occurs:

- There are blind holes or recesses in the workpiece and they are not accessible to the vapour.
- Vapour cannot remove the soil.

In either of the cases, the system comprises of vapour – spray – vapour stages. There are many other techniques that include boiling liquid/warm liquid-vapour, warm liquid-vapour systems and so on. Ultrasonic cleaning can also be used in combination with the vapour degreasing process.

The following figure lists the impact of vapour degreasing on different elements:

When a ferrous metal is vapour degreased, organic films are usually removed, and the metal is highly susceptible to atmospheric corrosion.

When precision steel parts with a high surface finish (e.g. antifriction bearings) are being degreased and complete rust prevention is desired, rust proofing by flushing or immersion should be included as an integral part of the degreasing system.

Fig. 5.1.7: Impact of vapour degreasing on different elements

5.1.5 White Residues on PCB

White residues themselves are salts, but this is not always true. These salts serve as 'activators' in the fluxes. When these salts come in contact with heat or other chemicals, it results in white residues that can corrode the delicate circuits.

Some of the possible sources of white residues may be boards, solvent and fluxes, processes, people, storage method of the fluxes and solder paste and even the weather. Hence, determining the cause of the problem is very hard.

Use of lead-free soldering materials increases the problems with white residues. These soldering materials operate at higher temperatures, use different ingredients and respond to the solvents in a manner which is different from the older products.

But lead-free soldering material is not the only source of residues. White residues can also result if a wrong flux is used or proper cleaning is not done. Even if the substrates are improperly cured, it can manifest white residues after reflow.

5.1.6 Storage and Handling of PCB after Cleaning

PCBs, particularly the multilayer PCBs, are extremely sensitive towards moisture. The humidity of the surrounding air is soaked by a strong capillary power, developed by the microscopic structure of the multilayer material. Even under dry conditions, water may accumulate in the stored PCBs over time. Also, the storage area should be ESD free. Usually ESD free racks are used for storage of PCBs after cleaning.

The following image shows ESD free racks are used for storage of PCBs:

Fig. 5.1.8: ESD free racks are used for storage of PCBs

Notes

UNIT 5.2: Inspection of PCBs

Unit Objectives

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

1. List the points of importance of visual inspection
2. Identify the attributes of automated optical inspection test
3. List the applications of automated x-ray inspection method
4. Apply in-circuit tests
5. Compare different visual inspection machines

5.2.1 Visual Inspection

During the PCB assembly process, visual inspection can be done after performing the steps. The equipment used for visual inspection is chosen according to the positions that are identified for inspection. For example, the inspection staff can detect conspicuous defects with their naked eyes after the printing of solder paste and placement of device. Such defects may be missing components and contaminative solder paste. The most common visual inspection that can be done is inspecting the reflow solder joints. This can be done by observing the light rays that get reflected from an ordinary prism at different angles. Generally, five joints can be tested in just one second by this type of test.

Validity of this inspection depends on the capability of the inspection staff, his/her consistency as well as the applicability of inspection standard. The staff must be well informed about the technical requirements of all kinds of solder joints. Each kind of joint may comprise around eight types of defect standards and, on different assembly devices, more than six types of joints may be available. Thus, visual inspection cannot be utilised to do quantitative measurement needed for efficient structural process control.

Moreover, visual inspection is unsuitable for checking hidden solder joints such as those made on ultra-micro fine square flat devices, J-lead devices having high density package, ball grid array (BGA) devices or surface array flip chips. Visual inspection is regarded as an economical and readily accessible technology that is applicable for checking large defects.

5.2.2 Automated Optical Inspection (AOI)

AOI is an automated visual inspection of the manufacturing process of a PCB. In this inspection, a camera autonomously scans the device that needs to be tested. The device is checked for both extensive failures such as a missing component and quality deficiencies such as defect in shape, fillet size or a component.

The following image shows an AOI equipment:

Fig. 5.2.1: AOI equipment

Necessity of AOI Test

A PCB has a crucial role to play in the electrical connection of various components that are assembled on bare boards. They are used in electronic devices which can be a simple equipment such as an electronic watch, a calculator, a handheld computer or a communication equipment, or an advanced electronic device such as a military, medical or aerospace product.

Modern circuits are more complicated than the earlier ones due to the advancement in technologies and higher demands for the advanced electronic devices. Furthermore, the introduction of SMT lead to the development and miniaturisation of circuit boards with high density. Presently, even a simple PCB has many layers and solder joints. Furthermore, the size of the components is constantly getting smaller with technological advancements. Hence, there is an increase in the usage of 0402 and 0201 components that help in ensuring correct application of appropriate components using effective polarity and values.

Manual inspection is rarely considered for modern circuit boards as it is unable to check their internal defects. Therefore, there is a need for a reliable and fast inspection method in the current market scenario.

Hence, using AOI becomes important to ensure that the products leaving the manufacturing house are correct and are performing as per the application expected in customers' devices or projects. Moreover, AOI test also detects the issues in early phases and thus enables a reduction of cost.

Attributes and Capabilities of AOI Test

The AOI test provides results with high accuracy and reliability. The following image shows an AOI equipment and attributes of AOI equipment:

Range	Tolerance
Accuracy	±0.0024mm
Speed	5in^2/sec (60FOV/sec)
PCB Max. size	400*330mm
Available Component	0201 chip and fine pitch

Attributes of AOI Equipment

Fig. 5.2.2: An AOI equipment and attributes of AOI equipment

The following figure lists the attributes and capabilities of AOI test:

Variety of Boards

- Depending on visual methods, AOI test can be applied to detect a lot of surface defects including scratches, nodules, stains, opens, shorts, insufficient or excessive solder, incorrect components, missing components, incorrect polarity of components etc.
- AOI is capable of detecting issues that could have been exposed during manual visual inspection. However, AOI is used over manual inspection as it is faster and more accurate.

Multiple Inspection Objects

- AOI test works perfectly for both bare PCBs and PCBAs.
- For PCB inspection, typical defects are checked such as shorts, opens and insufficient solder.
- For PCBA inspection, major issues are inspected including component soldering, polarity and values.

Flexibility

- AOI can be arranged in any stage of manufacturing line in accordance to the customers' needs and cost tolerance capacity.
- In order to increase inspection efficiency and reduce corresponding cost, it's optimal to place it after reflow soldering because most defects result from non-conformance occurring during soldering process.
- The flexibility attribute of AOI test leads to reduction of cost since it is an in-process test and as soon as issues are discovered, manufacturing or assembly parameters can be instantly modified so that later products will be correctly produced. As a result, more products won't be rejected during functional test or final inspection.

Low Cost

- Compared with Automated/Automatic X-ray Inspection (AXI), post-reflow, AOI is less expensive when it comes to solder joint defects inspection including bridges, broken joints, dry joints etc.

Fig. 5.2.3: Attributes and capabilities of AOI test

Working Principle of AOI Test

The AOI test attains its results by scanning the surface of the board. The AOI equipment can capture images of the PCB surfaces using high-definition cameras. For this purpose it needs light sources such as fluorescent lighting, LED lighting, infra-red or ultra-violet lighting. The captured image is then compared against the parameters of the board. These parameters have already been input into the computer. With its built-in processing software, the equipment provides a result of the comparison that indicates the differences, abnormalities or errors clearly. The whole process can be monitored every second.

AOI analyses a board to decide whether it is in good condition or has flaws by applying different algorithms. Pixel-counting algorithm is utilised to check simple applications.

The following figure lists the methods of a pixel-counting algorithm:

Template matching

- Template-matching method, also called area-based method or correlation-like method, has been popular for a couple of decades.
- Based on pixel-by-pixel method, a small template is applied to a large inspection image through sliding template window.
- Then, normalized cross correlation (NCC) will be calculated between the template and inspection image.
- The larger the value of NCC is, the higher matching between them will be.

Object recognition

- Object recognition conforms to the same principle as view method in that difference is observed through comparison between an ideal image and the captured image of an object.

Blob analysis

- Blob analysis refers to a process during which the object is separated from the background first.
- Then with a pixel-based image applied, a blob is generated through grouping of object pixels to inspect issues of objects.

Fig. 5.2.4: Methods of a pixel-counting algorithm

Vectoral imaging technology is a new method that plays a major role in PCB or PCBA inspection. Vectoral imaging is a pattern location search technology that is based on geometric feature extraction rather than on complete grey scale pixel values. Under such circumstances, non-liner changes or colour changes do not influence the image analysis. Vectoral imaging performs better in reducing the false failures due to the elimination of attribute of background.

5.2.3 Automated X-ray Inspection (AXI)

AXI is a technology that is based on the same principles as those of AOI. It utilises X-rays instead of visible light as its source to check the features that are usually hidden from view. AXI is widely used in different industries and applications. The following figure lists the major goals of AXI:

Process optimization, i.e. the results of the inspection are used to optimize following processing steps	Anomaly detection, i.e. the result of the inspection serve as a criterion to reject a part (for scrap or re-work)

Fig. 5.2.5: Major goals of AXI

AOI is primarily linked with electronics manufacturing. On the other hand, AXI has many applications. These range from performing quality inspection of alloy wheels to identifying bone fragments within processed meat. To ensure that quality is maintained and to improve the yield in processing and manufacturing, which entail production of large numbers of very similar items according to defined standards, AOI is used in combination with advanced image processing and pattern recognition software. The following image shows an AXI equipment:

Fig. 5.2.6: An AXI equipment

Principle of Operation

The image produced by the camera in AXI equipment is processed by image processing software. The following figure lists the features detected by the processing software:

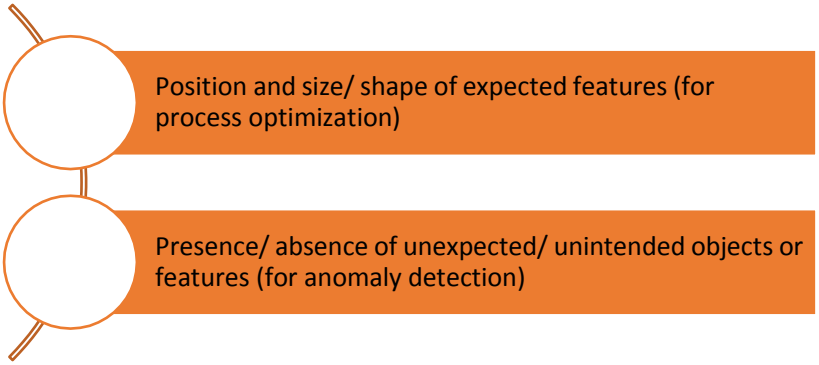


Fig. 5.2.7: Features detected by the processing software

AXI passes x-rays that are generated by an x-ray tube through the target object. There is a detector opposite to the x-ray emitter. The detector does one of the following actions:

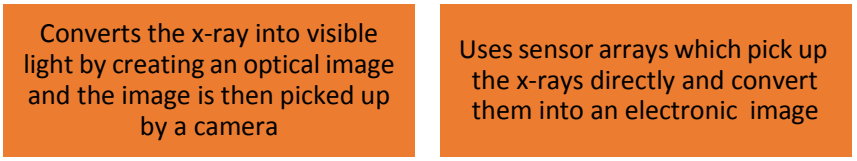


Fig. 5.2.8: Actions of a detector

The image is produced as a result of different levels of absorption of the x-rays in different parts of the object as the rays pass through it. Thus, it is able to reveal the inner structures of the object which were not visible earlier.

Application

The application of AXI is constantly growing with the advancement of image processing software. AXI was first applied in the industries where a careful inspection of each part produced is required to ensure the safety aspect of the components. An example is welding the seams of metal parts in nuclear power stations.

The technology was costly earlier but with greater adoption of the technology, the prices reduced considerably and AXI was easily available to a much wider field with safety requirements such as processed food industry for detection of glass, metal or other materials. In food processing, AXI was also utilised to improve the yield and to optimise processing. For example, identification of size and location of holes in cheese to optimise the slicing patterns.

An early detection of defects, in mass production of complex items, can reduce overall cost drastically. It is because the early detection prevents the defective parts from being used in subsequent steps of manufacturing. The following figure lists the benefits of early detection of defects:

It provides feedback at the earliest possible state that materials are defective or process parameters got out of control.

It prevents adding value to components that are already defective and therefore reduces the overall cost of a defect.

It increases the likelihood of field defects of the final product, because the defect may not be detected at later stages in quality inspection or during functional testing due to the limited set of test patterns.

Fig. 5.2.9: Benefits of early detection of defects

The following figure lists the advantages and disadvantages of AOI:

Advantage	Disadvantage
• It is able to see through chip packages with connections underneath. • It can inspect densely packed boards. • It provides thorough inspection of solder joints.	• Newer technology may not be thoroughly understood by AOI equipment. • Investment may only make sense in situations in which BGAs, CSPs and similar packages are used or in which board density is beyond AOI's capabilities.

Fig. 5.2.10: Advantages and disadvantages of AOI

5.2.4 In-circuit Testing (ICT)

In-circuit test equipment measures all the components to check that they are correct and in place. ICT ensures whether a populated PCB has correctly been made by checking for shorts, opens, capacitance, resistance and other parameters using an electrical probe. The following image shows an ICT setup:

Fig. 5.2.11: ICT setup

ICT can be performed with a flying probe setup or with a bed-of-nails test fixture. The following figure explains the bed-of-nails test fixture approach and flying probe approach:

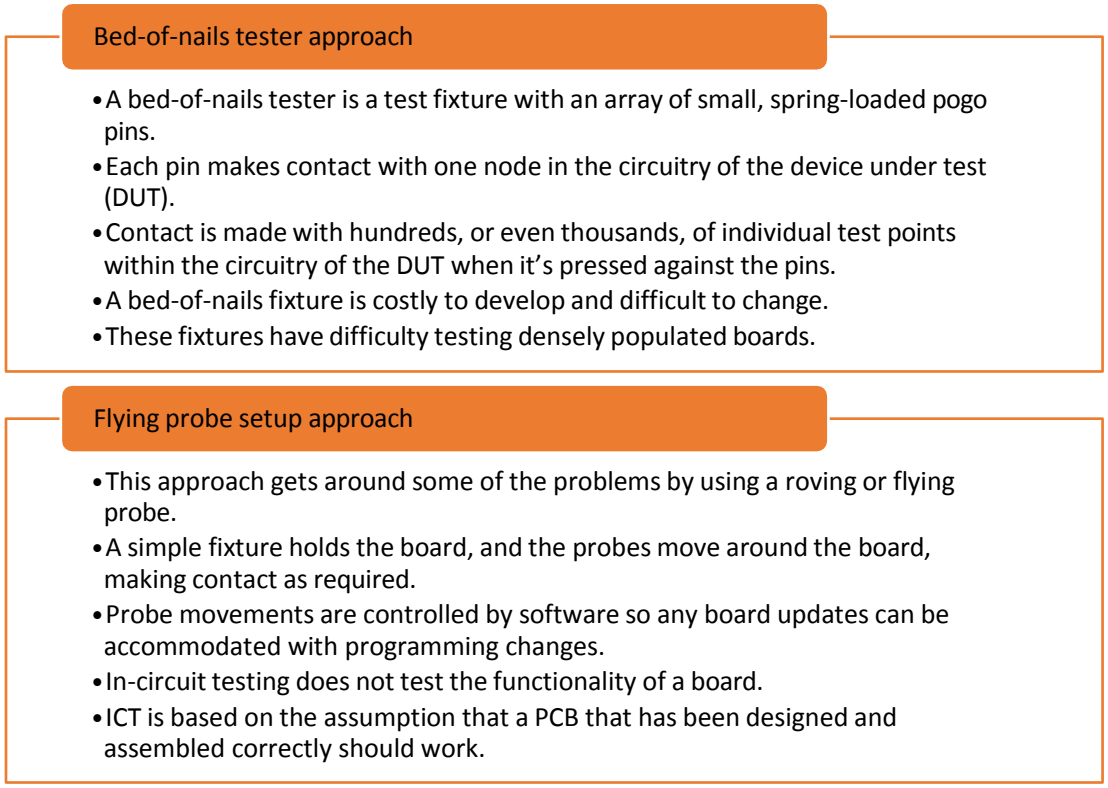


Fig. 5.2.12: Bed-of-nails test fixture and flying probe approach

5.2.5 Comparison between Visual Inspection Machines

The following table lists the comparison between the three visual inspection machines:

Defect Type	AXI	AOI	ICT
Soldering Defect			
Open circuits	YES	YES	YES
Solder Bridge	YES	YES	YES
Solder Short	YES	YES	NO
Insufficient solder	YES	YES (But not Heel)	NO
solder void	YES	NO	NO
Excess solder	YES	YES	NO
Solder Quality	YES	NO	NO
Components Lifted			
Lifted Lead	YES	YES	YES
Missing Component	YES	YES	YES
Misplaced Components	YES	YES	YES
Incorrect components value	NO	NO	YES
Faulty components	NO	NO	YES
BGA and CSP			
BGA short	YES	NO	YES
BCA open circuit Connection	YES	NO	YES

Table 5.2.1: Comparison between the three visual inspection machines

Exercise

1. List the different types of contaminations in PCBs.

2. List the advantages and disadvantages of the AOI.

Notes

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6. Industrial Education

Unit 6.1 – Workplace Communication

Unit 6.2 – Maintenance Procedure and QC Tools

Unit 6.3 – Standard Operating Procedures

Key Learning Outcomes

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

1. Define workplace communication
2. Assess the different types of communication at workplace
3. Demonstrate the ways to communicate effectively with clients and customers
4. List the QC tools used for quality check
5. Identify the maintenance procedures used in an organisation
6. List the functions of store management
7. List the advantages of codification
8. List the Industrial acts or company standards
9. Analyse the important points related to Standard Operating Procedures

UNIT 6.1: Workplace Communication

Unit Objectives

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

1. Define workplace communication
2. Assess the different types of communication at workplace
3. Demonstrate the ways to communicate effectively with clients and customers

6.1.1 What is Workplace Communication?

Workplace communication is defined as the exchange of information, verbally and non-verbally, in an organisation. There are different means of communication. To become a valuable and an effective member at the workplace, it is important to achieve skills in all the different methods of communication.

An effective communication at the workplace ensures an increase in the productivity and efficiency of the organisation. Such communication is tremendously important for organisations because it leads to them achieving their organisational objectives. The disadvantage of ineffective workplace communication is that it creates a communication gap among the employees, which creates confusion, wastage of time and reduced productivity. Effective communication can help in avoiding the misunderstandings that cause friction between people.

A sender and a receiver are required for a communication to occur and it must occur irrespective of the form of communication. For communication to be effective, the receiver should have understood it so that he or she can respond accordingly. This means that communication involves reading, speaking, reasoning and listening skills.

During the communication between a sender and a receiver, there is a chance for its original meaning to change. Therefore listening, speaking, feedback and reasoning are all important parts of the communication process and are required to be done properly to make sure that the receiver understands the message sent by the sender.

Tips

"Noise" is the other consideration associated with communication which can have a big impact on the message the receiver decodes.

6.1.2 How to Communicate in the Workplace

Communication should occur in a way that brings a positive change to individual differences. The points to be used while communicating with any individual are as follows:

- Value individuals and treat them with respect and courtesy
- Understand the cultural differences of the individuals
- Maintain positive relationship and confidence through communication
- Follow basic strategies to minimise communication barriers

The way of communication affects the ability of an individual to get things done and get along with other people. Verbal, written and visual communication can happen in positive and negative ways. An individual should take feedback from others regarding how they perceive or interpret his or her way of communication. Sometimes it could be perceived as aggressive even though it is not intended.

The following figure describe the points for effective verbal communication:

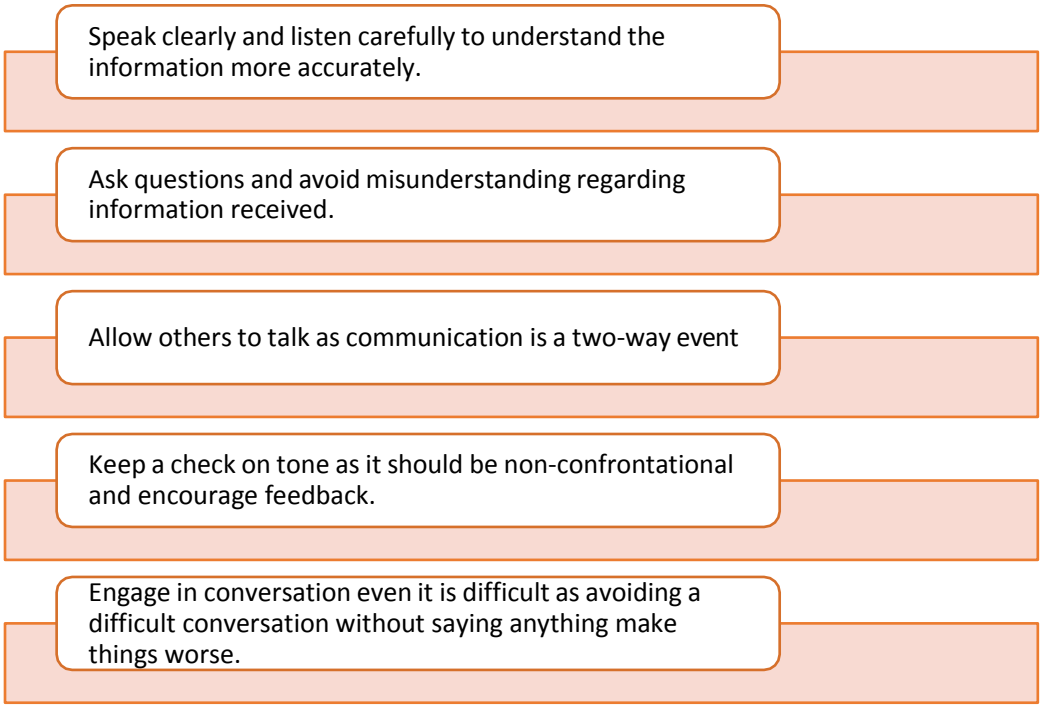

Fig. 6.1.1: Verbal Communication

The following figure describe the points for written communication or through email:

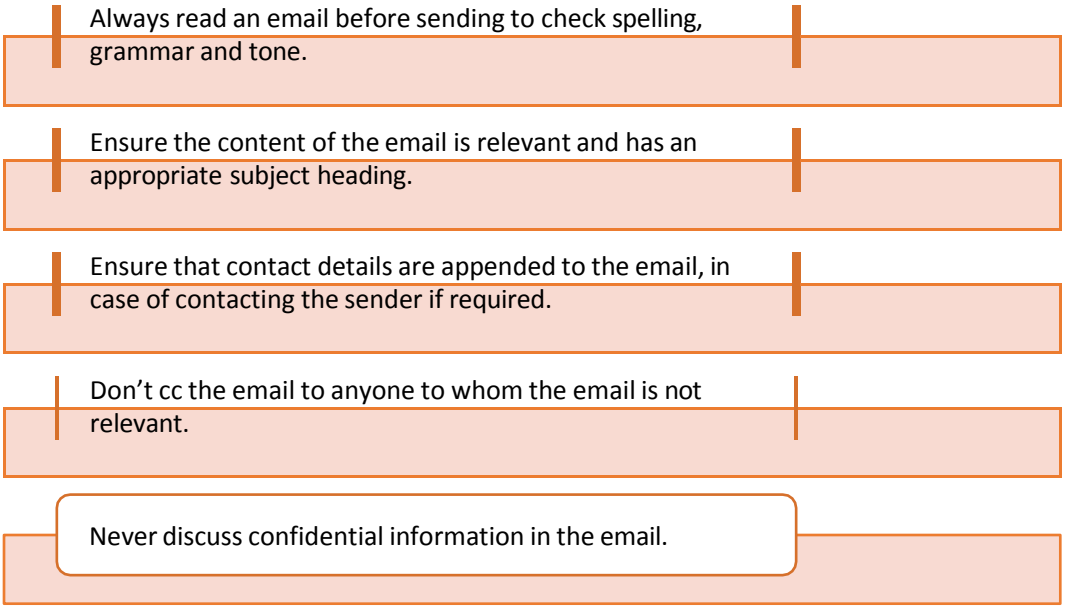

Fig. 6.1.2: Written Communication

The workplace is a professional place, so professional standard should also be maintained in the written communication. Some of the points related to written communication are:

- It should be simple and easy to understand.
- It should be to the point and should avoid unnecessary repetition or use of long rambling sentences.
- The usage of too many technical terms should be avoided.
- Similarly, the usage of slang and offensive, racist or sexist language should be avoided.

6.1.3 Communication with Clients and Customers

A customer or a client is defined as someone to whom a company provides service, completes a task for and sells a product to. The employees of the company should be polite and use verbal and non-verbal communication while responding to the customer and client request.

Miscommunication can create problems in the workspace and can occur in many ways. It can cause misunderstanding while communicating with the clients or customers due to the following reasons:

- Misinterpretation of the words
- Wrong body language
- Not listening properly to the client or client not listening properly

The following figure shows some tips that shows how to communicate effectively with clients and customers:

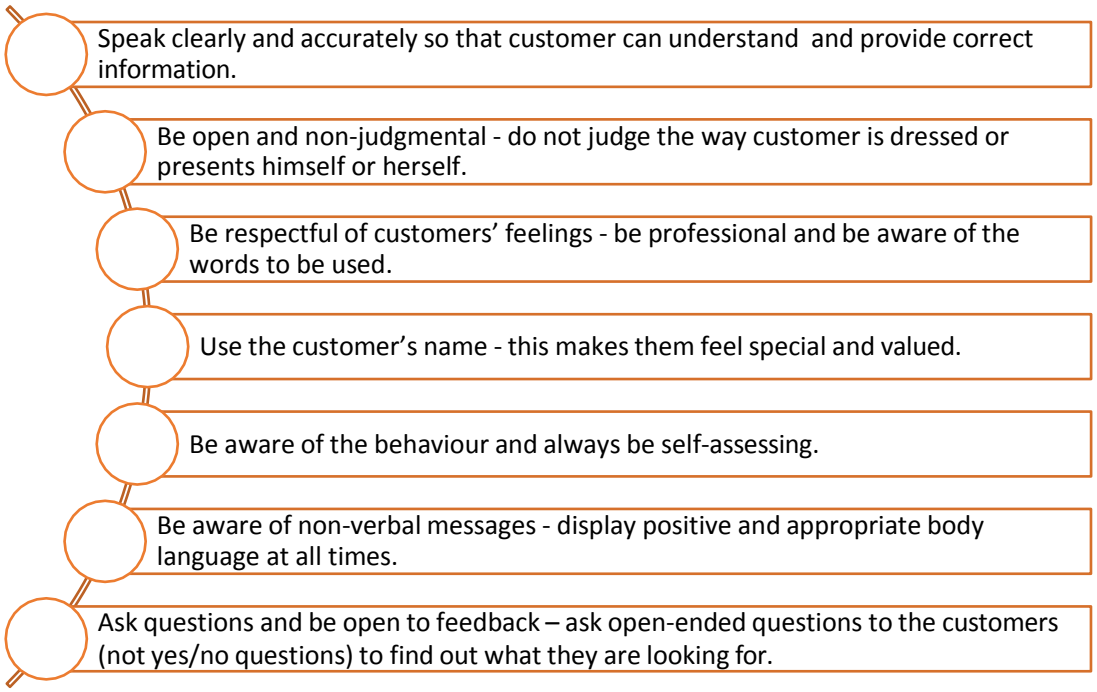

Fig. 6.1.3: Tips to communicate effectively with clients and customers

Notes

UNIT 6.2: Maintenance Procedure and QC Tools

Unit Objectives

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

1. List the QC tools used for quality check
2. Identify the maintenance procedures used in an organisation
3. List the functions of store management
4. List the advantages of codification

6.2.1 QC Tools

The basic tools of quality check are also referred as 7 QC Tools. They originated in Japan during the quality revolution time period of the country and thus become an important and mandatory topic of Japanese industrial training program. These tools consist of statistical techniques and simple graphical techniques which help in solving any critical quality issues. These tools are called as basic tools as any person who has basic training in statistics can implement them. 7 QC tools are applied in many industries from the product deployment phase till the delivery of the product. The detailed description of these seven QC tools are as follows:

1. **Check Sheet:** Check sheet is a form that is used to gather data in real time at the location where the data is generated. The captured data can be quantitative or qualitative. In case of quantitative data, the check sheet is known as tally sheet. The check sheet consists of heading which answers five Ws as follows:
   - Who has filled the check sheet?
   - What type of data was collected?
   - Where the data collection has happened?
   - When the collection has taken place (shift or day of the week)?
   - Why the data was collected?

   The following diagram shows a check sheet:

Motor Assembly Check Sheet

Name of Data Recorder: Lester B. Rapp
Location: Rochester, New York
Data Collection Dates: 1/17 - 1/23

Defect Types/ Event Occurrence	Dates							TOTAL
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	
Supplied parts rusted		|||||| |||| |||| ||			20
Misaligned weld			|||		||		5
Improper test procedure								0
Wrong part issued				||			3
Film on parts								0
Voids in casting				||||	||			6
Incorrect dimensions						||		2
Adhesive failure								0
Masking insufficient								1
Spray failure			|||||				5
TOTAL		10	13	10	5	4		

Fig. 6.2.1: A sample check list

The following figure shows the uses of a check list:

To check the shape of the probability distribution of a process
To quantify defects by type
To quantify defects by location
To quantify defects by cause (machine, worker)
To keep track of the completion of steps in a multistep procedure

Fig. 7.2.2: Uses of check list

1. **Control Chart:** Control chart, also known as Shewhart Chart named after Walter A. Shewhart, is a statistical chart to determine if an industrial process is capable to meet the customer specification limits and is within control.

   In the control chart, the data is plotted in X-axis versus time. These charts have following lines which are determined from historical data:

   - A central line that denotes the average or mean
   - An upper line that denotes the upper control limit
   - A lower line that denotes the lower control limit

   The experts can draw conclusions by comparing data to these lines. These include determining whether the consistency exists in process variation; whether it is in control and is affected by usual causes of variation or it is out of control that is unpredictable and is affected by a special cause of variation. It distinguishes usual causes from special causes of variation.

   Control chart helps in understanding the various production patterns, predicting process performance and studying the process changes or shifts from normally specified control limits over a period. The following diagram shows a control chart:

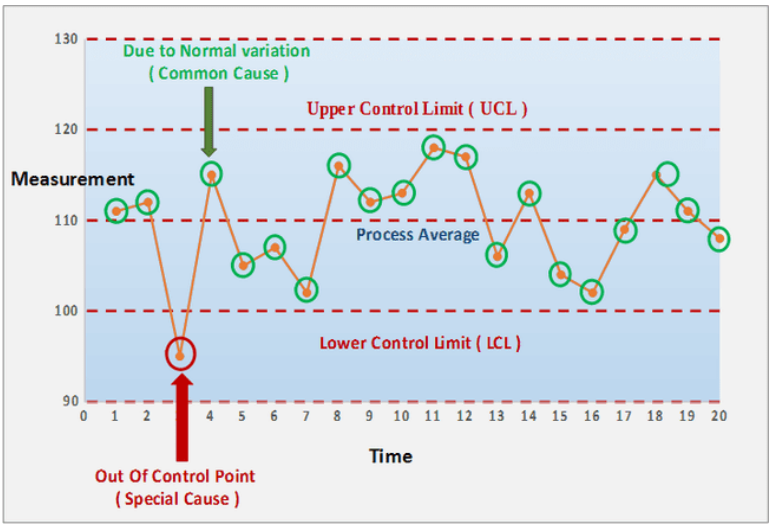

Fig. 6.2.3: Control chart

3. **Stratification:** Stratification is a technique of dividing and classifying data based on division, class, group or levels. It enables deriving meaningful information that helps in understanding the existing problem.

   The purpose of this technique is to achieve meaningful information for solving a problem. The two types of stratification data are:

   - **Unstratified data:** An employee arrived late to office on the following dates: 5 Jan, 12 Jan, 13 Jan, 19 Jan, 21 Jan, 26 Jan, 27 Jan
   - **Stratified data:** In this, the same data is classified as shown in the following diagram:

Day	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Frequency - Late in Office	4	2	1	0	0	0	0

Fig. 7.2.4: Stratified data

4. **Pareto Chart**: This chart is used for identifying a set of priorities. With this, any number of variables or issues can be charted which are related to a specific concern and the occurrences can be recorded. It helps to figure out the parameters that have the impact on the specific concern. The following diagram shows a Pareto chart:

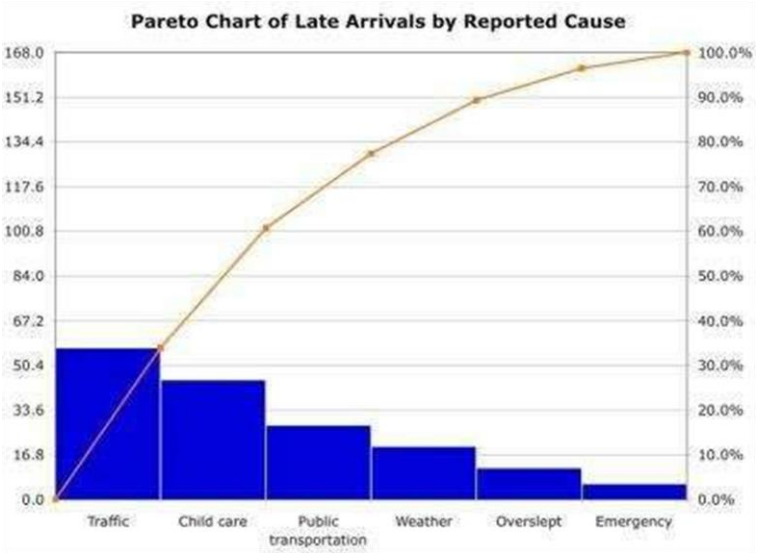

Fig. 7.2.5: Pareto chart

5. **Histogram**: Histogram illustrates the frequency and the extent in the terms of two variables. It is a chart that consists of columns and represents the distribution by mean. In case the histogram is normal, the graph will have the shape of a bell-curve and if it is not normal, it can have various shapes depending on the distribution conditions.

The following diagram shows a histogram that represents morning attendance of a class where X-axis represents the number of students and Y-axis represents the time of the day:

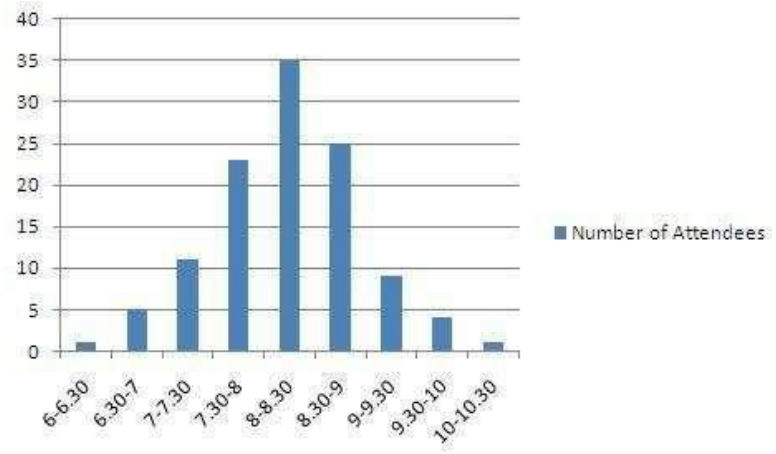

Fig. 7.2.6: Histogram

1. **Cause-and-Effect Diagram:** This diagram is also known as Ishikawa diagram. It is used to understand causes of the problems in an organisation or a business. It is made by teamwork and helps in understanding the causes of problems faced by an organisation every day.

   Brainstorming sessions are required to analyse the causes of the problems and draw an effective cause and effect diagram. In this diagram, all the main components of the problem and their possible causes are listed. Then, most occurring causes of that problem are identified to carry out the analysis. The following figure shows a cause-and-effect diagram:

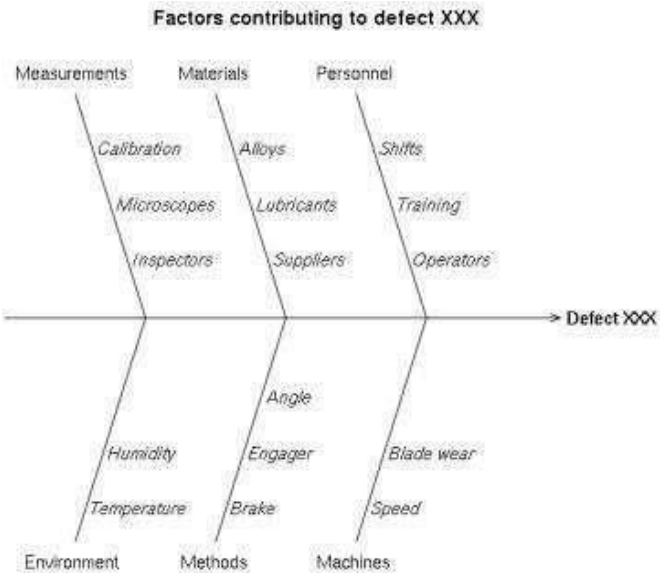

Fig. 6.2.7: Cause-and-Effect diagram

7. **Scatter Diagram:** The value of two variables can be effectively represented by a scatter diagram. It represents the relationship between the two variables and illustrates the result on a Cartesian plane. Further analysis of these variables can be performed such as trend analysis. The following figure shows a scatter diagram:

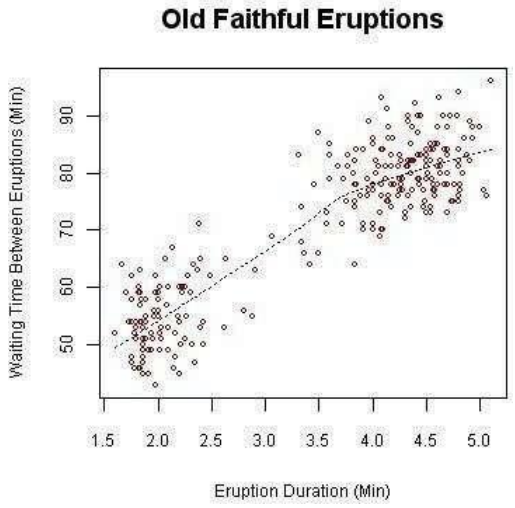

Fig. 6.2.8: Scatter diagram

6.2.2 Maintenance Procedure

Maintenance is defined as the process of maintaining a situation or condition or the state of being maintained.

The following figure shows different types of maintenance procedures:

Preventive maintenance	Corrective maintenance	Predictive maintenance
• This maintenance is performed with the intent of avoiding failures, safety violations, unnecessary production costs and losses. • It is also helpful to conserve original materials of fabrication.	• This maintenance is used for equipment after their breakdown or malfunction and is often very expensive. • It consequentially repairs the equipement and reduces replacement costs but the loss of revenues due to downtime during overhaul can be significant.	• This maintenance strategy uses sensors to monitor key parameters within a machine or a system. • It uses this data along with analysed historical trends to continuously evaluate a system's health and predict a breakdown before it happens.

Fig. 7.2.9: Types of maintenance procedures

6.2.3 Store Management

Store management plays an important role in the operation of a company and is in direct contact with the user department's day-to-day activities. Its most important motive is to provide uninterrupted service to the manufacturing divisions.

The following figure shows the functions of store management:

Fig. 6.2.10: Functions of store management

Codification

Codification is one of the functions of store management. It is defined as the process in which each item is represented by a number. The digits of this number indicate the group, the sub-group, the type and the dimension of the item. The organisations in private and public sectors and in railways have their unique system of codification which varies from eight to thirteen digits. The first two digits are for major group which includes raw materials, spare parts, hardware items, oil and so on. The sub-groups such as ferrous are represented by the next two digits. Dimensional values for width, length and so on are represented by three digits and the last digit is for minor variations.

Each code represents one item and it should be simple enough to be understood. Codification must be concise, compact and flexible to accommodate any new item. Each digit should be of significance and must show some characteristic of the item.

The following figure shows the advantages of codification:

Advantages of Codification	As a result of rationalised codification, many firms have reduced the number of items.
	It enables systematic grouping of similar items and avoids confusion caused by long description of items
	Standardisation of names is achieved through codification as it serves as the starting point of simplification and standardisation
	Codification enables easy recognition of an item in stores, thereby reducing clerical efforts to the minimum.
	It helps in avoiding duplication of items and results in the minimisation of the number of items, leading to accurate record.

Fig. 6.2.11: Advantages of codification

Notes

UNIT 6.3: Standard Operating Procedures

Unit Objectives

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

1. List the Industrial acts or company standards
2. Analyse the important points related to Standard Operating Procedures

6.3.1 Industrial Act and Company Standards

The labour legislations provided by the Central Government can be classified into different broad categories as shown in the following figure:

Laws Relating to Industrial Relations	1. Industrial Disputes Act, 1947 2. Trade Unions Act, 1926
Laws Relating to Wages	1. Minimum Wages Act, 1948 2. Payment of Wages Act, 1936 3. Payment of Bonus Act, 1965
Laws Relating to Social Security	1. Employees' Provident Funds and Miscellaneous Provisions Act, 1952 2. Employees' State Insurance Act, 1948 3. Labour Welfare Fund Act (of respective states) 4. Payment of Gratuity Act, 1972 5. Employee's Compensation Act, 1923
Laws Relating to Working Hours, Conditions of Services and Employment	1. Factories Act, 1948 2. Industrial Employment (Standing Orders) Act, 1946 3. Shops and Commercial Establishments Act (of respective states) 4. Contract Labour (Regulation and Abolition) Act, 1970 5. Inter-State Migrant Workmen (Regulation of Employment and Conditions of Service) Act, 1979 6. Weekly Holiday Act, 1942 7. National and Festival Holidays Act (of respective states) 1963 8. The Plantation Labour Act, 1951 9. The Mines Act, 1952 10. The Dock Workers (Safety, Health & Welfare) Act, 1986
Laws Relating to Equality and Empowerment of Women	1. Equal Remuneration Act, 1976 2. Maternity Benefits Act, 1961
Prohibitive Labour Laws	1. Bonded Labour System (Abolition), Act, 1976 2. Child Labour (Prohibition & Regulation) Act, 1986 3. The Beedi and Cigar Workers (Conditions of Employment) Act, 1966 4. The Sexual Harassment at the Workplace (Prevention, Prohibition and Redressal) Act, 2013
Laws Relating to Employment and Training	1. Apprentices Act, 1961 2. Employment Exchanges (Compulsory Notification of Vacancies) Act, 1959

Fig. 7.3.1: Industrial Acts

6.3.2 Standard Operating Procedures (SOP)

An SOP is a complete step by step set of instructions made by an organisation to assist the workers in performing complex routine operations. The SOP aims at achieving quality output, efficiency and uniformity in the performance of all personnel in the organisation and minimising miscommunication and failure to adhere to industry regulations.

The following figure shows the points that should be kept in mind while designing an SOP:

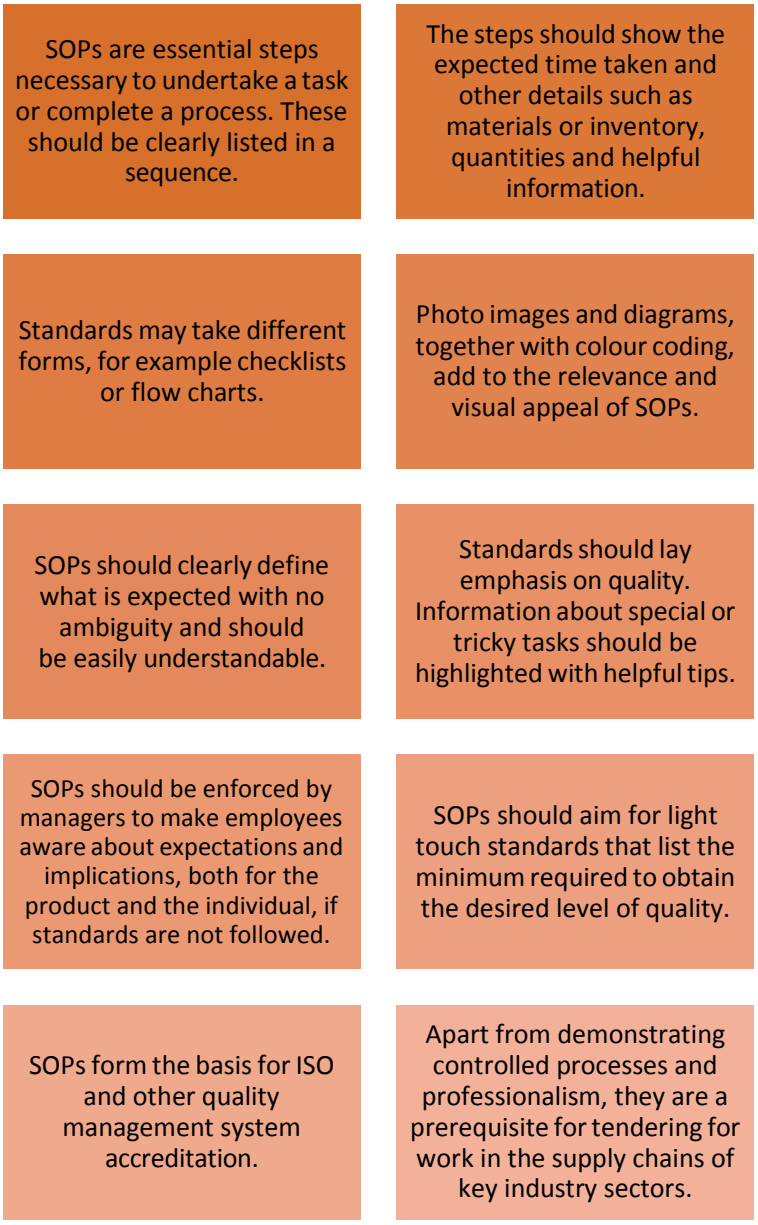

Fig. 6.3.2: Points to be kept in mind for SOPs

Exercise

1. List points for effective verbal communication.

2. What are the functions of store management?

Notes

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7. Organize Resources and Work Effectively and Safely

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Key Learning Outcomes

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

1. Explain about the work place health and safety
2. Differentiate various health hazards
3. Demonstrate various first aid techniques
4. Importance of safety at workplace
5. Understand Basic hygiene Practices and hand washing techniques
6. Explain the need for social distancing
7. Understand the reporting of hazards at workplace
8. Explain e-waste and process of disposing them
9. Explain Greening of jobs

UNIT 7.1: Workplace health & safety

Unit Objectives

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

- Understand about workplace health and safety
- Explain tips to design a safe workplace
- Explain precautions to be taken at a workplace

7.1.1 Safety: Tips to Design a Safe Workplace

Workplace health and safety policy defines the best possible work conditions and safety for the employees. Employees have a right to feel safe in their workplace. Hence the organizations create and follow legal standards and ensure a hazard-free workplace.

Every organization is obligated to ensure that the workplace follows the highest possible safety protocol. When setting up a business some tips to remember:

- Use ergonomically designed furniture and equipment to avoid stooping and twisting
- Provide mechanical aids to avoid lifting or carrying heavy objects
- Have protective equipment on hand for hazardous jobs
- Ensure presence of emergency exits and they are easily accessible
- Set down health codes and ensure they are implemented
- Follow the practice of regular safety inspections in and around the workplace
- Get expert advice on workplace safety and follow it
- Get regular inspection of electrical wiring and also the electrical switches and gadgets
- Install fire extinguishers and fire alarms.

7.1.2 Precautions to be taken while at work

Every employee is obligated to follow all safety protocols put in place by the organization.

All employees must make it a habit to:

- Immediately report unsafe conditions to the supervisor
- Recognize and report safety hazards that could lead to slips, trips and falls
- Report all injuries and accidents to the supervisor
- Wear the correct protective equipment when required
- Learn how to correctly use equipment provided for safety purposes
- Be aware of and avoid actions that could endanger other people
- Always be alert
- Educate the employees about the first/emergency exits on the floor, and also where the fire extinguishers are kept.

Tips

1. Be aware of what emergency number to call at the time of a workplace emergency
2. Practice evacuation drills regularly to avoid chaotic evacuations

UNIT 7.2: Different types of Health hazards

Unit Objectives

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

1. Understand the health hazards
2. Demonstrate First Aid Techniques

7.2.1 First Aid

Illness, injuries, and pain are part of human life. This can happen anyway. Every individual is prone to illness and injuries at any time and anywhere.

In case of any of these, some kind of immediate medical attention or treatment is needed to reduce the discomfort, pain, and deterioration of the condition. The medical attention that is given at the first instance before seeking professional medical help is called “First Aid”. First aid is the immediate and temporary treatment given to the victim of an accident or sudden illness while awaiting the arrival of “Medical Aid”. First Aid means providing the initial treatment and life support for people with an injury or illness. However, First Aid has its limitations and does not take the place of professional medical treatment. Proper early assistance given by First Aider helps in saving the life of a patient.

Illness and injuries can happen anywhere, be at home, the workplace, or in the market place. Whatever safety measures we adopt, we are all prone to illness sometime or the other.

Some common injuries and their rescue techniques:

7.2.1 First Aid Techniques

- Direct pressure must be applied to the cut or wound with a clean cloth, tissue, or piece of gauze, until bleeding stops.
- If blood soaks through the material, it is highly recommended not to remove it.
- More cloth or gauze must be put on top of it, and pressure must be continued.
- If the wound is on the arm or leg, the limb must be raised above the heart to help slow the bleeding.
- Hands must be washed again after giving first aid and before cleaning and dressing the wound.
- A tourniquet must not be applied unless the bleeding is severe and not stopped with direct pressure.

Click / Scan the QR code for First Aid Techniques

Fig. 6.2.1a: Clean cut or wound

Clean cut or wound

- The wound must be cleaned with soap and lukewarm water.
- To prevent irritation and burning sensation, the soap solution must be rinsed out of the wound.
- Hydrogen peroxide or iodine must not be used to clean or treat the wound since they are corrosive and can damage live tissues.

Fig. 6.2.1b: apply hydrogen peroxide or iodine

Protect the wound

- Antiseptic cream or solution must be applied to the wound to reduce the risk of infection.
- Then the wound must be gently covered with a sterile bandage.
- Till the wound heals, the bandage must be changed (dressed) daily to keep the wound clean and dry.

Fig. 6.2.1c: Protect the wound

Call the Emergency Helpline if:

- The bleeding is severe and deep
- You suspect Internal Bleeding
- Abdominal or Chest wound exists
- Bleeding continues even after 10 minutes of firm and steady pressure

For Burns:

- Immediately put the burnt area under cold water for a minimum of 10 minutes
- If the burned area is covered, take clean scissors, cut and remove the fabric covering the area
- In case clothing is stuck to the burned area, leave it as it is
- Before sterile dressing application, remove jewellery (if any)
- It is better to leave the burned area open
- Do not apply any medication or ointment
- Breaking a blister – it is an absolute no-no!

Fig. 6.2.1d: Put Burnt Area under Water

For Broken Bones and Fractures

- **Protruding bone must be left alone**
  - If a bone has broken through the skin, it must not be pushed back into place.
  - The area must be covered with a clean bandage and immediate medical attention must be sought.
- **Bleeding must be stopped**
  - Steady and direct pressure must be applied with a clean piece of cloth for 15 minutes and the wound must be elevated.
  - If a blood soaks through, one must apply another cloth over the first and seek immediate medical attention.
- **Swelling must be controlled**
  - The RICE (Rest, Ice, Compression and Elevation) therapy must be applied to control and reduce swelling.
  - Rest the injured part by having the person stay off of it.
  - Ice must be applied on the area with the help of an ice pack or by wrapping the ice in a clean cloth. Ice must not be directly placed against the skin.

For Heart Attack/Stroke

- Think FAST. Face: is there weakness on one side of the face? Arms: can they raise both arms? Speech: is their speech easily understood? Time: to call Emergency helpline
- Immediately call medical/ambulance helpline or get someone else to do it

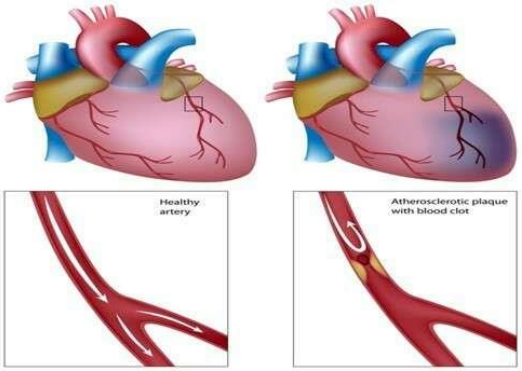

Fig 6.2.1e: Anatomy of Heart Attack

For Head Injury

- Ask the victim to rest and apply a cold compress to the injury (e.g. ice bag)
- If the victim becomes drowsy or vomits, call Medical helpline or get someone else to do it

Steps of using breathing apparatus:

Check the parts of the breathing apparatus thoroughly.

Check the bypass knob (red). Close it if you see it open. After this, press the reset button (area above bypass nob – black)

Inspect the facemask to see that it is undamaged.

Lift the cylinder ensuring that on the top the cylinder valve should be present. The back plate of the cylinder should face the wearer. Wear the breathing apparatus on the shoulder like a bag pack and by the neck strap, hang the facemask.

After wearing the breathing apparatus tighten shoulder straps and fasten the waist belt.

The cylinder valve should be opened slowly to inspect the pressure gauge.

Make sure that 80% of the cylinder is full.

Wear the mask slowly by resting your chin in the resting cusp and pull the head strap slowly over your head.

Pull the head straps for a snug but comfortable fit.

Breath in and normally to see if you can breathe normally or not.

Now insert a finger sidewise of the facemask for easy outward airflow.

Slowly close the cylinder valve without leaving the knob.

Be steady for 10 minutes and hold your breath or extremely slow to listen to any wheezing sound.

Also, check the pressure gauge for any dip in the pressure.

Normally Breathe to vent system
Listen for a whistle alarm while observing the pressure gauge
at 55 bar (+/-5 bar)

Briefing and Guidance for Fire Fighters

There are basically three methods with the help of which people can be rescued from a building engulfed in a blazing fire. To ensure on-site reception, here are two of the important steps that we will discuss now. These come under the best safe lifting and carrying practices.

Conventional Technique: This is a good method if there is an open area close by. The first rescuers will make the victim sit reach under their armpits and finally, grab their wrist. The other rescuer will cross the ankle (victim), pull up that person's legs on his shoulder. Finally, on the count of 3, both will lift the person up and move out.

Fig. 6.2.1f: Fast Strap

Fast Strap: In case the victim is completely incapable of moving out of the fire zone. The rescuers should follow this method. One of the rescuers will place their knee between victim's shoulder and head. Pin the loop of webbing to the ground with the help of the knee. This acts as an anchor. With the non- dominant hand hold the other end of the webbing and make a loop. With steady hands, pull the victim's hand in from the loop, tie it securely and finally clip the webbing loops.

Fig. 6.2.1g: Fast Strap

Essentials for Smooth Evacuation: The following are essential to have a smooth evacuation during an outbreak:

- Clear passageways to all escape routes
- Signage indicating escape routes should be clearly marked
- Enough exits and routes should be present to allow a large number of people to be evacuated quickly
- Emergency doors that open easily
- Emergency lighting where needed
- Training for all employees to know and use the escape routes
- A safe meeting point or assembly area for staff
- Instructions on not using the Elevator during a fire

Special Evacuation Requirements For Specially Abled Persons

- **The Visually Impaired**
  - Announce the type of emergency
  - Offer your arm for help

- **With Impaired Hearing**
  - Turn lights on/off to gain the person's attention, or indicate directions with gestures, or write a note with evacuation directions

- **People with Prosthetic Limbs, Crutches, Canes, Walkers**
  - Evacuate these individuals as injured persons.
  - Assist and accompany to evacuation site if possible.
  - Use a sturdy chair, or a wheeled one, to move the person to an enclosed stairwell
  - Notify emergency crew of their location

7.2.2 Importance of Fire Safety Drills

Fire drills are indispensable in any workplace or public building for rehearsing what to do in the event of a fire. They are also a lawful obligation under the Fire Safety Order of 2005 and all workers in a company must partake. Here's how to get the most out of your fire practice.

Why have fire drills?

There are numerous reasons why fire drills are vital; first of all, fire drills are a chance to practice evacuation techniques to make sure all staff are acquainted with them. The staff will vacate the building quickly and therefore in a real life situation panic will be decreased, as everyone will know what they need to do. Fire drills are also beneficial for testing escape methods to assess their efficiency.

During fire drills, checks can also be carried out on alarm systems to make certain they are working properly and that emergency exits are passable. Overall fire drills help increase safety, so that you will be best equipped if a real fire does happen.

How often?

Ideally there should be two fire drills a year, although this may vary according to the workplace and after checking the firm's risk assessment. If there are people who work in shifts, suitable preparations should be made to ensure all staff partake in at least one fire drill per year and to educate them as to how to handle the situation.

Should you inform staff beforehand?

There are arguments for and against making people conscious of fire drills before they take place. Some people contend that not notifying staff gives an element of surprise, so that people take drills more sincerely. However, this can also have the reverse effect in a real fire, as on overhearing the alarm people may reason that it's only a drill.

The benefit of notifying all staff of fire drills in advance is that initially, they will not panic, which circumvents potential injuries that could be instigated in a rush to exit a building. Furthermore, if the alarm sounds, lacking a prior warning, there will be no uncertainty as to if it is a drill or not and people will act correctly. In public places such as shopping centres, it is prudent to make members of the public alert when a drill is about to happen.

UNIT 7.3: Importance of Safe Working Practices

Unit Objectives

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

1. Explain Basic Hygiene Practices
2. Understand the importance of Social Distancing
3. Demonstrate the safe working practices

7.3.1 Basic Hygiene

We are living in an environment with millions of germs and viruses. And our body can be a breeding space for these microbial organisms. They grow and multiply and cause many diseases which sometimes can prove to be fatal for the human beings. These disease-causing microbial organisms kill over 17 million people every year. Some simple hacks and little changes of basic personal hygiene habits can bring amazing changes to all of us. We can prevent contracting these diseases if we follow these hygiene practices every day.

Personal Hygiene

Personal hygiene is all about managing your body hygiene, essentially caring for your well-being incorporating some physical hygiene habits. Also, there are mental health benefits as well, as they affect each other immensely.

What are good personal hygiene habits?

Good personal hygiene includes but not limited to-

- Take regular shower
- Maintain oral hygiene
- Wash your hands frequently
- Wash your genitals
- Keep your clothes and surrounding dry and clean

These habits should be practiced on a regular basis, at home, at work, basically where you are! That's the whole idea of preventing your body system collapse over a tiny microbe!

Personal Hygiene Practices at Home

Your home should be the most comfortable and convenient for you to keep up your personal hygiene level to a standard, yet, we find ourselves procrastinating over hygiene issues when we are at home. Even though some of these tasks barely take a minute.

1. **Take Regular shower**

Do not wait up to feel the dried sweat in your body to feel the urge to take shower, make it a routine, you have the choice to either take them before you head to work or after the long day or even before you head to sleep, whichever one suits your routine. Make sure to rinse your body thoroughly, especially the genitals and underarms as they produce more sweat and are more prone to fungal activities.

2. **Wash your hands frequently**

We use our hands to do our most physical acts, from picking up the keys, browsing through our phones, cooking or eating to attending our pets. While we agree and accept the importance of washing hands before eating and after visiting the toilet, it is also ***important to wash our hands*** with soap or sanitizer every now and then. The pandemic covid-19 which crippled the life all over the world has taught us an important lesson that sanitizing our hands regularly is the only way we can avoid transmission of the disease. Use ***alcohol based sanitizer*** to wash hands well to prevent the spread of communicable diseases

6.3.1 7 steps for Handwashing

Click/Scan the QR Code to know more about handwash techniques

3. Maintain oral hygiene practices

It is very important to take care of the teeth and gum, to prevent tooth decay and bad odour. Just brushing them twice a day is not enough, but using fluoride toothpaste and brushing properly is very essential. And wash it well with water to remove any food particles that is stuck in the gap in between the teeth. It is advised to wash the teeth everyday twice to maintain healthy teeth and gum.

4. Nails and hairs hygiene

The cleanliness of nails and hair is also very important. They store dirt and grease. And even the microbes could be in there stuck and spreading. If the nail is not clean they can cause severe food poisoning, as we use our hands to eat food. Trim the nails once in a fortnight and wash hair at least twice a week with a shampoo to keep them healthy

5. Nose and ears hygiene

Wherever we are most likely to breathe in some pollutants, and most of the particles are bound to be stuck in the nasal hair. So, rinse the nose and ear with warm water once you return from outside.

6. Wear fresh and clean clothes

Changing into neat and clean clothes will prevent many infectious diseases. It will also give the mental effect immediately and it will boost the mind. Wash clothes with a good detergent every day and dry it in the sun. This will ward off any microbes attached to the clothes. If possible, Dettol can be used while rinsing which is an anti-disinfectant.

7. Food hygiene

You can get severely sick from food-borne diseases, as most of your foods are raw, purchased from outside, they risk being cross-contaminated with harmful microbes. Food hygiene is basically the idea of better storage, handling, and preparation of food to prevent contamination and to prevent food poisoning.

7.3.2 Importance of Social Distancing

Preventing communicable diseases:

All these above practices will help us to prevent communicable diseases. These diseases are highly infectious and contagious and spread through air, urine, feaces, saliva, skin (through touch) and using same towels and utensils.

Social Distancing and isolation, Self-Quarantine:

Ever since the spread of the pandemic covid-19, several health organisations have been insisting on following social distancing and isolation. Communicable diseases mainly spread through coming close to the infected individual and through physical touch. If a person is infected with diseases like normal flu or cold and spread it to others, the symptoms and may remain with the infected person for a day or two. The virus may be destroyed by taking an antibiotic. But in severe cases like corona virus the infection is severe and can prove fatal to the affected people. To prevent the spread of the virus, the entire world adopted lockdown, ***social distancing*** and compulsory face mask. And the infected person has to be in ***self isolation*** and ***quarantine*** till the time the symptoms are over. This was the advisory from the World Health Organisation, and the entire world followed it to prevent the rapid spread of the virus. The same can be applicable to all types of communicable diseases that are spread mainly through air and touch.

As communities reopen and people are more often in public after the pandemic, the term "physical distancing" (instead of social distancing) is being used to reinforce the need to stay at least 6 feet from others, as well as wearing face masks. Historically, social distancing was also used interchangeably to indicate physical distancing which is defined below. However, social distancing is a strategy distinct from the physical distancing behavior.

What is self-quarantine?
Self-quarantine was imposed on people who have been exposed to the new covid-19 and who are at risk for getting infected with the virus were recommended to practice ***self-quarantine***. Health experts advised the self-quarantine for 14 days or two weeks. Two weeks provides enough time for them to know whether or not they will become ill and be contagious to other people.

self-quarantine was also recommended for people who have recently returned from traveling to a part of the country or the world where COVID-19 was spreading rapidly, or if a person has knowingly been exposed to an infected person.

Self-quarantine involves:

- Using standard hygiene and washing hands frequently
- Not sharing things like towels and utensils
- Staying at home
- Not having visitors
- Staying at least 6 feet away from other people in your household

Once your quarantine period has ended, if the symptoms are not there, then the person may return to normal routine as per doctor's advice.

What is isolation?
Anybody who is infected with a contagious disease needs to practice isolation in order to prevent the spread of the germs to their near and dear ones. This became very popular and was strictly adhered to during the covid-19 pandemic. People who were confirmed to have COVID-19, **isolation** was mandatory. Isolation is a health care term that means keeping people who are infected with a contagious illness away from those who are not infected. Isolation can take place at home or at a hospital or care facility. Special personal protective equipment will be used to care for these patients in health care settings. They are attended by well trained nurses and specialised doctors. And these people have to be in the PPE kits all through their presence in the hospital.

Complete PPE Kit

Complete PPE Kit

Disposing off the PPE Kits

The PPE kits are worn by health workers and doctors who are attending to patients with highly infectious diseases and who are kept is isolation in order to arrest the spread. They have to wear it every time they go near the patient and have to remove it once their duty is over. Most of the PPE components are used for single use, however the face mask and goggles can be reused provided they are sanitised properly. The PPE kits have to be disposed off safely as they might have contaminants stuck to them and they may infect the healthy person if they are not discarded properly. The health workers may be all the more vulnerable

7.3.3 Safe Workplace Practices

Every company has the provision of first aid box. As you have already read about the types of injuries that technicians can receive in their field of work, it is imperative for the companies to have appropriate first aid accessories.

The basic first aid supplies and accessories that a first aid box should have are:

Supplies and Accessories in the First Aid Box

Splint

Elastic wraps

Latex gloves

Adhesive tape

Tweezers

Blanket

Scissors

Wound cleaning agent

Triangular bandages

Gauze roller bandage

Adhesive bandages

Gauze pads

Antiseptic cleansing wipes

Burn cream or gel

Eyewash liquid

CPR Kit

Chemical hazards are caused by toxic materials, which are poisonous. And being poisonous in nature, they can either be fatal or cause serious damages in case the preventive actions are not taken on time. Now, the exposure to chemicals can be in 3 forms.

They can be:

- Inhaled (entering the body through nose)
- Directly in contact with skin
- Ingested (consumed)

The symptoms, in this case, will be:

- Seizures
- Partial or complete loss of responsiveness
- Burning sensation
- Stomach Cramping with bouts of excruciating pain
- Nausea
- Vomiting (and in times with blood-stains)

Now, where there are problem, their solutions come side by side. In such situations, the person giving first aid requires to be calm and take certain preventative actions.

Some of the essential actions are:

- Using insulated equipment
- Wearing protective clothing, goggles, masks, shoes and gloves
- Ensuring the place has enough ample ventilation

Remedial action

- The foremost thing that one should do is to provide immediate first aid. However, it is to be remembered that the victim should not be given any kind of fluid (water, milk) until doctors from Poison control unit gives a green signal.
- Aside from this, there are a few things a person can perform to the victim of toxic material exposure.
- Remove the victim from the toxic zone or vicinity
- Call for an ambulance
- Remove contaminated clothing
- Splash water in the eyes
- If ingested, do not try to make the victim puke (vomit)
- Wash their mouth with water

Fig. 6.4.2: CPR

- In case the victim's breathing has stopped, give CPR (Cardiopulmonary resuscitation)
- In case of burning due to toxic material, apply burn gel or water gel on that area.
- Avoid any cream based or oil based lotion or ointment

Even though giving first aid is the right thing to do in the first place, it is also important to report the incident to their supervisor.

Click/Scan the QR code to know CPR better

Exercise

1. Burnt area should be kept under _____for a minimum of 10 minutes
2. _____exits should be easily accessible in case of fire.
3. _____ or _____ must be applied to the wound to reduce the risk of infection
4. The RICE which is_____,_____,_____ and _____ therapy must be applied to control and reduce swelling.
5. CPR is _____.

UNIT 7.4: Reporting Safety Hazards

Unit Objectives

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

- Discuss the process of reporting in case of emergency (safety hazards)
- Understand methods of reporting hazards

7.4.1 Methods of Reporting Safety Hazards

Every organization, from every industry, has a standard reporting protocol, comprising the details of people in the reporting hierarchy as well as the guidelines to be followed to report emergencies. However, the structure of this reporting hierarchy varies between organizations, but the basic purpose behind the reporting procedure remains same.

The general highlights of the Organizational Reporting Protocol, commonly known as the 6Cs, are:

- Communicate First
  - The first source of information during emergency is the preferred source.
  - Crises situations are time-bound and hence it is important to communicate promptly.
- Communicate Rightly
  - Distortion of information due to panic must be avoided.
  - Proper, accurate information must be provided to concerned authorities and this can save lives.
- Communicate Credibly
  - Integrity and truthfulness must never be forgotten during emergencies.
- Communicate empathetically
  - One must wear the shoes of the victims while communicating emergencies.
- Communicate to instigate appropriate action
  - Communicating to the right authorities help in taking the necessary action.
- Communicate to promote respect
  - Communicating with the victims with respect help in earning their trust and thus eases the disaster management process.

Hazards and potential risks / threats can be identified and then reported to supervisors or other authorized persons in the following ways:

While identifying and reporting a hazard / potential threat / potential risk, one must describe the following:

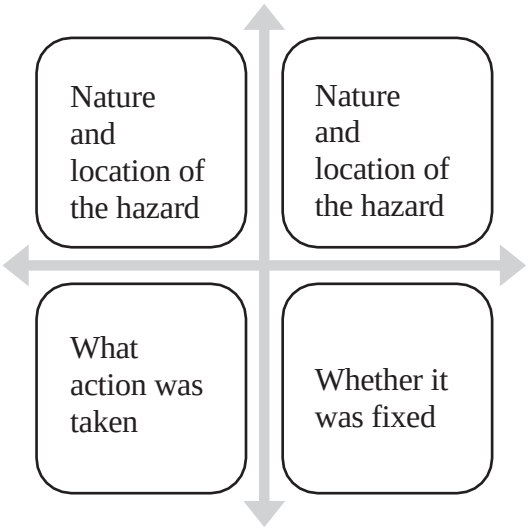

Fig. 6.4.1a: Describing hazard matrix

Part A: To be completed by the Worker Details Required:

- Name of Worker
- Designation
- Date of filling up the form
- Time of incident / accident
- Supervisor / Manager Name
- Work Location / Address
- Description of the hazard / what happened (Includes area, task, equipment, tools and people involved)
- Possible solutions to prevent recurrence (Suggestions)

Part B: To be completed by the Supervisor /

Manager Details Required:

- Results of Investigation (Comment on if the hazard is severe enough to cause an injury and mention the causes of the incident / accident)

Part C: To be completed by the Supervisor /

Manager Details Required:

- Actions taken / Measures adopted (Identify and devise actions to prevent further injury, illness and casualty)

Action	Responsibility	Completion Date

Any job role and any occupation in this world have some hazards, in varying severity, associated with it. These are called Occupational Hazards. Occupational Hazard can be defined as "a risk accepted as a consequence of a particular occupation". According to the Collins English Dictionary, it is defined as "something unpleasant that one may suffer or experience as a result of doing his or her job". Occupational Hazards are caused by the following:

Hazard Report Form	
Name:	Date:
Location:	
Tool/Equipment:	
Description of the hazards:	
Suggested corrective action:	
Signature:	
Supercisor's remarks:	
Corrective action taken:	
Signature of Supervisor:	Date:

Fig 6.4.1b: Sample form of reporting hazards

UNIT 7.5: Waste Management

Unit Objectives

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

- Understand what is e-waste
- Understand the concept of waste management
- Explain the process of recycling of e-waste

7.5.1 Introduction to E-Waste

Electrical and electronic products are all around us. We can't imagine a world without these gadgets. Our life is indispensable without electricity and electronic devices. Growth in the IT and communication sectors has increased the usage of electronic equipment immensely. Frequent change on the technological features of electronic products is forcing consumers to discard their old electronic products very quickly, which, in turn, adds to e-waste to the solid waste pool. What this translates to is mountainous masses of electrical and electronic waste which has a high potential to pollute the environment. This growing menace of e-waste calls for a greater focus on recycling e-waste and better e-waste management.

E-waste means electrical and electronic equipment, whole or in part discarded as waste by the consumer or bulk consumer as well as rejects from manufacturing, refurbishment, and repair processes. E-waste usually is made up of usable and non-usable material. Some of the waste if left unattended will be destructive to the environment. E-waste is made up of hazardous substances like lead, mercury, toxic material, and gases.

There are many companies these days who are engaged in the collection, handling, and disposal of this e-waste in a safer and more secure place to protect the environment.

7.5.2 What is E-Waste?

The amount of e-wastes comprising computers and computer parts, electronic devices, mobile phones, entertainment electronics, refrigerators, microwaves, TV, fridges, and industrial electronics that are obsolete or that have become unserviceable is growing. All these electronic devices contain plastics, ceramics, glass, and metals such as copper, lead, beryllium, cadmium, and mercury and all these metals are harmful to humans, animals, and the earth. Improper disposal only leads to poisoning the Earth and water and therefore all life forms. Our effort is meant to preserve the environment and prevent pollution by proper handling of e-waste. While it will take a lot of effort to educate people to dispose of such wastes in the right way, we are doing our part by providing a channel to collect e-wastes and dispose off them in a sustainably safe manner. We convert waste to usable resources.

The electronic industry is not only the world's largest industry but also a fast-growing manufacturing industry. It has been instrumental in the socio-economic and technological growth of the developing society of India.

At the same time, it poses a major threat in the form of e-waste or electronics waste which is causing harmful effects on the whole nation

e-waste is creating a new challenge to the already suffering Solid waste management, which is already a critical task in India.

7.5.3 Electronic goods/gadgets are classified under three major heads:

White goods: Household appliances,

Brown goods: TVs, camcorders, cameras etc.,

Grey goods: Computers, printers, fax machines, scanners etc.

The complete process is carried out as per the government guidelines.

7.5.4 E-waste Management Process

- Collection of e-waste from all the electronic stores, manufacturing companies, etc.
- Transport of e-waste to the disposal units
- Segregation of e-waste at the disposal unit
- Manual dismantling of e-waste to segregate components into various types such as metal, plastics and ceramics
- Convert into raw material (recycle and reuse)

7.5.5 E-waste Management Process (contd.)

Waste management is carried out to ensure that all types of waste and garbage are collected, transported, and disposed of properly. It also includes recycling waste so that it can be used again

Click/Scan the QR code to understand more about E-Waste management process

7.5.6 Recyclable and Non-Recyclable waste

Recyclable waste is **renewable or can be reused**. This means that the waste product is converted into new products or raw material, like paper, corrugated cardboard (OCC), glass, plastics containers and bags, hard plastic, metal, wood products, e-waste, textile, etc

Recycling not only conserves important areas in our landfills but also assists decrease greenhouse gas emissions.

Contrary to this, Non-recyclable waste cannot be recycled and cause a major threat to the environment.

The following items cannot be recycled:

Shredded paper, aerosol cans, paper coffee cups, milk and juice cans, used baby diapers, and bottle caps.

Recycling is one of the best ways to have a favorable influence on the world where we live.

Recycling will greatly help us to save both the environment and us from pollution. If we take immediate action, we can control this, as the quantity of waste we are accumulating is increasing all the time.

7.5.7 Colour codes of waste collecting bins

Waste collecting bins colour code

India's urban population of 429 million citizens produce a whopping 62 million tonnes of garbage every year. Out of this, 5.6 million tonnes is the plastic waste, 0.17 million tonnes is the biomedical waste, 7.90 million tonnes is hazardous waste and 15 lakh tonnes is e-waste. According to an estimate, 40% of municipal waste in the city is 'wet' waste, which can easily be composted and used as manure. Nearly 30% of the municipal waste comprises of plastic and metal, which can be sent to an authorized dealer for recycling, and about 20% of it is e-waste, from which precious metals can be taken apart and recycled. However, out of the total municipal waste collected, 94% is dumped on land and only 5% is composted. To gather the garbage two color bin system was suggested. Green bin for wet waste and blue for dry waste. However, there is a drawback in that system. People do through the sanitary napkins and children's diaper along with wet waste causing the contamination of things. Hence the government has come up with three colored garbage collection bins.

1. Green Bin

The green coloured bin is used to dump biodegradable waste. This bin could be used to dispose off wet/organic material including cooked food/leftover food, vegetable/fruit peels, egg shell, rotten eggs, chicken/fish bones, tea bags/coffee grinds, coconut shells and garden waste including fallen leaves/twigs or the puja flowers/garlands will all go into the green bin.

2. **Blue bin**

The blue coloured bin is used for segregating dry or recyclable left over. This category includes waste like plastic covers, bottles, boxes, cups, toffee wrappers, soap or chocolate wrapper and paper waste including magazines, newspapers, tetra packs, cardboard cartons, pizza boxes or paper cups/plates will have to be thrown into the white bin. Metallic items like tins/cans foil paper and containers and even the dry waste including cosmetics, hair, rubber/thermocol (polystyrene), old mops/dusters/sponges.

3. **Black bin**

Black bin, make up for the third category, which is used for domestic hazardous waste like sanitary napkins, diapers, blades, bandages, CFL, tube light, printer cartridges, broken thermometer, batteries, button cells, expired medicine etc.

7.5.8 Waste disposal methods:

- Incineration: Combusting waste in a controlled manner to minimize incombustible matter like waste gas and ash.
- Waste Compaction: Waste materials are compacted in blocks and are further sent away for recycling.
- Landfill: Waste that can't be recycled or reused can be thinly spread out in the low-lying areas of the city.
- Composting: Decay of organic material over time by microorganisms.
- Biogas Generation: With the help of fungi, bacteria, and microbes, biodegradable waste is converted to biogas in bio-degradation plants.
- Vermicomposting: Transforming the organic waste into nutrient-rich manure by degradation through worms.

7.5.9 Sources of Waste

1. **Construction waste** – waste coming from construction or demolition of buildings.
2. **Commercial waste**- waste from commercial enterprises
3. **Household waste**- garbage from households is either organic or inorganic
4. **Medical or clinical waste** -wastes from the medical facilities- like used needles and syringes, surgical wastes, blood, wound dressing
5. **Agricultural waste**- Waste generated by agricultural activities that include empty pesticide containers, old silage packages, obsolete medicines, used tires, extra milk, cocoa pods, wheat husks, chemical fertilizers, etc.
6. **Industrial waste**-The waste from manufacturing and processing industries like cement plants, chemical plants, textile, and power plants
7. **Electronic waste**-The defective, non-working electronic appliances are referred to as electronic waste. These are also called e-waste. Some e-waste (such as televisions) contains lead, mercury, and cadmium, which are harmful to humans and the environment
8. **Mining waste**- chemical gases emitted in mine blasting pollutes the environment. And the mining activity greatly alters the environment and nature.
9. **Chemical waste**-waste from the chemical substance is called chemical waste.
10. **Radioactive waste**: radioactive waste includes nuclear reactors, extraction of radioactive materials, and atomic explosions.

7.5.10 Sources of Pollution

All these above-mentioned waste also adds to environmental pollution. The contaminants that cause detrimental change to the environment are called pollution. It is one of the most serious problems faced by humanity and other life forms on our planet. The earth's physical and biological components have been affected to such an extent that normal environmental processes could not be carried out properly.

7.5.11 Types of Pollution

Types of Pollution	Detail/Pollutants involved
Air pollution	▪ Solid particles and gases mixed in the air cause air pollution ▪ Pollutants: emissions from the car, factories emitting chemical dust, and pollen
Water pollution	▪ Water gets polluted when toxic substances enter water bodies such as lakes, rivers, oceans, and so on. They get dissolved in it and cause it unfit for consumption. ▪ Pollutants that contaminate the water are discharges of untreated sewage, and chemical contaminants, release of waste and contaminants into surface
Soil pollution	▪ It is the presence of toxic chemicals (pollutants or contaminants) in soil, in high enough concentrations to pose a risk to human health and/or the ecosystem ▪ Sources of soil pollution include metals, inorganic ions, and salts (e.g. phosphates, carbonates, sulfates, nitrates),
Noise pollution	▪ Noise pollution happens when the sound coming from planes, industry or other sources reaches harmful levels ▪ Underwater noise pollution coming from ships has been shown to upset whales' navigation systems and kill other species that depend on the natural underwater world
Light pollution	▪ Light pollution is the excess amount of light in the night sky. ▪ Light pollution, also called photo pollution, is almost always found in urban areas. ▪ Light pollution can disrupt ecosystems by confusing the distinction between night and day.

UNIT 7.6: Organizations' focus on the Greening of jobs

Unit Objectives

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

- Understand the concept of ESG
- Explain the different factors of ESG

7.6.1 What is ESG?

The ESG is the short form of environmental, social, and governance. ESG guidelines are used to evaluate businesses on how well they control emissions, governance, human rights, and other factors of their business.

Several companies audit these companies for ESG compliance. They will let the companies know how well the ESG policies are implemented in their company hat let companies know how well their ESG policy is working.

Every business enterprise is deeply intertwined with Environmental, Social, and Governance (ESG) issues. ESG has been looked at seriously by the corporate, government establishments and stakeholders.

ESG is important as it creates high value, drives long-term returns, and global stakeholders are paying attention to the topic.

ESG is said to have created high value, and focuses on long-term returns, and stakeholders are focusing more on this concept.

7.6.2 Factors of ESG

Several factors are used to determine how well a business is doing in maintaining its ESG policies. For creating the ESG Policy, thorough knowledge of these factors are critical.

The factors are divided into three categories; environmental, social, and governance. Knowing about these factors come a long way in designing the effective ESG policy.

Environmental

Environmental factors relate to a business's impact on the environment. Examples include:

- Usage of renewable energy
- Effective waste management
- Policies for protecting and preserving the environment

Social

Social factors relate to the people of the organization. How they are treated in the organization is what it focuses on. The major entities are the stakeholders, employees, and customers. Examples include:

- diversity and inclusion
- proper work conditions and labor standards
- relationships with the community

Governance

Governance factors relate to the company policies for effectively running it. They include:

- tax strategies
- structure of the company
- relationship with stakeholders
- payments to the employees and CEO

Every factor is important and matters a lot to the overall rating of the company in ESG compliance. Ignoring one aspect in favor of another can affect the rating and in turn the reputation of the company.

The companies make a clear communication about these policies to all the employees, and to the public, they should mention what their various activities are that will protect the environment, people, and the governing factors.

Exercise

1. ESG stand for _____, _____, _____.
2. Governance factors include _____, _____, _____, _____.
3. The three causes of air pollution _____, _____ and _____.
4. Mining waste includes_____.
5. Landfill is a _____.
6. _____,_____ and _____ coloured bins are used for disposing the waste.
7. The plastics cans are trashed in _____coloured bin.
8. _____,_____and _____ are considered as e-Waste
9. _____ part of e-waste is recycled and used again
10. E-waste is made up of hazardous substances like _____,_____,_____ and _____

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Council

8. Communication and Interpersonal Skills

Unit 8.1 – Interaction with supervisors, peers ,customers and differently-abled persons

Unit 8.2 - Explain the importance of developing sensitivity towards disabled persons

TEL/N9102

Key Learning Outcomes

At the end of this module, you would be able to

- Understand what is communication and the importance of communication in the workplace
- Understand effective communication and communicate effectively for success
- Discuss types of communication -verbal and non-verbal
- Communicate at workplace
- Communicate effectively with superiors
- Communicate effectively with colleagues and customers using different modes viz face-to face, telephonic and email communication
- Understand the hurdles for effective communication
- Conduct professionally at work place
- Respect differences in gender and ability

UNIT 8.1: Interaction with supervisor, peers and customers

Unit Objectives

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

1. Understand the importance of communication
2. Understand types of communication

8.1.1 Why is Communication Important?

- Communication Skills are more important than ever, for all fields of endeavor.
- Whatever the role a person is holding in the organization, having a firm grasp of effective communication will undoubtedly be a key role in the individual's as well as the organization's success
- Oftentimes, people with excellent technical skills don't get promoted to higher roles because of their inability to communicate effectively
- Hence one fundamental skill everybody should be proficient along with the technical skill is ***Communication Skills***
- Effective communication help us to build rapport with the customer both internal and external and help us *resolve issues* and *conflicts* easily and quickly.

8.1.2 What is Communication?

- Communication is the process of sending and receiving information among people.
- It is imparting or exchanging of information by speaking, writing, or using some other medium
- The purpose of communication is to convey your thoughts and opinions to others.
- Communication is said to be successful only when both the sender and the receiver perceive it in the same way.
- In your personal and professional life, you would be communicating with the following people-
    - Colleagues
    - Customers

8.1.3 Effective Communication

Effective communication is the process of delivering messages to a target audience in a way that guarantees satisfactory reception and understanding. If the communication is effective, both the sender and the receiver will share the same information at the end of the process. Effective communication is about more than just exchanging information. It's about understanding the emotion and intentions behind the information.

8.1.4 Effective Communication for Success

Effective Communication is critical to a business's success. From top to bottom, among colleagues, from subordinates to superiors, and from the organization to the outside, several messages are delivered daily. All the people must communicate these messages properly. Content, language, remarks, tone of voice, and non-verbal communication are elements that affect the effectiveness of messages

Clear and effective communication will

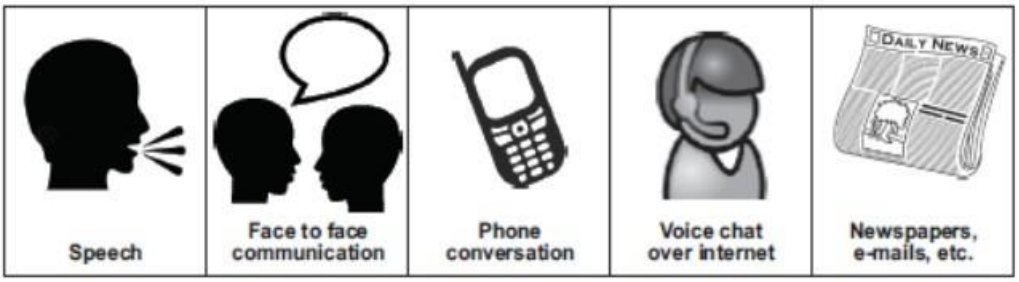
- Increase customer satisfaction
- Bring more business to the company
- Increase productivity among team members

8.1.5 Types of Communication

Communication has been divided into two types:-

- Verbal Communication
- Non-Verbal Communication

Verbal communication takes place when people exchange words with each other, either spoken or written. It includes the **choice and use of words and language to convey a message**. Examples of verbal communication are face-to-face conversation, telephonic conversation, and a speech or presentation.



Click/Scan the QR code to understand types of communication

Speech has certain characteristics which will affect the message that is being spoken:

- Volume – loud speech may sound bossy, very quiet speech cannot be heard.
- Tone – use warm tones without sounding over-friendly. Cool tones are very unwelcoming.
- Pace – fast speech is not easy to follow. Speak at a reasonable pace so that the other person has a chance to understand.

Correct body language also plays an important role in effective communication. For example, a warm smile accompanying 'Have a nice day' or looking directly at the person who is being spoken to give a positive image of the organisation.

Non –Verbal Communication

Non-verbal communication includes the overall body language of a person. There are two kinds of non-verbal communication:

1. **Signs and symbols:** for example pictures, or notices, or signboards, or even photographs, sketches and paintings. Here are some examples of different signs and symbols:

2. **Gestures and expressions:** hand signs, facial expressions, body postures or body language that can help to convey a message. You can learn to communicate better with others if you learn to recognise some of these.

   Facial expressions - A smile or a frown

   Gestures - movements of hands and body to help explain or emphasize the verbal message

   Body posture - how we stand or sit. Maintain a good posture. When you are talking to a colleague or guest, remember to stand up straight, look professional and be positive. Do not slouch, lean against something or fidget with equipment or your hands.

   Orientation - whether we face the other person or turn away

   Eye contact - whether we look at the other person and for how long

   Proximity - the distance we are from a person

   Head nods - for encouragement, indication of agreement or disagreement

   Appearance - dress and grooming

   Non-verbal aspects of speech - tone and pitch of voice

These non-verbal clues are important as they can be used to improve the quality of communication. They can be used to reinforce any verbal communication; for example, leaning forward and looking at the person you are speaking to and smiling naturally. Your expressions, posture and appearance must be appropriate and should tell the guest that you are professional, competent and willing to help.

8.1.6 Communication at workplace

In every situation, while interacting with people, we make use of both verbal and Non-Verbal Communication. It is the key to the success of any organization. Be it communication with customers, supervisors, or peers. In today's scenario having technical skills alone is not enough to get the work done, but communication skill is also equally important. Completing the task must require the support of the whole team, and without proper communication, it cannot happen. Effective Communication helps managers to perform their jobs and responsibilities and it serves as a foundation for planning.

8.1.7 Communication with supervisors

Effective and open communication within a team will build a common purpose among team members that will allow them to reach their goals. Team leaders know that group communication enhances organizational efficiency. The team members should always follow the communication guidelines. Some of the points to remember while interacting with supervisors:

1. Be aware of the communication guidelines of the organization.
2. Understand and interpret clearly, the work requirements from the supervisor.
3. Keep the supervisor informed about the progress of the task assigned.
4. Participate in all the discussions which call for decision-making, and provide facts and figures
5. Give/ accept suggestions during the discussions.
6. Accept the feedback positively and work towards rectifying errors if any. Make sure the same mistakes are not repeated.

8.1.8 Communication with colleagues & customers

- The main responsibility of a Customer Care Executive is to handle customers' concerns.
- Interaction with colleagues/peers is also equally essential and it enhances productivity in the workplace.
- Be polite in speaking to your peers at the office.
- Value other people's time as much as you value your own.
- Before you begin discussing something, ask your coworker if it is the right time to talk, and give a true picture of how much time you expect to take. Always start the conversation
- Communication with colleagues/customers can be through face-to-face, telephonic, or email.
- Keeping a few points in mind while communicating will make the interaction pleasant and fruitful.

Click/Scan the QR Code to know more about Communication with Colleagues and Customers

8.1.9 Face-to-face Communication

This is an important medium of oral communication, wherein two or more persons talk to each other and see each other physically. This form of communication is direct or straight. Things to remember while you are communicating face to face

1. Adjust the tone of voice, don't be too loud
2. Make eye contact
3. Use appropriate language
4. Maintain adequate distance
5. Acknowledge, nod during interaction
6. Use appropriate non-verbal gestures to communicate with persons with disabilities

Benefits of face-to-face communication

1. Instant feedback
2. Information conveyed clearly
3. Build rapport

8.1.10 Telephonic Communication

Another widely adopted mode of communication is through the telephone. This is the person-to-person conversation where nobody sees others but hears each other and interacts instantly. Nowadays mobile phones are becoming more popular along with landlines as a mechanical media of oral communication.

The following suggestions are recommended to follow while making telephone calls-

1. Make the call at the appropriate time
2. Provide details about your identity like name, company, department, etc.
3. Discuss the purpose of the call
4. Think about the tone of your voice
5. Listen carefully
6. Speak clearly
7. If you don't understand something, ask
8. Use please, thank you, sorry wherever necessary
9. Follow the organization's policies and procedures while interacting on the telephone.

Click/Scan the QR Code to know more about telephone communication

8.1.12 Email Communication

Email or Electronic mail is a method of exchanging messages using electronic media. The official or business communication between colleagues or inter-department communication usually happens through email. The advantage of email is you can send communication to many people at the same time.

Points to remember in email communication

1. Be clear and concise
2. Keep the content short and to the point
3. Avoid using jargon and short forms
4. Re-read the message, before sending it for grammar and spelling mistakes
5. The subject line should describe the main mail content
6. Use readable font size (don't keep it too small)
7. Add signature at the bottom of the mail body
8. Check the attachments for viruses before sending

8.1.13 Importance of timely completion of tasks

Time is a major factor that evaluates **the success or failure of a project**. Even when the whole team has done a wonderful job and produced high-quality results, with half the cost allotted to the project, everything will be a waste if it was not delivered on time. Any deviation from the timeline will call for a penalty and sometimes may result in losing the project and eventually the customer. so adhering to the timeline is important when it comes to any organization who are into products and services.

Benefits of adhering to timelines:

1. Increased and improved customer satisfaction
2. Increased productivity and efficiency of the individual
3. Team feels motivated
4. Sense of adhering to the SLA's and Standard Operating Procedures
5. Shows the commitment toward the work and the organization
6. Good word of mouth from the customers

8.1.14 Standard Operating Procedure

A ***Standard Operating Procedure (SOP)*** is a standardized process that outlines a set of detailed instructions to help workers perform complex tasks properly and safely. The main objective of standard operating procedures is to develop an effective quality system and comply with industry-specific regulations and standards. Failure to follow SOPs can cause significant errors in operations and services.

For a mobile repairing center, the SOP defines the different process of operations, namely handling customer, repairs, sales and interaction among the staff within the repair center.

SOP also clearly defines the responsibility of each and every designated person in the organisation and what is expected from them. It further defines what the various levels of engineers will handle with respect to the handsets coming for repair.

The escalation matrix specifies how the different levels escalate the issue to the next level and adhere to the timelines for repair and communication to the customer.

SOP is created keeping in mind the customer satisfaction as a main motive.

Each and every person in the organisation is expected to read the SOP thoroughly and work accordingly. Because every customer when they go for purchasing a product, one of the main things they see is the post-sales Support. If they find the brands deliver good service support then they don't mind even spending few extra moneys.

8.1.15 Escalation Matrix

Escalation matrix is made up of several levels of contact based on the specific problem at hand. This is being followed by all who are working on that product and have to adhere to the service guidelines. And the problem has to be closed at a minimum turnaround time, and for any reason the repair is taking time proper reason has to be mentioned and notified to all the people concerned including the customer.

8.1.16 Escalation Mechanism

Customer service is a very important aspect of a typical service industry. Giving committed service to customers every time and on time is very crucial for the success of the brand. In recent times, customers do research on how the after-sales support of a product is, and based on that rating they will decide which brand to buy. If the customer service is not good, they will not go for that product even though the product is very good. Hence customer service is a second important aspect of a product and services organization.

For electrical home appliances, the customer logs a complaint and the service engineer is sent to the site for looking into the problem and repairing.

For electronic devices like mobile phones and tablets, the customer is expected to take the product to their service center to get it checked and repaired.

The resolution time matters a lot, as mobile phones have become an indispensable device for people. Their business cannot function without that. Hence too much downtime is also not good.

Once at the service center, the technicians at L1 level look for the problem and try to resolve it. If it's beyond their area of resolution the same is escalated to the next level. Every organization has ***Standard Operating Procedures*** clearly state the workflow for the repair of the smart phones. Every individual working there must be aware of the same and adhere to the deadline for faster service and enriched customer satisfaction.

8.1.17 Escalation through CRM

Customer Relationship Management is a software, through which most of these companies who are into customer service, manage their customers. The customer details are entered in the system and also the services which are logged against a particular customer. This is the automated system, which takes a particular action after a period of time. For example, if a service request is assigned to an engineer for rectifying a problem of a client, and if the engineer does not update the status of the service in the system within a specified period of time, the problem is automatically escalated to the next level for resolution. Then the new engineer who is responsible for resolving pick it and try to find a solution. This system helps to maintain a track of a particular problem and the current status which will help the organization in effectively managing the customer queries. The complete escalation route is mentioned in the SOP and the same is implemented through the CRM software. This eases the manual escalation procedure which is time consuming and slow.

8.1.18 Escalation issues at work

Whether an issue arises among team members or with customers, sometimes the severity of the circumstance requires an escalation to management. Understanding how to approach an escalation can help you better find a solution when conflicts arise. We explore what it means to escalate an issue in the workplace and provide tips for how to do so successfully.

What does it mean to escalate an issue at work?

Escalating an issue in the workplace is the process of bypassing those involved by contacting upper/senior management. It involves raising awareness of the context to the right people in order to resolve a challenging situation. Typically, escalation occurs when there is an issue that the current staff working on the problem can't resolve and requires assistance from those with more authority and resources

When should you escalate an issue at work?

Deciding when to escalate an issue depends on the amount of risk it can bring to the company. Because escalating an issue can lead to difficult meetings and cause disruptions in work, you should reserve them for issues that truly require escalation. You can often avoid escalating an issue by solving the problem with the individual first.

However, some issues require support from those with higher authority. Consider escalating an issue at work when:

- You have already tried other strategies but that did not work.
- Resolving may incur additional cost to the company or the customer, while rectifying the problem.
- Because of the non-availability of certain parts the repair work is taking longer than usual.
- The engineer broke another part while repairing a part. So escalation is required to get the approval to replace the broken part by the company.

8.1.19 Hurdles for Effective Communication

Following are factors contribute to communication not being effective.

Stress and out-of-control emotion. When you are stressed or emotionally disturbed, you're more likely to misread other people and send confusing non-verbal signals. Calm down before continuing the conversation.

Lack of focus. You can't communicate effectively when you're multitasking. If you're checking your phone, planning what you're going to say next, or daydreaming, you're almost certain to miss nonverbal cues in the conversation. To communicate effectively, you need to avoid distractions and stay focused.

Inconsistent body language. Nonverbal communication should support what is being said, not contradict it. If you say one thing, but your body language says something else, your listener will likely feel that you're being dishonest. For example, you can't say "yes" while shaking your head no.

Negative body language. If you disagree with or dislike what's being said, you might use negative body language to ignore the other person's message, such as crossing your arms, avoiding eye contact, or tapping your feet. You don't have to agree with, or even like what's being said, but to communicate effectively and not put the other person on the defensive, it's important to avoid sending negative signals.

8.1.20 Professional Conduct

There are six basic rules to be followed for professional conduct:

- **Be on time:** Being late impedes a company's operations and demonstrates a lack of consideration of the time concerns of others. If you are constantly late for work, meetings, or are always late with your reports and other tasks; it demonstrates to others that you are probably not executive material because you disregard the value of time.
- **Be discreet:** Keep company secrets such as new product designs, sales figures or any other confidences to yourself.
- **Be courteous, pleasant, and positive:** No matter how demanding your clients, customers, co-workers or employees might be; always remain upbeat and positive. Projecting a positive company image has the same effect.
- **Be concerned with others, not just yourself**: Finding out a customer or client's point of view naturally helps you get ahead in any industry. Concern for others should include your superiors, co-workers and subordinates as well.
- **Dress appropriately:** Dress to be comfortable in your environment. Dressing poorly or too casually does not convey a good image, neither does overdressing, which breeds suspicion and mistrust, and will be seen as inappropriate.
- **Use proper written and spoken language:** People who can express themselves clearly are at an advantage. This goes beyond using good grammar, proper spelling, and appropriate diction in all your communications; you should also speak and write to the point.

8.1.21 Respect Gender Differences

In any business, be it a small company to a big corporate, the workforce is a mix of both genders. The ratio of men vs. women varies from 70:30 or 60:40. Studies show that business teams with an equal gender mix perform significantly better than male-dominated teams when it comes to both sales and profits. No two women or men are alike and yet at the same time there are some work-related traits that are gender specific. Both men and women approach their work in a different way and deal with many hurdles that come their way. Since they all share the same workspace every organization has devised a policy as to how they treat the opposite gender at the workplace and what are the implications of any abuses

Some of the points to remember while interacting with female colleagues

1. Treat them with respect
2. Support them in case they approach you
3. Value their opinion and suggestions
4. Involve and include the opposite gender in all the discussions

Unit 8.2: Explain the importance of developing sensitivity towards disabled persons

Unit Objectives

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

- Respect differences in gender and ability
- Communicate effectively with person with disabilities
- Respect people with disability at work

8.1.22 Communication with Disabled Person

A **disability** is any condition that makes it more difficult for a person to do certain tasks or interact with the people around them (socially or materially). These conditions, or defects, may be cognitive, developmental, intellectual, mental, physical, sensory, or a combination of multiple conditions. Defects may be present from birth or can be acquired during a person's lifetime. Often, disabled people are excluded from full participation in any activity."

But things are changing; every organization has allotted some percentage of employees from this section of the society. They are also allowed to exhibit their skills in a few jobs which they can perform without putting their life at risk

General tips for communication with disabled people

1. Speak to them as you would speak to anyone else in a soft and low tone.
2. Respect the person first, not their disability. For example, use the term 'a person with disability' rather than 'a disabled person'.
3. Do not use phrases such as 'suffers from' and 'crippled' rather the phrase should be 'people who use a wheelchair' rather than 'wheelchair bound.
4. Don't drag or push a person's wheelchair, and don't move their crutches or walking stick without their permission. It has to be in their personal space.
5. When talking to a person who is in a wheelchair, try to sit in such a way you could reach their eye level. This would not strain them much, to lift their head and talk.

8.1.23 Communicating with people with a hearing impairment

Keep these points in mind while interacting with people with a hearing problem

1. Draw the person's attention before you speak. Give a gentle tap on their shoulder, a wave of some other visual signal to the person's attention
2. Stand in front of the person and maintain eye contact
3. Don't cover the mouth while talking. They can figure out what is being said by just looking at the lip movement
4. Speak at a normal pace don't speak fast or slow
5. Choose the words wisely
6. Use short sentence
7. Be gentle while speaking don't raise the tone

8.1.24 Respect people with disability

Learn the proper way to act and speak around someone with a disability.

1. Do not use offensive or derogatory words like 'handicapped', 'crippled', and retarded etc.
2. Don't criticize or blame them. Don't shout at them or use abusive language
3. Talk slowly with a low tone. Pause while talking
4. Avoid excessive whispering, joking and laughing unnecessarily
5. Assuming things about them or their situation.
6. Don't make jokes about their condition or be sarcastic
7. Don't look down upon them because of their disability
8. Appreciate them for their efforts and work, and motivate them to perform better

8.1.25 Safety at workplace for people with disability

Disabilities of all types affect employees and can pose various mental or physical challenges. In many situations, a disability may impact the amount of time it takes for an employee to complete a task or get from one part of a facility to another. Some disabilities may be known while others remain unknown to an employer.

Health and safety legislation should not prevent disabled people from finding or staying in employment so it should not be used as an excuse to justify discrimination against them.

Disabled people and those with health conditions, including mental health conditions, should be given the opportunity to both get into and stay in work.

Responsibilities of an employer towards disabled people

The employer is responsible for the health, safety and welfare of all of their employees, whether they have a disability or not.

Disability is not always obvious so one might not realise a worker is disabled or they might choose not to tell you, particularly if their disability has no impact on their ability to do their job.

Workers do not have to tell anybody unless they have a disability that could foreseeably affect the safety of themselves or anyone else connected to their work. If they do not reveal and there are no obvious indicators of any disability, then the organization are not under any obligation to make workplace adjustments.

Periodically, consult with the employees (whether directly or through their representatives) on issues relating to health and safety. These discussions reflect good safety practice because employees have day-to-day understanding of the job, so they are likely to have good ideas on keeping themselves and others safe.

8.1.26 Workplace adaptations for people with disability

Few changes in the workplace to make it a safe place for the disable people will go a long way in the employee satisfaction for an organisation.

Workplace Adaptations

Workplace should be easily accessible for these people with special needs. One major compliance concern deals with accessibility. For example, if workplaces have been adjusted or created more accessible entrances and exits to their facilities, allowing more independence for persons in wheelchairs, would be a great idea. Other subtle changes may include the width of bathroom stalls, hand rails inside the stalls and long ramps instead of stairs. The path of travel that employees take should never be obstructed; there should be no barriers to prevent someone from getting to safety in an emergency.

Workstations easily can be adapted to follow this universal design. Many companies now use slide-out keyboard trays and monitors on swinging arms to allow employees to adjust to their needs. Desks can accommodate wheelchairs in place of regular chairs, and general work spaces can be lowered to allow easier access. The main goal is to remove all barriers and allow everyone to concentrate more on completing their tasks.

The biggest challenge with universal design is accommodating the multitude of challenges that different disabilities present. Not all disabilities are the same, and not all will present the same challenges for employees. Some employees may have issues with their right hand while others have issues with their left. For some, it may involve not being able to stand or sit. Some may need low lighting, while others need bright lighting. Designing a facility to accommodate all is always going to be a challenge.

Complying with government guidelines can be more difficult in regards to employees with disabilities. This difficulty lies with ensuring that employees are aware of all hazards in the workplace. Multiple disabilities will create multiple reasons that may keep employees from recognizing hazards. Employees with impaired vision, for example, must have other means of identifying hazards. This may be remedied with audible alarms or touch-activated devices that warn employees not to go in an area. Other employees may have difficulties reading and may benefit from shapes or colors to further identify hazardous areas. For workers who lack hearing ability, employers can utilize signs to demonstrate hazards or use flashing strobes to identify when employees need to evacuate an area and head to safety.

Exercise

1. What are the three points you will focus on when you talk to people face to face?

_____

_____

Fill in the blanks

1. Before sending the mail it's important to check the _____ and _____ of the content.
2. When you interact through phone, provide your identity details like _____,_____ and _____
3. Add your _____ at the bottom of your mail.
4. The Customer Care Executive is mainly responsible for handling _____.

Notes

Annexure

Chapter No.	Unit No.	Topic Name	Page No.	QR Code
1	1.3	Printed Circuit Board PCB	41	Click/Scan the QR code to access the related video
2	2.1	Screen printing process	75	Click/Scan the QR code to access the related video
3	3.2	Pick and Place PCB machine, PCB Assembly Process, PCB component Mounting, Soldering	97	Click/Scan the QR code to access the related video
4	4.2	Reflow Soldering Machine	115	Click/Scan the QR code to access the related video
7	7.2	First Aid Techniques	210	Click/Scan the QR code to access the related video
6	6.3	Handwashing Techniques	219	Click/Scan the QR code to access the related video
7	7.3	CPR	226	Click/Scan the QR code to access the related video
7	7.5	E-waste Management Process	232	Click/Scan the QR code to access the related video
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Annexure (Contd.)

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