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GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
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RE IMAGINE FUTURE

Telecom Sector Skill Council

Participant Handbook

Sector
Telecom

Sub-Sector
Handset

Occupation
Communication Electronics

Reference ID: **TEL/Q2502,** Version **5.0**
NSQF level **3**

Line Assembler – Telecom Products

This book is sponsored by
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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

Certificate

COMPLIANCE TO QUALIFICATION PACK– NATIONAL OCCUPATIONAL STANDARDS

is hereby issued by the

TELECOM SECTOR SKILL COUNCIL

for

SKILLING CONTENT : PARTICIPANT HANDBOOK

Complying to National Occupational Standards of

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The preparation of this 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

Welcome to the "Line Assembler - Telecom Products" training programme. This PHB intends to facilitate the participants with detailed knowledge about the concept of Telecom industry, Communication Electronics profession and their functioning. This Participant Handbook is designed based on the Qualification Pack (QP) under the National Skill Qualification framework (NSQF) and it comprises of the following National Occupational Standards (NOS)/ topics and additional topics.

1. TEL/N2506 (Preparing workspace for assembly operations)
2. TEL/N2507 (Assembly operations in production line)
3. TEL/N2510: Assembly of Mobile Phone Accessories
4. TEL/N2508 (ESD safe procedures and practices)
5. TEL/N9107: Follow sustainability practices in telecom production and assembly line processes
6. DGT/VSQ/N0101: Employability Skills (30 Hours)

We trust this Participant Handbook will offer strong learning support and help budding professionals carve out engaging and rewarding careers in India's dynamic telecom industry.

Symbols Used


Key Learning Outcomes


Steps


Tips


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Practical


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It is recommended that all trainings include the appropriate Employability skills Module. Content for the same is available here: https://www.skillindiadigital.gov.in/content/list

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Unit 1.2 - Fundamentals of Electronics

Unit 1.3 - Active and Passive Components

Unit 1.4 - Understanding of Diodes, Transistors, and Logic Gates

Unit 1.5 - Fundamentals of PCB

Unit 1.6 - Fundamentals of Copper Clad Laminates (CCL)

Key Learning Outcomes

By the end of this module, the paricipants will be able to:

1. Explain the procedures and standards for conducting telecom store counter operations.
2. Demonstrate professional customer interaction techniques to enhance service quality and sales.
3. Apply correct transaction processing methods in line with company policies and telecom regulations.
4. Describe visual merchandising principles, stock management procedures, and grooming standards.
5. Record and report sales, stock movements, and customer feedback accurately.

UNIT 1.1: Introduction to the sector and the job role of a Line Assembler - Telecom Products

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the significance of the telecom sector in the manufacturing and assembly of telecom products.
2. Elucidate the key skills and technical expertise required for a Line Assembler - Telecom Products.
3. Describe the challenges faced in assembling and testing telecom equipment.
4. Determine the impact of precision and quality control in telecom product assembly.
5. Discuss the roles and responsibilities of a Line Assembler - Telecom Products in ensuring efficient production.

1.1.1 Telecom Sector

India's telecom sector is one of the largest in the world, both in terms of subscriber base and infrastructure. It plays a pivotal role in enabling digital communication, powering industries, and connecting remote and urban areas alike. As of 2025, India is advancing rapidly in 5G deployment, fiber optic expansion, IoT infrastructure, and satellite communication networks.

With initiatives such as Digital India, Make in India, and PLI (Production Linked Incentive) schemes, the telecom manufacturing ecosystem is seeing rapid localization. Domestic manufacturing and assembly of telecom equipment—ranging from mobile handsets and routers to 5G radios and optical fiber cables—is on the rise. This growth is creating a significant demand for skilled professionals in telecom product assembly. We need to build and use a lot of equipment like mobile towers, special internet boxes, and fiber optic cables.

Instead of buying all this equipment from other countries, India is now:

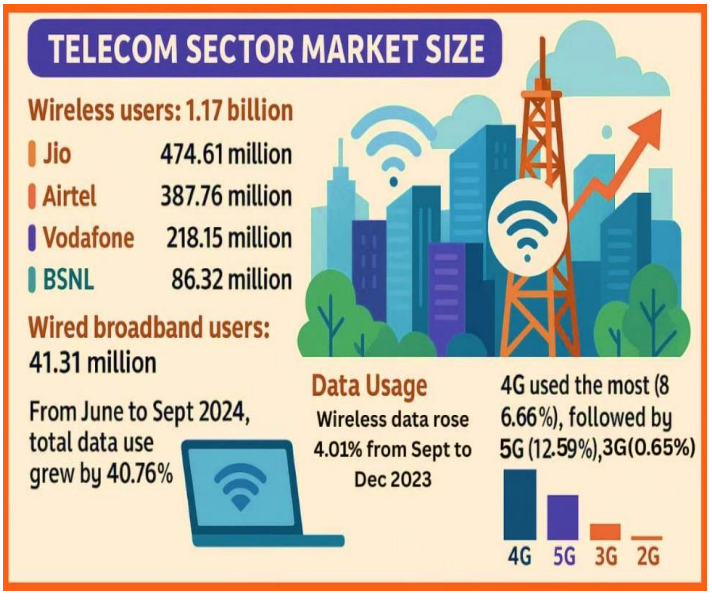


Fig. 1.1.1: Telecom Sector Market Size

1.1.2 Telecom Manufacturing Importance

1. Imagine you want to talk to your friend across the city, or watch a video online. You need a phone, and your phone needs to connect to a network. That network is made up of many pieces of equipment – from the antennas on mobile towers to the cables running underground.

Here's why making these telecom products in India is so important:

- Lots of Demand (People Need It!): Billions of people in India use phones and the internet. Every time someone buys a new 5G phone or gets a faster internet connection, more equipment is needed. This creates a huge demand for factories to build these products.
- Creates Jobs (Your Job!): When factories build telecom products, they need workers – people like you! This means more jobs for assemblers, testers, quality checkers, and many others. It also helps other businesses that supply parts to these factories.
- Makes India Stronger (No More Waiting!): If we can build our own telecom equipment, we don't have to wait for other countries to send it to us. This makes India independent and ready for any challenge. It's like building your own house instead of always renting.
- New Ideas and Technology: When we build things ourselves, we learn how to do it better and sometimes come up with new, even smarter ways to make things. This helps our technology grow.
- We Can Sell to Others (Export!): If we get good at making telecom products, we can even sell them to other countries, bringing more money into India.

2. Skills Required to be Line Assembler for Telecom Products

As a Line Assembler, you are like a builder of electronic parts. You need to be careful, focused, and have certain skills.

Here are the key skills you will need:

- Understanding the Basics (Knowing Your Parts):
  - Knowing the Components: You need to learn to identify different small electronic parts like resistors, capacitors, and connectors. They might look similar, but each has a specific job.
  - Using Tools: You will use hand tools like screwdrivers, pliers, wire cutters, and maybe even soldering irons. You need to use them correctly and safely.
  - Reading Instructions: You will get instructions, often with pictures, showing you exactly where each part goes. You must be able to read and follow these carefully.
- Being Careful and Accurate (Precision):
  - Steady Hands: Many parts are tiny, so you need steady hands to place them correctly.
  - Attention to Detail: You must notice small things – like if a part is slightly bent or in the wrong place. Missing tiny details can cause big problems later.
- Caring About Quality (Doing it Right the First Time):
  - Following Rules: You must always follow the steps and rules given for assembly. Don't take shortcuts!
  - Checking Your Work: After you finish a step, quickly check if you've done it correctly before moving on. This helps catch mistakes early.
- Solving Small Problems (If Something Goes Wrong):
  - Spotting Issues: If a part doesn't fit or looks wrong, you need to spot it.
  - Telling Your Supervisor: When you find a problem, you must tell your supervisor so they can help fix it.
- Working with Others (Teamwork):
  - Helping Each Other: You'll be part of a team on the assembly line. Sometimes you might need to help a teammate or ask for help.
  - Clear Talking: If you find a problem or need something, tell your supervisor clearly.

- Being Safe (Your Safety First!):
  - Following Safety Rules: Always follow safety rules when using tools or working near machines.
  - ESD (Electro-Static Discharge) Safety: This is very important! Some electronic parts are very sensitive to static electricity from your body (like when you rub your feet on a carpet and get a small shock). You will learn how to wear special wrist straps or clothes to prevent this from damaging the parts.

Fig. 1.1.2: Various hard skills needed to do line assembling work better

3. Challenges in Assembling and Testing Telecom Equipment

Even though it's an exciting job, assembling and testing telecom equipment can have its difficulties. Knowing them helps you be prepared!

- Tiny Parts, Big Jobs: Telecom products are getting smaller and smaller, but they do more things. This means the parts inside are very tiny and packed closely together. It's like building a very small, complicated machine.
- Many Different Parts: A single telecom product can have hundreds or thousands of different types of small electronic parts. Remembering and placing each one correctly is a challenge.
- Static Electricity (ESD): As mentioned, static electricity can be a big problem. Even a tiny static shock from your finger can damage a sensitive electronic chip without you even knowing it. This is why following ESD rules (wearing wrist straps, working on special mats) is crucial.
- Heat Management: Phones and network equipment can get hot when they work. During assembly, you might need to make sure parts that get hot have proper cooling attached, like special pads or small metal pieces (heat sinks). If not done correctly, the product might overheat and stop working.
- Radio Signals (RF): Telecom equipment deals with radio signals (like Wi-Fi or mobile signals). The way you put parts together can affect how well these signals work. So, being precise is very important for the product to function correctly.
- Cleanliness Matters: Dust or dirt can damage sensitive electronic parts or block connections. The assembly area needs to be kept very clean.
- Checking Everything (Testing is Hard!): After assembly, every product needs to be tested to make sure it works perfectly. This involves many different types of tests – checking if it turns on, if the signals are strong, if it can connect to the internet, and if it can handle different temperatures. This testing can be complex and takes time.

- Software and Hardware: Modern telecom products also have computer programs (software) inside them. After you assemble the hardware, someone needs to load and test the software, which adds another layer of complexity.

4. Importance of Precision and Quality

Imagine your phone drops calls all the time, or your internet is always slow. You'd be unhappy, right? This is why precision (being exactly right) and quality control (making sure it's perfect) are so incredibly important in telecom product assembly. It's not just about building it; it's about building it right.

Here's why they are so vital:

- Products Work Better and Last Longer:
  - Clear Signals: If parts are assembled precisely, your phone calls will be clear, and your internet will be fast. If not, signals can be weak or drop.
  - Don't Break Easily: Products built with high quality last longer. They don't break down often, meaning fewer repairs and less frustration for the user.
- Happy Customers, Good Reputation:
  - People Trust the Brand: When products are good, customers are happy and trust the company. They will buy from that company again and tell their friends about it.
  - Bad News Spreads Fast: If products are low quality, people will complain, and the company's reputation will be damaged.
- Saves Money for the Company:
  - Less Waste: If you build it right the first time, fewer products will be thrown away or need to be fixed, which saves money.
  - Fewer Repairs: If products don't break often, the company doesn't have to spend money on fixing them or replacing them for customers.
  - Smooth Production: When everyone works precisely, the assembly line runs smoothly without constant stops to fix mistakes.
- Meets Rules and Regulations:
  - Safety First: Telecom products must meet strict safety rules set by the government. Good quality control ensures these rules are met, preventing accidents or fines.
- Stays Ahead of Competition:
  - Better Than Others: In a market with many companies, the one that makes the best quality products will attract more customers and be more successful.

5. Role and Responsibilities of a Line Assembler

As a Line Assembler, you are a critical part of the production team. Your actions directly affect how fast and how well products are made.

Here are your main roles and responsibilities:

- Putting Parts Together Correctly:
  - Exact Placement: Your most important job is to put each part in its exact correct place, following the instructions perfectly.
  - Proper Connections: Making sure all wires are connected properly, and all screws are tightened just right.
  - Careful Handling: Handling sensitive components with care to avoid damage.

Fig. 1.1.3: Facility of Line Assembling work station

- Following Instructions Every Time:
  - No Shortcuts: Always follow the Standard Operating Procedures (SOPs) – these are the official step-by-step guides. Don't try to guess or skip steps.
  - Consistency: Every product you assemble should be made exactly the same way.
- Checking Your Own Work (Be Your Own Quality Checker!):
  - Visual Check: After you finish a step, quickly look at your work. Does it look right? Is anything missing?
  - Spotting Problems: If you see a part that looks damaged, or something is not fitting correctly, report it immediately. Don't try to fix something you're not trained for.
  - Keeping it Clean: Make sure your workstation and the product are free of dust or debris.
- Using Tools Properly:
  - Right Tool, Right Job: Use the correct tools for each task.
  - Care for Tools: Take care of your tools. Report if a tool is broken or not working well.
- Keeping Records and Talking Clearly:
  - Filling Forms: You might need to fill out simple forms to record what you've assembled or if you found any issues.
  - Speaking Up: If you find a problem, or if you're not sure about something, speak clearly to your supervisor or the quality control team. Don't stay quiet!
- Working Safely:
  - Your Safety First: Always wear your safety gear (like gloves or safety glasses, if required) and follow all safety rules in the factory.
  - Clean Workspace: Keep your work area neat and tidy to prevent accidents.

Notes

UNIT 1.2: Fundamentals of Electronics

Unit Objectives

By the end of this unit, the participants will be able to:

1. Evaluate the fundamentals of electronics
2. Demonstrate the basics of electronic circuit

1.2.1 Fundamentals of Electricity

Defining Electricity:

In the modern world, electricity is essential for the functioning of computers, cell phones, lights, air conditioners, soldering irons, etc. Escaping electricity is impossible because it occurs naturally, from lightning to human bodies.

Electricity is a natural phenomenon that comes in various forms. Electricity is the movement of electric charge.

Fig 1.2.1: Electric bulb: an example of electronic product used in daily life

Concept of current and voltage:

All basic electrical or electronic circuits consist of three different, but very much related electrical quantities which are:

- Voltage, (v),
- Current, (i) and
- Resistance (Ω)

Electrical Voltage:

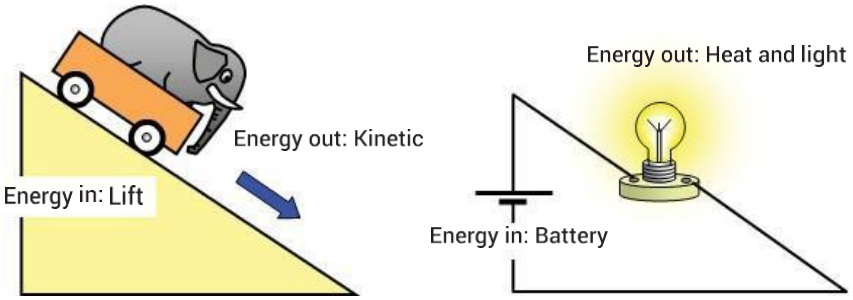


Fig 1.2.2: An analogy between energy lift and electronic circuit

Voltage, (V) is defined as the potential energy of an electrical supply accumulated in the form of electrical charge. Voltage can be perceived as the force that pushes electrons through a conductor and the higher the magnitude of voltage, the greater is its strength to "push" the electrons through a circuit.

What are joules?

A "Joule" is a standard unit of work or energy in the International System of Units (SI), which denotes the work done by one-Newton force when its point of application moves through one-meter distance along the direction of the force. One joule is equal to 107ergs and one watt-second. It is also called Newton-meter.

The difference in voltage between the terminal points, junctions or connections in a circuit is called the Potential Difference (also known as the Voltage Drop).

The potential difference between two nodes is measured in the unit Volts (symbol "V" or "v")

A constant source of voltage is called a DC (Direct Current) voltage while a voltage that keeps on varying periodically is known as an AC (Alternating Current) voltage. Batteries or other power supplies are used to generate a steady D.C. voltage source such as 5v, 12v, 24v, etc. in systems and electronic circuits. While A.C. voltage sources are available for industrial power, domestic house and power transmission as well as lighting.

What is an Ohm?

(The ohm is the standard unit of electrical resistance in the International System of Units (SI). Ohms are also used, when multiplied by imaginary numbers, to denote reactance in alternating-current (AC) and radio-frequency (RF) applications. Reduced to base SI (Système international) units, one ohm is the equivalent of one kilogram meter squared per second cubed per ampere squared (1 kg times m 2 • s -3 • A -2 . The ohm is also the equivalent of a volt per ampere (V/A))

Generally circuits operate on low voltage DC battery supplies. The circuit symbol for a DC voltage source usually given as a normal battery symbol.

Voltage Symbols

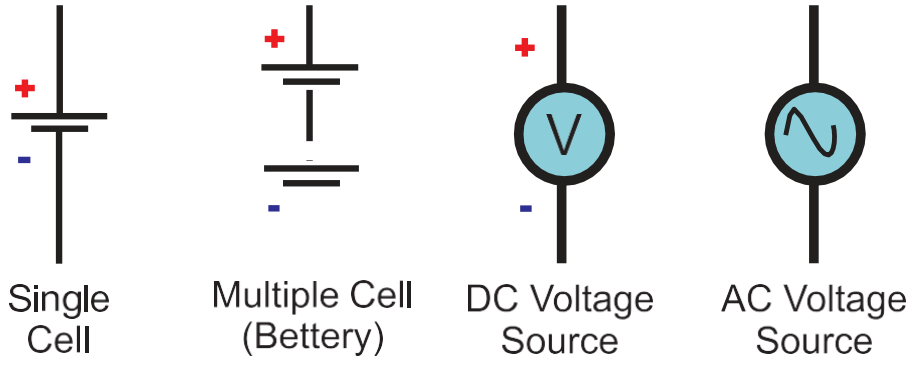


Fig 1.2.3: Symbols associated to an electronic circuit

Electric Current

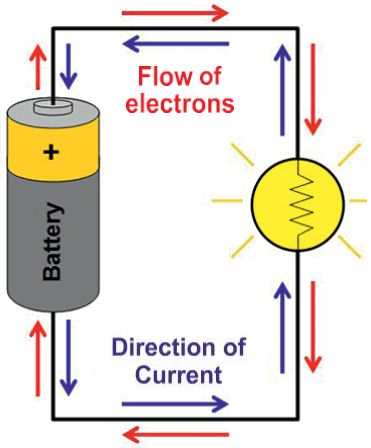


Fig 1.2.4: An example of electronic circuit

Electrical Current (I) is the flow of electric charge. Electrical current is measured in the unit **Amperes** (symbol i). It is the constant and uniform flow of electrons around a circuit which are pushed by the voltage source. In reality, electrons flow from the negative terminal to the positive terminal of the circuit. The current flows opposite to the flow of electrons.

Typically in circuit a diagram, the flow of current is usually represented by an arrow associated with the symbol, I to indicate the current flow direction.

Conventional Current Flow

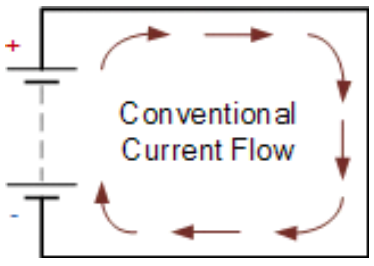


Fig 1.2.5: How current flows conventionally

	Alternating Current (AC)	Direct Current (DC)
Amount of energy that can be carried	Can deliver more power and is safe for long-distance transfer	DC voltage starts losing energy while travelling far
The direction of electron flow	Rotating magnetism, which can be found along and throughout the wire	Steady magnetism, which can be found along and throughout the wire
Frequency	Ranges between 50-60Hz (country-specific)	NIL
Direction	Reversed	Unidirectional
Current	Time-dependent	Constant and independent of changes in time
Flow of Electrons	Enables both backward and forward directions of electrons; the electrons keep on switching between backward and forward directions	Enables only the forward direction of electrons
Obtained from	The main power supply and AC generator	Battery or cell
Passive Parameters	Only impedance	Only resistance
Power Factor	Ranges between 0-1	Always equal to 1
Types	Sinusoidal, triangular, trapezoidal and square	Pulsating and pure
Direction of flow of electrons	Bidirectional	Unidirectional
Polarity	Has polarity (+ OR -)	Does not have polarity
Type of load	Their load is resistive, inductive or capacitive.	Their load is usually resistive in nature.
Convertible	Easily convertible into direct current	Easily convertible into alternating current
Substation	Only a few substations are needed for transmission and generation	A higher no. of substations are needed for transmission and generation
Hazardous	Dangerous	Very dangerous
Application	Factories, Industries and for domestic purposes	Electroplating, Electrolysis, Electronic Equipment, etc.

Fuses

Fuses are used in electronic circuits to protect them from electric overload. They have a protective function.

A fuse is made of a low resistance metallic wire placed in a non-combustible material. In the event of a short circuit, over current or mismatched load connection, the thin wire inside the fuse melts. This is caused by the heat generated by the heavy current flowing through it. The electrical system, which supplies current, must be disconnected from the power supply. The regular operation of the system, connected to the power supply, is not hampered by fuses. The commonly available types of fuses are: AC fuses and DC fuses.

Resistance

Resistance, (R) is the property of a material to prevent or resist the flow of current, specifically, the flow of electric charge within a circuit. The circuit element which performs this is called the Resistor.

Ohm(Ω, Omega), the unit of Resistance, comes with prefixes used to denote Kilo-ohms (1 kΩ = 10^3Ω) and Mega-ohms (1 MΩ = 10^6Ω). Resistance cannot be negative in value, it is always positive.

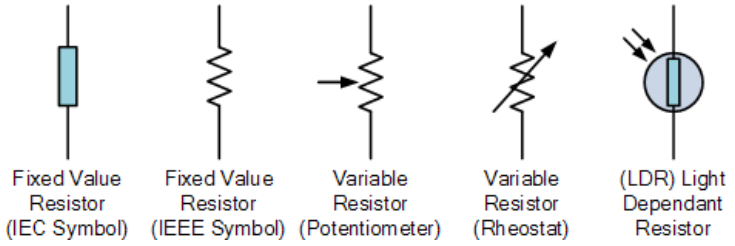


Fig 1.2.6: Resistor Symbols

The amount of resistance is controlled by the relationship of the current flowing through it to the amount of voltage across it, which decides whether the circuit element has low resistance or high resistance. Low resistance circuit is a good conductor made from materials like aluminium, copper, or carbon while a high resistance circuit is a bad conductor comprises insulating materials such as porcelain, plastic or glass.

The relationship between current and voltage in a constant-resistance circuit would generate a straight line i-v relationship with slope equal to the resistance value as depicted in the figure below:

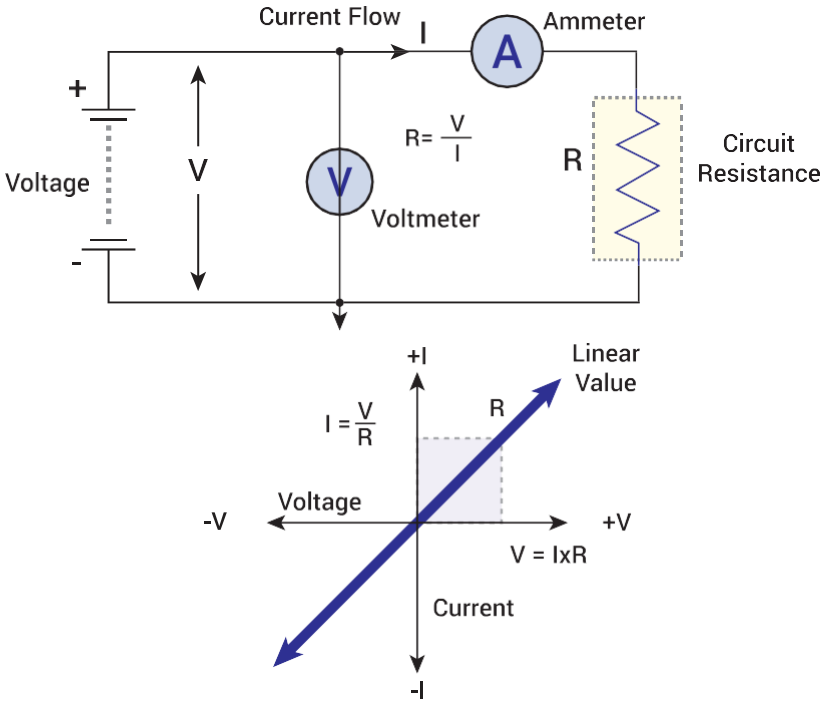
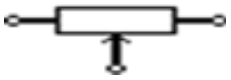
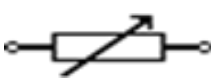
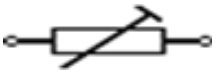


Fig 1.2.7: The relationship between Voltage, Current and Resistance

The three units can be summarized as:

- Voltage or potential difference is the measure of potential energy between two points in a circuit and is commonly referred to as its "volt drop"
- When a voltage source is connected to a closed loop circuit the voltage will produce a current flowing around the circuit
- In DC voltage sources the symbols +ve (positive) and -ve (negative) are used to denote the polarity of the voltage supply
- Voltage is measured in ''Volts" and has the symbol ''V" for voltage or ''E" for energy
- Current flow is a combination of electron flow and whole flow through a circuit
- Current is the continuous and uniform flow of charge around the circuit and is measured in "Amperes" or "Amps" and has the symbol "I"
- Current is directly proportional to voltage
- The effective (rms) value of an alternating current has the same average power loss equivalent to a direct current flowing through a resistive element
- Resistance is the opposition to current flowing around a circuit
- Low values of resistance imply a conductor and high values of resistance implies an insulator
- Current is Inversely Proportional to Resistance (I $1/\propto$ R)
- Resistance is measured in "Ohms "and has the Greek symbol "Ω" or the letter "R "

Resistor Symbols		
	Resistor [IEEE] (Institute of Electrical and Electronics Engineers)	Resistor - decreases the flow of current
	Resistor [IEC] (International Electro Technical Commissions)	
	Potentiometer [IEEE]	Adjustable resistor (with three terminals)
	Potentiometer [IEC]	
	Variable Resistor / Rheostat [IEEE]	Adjustable resistor (with two terminals)
	Variable Resistor / Rheostat [IEC]	

Resistor Symbols		
	Trimmer Resistor	This is a pre-set resistor
	Photoresistor / Light dependent resistor [LDR]	Changes resistance with changes in light intensity

1.1.2 Components of Electronic Circuits and their Functions

Transmitter: Transmitters are instruments that are used to send data as radio waves in a particular band of the electromagnetic spectrum to fulfil a specific communication requirement, irrespective of voice or general data. To perform this, a transmitter consumes energy from a source and transforms it into a radio frequency. When the rapidly changing energy is directed through a conductor, electromagnetic waves are radiated outwards to be received by a receptor.

A transmitter comprises:

- **Power supply —** Power supply is an energy source used to power on the device and create energy for broadcasting.
- **Electronic oscillator —** Electronic oscillator produces a wave known as the carrier wave where data is imposed and borne through the air.
- **Modulator —** Modulator adds the actual data to the carrier wave by varying some aspects of the carrier wave.
- **RF (Radio Frequency) amplifier —** RF amplifier raises the signal power to augment the range where the waves can reach.

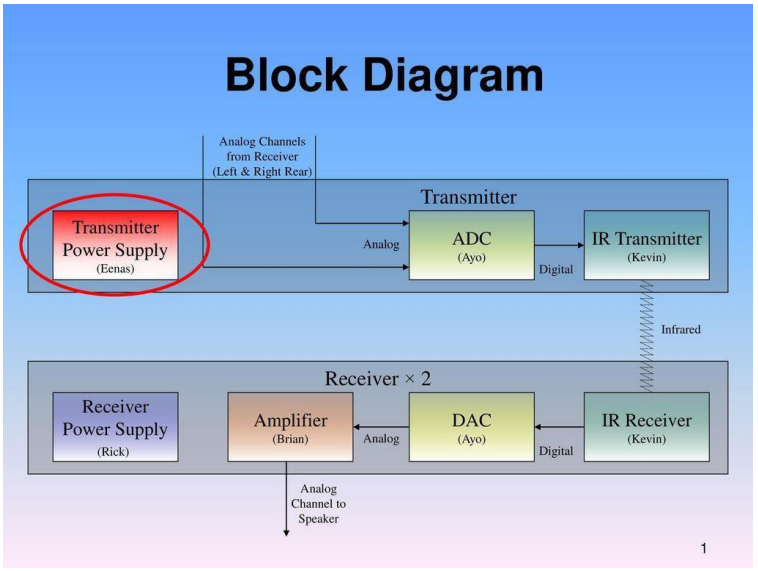


Fig 1.2.8: Block diagram of transmitter and receiver

Bridge rectifiers:

Evolution of rectifiers

Rectifiers can be broadly classified into three types:

- Bridge rectifier
- Half-wave rectifier
- Centre-tapped full-wave rectifier

The above rectifiers have a common aim of converting Alternating Current (AC) into Direct Current (DC).

In **half wave rectifier**, only a half cycle is permitted while the other half is blocked. As an outcome, almost half of the applied power is wasted. The output voltage or current produced by half wave rectifier is not beneficial because it is not purely DC.

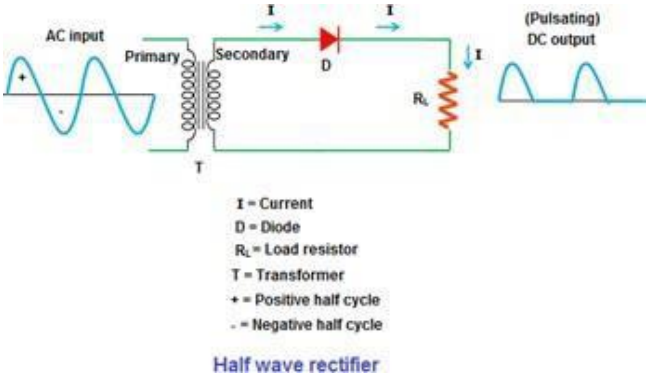


Fig 1.2.9: Circuit diagram of half wave rectifier

To overcome the above problem, the centre tapped full wave rectifier is used.

The chief advantage of **centre tapped full wave rectifier** is that it permits electric current during both positive and negative half cycles.

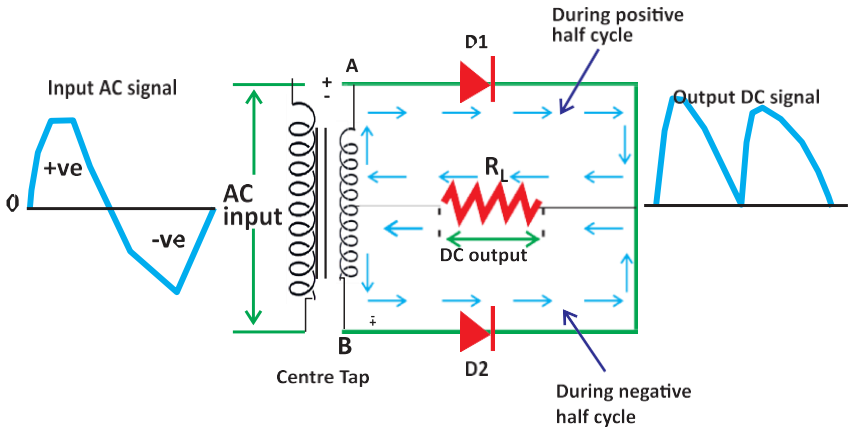


Fig 1.2.10: An illustrated diagram of the flow of current and input-output through full wave rectifier

The centre tapped full wave rectifier has one drawback, that is, the centre-tapped transformer is very costly and occupies a large amount of space. To reduce this cost, scientists have developed the bridge rectifier.

In a **bridge rectifier**, no centre tap is required. If stepping up/down of voltage is not essential, the transformer can be removed from it.

The efficiency of a bridge rectifier is almost equal to the centre-tapped full wave rectifier. The only benefit of the bridge rectifier over the centre-tapped full wave rectifier is the cost reduction.

In a bridge rectifier, instead of using the centre-tapped transformer, four diodes are used.

Working of Bridge Rectifier

When an input AC signal is applied across the bridge rectifier, during the positive half cycle, diodes D1 and D3 are forward-biased and allow electric current while the diodes D2 and D4 are reverse biased and block electric current. On the contrary, during the negative half cycle, diodes D2 and D4 are forward-biased and permit electric current while the diodes D1 and D3 are reverse-biased and hinder electric current.

Terminal A becomes positive and B becomes negative during the positive half cycle. This causes the diodes D1 and D3 to be forward-biased and simultaneously, it causes the diodes D2 and D4 to be reverse-biased.

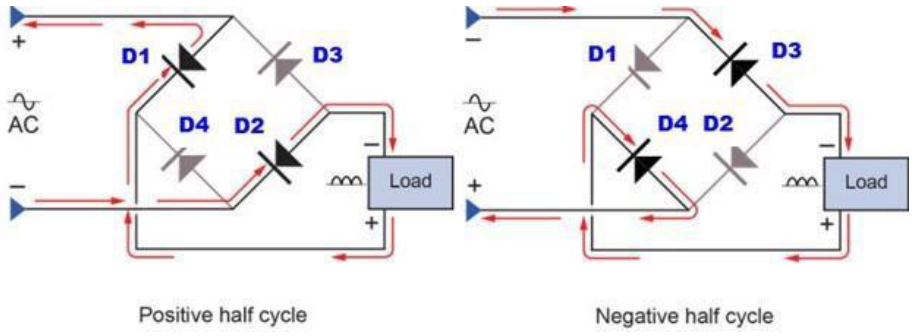


Fig 1.2.11: Flow of current through Bridge Rectifier

Terminal B becomes positive and A becomes negative during the negative half cycle. This causes the diodes D2 and D4 to be forward-biased and simultaneously, it causes the diodes D1 and D3 to be reverse-biased.

Integrated Circuits:

What is IC

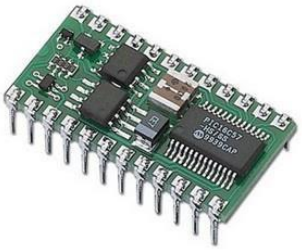


Fig 1.2.12: Sample IC (Integrated Circuit)

An integrated circuit (IC), also known as a microchip or chip, is a semiconductor wafer on which tiny capacitors, resistors, and transistors are attached. An IC can function as an oscillator, timer, amplifier, computer memory, counter or microprocessor.

Digital ICs come in many different types. The following list shows the ICs used for different applications.

- Microcomputers, which are ICs that carry out various types of processing
- Memory, which comprises data-storing ICs
- Custom logic ICs, which comprise original dedicated circuitry implemented by or for the needs of a particular user

Applications and Uses of Integrated Circuits

The advantages of Integrated Circuits are:

- Very small size - Hundred times smaller than discrete circuits
- Lesser weight – Weight is reduced since a large number of components can be packed into a single chip
- Less cost - The mass production has helped in price reduction
- High reliability – The absence of soldered connection, negligible temperature surge, and less no. of interconnections, the failure rate is low in ICs
- Less power requirement – Power consumption is less since the size is
- Easy replacement – Chips are easily replaceable in case of failure

Multiplexer: The multiplexers and demultiplexers are digital electronic devices that are used to monitor applications. A multiplexer allows several input signals and generates a single output signal. In multiplexing, many embedded system devices share a single bus or transmission line while communicating with the device. Each successive device has a brief amount of time to send and receive the data.

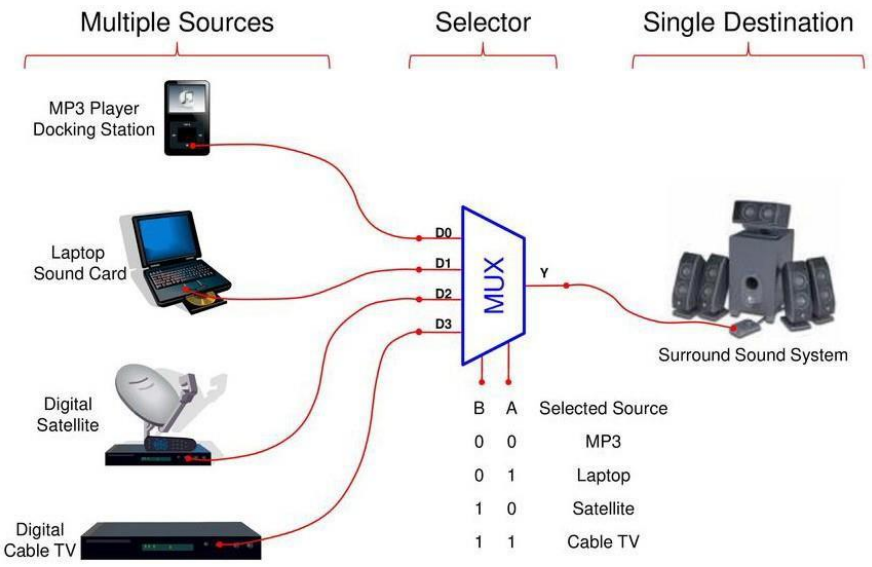


Fig 1.2.13: Various functions of a multiplexer

Sensors:

Fig 1.2.14: Sensor

What is a Sensor?

Sensor is a tool that detects the minute variations in physical, electrical or other quantities. It generates an output as per the change in the quantity.

Types of sensors and their uses:

Speed Sensor: Sensors used to detect the speed of an object are called Speed sensors. There are various types of sensors to detect speed such as speedometers, Wheel speed sensors, LIDAR (Light Detection and Ranging), pitometer logs, pitot tubes, ground speed radar, air speed indicators, Doppler radar, etc.

Fig 1.2.15: Speed Sensor

Temperature Sensor

Fig 1.2.16: Temperature Sensor

An instrument, which provides temperature measurement in the form of an electrical signal, is called Temperature sensor. The electrical signal is typically in the form of electrical voltage. There are several types of sensors available in the market used for measuring temperature such as:

- Contact type temperature sensors
- Non-contact type temperature sensors

PIR Sensor: The electronic sensor used to measure the infrared light radiation exuded from objects in its field of view is called a Pyroelectric sensor or PIR (Passive Infrared Sensor) sensor.

Fig 1.2.17: PIR Sensor

Ultrasonic Sensor

Fig 1.2.18: Ultrasonic Sensor

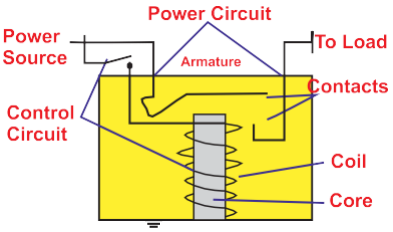
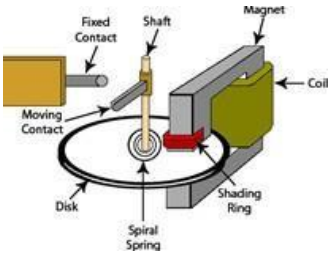
The concept of ultrasonic sensor is to interpret echoes from sound waves or radio to determine the attributes of a target by producing the sound waves of high-frequency.

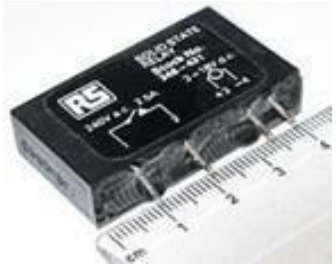
Relays and their types

What are Relays?

A relay is a switching device used to isolate or convert the state of an electric circuit into another.

Fig 1.2.19: Relays

Type of Relay	Image	Function
Electromagnetic Relays		Electromagnetic relays comprise electrical, magnetic, and mechanical components. Furthermore, they comprise mechanical contacts and an operating coil. The mechanical contacts open or close when a supply system activates the coil. This supply system can be DC or AC.
AC and DC Relays		The functioning of DC and AC relays is based on the principle of electrmagnetic induction. However, their constructions are different and depend on their applications. In DC relays, the coil is deenergised by a freewheeling diode while in AC relays, eddy current losses are prevented with the help of laminated cores.
Attraction Type Relays		Attraction type relays, when supplied with DC or AC power, attract a metal piece or bar. This metal piece or bar can be in the form of an armature attracted towards electromagnet poles or a plunger drawn towards the solenoid.
Induction Type Relays		These relays are constructed with electrical, mechanical and magnetic components, and have an operating coil and mechanical contacts. When the coil gets activated by a supply system, these mechanical contacts gets opened or closed. The type of supply can be AC or DC.
Magnetic Latching Relays		Permanent magnets or high-remittance parts are used in these relays so that, on removal of the coil power supply, the armature remains at the same point.

Type of Relay	Image	Function
Solid State Relays		Solid State relays perform the switching operation, with the help of solid state components, without moving any parts.
Hybrid Relays		Hybrid relays comprise electronic components and electromagnetic relays. The output part comprises electromagnetic relay while the input part comprises electronic circuitry, which performs control functions and rectification.
Thermal Relays		In thermal relays, the rise of the ambient temperature above the stipulated limit makes the contacts swich between positions. Primarily implemented in protecting motors, thermal relays comprise control elements as well as bimetallic elements like temperature sensors.
Reed Relays		Reed relays comprise paired magnetic strips called reeds, which are sealed in a glass tube and act as both a contact blade and an armature. The reeds can be moved by applying a magnetic field to the coil around the tube. Thus, switching operations can eb performed.

Registers: The microprocessor is responsible for most of the central processing unit (CPU) functions and is triggered when the computer is switched on. Registers are tiny number-storing locations, which are used by the microprocessor for performing arithmetic and logic operations.

Notes

UNIT 1.3: Active and Passive Components

Unit Objectives

By the end of this unit, the participants will be able to:

1. Compare various electronic part
2. Discuss various types of active and passive electronic components

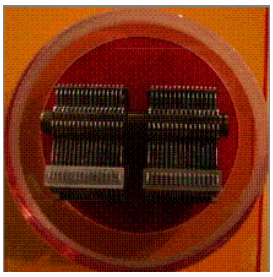
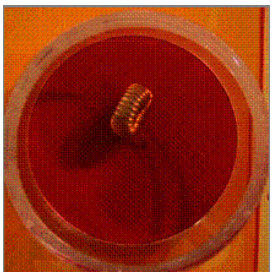
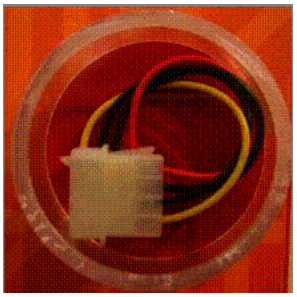
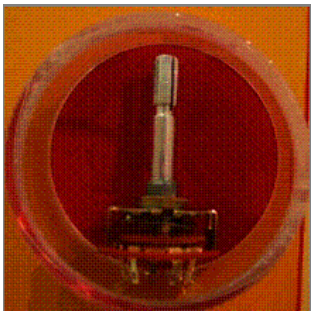
1.3.1 Introduction

Electronics is the field that involves electronic components, circuits, and device characteristics to fabricate electronic systems. Electronic components have a number of leads or electrical terminals, which connect to fabricate an electronic circuit with a given function (an amplifier, a radio receiver, an oscillator, etc.). Components can be classified as passive and active.

1.3.2 Passive Component

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

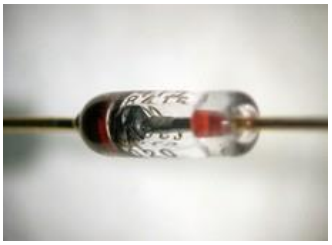
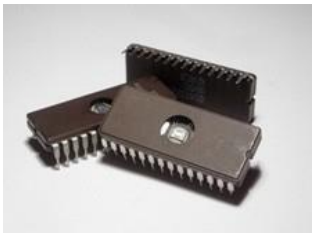
Name of the Component	Image	Function
Resistor		They resist the flow of electric current. The resistance is measured in Ohms (Ω). R=V/I, where: R=Resistance, V=Voltage and I=Current.
Potentiometer		It is a resistor with a tap or contact which can be moved to change the resistance.

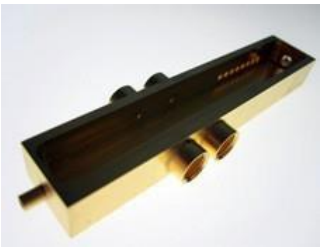
Capacitor		Capacitors store energy in its electric field. The capacitance is measured in Farads (F). C=Q/V, where: C=Capacitance, Q=Charge and V=Voltage. Capacitors stop direct current flow (DC). They are an open circuit to DC.
Variable Capacitor		The capacitance of these capacitors can be changed to adjust a circuit.
Inductor		Inductors store energy in its magnetic field. They are measured in Henrys (H). L=N
Connector		These connect one part of an electric circuit with another. Connectors are designed for different power levels and signal types.
Switch		Switches can be on-off controls (single throw) or change the connection from one circuit to another (double throw). Complex switches can control many circuits at the same time.

Relay		A relay is a switch that is turned on and off by an electromagnet, or a solid state switch controlled by an optical coupler.

1.3.2 Active Component

Active components depend on a source of energy (usually from the DC circuit). Active components include amplifying components like transistors, tunnel diodes, and triode vacuum tubes (valves).

Name of the Component	Image	Function
Diode		The most common function of a diode is to allow an electric current to pass in one direction (called the diode's forward direction), while blocking it in the opposite direction (the reverse direction). As such, the diode can be viewed as an electronic version of a check valve.
Transistor		The transistor can amplify and switch electrical power and electronic signals. Transistors are built up of semiconductor material with three or more terminals, which are used to connect to an external circuit. A change in current can be induced by applying current or voltage to one of the pairs of the terminals.
Integrated Circuit		Commonly known as a microchip or chip, an Integrated circuit (IC) is a semiconductor-based wafer on which millions of small capacitors, resistors, and transistors are connected. An IC can function as an oscillator, amplifier, timer, computer memory, counter, or microprocessor.

Optoelectronic devices		Optoelectronic devices are optical-to-electrical or electrical-to-optical transducers, or instruments that use such devices for functioning.
Valve		Solenoid valves can measure, close, mix, or distribute the fluid (gas or liquid) flow in a pipe. The circuit function of a solenoid valve denotes its exact purpose. 2/2 way valves comprise two ports (outlet and inlet) and two positions (closed or open).

Resistor Colour Coding

Colour	Digit	Multiplier	Tolerance
Black	0	1	
Brown	1	10	± 1%
Red	2	100	± 2%
Orange	3	1,000	
Yellow	4	10,000	
Green	5	100,000	± 0.5%
Blue	6	1,000,000	± 0.25%
Violet	7	10,000,000	± 0.1%
Grey	8		± 0.05%
White	9		
Gold		0.1	± 5%
Silver		0.01	± 10%
None			± 20%

Notes

UNIT 1.4: Understanding of Diodes, Transistors, and Logic Gates

Unit Objectives

By the end of this unit, the participants will be able to:

1. Analyze components like diode, transistors and logic gates

1.3.1 Diodes, Transistors, and Switches

What is diode?

A semiconductor device with two terminals, typically allowing the flow of current in one direction only

What is transistor?

A semiconductor device with three connections, capable of amplification in addition to rectification

Photo Transistor

The resemblance of a phototransistor is quite similar to that of a transistor with a small exception. The base terminal is present in transistor but absent in phototransistor. Production of base current takes place when light strikes the base region (photosensitive semiconductor. The incident light is converted into photocurrent by the help of collector-base p-n junction.

Phototransistor structure

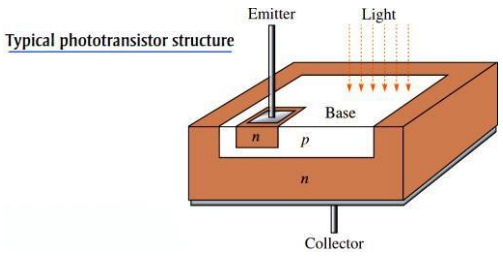


Fig 1.4.1: Phototransistor

Typical package

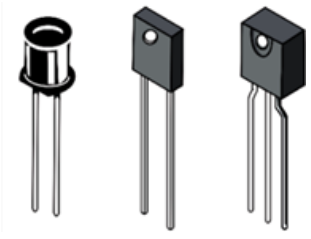


Fig 1.4.2: Package diode

Schematic symbol

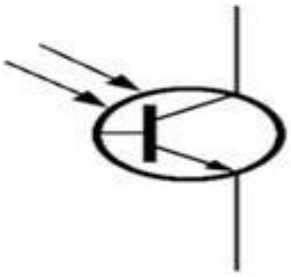


Fig 1.4.3: Diode symbol

Phototransistor circuit

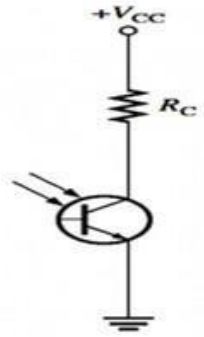


Fig 1.4.4: Phototransistor circuit

Switch types

Different types of switches are used for different applications. It is a recommended practice to use the correct switch for a specific application.

Rotary switch: Operated by rotation, rotary switches are used when more than two positions are needed. For example, while modifying bands on a radio receiver. The rotary switch comprises a spindle or rotor and there is an array of terminals, which the circular contactor makes contact with. This array is dependent upon the spindle position.

Fig 1.4.5: Rotary switch

Toggle switch: A toggle switch can be manually actuated by a mechanical lever, handle, or rocking mechanism. It generally has two positions. Once the arm is actuated the mechanical mechanism tends to hold it positively in one position or another. The internal mechanics are such that once the arm is moved it passes a certain point and it snaps into the other position. Thus, the switch is held firmly in one position or another.

Fig 1.4.6: Toggle Switch

Rocker switch: This type of switch has many similarities with the toggle switch in that it often has just two positions. However a toggle mechanism is not included and therefore the switching action is not quite as positive.

Fig 1.4.7: Rocker Switch

Electronic switch: FETs and also bipolar transistors as well as SCRs (Semiconductor Controlled Rectifiers) can be used for switching electronic and electrical circuits. When semiconductor technology alone is used to provide switching, these switches are often referred to as electronic switches.

Fig 1.4.8: Electronic Switch

List of semiconductor materials

Material	Chemical Symbol / Formula	Details
Germanium	Ge	Germanium, a semiconductor material, was commonly used in the first transistors as well as radar detection diodes. Germanium-based diodes exhibit a high temperature coefficient and reverse conductivity. This is why early transistors often suffered from thermal drainage.
Silicon	S	Silicon, the most common semiconductor, can be easily fabricated and exhibits good mechanical and electrical properties. When silicon is used in integrated circuits (ICs), it results in the formation of high-quality silicon oxide, which acts as an insulation layer between the IC's active elements.
Gallium arsenide	GaAs	After silicon, Gallium arsenide is the most popular semiconductor. Its high electron mobility is very useful for fabricating high-performance RF devices. Gallium arsenide is also commonly used as a substrate for a few other semiconductors like GaInNAs and InGaAs. However, its brittle nature and lower hole mobility as compared to Silicon restricts its application in P-type CMOS (Complementary Metal-Oxide Semiconductor) transistors.
Silicon carbide	SiC	Silicon carbide is commonly used in power devices where its losses are considerably lesser and operating temperatures can be greater than those of silicon-based devices. Silicon carbide has a breakdown capability about ten times that of silicon itself.
Gallium Nitride	GaN	Gallium nitride is now being commonly used in microwave transistors since these require high temperature and power. It is also being used in a few microwave ICs. GaN (Gallium nitride) is difficult to dope to create p-type regions and it is also sensitive to ESD (Electrostatic Discharge), but relatively insensitive to ionising radiation. It is also used in a few blue LEDs (Light Emitting Diodes).
Gallium phosphide	GaP	Gallium phosphide is a semiconductor material that has found many uses in LED technology. It was used in numerous early low to medium-brightness LEDs producing a variety of colours, which depended upon the addition of other dopants. Pure Gallium phosphide produces a green light. When nitrogen-doped, it emits yellow-green and when ZnO-doped it emits red.

Material	Chemical Symbol / Formula	Details
Cadmium sulphide	CdS	Used in solar cells and photoresistors.
Lead sulphide	PbS	Used as the mineral galena, Lead sulphide was used in the early radio detectors called 'Cat's Whiskers'. A point contact was created with the tin wire onto the galena to rectify signals.

Diodes

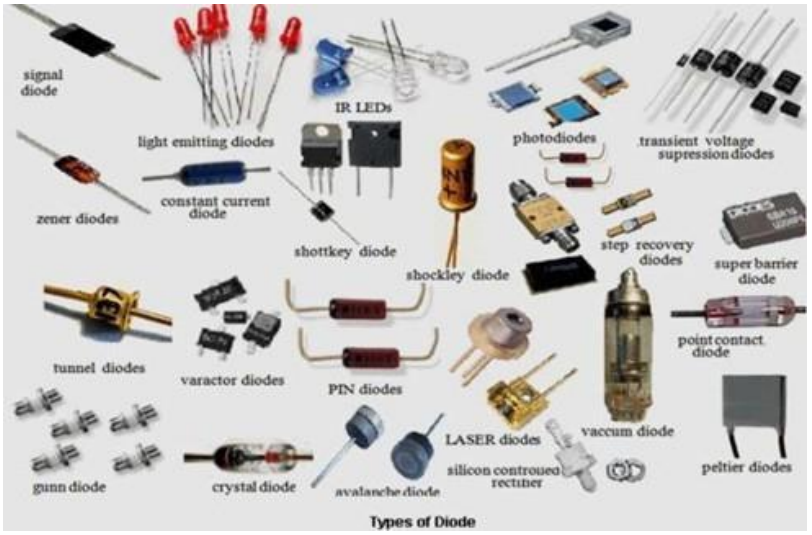


Fig 1.4.9: Different types of Diode

Diodes are electronic components functioning as one-way valves. This implies that they allow current to move in one direction. These diodes are produced with the help of the semiconductor materials germanium, silicon and selenium. The function of diode can be classified in two ways, if it allows the current then, it is forward-biased, otherwise it is reverse-biased.

Some of the diodes are listed below.

Small Signal Diode: An instrument with out-of-proportion features, the uses of a small signal diode are mostly involved with extremely low-current devices like radios and televisions, etc., and at high frequencies. It is enveloped with a glass in order to prevent contamination. Hence, it is also called Glass Passivated Diode, which is extensively used as 1N4148.

As compared to the power diode, the appearance of signal diode is very small. To indicate the cathode terminal, one of the edges is marked with black or red colour. For high-frequency applications, the performance of the small signal diode is very effective.

Fig 1.4.10: Small signal diode

Large Signal Diode: The PN junction layers in large signal diodes make the conversion of AC to DC voltages unlimited. This raises the reverse blocking voltage and the current forward capacity. Such large signals disrupt the operational points also. This is the reason why a large signal diode is unsuitable for high-frequency applications.

Fig 1.4.11: Large signal diode

Large signal diodes are primarily used in battery-charging devices like inverters. In these diodes, the forward resistance is measured in Ohms while the reverse blocking resistance is measured in mega Ohms.

Zener Diode: The zener diode is a passive element that works on the basis of Zener breakdown. Similar to normal diodes in forward direction, this was first produced by Clarence Zener in 1934. When the applied voltage hits the breakdown voltage, the zener diode allows current in a reverse direction. It is designed to stop the other semiconductor devices from momentary voltage pulses. The zener diode acts as voltage regulator.

Fig 1.4.12: Zener diode

Light Emitting Diode (LED): In light emitting diode, electrical energy is converted into light energy. It goes through the electroluminescence process in which electrons and holes are recombined to generate energy in the form of light in forward-bias condition. Light emitting diodes are mostly used in applications like aviation lighting, traffic signals, camera flashes, etc.

Fig 1.4.13: Light emitting diode

Constant Current Diodes: Commonly known as constant-current diode, current-limiting diode or current-regulating diode, the purpose of the diode is controlling the voltage at a given current. It works as a two-terminal current limiter.

Fig 1.4.14: Constant current diode

Schottky Diode: The junction in Schottky diode is created by contacting a metal with the semiconductor material. Thus, the forward voltage drop is reduced to minimum . The semiconductor material is N-type silicon that acts as an anode and the metal acts as a cathode. The metal may be platinum, chromium, tungsten, etc.

These diodes, due to the metal junction, enjoy high conducting capability and thus the switching time reduces. This is why Schottky is widely used for switching applications. Due to the metal-semiconductor junction, the voltage drop is low, which in turn increases the diode performance and reduces power loss.

Fig 1.4.15: Schottky diode

Shockley Diode: One of the first semiconductor devices, the shockley diode has four layers. It is also known as PNPN diode. It is equivalent to a thyristor without a gate terminal, which implies that the gate terminal is disconnected. As there are no trigger inputs, the only way the diode can conduct is by providing forward voltage. The diode works in two states, namely, conducting and non-conducting. In the non-conducting state, the diode conducts with less voltage.

Fig 1.4.16: Shockley diode

Step Recovery Diodes: It is also called charge-storage or snap-off diode. These are special types of diodes that store the charge from positive pulse and use this in the sinusoidal signals' negative pulse. The current pulse's rise time is equal to the snap time. This phenomenon is responsible for the speed recovery pulses. These diodes are used in higher order multipliers and in pulse-shaper circuits. These diodes have a very high cut-off frequency, which is nearly of the Giga hertz order.

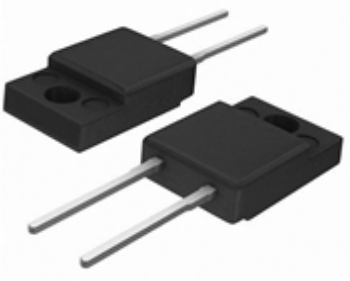


Fig 1.4.17: Step recovery diode

As a multiplier, this diode has the cut-off frequency ranging between 200 - 300 GHz. The efficiency is high for lower-order multipliers.

Tunnel Diode: It is used as high-speed switch of the nano-second order. Due to its tunneling effect, it enjoys very fast operation in microwave-frequency region. It is a two-terminal device comprising very high concentration of dopants. It is mainly used in microwave oscillators and amplifiers. It acts similar to most negative-conductance devices. Tunnel diodes can be tuned in both electrically and mechanically.

Fig 1.4.18: Tunnel diode

Varactor Diode: Also called Varicap diode, this acts like a variable capacitor. This performs mainly at the reverse-biased state. These diodes are very famous due to their capability of changing the ranges of capacitance within the circuit in the presence of a constant voltage flow.

Fig 1.4.19: Varactor diode

In a Varactor diode, by changing the reverse bias voltage, we can decrease or increase the depletion layer or barrier potential. These diodes are commonly used as voltage-controlled oscillator for cell phones, frequency multipliers, satellite pre-filters, FM (Frequency Modulation) transmitters, etc.

Laser Diode: This is similar to an LED in which active region is formed by p-n junction. Electrically, laser diode is a p-i-n diode in which the active region is in the intrinsic region. These are implemented in fiber optic communications, laser pointers, barcode readers, CD (Compact Disc)/DVD (Digital Versatile Disc)/ Blu-ray reading and recording, laser printing, etc.

Fig 1.4.20: Laser diode

Types of Laser Diode:

- **Double Heterostructure Laser:** Free electrons and holes are simultaneously available in the region.
- **Quantum Cascade Lasers:** These are heterojunction lasers that enable laser action at relatively long wavelengths.
- **Distributed Bragg Reflector Lasers:** These can be VCSELS (Vertical-Cavity Surface-Emitting Lasers) or edge-emitting lasers.
- **Multi Quantum Well Lasers:** Lasers with more than one quantum well are known as multi quantum well lasers.
- **Separate Confinement Heterostructure Lasers:** Separate confinement heterostructure lasers are used to compensate for the thin-layer problem in quantum lasers.

Transient Voltage Suppression Diode:

Transients occur in semiconductor devices due to the sudden change in the state voltage. They are capable of damaging the device output response. voltage suppression diodes are used to overcome this problem. The voltage suppression diode's operation is similar to Zener diode operation.

Similar to p-n diodes, the operation of these diodes is normal but at the time of transient voltage the operation varies. These are spontaneously very fast. Used in medical fields, telecommunication, microprocessors and signal processing, these diodes respond to excess voltages faster than varistors and gas discharge tubes.

Fig 1.4.21: Transient Voltage Suppression Diode

Gold Doped Diodes: These diodes use gold as a dopant. Faster than other diodes, these diodes enjoy very less leakage current in reverse bias condition. Even at a higher voltage drop, the diode can operate in signal frequencies. In these diodes, gold helps the faster recombination of minority carriers.

Fig 1.4.22: Gold doped diode

Super Barrier Diodes: It is a rectifier diode with low forward voltage drop similar to the Schottky diode and with low reverse-leakage current and surge-handling capability like the p-n junction diode. It was fabricated for speedy switching, high power, and low-loss applications. Super barrier rectifiers come with lower forward voltage as compared to Schottky diodes.

Fig 1.4.23: Super barrier diode

Peltier Diode: In this diode, heat is generated at the two material junction of a semiconductor, which flows from one terminal to another. This flow is in only a single direction, which is equal to the direction of current flow. Primarily used in heating and cooling applications, this type of diode is used as sensor and heat engine for thermo-electric cooling.

Fig 1.4.24: Peltier diode

Crystal Diode: Also known as Cat's whisker, this is a type of point-contact diode. Its function depends on the pressure of contact between the point and the semiconductor crystal.

Fig 1.4.25: Crystal diode

In this, a metal wire is pressed against the semiconductor crystal. The semiconductor crystal acts as cathode and the metal wire acts as anode. These diodes are obsolete in nature. They are mainly used in microwave receivers and detectors.

Avalanche Diode: This is a passive element and works under the principle of avalanche breakdown. It works in reverse bias condition. It results in large currents due to the ionization produced by p-n junction during reverse bias condition. These diodes are specially designed to undergo breakdown at specific reverse voltages to prevent the damage. These are used in **RF** (Radio Frequency) **Noise Generation, Microwave Frequency Generation and Single Photon Avalanche Detector.**

Fig 1.4.26: Avalanche diode

Vacuum Diodes: Vacuum diodes comprise two electrodes that act as anode and cathode. The cathode is made up of tungsten, which emits electrons in the anode's direction. The electrons will always flow from cathode to anode. Thus, it acts like a switch.

Fig 1.4.27: Vacuum diode

If the cathode is plated with oxide material, its electron emission capability is high. The anode is longer in size and in a few cases their surfaces are rough to decrease the chances of temperatures developing in the diode. The diode will conduct only when the anode is positive w.r.t to the cathode terminal.

PIN Diode: The PIN diode is the improved version of the normal P-N junction diode. In PIN diode, doping is not necessary. The intrinsic material that has no charge carriers is inserted between the P and N regions. This increases the area of depletion layer. Applications of these are RF switches, photo detectors, etc.

Fig 1.4.28: Pin diode

Point Contact Devices: A tungsten or gold wire is used to act as a point contact for fabricating a PN junction region by transmitting a high electric current. A small region of PN junction is formed around the wire edge, which is connected to the metal plate.

In the reverse bias condition, the wire acts similar to an insulator. The diode acts as a capacitor since the insulator is between the plates.

Fig 1.4.29: Point contact diode

Gunn Diode: Gunn diode is fabricated only with n- type semiconductor material. In two N-type materials, the depletion region is very thin. When the circuit voltage increases, the current also increases. The current will exponentially decrease after reaching a certain voltage level. Thus, Gunn diode exhibits negative differential resistance.

Gunn diode comprises two electrodes with Indium Phosphide and Gallium Arsenide. This results in negative differential resistance. Gunn diode is also called transferred electron device. It produces microwave RF signals. Hence, it is primarily used in Microwave RF devices. It can also be used as an amplifier.

Fig 1.4.30: Gunn diode

Types of Transistors

Bipolar Junction Transistor (BJT)

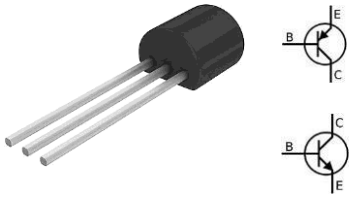


Fig 1.4.31: Bipolar junction transistors

These are transistors built of three regions, namely, the base, the emitter, and the collector. Bipolar Junction transistors are current-controlled devices. A small current entering the base region of the transistor results in more current flow from the emitter to the collector region. Bipolar junction transistors are of the below types:

- NPN (Negative, Positive, Negative) - Where the majority of current carriers are electrons
- PNP (Positive, Negative, Positive) - Where the majority of current carriers are holes

Field Effect Transistor

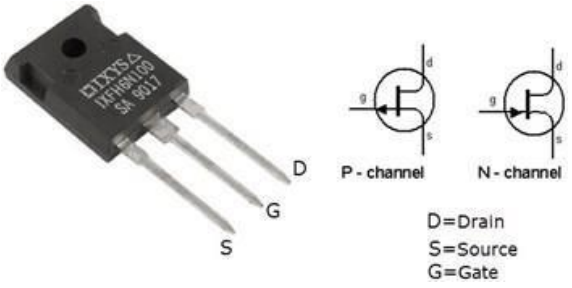


Fig 1.4.32: Field effect transistor

These comprise three regions, namely, a source, a gate, and a drain. Different from bipolar transistors, FETs are voltage-controlled devices. Field Effect Transistors enjoy very high input impedance, ranging between several mega ohms (MΩ) of resistance to even larger values. Such high input impedance results in very less current running through FETs. FETs draw very little current from a power source. Field Effect Transistors can be classified into two main types:

- JFET (Junction Field Effect Transistor)
- MOSFET (Metal Oxide Semiconductor Field Effect Transistor)

MOSFETs and JFETs are very similar but MOSFETs have even higher input impedance values as compared to JFETs.

Heterojunction Bipolar Transistor (HBT)

Heterojunction bipolar transistors (HBTs) are implemented for both digital and analog microwave applications with frequencies as high as the Ku band. HBTs can supply quicker switching speeds as compared to silicon bipolar transistors mostly because of reduced base-resistance and collector-to-substrate-capacitance. HBTs are used in both high-reliability and profitable applications, like power amplifiers in laser drivers and mobile telephones.

Darlington Transistor

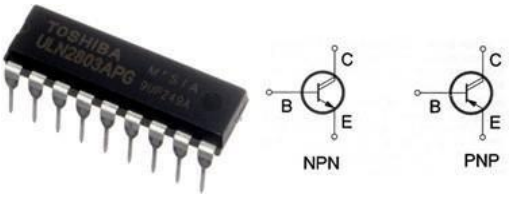


Fig 1.4.33: Darlington transistor

A Darlington transistor, commonly known as a Darlington Pair, is a transistor circuit built of two transistors. Invented by Sidney Darlington, it enjoys much higher current-gaining ability. The circuit can be inside an IC or made from two discrete transistors.

Schottky Transistor

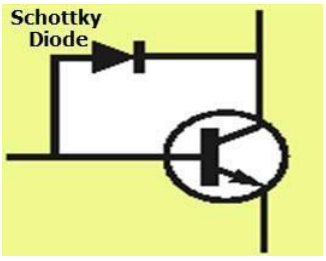


Fig 1.4.34: Schottky transistor

It is a combination of a Schottky diode and a transistor. The Schottky diode hinders the transistor from saturating by bypassing the extreme input current. It is also called a Schottky-clamped transistor.

Multiple-Emitter Transistor

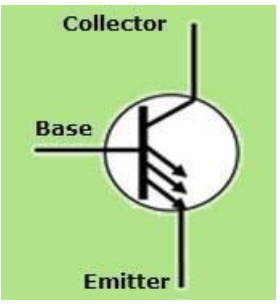


Fig 1.4.35: Multiple emitter transistor

A multiple-emitter transistor is a specialized bipolar transistor frequently used as the inputs of transistor logic (TTL) (Transistor-Transistor Logic) NAND (NOT AND) logic gates. Input signals are applied to the emitters.

Dual Gate MOSFET

The dual gate MOSFET is very popular in several RF applications. Used in many RF applications where two control gates are required in series, the dual gate MOSFET can be used in applications like RF amplifiers, RF mixers /multipliers, amplifiers with gain control, etc.

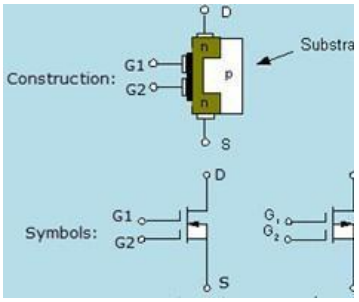


Fig 1.4.36: Dual gate MOSFET

Junction FET Transistor

Instead of PN junctiions, the Junction Field Effect Transistor (JUGFET (Junction Gate Field Effect Transistor) or JFET) has a narrow high resistivity semiconductor material creating a P-type or N-type silicon channel for the majority of the carriers to flow through two ohmic electrical connections at either end. These are called the source and the drain. The N-channel JFET and the P-channel JFET are the two basic configurations of junction field effect transistor.

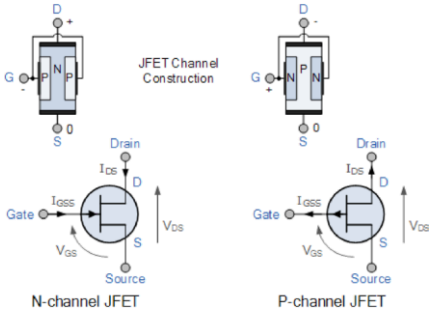


Fig 1.4.37: Junction FET transistor

Avalanche Transistor

This is a bipolar junction transistor fabricated for processing in the region of its collector-to-emitter voltage/collector-current characteristics beyond the collector-to-emitter breakdown voltage, known as the avalanche breakdown region. This region is described by the avalanche breakdown, a phenomenon similar to the negative differential resistance. Operations in the avalanche breakdown region are called avalanche-mode operation, during which avalanche transistors are empowered with the capability to switch very high currents with less than a nanosecond rise and fall times (transition times).

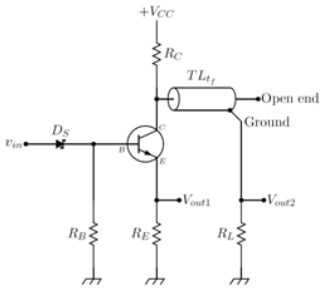


Fig 1.4.38: Avalanche transistor

Diffusion Transistor

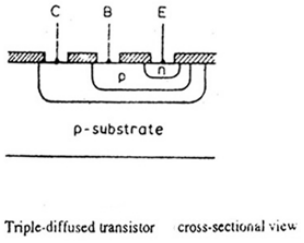


Fig 1.4.39: Diffusion transistor

This is a bipolar junction transistor (BJT), which is fabricated by means of diffusing dopants onto a semiconductor substrate. Diffusion is implemented later than the alloy junction and grown junction processes.

Testing transistors using multimeter

Fig 1.4.40: Multimeter

The things you require are very simple.

Step 1 First, you need a multimeter and secondly the transistors you want to test.

Step 2 Now comes the part of testing the transistors.

The NPN (Negative, Positive, Negative) transistor has the collector and emitter as negative and the base as positive, which is just opposite in PNP (Positive, Negative, Positive) transistors.

Step 3 The multimeter must be set at the transistor-testing mode.

The leads of the multimeter must be connected to the transistor leads. The negative lead must be connected to the negative terminal while the positive lead must be connected to the positive terminal. The multimeter shows a reading.

Step 4 The negative lead must now be connected to the other negative terminal. The multimeter shows a reading.

It must be noted that the readings in both cases are almost equal.

Step 5 How to detect a bad transistor

The leads must be connected to both the negative terminals. If the multimeter reads 1, the transistor is okay. If this is not the case, the multimeter produces a buzzing sound and reads 000, thus indicating that the transistor is bad and not recommended for use.

Step 6 PNP TRANSISTORS

The leads must now be connected to the opposite terminals. The PNP transistor will show a reading only when the positive lead is connected in the middle and the negative lead at the sides.

Thus, the above tests can be used for comparing NPN and PNP transistors.

Transistor configuration

The three types of transistor configurations are:

A. Common base transistor configuration
B. Common collector transistor configuration
C. Common emitter transistor configuration

Common Base Transistor Configuration (CB)

This transistor configuration produces a low input while giving high output impedance. The current gain and overall power gain is low when the voltage of the CB transistor is high, as compared to the other configurations. The main characteristic of the B transistor is that the transistor's input and output are in phase. In the given circuit, the base terminal is mutual to both input and output circuits.

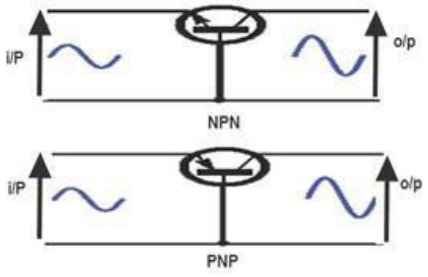


Fig 1.4.41: Common base transistor

The collector current (output current) to emitter current (input current) relationship is denoted by alpha, which is calculated by:

α= (ΔIc)/ΔIE

If the input current (IE) in a common base current changes from 2mA to 4mA and the output current (IC) changes from 2mA to 3.8 mA, the gain of the current will be 0.90.

$$\alpha = \frac{\Delta I_C}{\Delta I_E} = \frac{18 \times 10^{-3}}{2 \times 10^{-3}} = 0.90$$

The CB current gain is < 1 when the emitter current flows into the base terminal and does not function as collector current. This current is always less than the causal emitter current. The common base configuration gain is always < 1. The given formula is used to calculate the current gain of the CE (α) when the CB value is given i.e. (β).

Common Collector Transistor Configuration (CC)

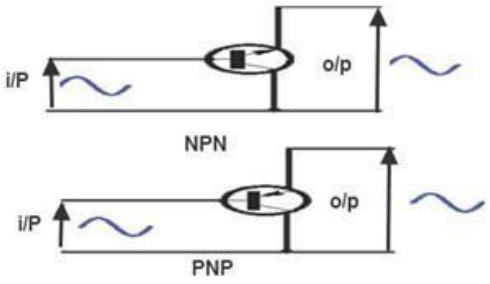


Fig 1.4.42: Common collect transistor

Also called the emitter follower, the emitter voltage of this transistor follows the base terminal of the transistor. Offering high input and low output impedances, it is used as a buffer. The transistor has a voltage gain of 1, the current gain is high and the output signals are in phase. The collector terminal is mutually shared by both input and output circuits.

The CC circuit's current gain is indicated as γ and is calculated using the below formula.

$$\gamma = \frac{\Delta I_E}{\Delta I_B}$$

This gain is related to the CB current gain beta (β), and the CC circuit gain is calculated, when the b value is given.

$$\gamma = \beta + 1$$

When the transistor is connected in any one of the CE, CB and CC configurations, there exists a relationship between beta, alpha, and gamma.

$$\alpha = \frac{\beta}{\beta + 1} \quad \beta = \frac{\alpha}{1 - \alpha} \quad \gamma = \beta + 1$$

For example, if the current gain of the common base value (α) is 0.90, the beta value is:

$$\beta = \frac{\alpha}{1 - \alpha} = \frac{0.90}{1 - 0.90} = \frac{0.90}{0.1} = 9$$

Thus, a change in the base current of this transistor will impart a change in collector current. This change in collector current will be nine times bigger. In order to use the same transistor in CC configuration, we need to calculate gamma by the following equation.

$$\gamma = \beta + 1 = 9 + 1 = 10$$

Common Emitter Transistor Configuration (CE)

One of the most widely used configurations, the circuit of CE transistor configuration provides moderate input and output impedance levels. The voltage and current gains can be defined as a medium, but the output is opposite to the input, thus indicating a 1800 change in phase. This improves performance and is frequently thought of as the most commonly used configuration. The below diagram depicts the CE transistor configuration. In this type of circuit, the emitter terminal is mutually shared by both input and output.

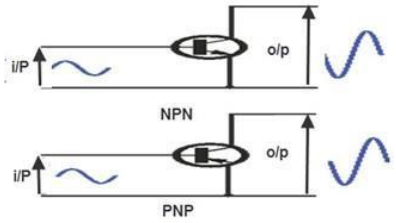


Fig 1.4.43: Common emitter transistor

The common emitter (CE) circuit's current gain is denoted by beta (β). It is the relationship between the base and collector currents. The below formula is used to calculate beta (β). Delta denotes a minor difference.

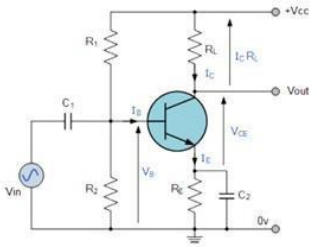
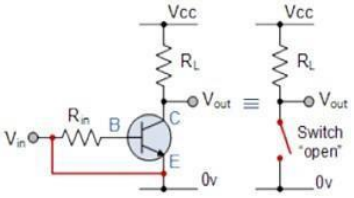
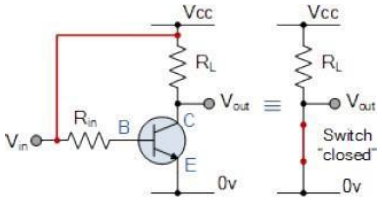
$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

Let us consider an example. If the input current (IB) in a CE changes from 50 mA to75 mA and the output current (IC) varies from 2.5mA to 3.6mA, the current gain (b) becomes 44.

$$\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{11 \times 10^{-3}}{25 \times 10^{-6}} = 44$$

From the above, it can be interpreted that a change in base current results in a modification in collector current, which is 44 times larger.

Basic Conversion of Transistor

Type of Conversion	Image	Description
Transistor as amplifier		The most common amplifier configuration for an NPN transistor is that of the Common Emitter Amplifier circuit.
Transistor as switch: Cut-off Characteristics		• The input and Base are grounded (0v) • Base-Emitter voltage VBE < 0.7v • Base-Emitter junction is reverse biased • Base-Collector junction is reverse biased • Transistor is “fully-OFF” (Cut-off region) • No Collector current flows (IC = 0) • VOUT = VCE = VCC = ”1” • Transistor operates as an “open switch”
Transistor as switch: Saturation Characteristics		• The input and Base are connected to VCC • Base-Emitter voltage VBE > 0.7v • Base-Emitter junction is forward biased • Base-Collector junction is forward biased • Transistor is “fully-ON” (saturation region) • Max Collector current flows (IC = Vcc/ RL) • VCE = 0 (ideal saturation) • VOUT = VCE = ”0” • Transistor operates as a “closed switch”

1.4.2 Basic Logic Gates

Considered the building block of a digital circuit, a logic gate comprises two inputs and an output, which are related with the help of certain logic.

Logic gates are put to use with the help of electronic switches like diodes and transistors. Nowadays, CMOS technology, MOSFET (Metal Oxide Semiconductor FET)s and FETS are used to build basic logic gates.

Logic gates are used in microprocessors, microcontrollers, and embedded system applications and in electronic and electrical project circuits.

The basic logic gates are categorized into seven: AND, OR, XOR, NAND, NOR, XNOR and NOT. These logic gates with their logic gate symbols and truth tables are explained below.

Fig 1.4.42: Symbol of a logic gate

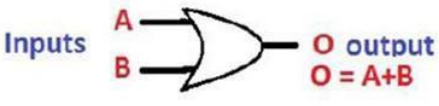
AND Gate

The AND gate, a digital logic gate, comes with 'n' number of inputs and only one output. The output performs logical conjunction on the basis of the input combination. The output of this gate becomes true only when all the inputs are true. The output of the AND gate becomes false only when one or more inputs are false.

Fig 1.4.43: Symbol and Truth Table of the AND gate

OR Gate

Comprising 'n' number of inputs and one output, the OR gate output becomes true only when one or more inputs are true. The output is false only when all inputs of the gate are false.



Symbol

Inputs		Output
A	B	O
0	0	0
0	1	1
1	0	1
1	1	1

Truth table

Fig 1.4.44: Symbol and Truth Table of the OR gate

NOT Gate

The NOT gate comprises one input and one output and operates an inverter operation of the input. The output of the NOT gate is the reverse of the input. When the input of the NOT gate is true then the output will be false and vice versa. With the help of this gate, the NOR and NAND gates can be constructed.

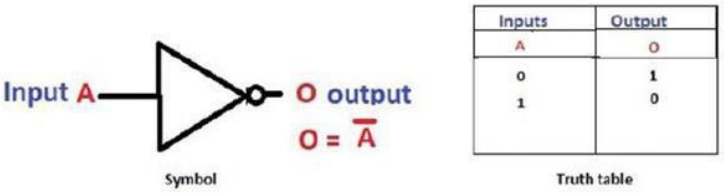


Fig 1.4.45: Symbol and Truth Table of the NOT gate

NAND Gate

Comprising 'n' inputs and only one output, the NAND gate executes the AND gate operation, which is followed by the NOT gate operation. The NAND gate is fabricated by combining the NOT and AND gates. The output will be low if the input is high.

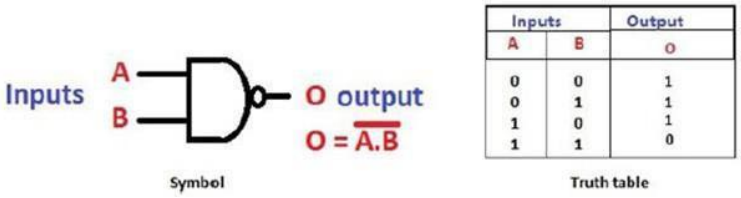


Fig 1.4.46: Symbol and Truth Table of the NAND gate

NOR Gate

Comprising 'n' inputs and one output, the NOR gate executes the OR gate operation, which is followed by the NOT gate. It is fabricated by combining the NOT and OR gates. The output is false when any one of the inputs is true.

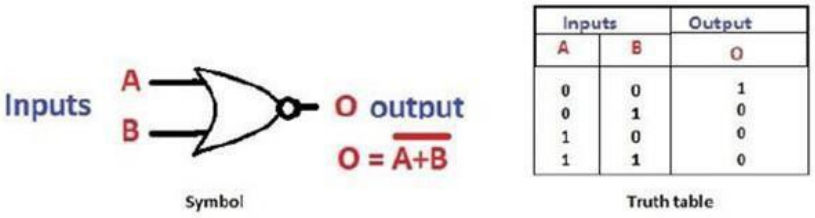


Fig 1.4.47: Symbol and Truth Table of the NOR gate

Exclusive-OR Gate

Comprising two inputs and one output, the short form of this gate is Ex-OR. It functions on the basis of OR gate operation. The output is high if any one of the inputs is high.

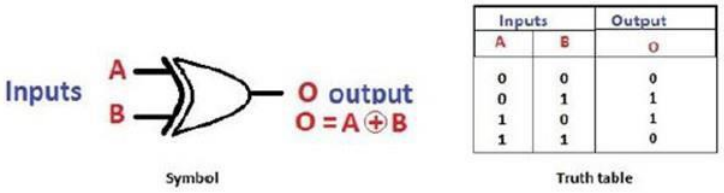


Fig 1.4.48: Symbol and Truth Table of the exclusively OR gate

Exclusive-NOR Gate

Comprising two inputs and one output, the short form of this gate is Ex-NOR. It operates on the basis of the NOR gate operation. The output of the gate is high when both the inputs are high. However, if any one of the inputs is high (but not both), the output will be low.

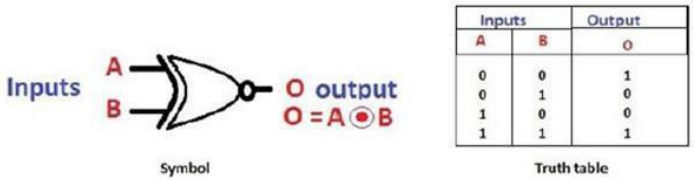


Fig 1.4.49: Symbol and Truth Table of the exclusively NOR gate

1.4.3 RF Transmitter and Receiver

RF Transceiver

A mixture of a receiver and a transmitter in a single package, the RF trans receiver is widely used in wireless communication for applications like handheld and mobile two-way radios, cellular telephones, and cordless telephone sets. It is also used in transmitter or receiver devices in optical fiber systems or cables.

Fig 1.4.50: RF Trans receiver module

In a radio transceiver, the receiver is quietened while transmitting. An electronic switch authorises the transmitter and receiver to be associated with the same antenna and prevents the transmitter output from damaging the receiver. Thus, it is difficult to receive signals while transmitting and this mode is named as half duplex.

A few types of transceivers are designed to allow signal reception via transmission periods. This full duplex mode needs the transmitter (TX) and receiver (RX) to work on different frequencies so the signal transmitted doesn't interfere with reception. Communication devices sets use this mode. Satellite communication networks frequently employ full-duplex transceivers at the surface based subscriber points. The transceiver-to-satellite (transmitted) signal is called the uplink, while the satellite-to-transceiver (received) signal is called the downlink.

Block Diagram of RF Transceivers

The size of the RF modules is quite small. RF modules operate with the help of voltage ranging from 3V to 12V.

Generally, such RF modules are 433 MHz RF TX and RX modules. The transmitter (TX) draws zero power while transferring logic zero while fully destroying the carrier frequency, thus consume considerable low power in battery operation. When logic1 is sent carrier is fully on to about 4.5mA with a 3V power supply. The information is sent serially from the transmitter (TX) which is received by the receiver. Transmitter (TX) and the receiver (RX) are duly interfaced to two Microcontrollers for transferring the data.

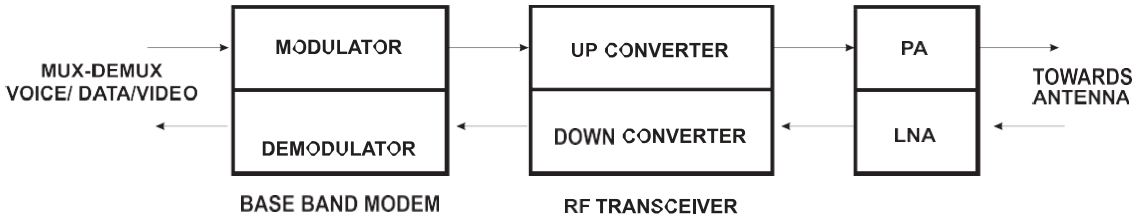


Fig 1.4.51: Block Diagram of RF Transceivers

RF modules can be used for different variants, sizes and shapes of electronic circuit boards. It can also be used for modules across a wide variety of uses and capacity. These modules generally include a PCB (Printed Circuit Board), RX or TX circuit, serial interface and antenna for communication to the main processor.

RF modules primarily comprise RF transmitter module, RF receiver module, RF transceiver module and SOC (System On a Chip) module. Three types of signal modulation techniques are popularly used in RF transmitter and RF receiver modules. These are ASK-amplitude shift keying, FSK-frequency shift keying, and OOK-On-Off Keying.

The RF transceiver module comprises both a transmitter and a receiver. The RF transceiver module circuit is designed for half-duplex operation and generally at a higher cost due to the higher complication.

RF Transmitter

An RF transmitter module is a small-size PCB used to transfer a radio wave and a modulating radio wave to transport data. RF transmitter modules are generally applied along with a microcontroller, which will offer data to the module under transmission. These transmitters are generally subject to controlling requirements that direct the maximum acceptable transmitter power output, harmonics requirements, and band edge.

RF Receiver

An RF receiver module accepts the modulated RF signal and demodulates it. Two kinds of RF receiver modules exist, namely the super-heterodyne receivers and the super-regenerative receivers. Generally, super-regenerative modules are low-power and low-cost designs deploying a series of amplifiers for getting rid of modulated data from a carrier wave. These modules change, usually inaccurate since their operation of frequency vary significantly with power supply voltage and temperature. The main advantage of the super-heterodyne receiver modules is high performance as compared to the super-regenerative variant. They offer improved accuracy and stability over a vast range of temperature and voltage. This stability is derived from a stable crystal design, which in turn, leads to a relatively more expensive product.

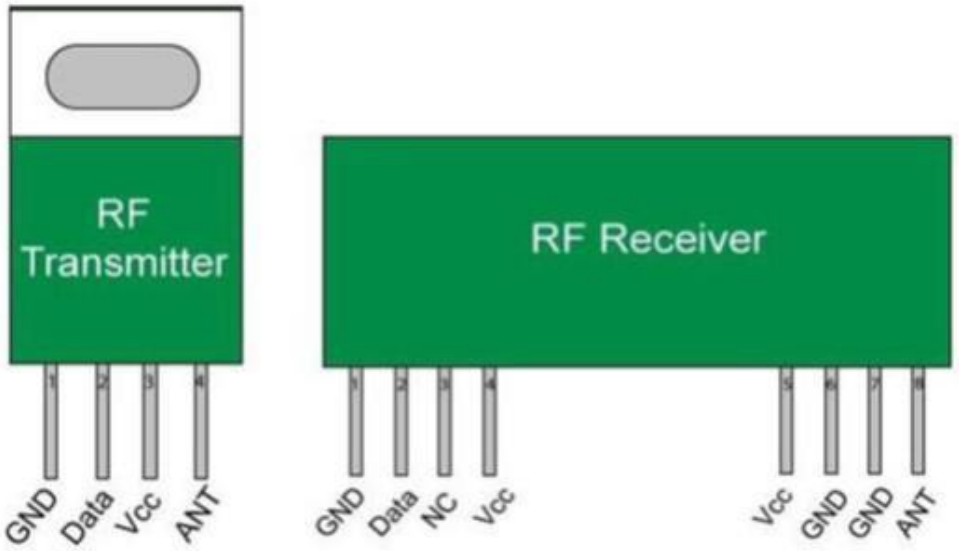


Fig 1.4.52: RF Transmitter and Receiver

RF transceiver module is used in a given device where both the transmitter and receiver remain in a single module. These devices transmit and receive RF signal and are called RF Transceivers. Generally, the position of RF transceiver module is between the Power amplifier/Low Noise Amplifier and the Baseband MODEM (Modular Demodulator) in common wireless communication systems. Baseband Modem comprises chip sets of several analogue or digital modulation techniques and analogue to digital conversion or digital to analogue conversion chips.

Applications of RF Transceiver

- RF transceiver module is used in radio transmission, satellite communication, for television signal transmission, reception and in Wimax or WLAN (Wireless Local Area Network), Zigbee or ITE (Information Technology Equipment) networks.
- Used widely in wireless communication, the transceiver is primarily used to convert data in the form of data/ voice / video suitable to be transmitted over wireless media.
- RF transceiver changes IF frequency to RF frequency and vice versa.

Radio-frequency engineering is a subset of electrical engineering that deals with devices that are designed to operate in the radio frequency (RF) spectrum. The range of operation for these devices is 3 kHz (Kilohertz) to 300 GHz (Gigahertz).

Radio-frequency engineering is assimilated into almost everything that transmits or receives a radio wave, which includes, but is not limited to, radios, mobile phones, Wi-Fi (Wireless Fidelity), and two-way radios.

Radio-frequency engineering is a highly specialized field falling typically in one of the below arenas:

1. Getting or producing signals to or from that transmission system to other communication circuitries or controls.
2. Controlling or enhancing coverage with the help of antenna/transmission systems
3. Performing tests for monitoring the performance of an electronic design

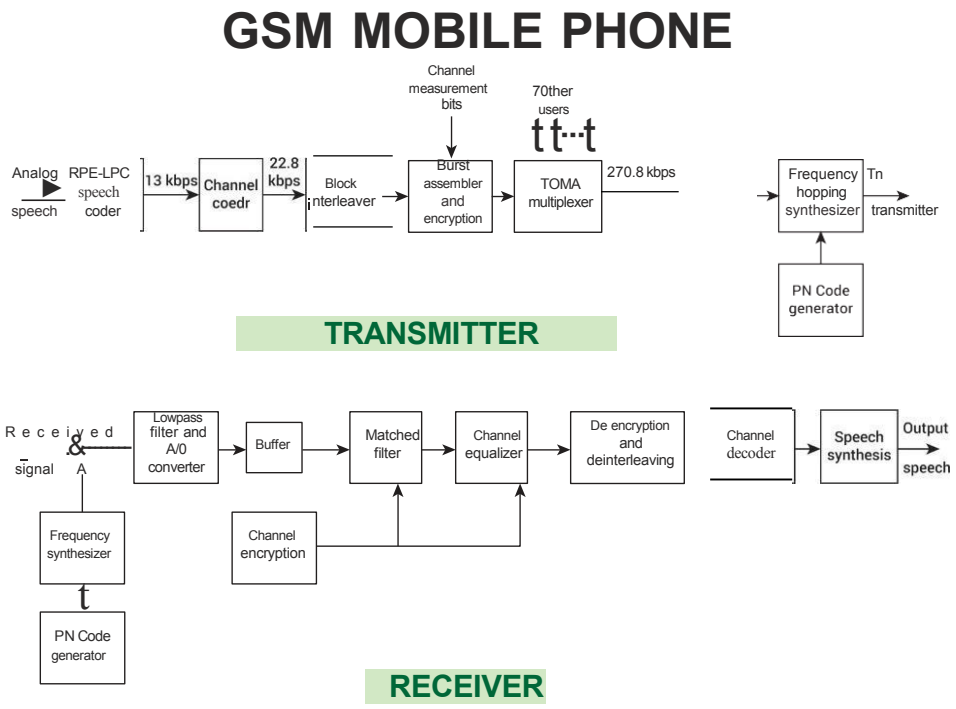


Fig 1.4.53: Usage of Transmitter and Receiver in GSM telephony

1.4.4 Amplifier, Multiplexer and Couplers

Amplifiers

An amplifier is an electronic device that enhances the voltage, current, or power of a signal. Amplifiers are used in wireless communications and broadcasting, and in all types of audio equipment. They are classified as either *weak-signal amplifiers* or *power amplifiers*.

Types of amplifiers

- **Weak-signal amplifiers** are used mainly in wireless receivers. They are also used in acoustic pickups, audio tape players, and compact disc players. A weak-signal amplifier is designed to deal with exceedingly small input signals, in some cases measuring only a few nanovolts (units of 10^{-9} volt). The most effective device for this application is the field-effect transistor.

- **Power amplifiers** are used in wireless transmitters, broadcast transmitters, and hi-fi audio equipment. The most frequently used device for power amplification is the bipolar transistor. However, vacuum tubes, once considered obsolete, are becoming increasingly popular due to its superior fidelity.

  Two important considerations in power amplification are *power output* and *efficiency*. Power output is measured in watts or kilowatts. Efficiency is the ratio of signal power output to total power input (wattage demanded of the power supply or battery). This value is always less than 1. It is typically expressed as a percentage. In audio applications, power amplifiers are 30 to 50 percent efficient. In wireless communications and broadcasting transmitters, efficiency ranges from about 50 to 70 percent. *Distortion* is also an important factor, in hi-fi audio power amplifiers as it measures the extent to which output waveform is constant imitation of the input waveform.

Multiplexer

A multiplexer (MUX) is a network device that allows one or more analog or digital input signals to travel together over the same communications transmission link. The purpose of multiplexing is to combine and transmit signals over a single shared medium in order to optimize efficiency and decrease the total cost of communication. Multiplexing techniques have become useful network optimization tools during the age of the Internet of Things, edge computing and 5G. Today, the following communication applications would be prohibitively expensive without multiplexing: telecom, satellites, telemetry and broadcasting.

How multiplexing works

Frequency division multiplexing, time division multiplexing and wavelength division multiplexing are the types of multiplexing most closely associated with telecom. For analog signals in telecommunications and signal processing, a time division multiplexer may select multiple samples of separate analog signals and combine them into one pulse amplitude modulated (PAM) wide-band analog signal. For digital signals in telecommunications on a computer network or with digital video, several variable bit-rate data streams of input signals (using packet mode communication) may be combined, or multiplexed, into one constant bandwidth signal. A multiplexer requires a demultiplexer to complete the process, to separate multiplex signals carried by the single shared medium or device. Often a multiplexer and a demultiplexer are combined into a single device (also often just called a multiplexer) in order to allow the device to process both incoming and outgoing signals.

Couplers

RF couplers are passive devices that sample a small amount of signal from an RF chain. Many RF components have an input port where the signal goes in, and an output port where the signal comes out. Couplers have an additional "coupled" port which taps the main signal at a small fraction of the power of the thru line. The ratio in dB of the signal power at the input port to the output power at the coupled port is the Coupling Ratio or Coupling Coefficient. The coupling ratio is a known parameter specified by the device manufacturer and can be selected according to the user's system requirements. Different types of couplers include directional couplers, bi-directional couplers, and dual directional couplers. Directional couplers sample signal from the main line in forward direction; bi-directional couplers have two coupled ports to sample signal from the forward or reflected signal paths as needed; and dual directional couplers allow simultaneous sampling of both thru- and reflected signal power. Couplers are widely used in RF systems for a variety of functions including power monitoring, antenna reflection monitoring, automated gain control, and electrical test and measurement among many others.

Notes

UNIT 1.5: Fundamentals of PCB

Unit Objectives

By the end of this unit, the participants will be able to:

1. Evaluate the fundamentals of PCB
2. Analyze the troubleshooting for PCB

1.5.1 PCB Basics

Defining PCB

- A PCB provides a mechanical support and connects electrically electronic components
- Making use of conductive tracks pads and other features that consists of one or more laminated copper of a substrate that is non-conductive
- Components are usually soldered onto the PCB for obtaining mechanical fastening and electrical connection
- Printed Circuit Boards (PCB) are used in the simplest of electronic products and also simple electric products like passive switch boards
- PCBs can be single, double or multisided
- Single sided is one copper layer; double sided is two copper layers on both sides of a substrate layer; multi sided layer outer a and inner side of copper layers with alternating layers of substrate

Electronic components or parts are basically packaged in a distinct manner with two or more than two connecting leads or metallic pads. It is usually done by attaching it to the Printed Circuit Board (PCB) so that an electronic circuit is created with a specific function. Some of the important electrical component would include; resistor, capacitor, transistor, diode and others

Types of electronic components-

There are basically two types of electronic components:

- Active Components
- Passive Components

Components and their Functions

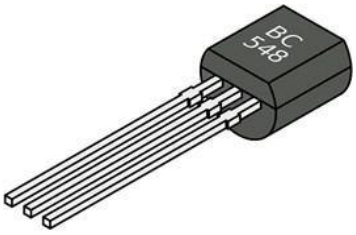
The functions of the components are listed below:

Components	Functions
Resistors	Electrical components that resist current
Capacitors	Components used to store electrical charge in electrical fields
Terminals and Connectors	Components that are used to make electrical connection
Switches	Components that are used to conduct or not to conduct (when switched off) the electricity

Magnetic or Inductive Components	Electrical components those use magnetism in their field
Network Components	Components that use one or more than one type of passive component
Piezoelectric devices, crystals, resonators	Components those are passive using piezoelectric effect
Semiconductors	Control components that are electric, with parts that are not moving A device that is a semiconductor, which has the capacity of amplification
Transistors	These are components that are capable of conducting the electricity in a specific or a single direction
Diodes	It is not a single component but rather a whole system, which is a micro-electronic computer electronic circuit that can be placed along with a chip or a semi-conductor
Integrated Circuits or ICs	An integrated circuit or monolithic circuit is also called as an IC, a chip and a microchip. It is a total set of integrated circuit on a small piece that is flat, that is a semiconductor material which is silicon

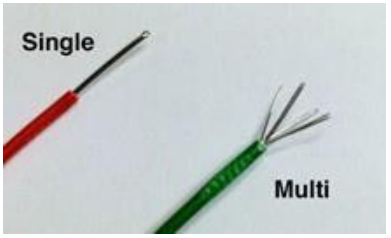
Images of the Electrical Components:

Components	Images
Resistors	
Capacitors	
Terminals and Connectors	
Switches	

Components	Images
Magnetic or inductive components	
Network components	
Piezoelectric components crystal resonators	
Semiconductors	
Transistors	
Diodes	
Integrated circuits or IC's	

List the wires, cables and modules- there are basically five types of wires:

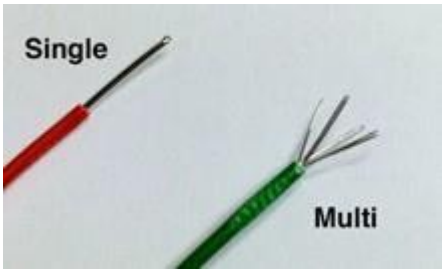
Wires	Description	Images
Triplex wires	• These wires are basically used as the service of single phase, and drop conductors, these form a connection between the power pole and weather heads • Their composition is mainly of two insulated wires which is wrapped with a third wire that is bare and neutral • The neutral wire is basically of a smaller gauge that is grounded at both the transformer and the electric meter	
Main Feeder Wires	• These are basically wires that connect service weather head to the house • It is made or composed mainly of stranded or solid THHN (Thermoplastic High Heat-resistant Nylon-coated) wire and the capacity of the cable is 25% more than what is required	
Panel Feed Wires	• These wires are generally black insulated wires that is again THHN • These are mainly used to power up the main junction box to the circuit breaker panels • These wires should also have the capacity of 25% more than what is required	
Non-Metallic Sheathed Wires	• Non- metallic sheathed wire is also called romex wire • Mostly used in homes, that has 2-3 conductors, that comes with a plastic insulation and a ground bare wire • This is covered with another layer on sheathing which is non-metallic • It is relatively cheaper as compared to others and is available in 15 and 20 amps it is used in in-house wiring	

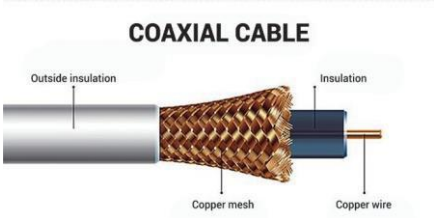
Wires	Description	Images
Single strand wires	• These wires also use THHN wire, and there can be or there is other variant • Each wire is separated and can be easily drawn through a pipe • Most popular that use pipes to contain the wires **TTHN** T- Thermoplastic insulation HH- High Heat resistance N- synthetic polymer, which is flame resistant	

Components of Electrical Cable – the electrical cable or power cable are used to transfer electrical power. The cables form a basis of communication between the electrical gadgets and all other devices that works on electricity. All the electrical cables differ in performance, size and configuration.

- The electrical cables come with two wires that are conducting and a jacket that forms an outer protection
- The conducting wires vary from high voltage to medium voltage carrying capacity that might be sheathed with a protective jacket and an insulating sheath
- These are usually made of copper, while the synthetic polymer make the outer jacket and protective insulating sheath

There are basically four types of cables:

Types of cables	Description	Images
Shielded Cable	• A shielded wire cable it consists of more than one insulated wire • That are collectively enclosed with the woven braid shielding an aluminium Mylar foil • This shielding prevents external radio and interference of power frequency for passage of single transmission smoothly • Commonly shielded cables are high voltage power cables • Twisted pair cable consists of insulated copper wires that are coded with colour • Twisted around each other • The diameter of each ranges from 0.4 to 0.8 mm, the number of pairs vary accordingly	

Types of cables	Description	Images
Twisted Pair Cable	• The more the amount of number of pairs the resistance of the cable is higher • Twisted pair cables are easily installed, flexible and inexpensive • This cable has a copper-plated core, that is surrounded by a di- electric insulator • These cables vary in size, performance, cost and flexibility • Hard link, leaky cable are types of coaxial cable	
Coaxial Cable	• Also called multi- wire planner electrical cable or flat wire cables. It consists of multiple insulated wire running parallel to each other • It is used for multiple signals of data transmission • Commonly used to connect network services. It connects the motherboard to the CPU (Central Processing Unit) • Most commonly used to interconnect network devices	
Ribbon cable		

A printed circuit board (PCB) helps in connecting electronic or electrical components with the help of conductive pads, tracks, and other structures etched from one or more copper sheet layers laminated onto and between non-conductive substrate sheet layers.

1.5.2 Multi layered PCB – important concepts

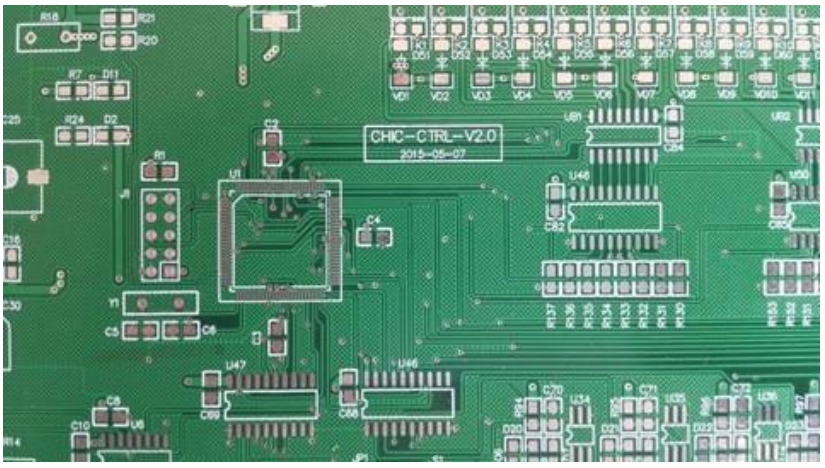


Fig 1.5.1: Sample PCB circuit board

It electrically supports and electrically connects electronic components or electrical components using conductive tracks, pads and other features. Printed circuit boards (PCBs) are implemented in almost all electronic items. PCBs are also used in some electrical products, say passive switch boxes. PCBs come in the following variants:

- double-sided, where two copper layers are on both sides of one substrate layer)
- single-sided with one copper layer
- multi-layer, where outer and inner layers of copper are placed, in alternating fashion, with layers of substrate

How to assemble PCBs and required materials:

- **RoHS compliant PCB:** The RoHS (Restriction of Hazardous Substances) is a legislature that restricts the use of hazardous substances. PCBs sold must be RoHS-compliant, which imples that all manufacturing processes must not involve the use of hazardous items like lead, the solder used must be free of lead, and all elements mounted on the PCB must be free of mercury, lead, cadmium, and other heavy metals.
- **Laminates:** Laminates are manufactured by curing under specific temperature and pressure conditions. Cloth or paper layers with thermoset resin are used to fabricate an uniform, integrated, and final piece. The size can vary up to 4 by 8 feet (1.2 by 2.4 m) in breadth and length. Various cloth thickness, weaves (threads per inch or cm), and resin percentage are used to accomplish the desired dielectric features and final thickness.
- **Substrate Parameters:** The composites contain a matrix (usually an epoxy resin) and a reinforcement (usually a woven, sometimes nonwoven, glass fibres, sometimes even paper), and in some cases a filler is added to the resin (e.g. ceramics; titan ate ceramics can be used to increase the dielectric constant).

Assembling Process:

Modern PCBs are designed with dedicated layout software, generally in the following steps:

- An electronic design automation (EDA) tool is used for schematic capture.
- Card template and dimensions are decided based on the essential circuitry and PCB case.
- The heat sink and component positions are determined.
- PCB layer stacks are determined, with one to several layers depending on the complexity. The power and ground planes are decided. A power plane is equivalent to a ground plane and behaves like an AC signal ground while supplying DC power to the PCB circuits. Signal interconnections are drawn on signal planes. Signal planes can be on the inner as well as outer layers. High frequency signals are transmitted to internal layers between ground or power planes for ensuring optimal EMI (Electromagnetic Interference) performance.

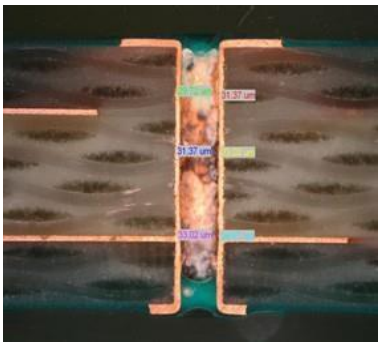
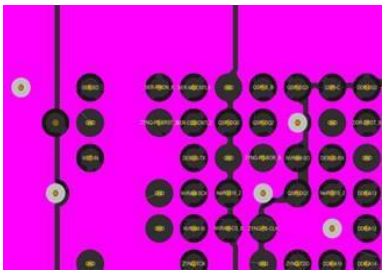
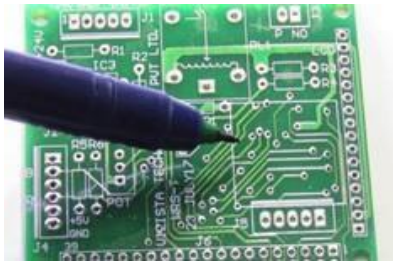
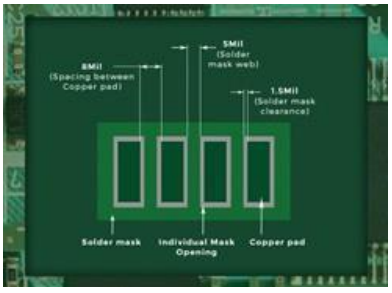
Fig 1.5.2: Layer stack on a PCB

- Line impedance is calculated with the help of dielectric layer thickness, trace width, and routing copper thickness. Trace separation is considered in case of differential signals. Micro-strip, strapline or dual strapline are used for routing signals.
- Components are placed and factors like geometry and thermal considerations are considered. Lands and vias are marked.
- Signal traces are routed while electronic design automation tools help in creating clearances and connecting power and ground planes automatically.
- Gerber files are generated for manufacturing.

Recording faults and passing the the faulty boards to the PCB assembly team

- The complications involved in the PCB manufacturing and designing processes lead to innumerable opportunities for PCB failure issues. A few failures are results of design oversights like inadequate clearances or inaccurate measurements. The other issues may result from problems in the manufacturing process like drilling errors, which can be equally dangerous

Some common faults are:

	**Plating Voids:** • These holes permit electricity to be carried from one side of the circuit board to the other. • A copper layer is added to the surface material and along the walls of these holes via an electroplating process. • While effective, the deposition process is imperfect, and can result in plating voids under certain circumstances. • Plating voids are holes or gaps in the circuit board plating, and are usually the result of problems during the deposition process.
	**Insufficient Copper-to-Edge Clearance:** • The copper is covered with other materials for preventing corrosion and protecting the copper from interacting with its environment. • While trimming a PCB, if the copper is very close to the edge, selected parts of this coating can be trimmed, thus exposing the copper layer underneath. • The exposed copper planes often make contact with each other by simultaneously touching a conductive material, thus causing a short.
	**Slivers:** • Slivers are narrow copper wedges or solder masks fabricated during PCB manufacturing, and can lead to serious problems during circuit board fabrication. • Slivers may float around in the chemical bath, and may land on another board, thus adding an undesired connection.
	**Missing Solder Mask Between Pads:** • This solder mask is placed on the top of the copper layer for insulating the traces of copper from accidental contact with solder, other metal, or conductive bits. • In a few circuit boards, the solder mask can be wholly or partially absent between pads. This exposes more copper than required, and often result in accidental solder bridges between pins. • This can lead to a short, as well as decreased corrosion protection, both of which can adversely affect the functionality and longevity of the circuit board.

	**Acid Traps:** • These are acute angles that trap acid during the PCB etching process. • Consequently, the acid can compromise a connection, making the circuit defective and causing more serious problems later on.

DFM means "Design for Manufacturability." In a nutshell, DFM checking is the process of inspecting a circuit board layout to reduce fabrication-related and assembly-related problems. There are several key factors in DFM, which ensure a consistent and correctly performing product. Unlike other standards that only consider how the circuit board will work, DFM focuses on how the circuit board may break.

DFM issues are topology-related problems of the circuit board. These may result in problems during the manufacturing process. A few of these problems include the ones discussed previously, like missing solder masks and slivers. Often, a majority of circuit boards manufactured with these design issues work normally, with only a small percentage reflecting defects. However, in the PCB industry, every scrapped board adds to the cost of production.

PCB Troubleshooting during assembling:

- Basic PCB troubleshooting can be done with just a few tools. The most versatile tool is a multimeter, but depending on the complexity of the PCBs and the problem, an LCR (Inductance Capacitance and Resistance circuit) meter, oscilloscope, power supply and logic analyzer may also be needed.

Fig 1.5.3: PCB sample

- Visual inspection of PCBs can find several potential issues. Overlapped traces, burnt out components, signs of overheating, and missing components can be found easily through a thorough visual inspection. Bulging components indicate problems, especially for electrolytic capacitors.

Fig 1.5.4: Multi-meter

1. Hot spots can be identified, without the involvement of expensive equipment, by touching the PCB surface and the on-board components.
2. The most apt techniques for PCB troubleshooting is to inspect each individual component. Testing each active component can be done with a multimeter or LCR meter.

Fig 1.5.5: LCR meter

3. ICs are the most challenging components to inspect. Most ICs can be detected with the help of their markings and many can be operationally tested using logic analysers and oscilloscopes.

How to troubleshoot?

It is the process of analyzing the behaviour or operation of a faulty circuit to determine what is wrong. It involves detecting the defective component(s) and repairing the circuit. Depending on the type of equipment, troubleshooting can be a very challenging task. In order to perform and record troubleshooting, an electrical technician needs to understand the key elements to be looked into.

Different modes of faults or failures during assembling:

1. Packaging failure
2. PCB failure
3. Relay failure
4. Semi-conductor failure
5. Passive element failure
6. MEMS (Micro-electromechanical systems) failure

- Thermal expansion produces electrical stress that causes material fatigue. Humidity and corrosive or reactive chemicals can lead to the corrosion of the packaging materials and leads, potentially breaking them and damaging the inside parts, leading to electrical failure.
- PCBs are vulnerable to environmental influences; for example, the traces are corrosion-prone and may be improperly etched leaving partial shorts, while the vias may be insufficiently plated through or filled with solder. Residues of solder flux may facilitate corrosion; those of other materials on PCBs can cause electrical leaks. CAFs (Conductive Anodic Filaments) or metallic filaments may grow within the boards along the fibres of the composite material, which can damage the affectivity of the PCB, as shown in the diagram below.

Fig 1.5.6: Metallic filaments on a PCB

- An electric arc appears between the contact points (electrodes) both during the transition from open to closed (make) or from closed to open (break). Apart from the physical contact damage, there appears a coating of carbon and other matters as well.
- Corrosion is a source of delayed failures for semiconductors and metallic interconnects. The surface of semiconductors is subjected to moisture as they have an oxide layer, as shown below.

Fig 1.5.7: Moisture coating on a PCB

- Electrostatic discharge (ESD) is an element of electrical overstress and may lead to immediate device failure, permanent parameter shifts and latent damage leading to increased degradation rate. ESD in real circuits results in an inhibited wave with rapidly alternating polarity, thus affecting performance.
- Resistors can turn open or short, along with their value changing under environmental conditions. Manufacturing defects causing recurrent problems. For example, improperly crimped caps on metal resistors can loosen and lose contact.

Fig 1.5.8: ESD discharge on a resistor

- Micro electro-mechanical systems suffer from various types of failures:
  - Particles travelling in the system and hindering their movements
  - Fractures causing loss of electrical parts.
  - Dielectric charging leading to change of functionality.

Notes

UNIT 1.6: Fundamentals of Copper–Clad Laminates (CCL)

Unit Objectives

By the end of this unit, the participants will be able to:

1. Identify the properties, layout designs and planning of CCL (Copper-Clad Laminates)

1.6.1 Understanding of Copper-Clad Laminates (CCL)

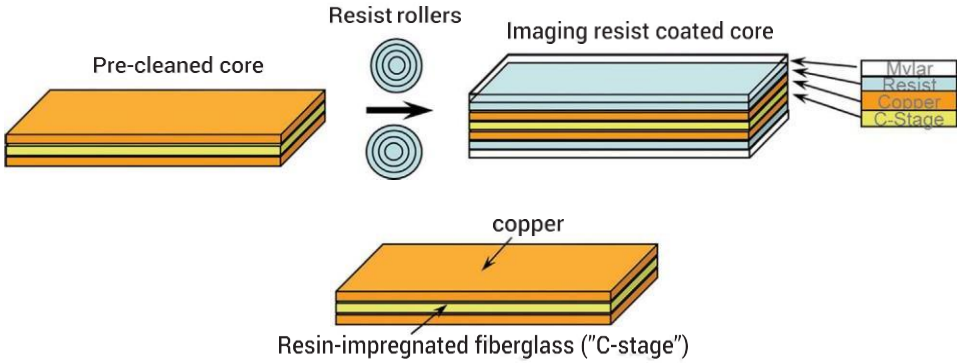
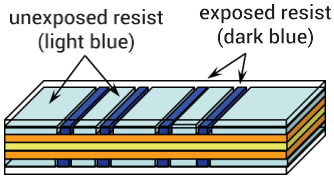
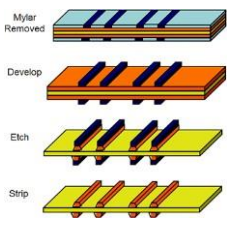
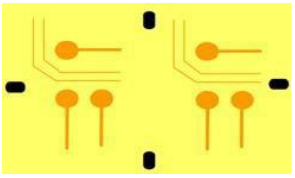
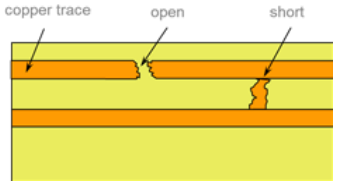
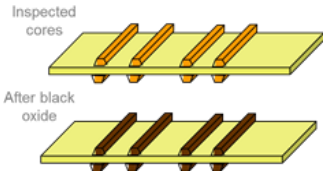
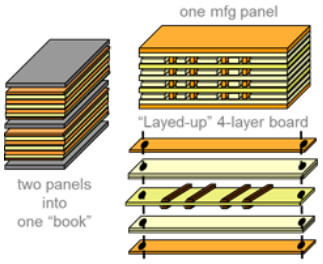
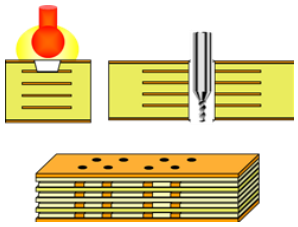
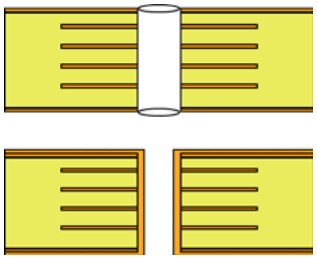


Fig 1.6.1: Copper Clad Laminates – pre-cleaning process

Name of the CCL component	Image	Description
Inner Layer Image Print of the CCL		• Negative polarity artwork film is laid on the resist-coated cores • The cores are exposed, on both sides, to UV light • The resist in the exposed areas is polymerised • The latest Laser Direct Imaging (LDI) technology utilises CAM (Computer Aided Manufacturing) files projected on the panel with the help of UV (Ultra Violet) light to do away with artwork film
Develop Etch Strip (DES)		• The protecting mylar sheet is removed • Boards are processed via a three-part conveyorised chemical line • The unexposed resist is removed, thus exposing bare copper • The unwanted copper is etched away via the subtractive process • The exposed protective resist is stripped away from the copper image

Post Etch Punch (PEP)		• This is a vital manufacturing step to drill registration in the inner layer • The etched targets in the border files are arranged linearly in an optical machine • The machine finds the best-fit target value • The punched holes or slots are used for aligning layers with the help of hard tooling pins for future steps
Automated Optical Inspection (AOI)		• AOI is the inspection process of the inner layer • Boards are examined by means of an optical machine against the known CAM files and discrepancies are reported • Defects and rework are validated by technicians, if needed • Non-conforming cores are scrapped and restarted with minimally added build cost
Oxide		• The copper surfaces are micro-roughened during the preparation of multilayer lamination • Copper roughening is done to improve the bond between the prepreg (B stage) layers and the oxidised copper • Most of the PCB manufacturing units use black oxide but a few other formulations are used as well
Lamination (Press)		• Foil, prepregs (B-stage), and etched cores are layered on pins via the PEP slots as per the stackup to create one manufacturing panel • Multiple panels are stacked together (separated by aluminium release sheets) in the form of a "book" • Several books are heated above the Tg of the material under pressure and vacuum • When the prepreg above the Tg is heated, it forms a gel, flows, and fills in between the Cu features, then pastes the layers together on cooling • Books are disintegrated into mfg panels and excess prepreg squeeze-out is cleaned up from around the panel edges

Drilling		• After lamination, holes are drilled or layered in the panel • The pads, which are already formed during the inner layer etching process, must be aligned to the drill • Smart drill machines conduct a registration pre-check to align the drill • The average no. of drills is about 25,000 per mfg panel • The boards are passed via an air knife deburr process for clearing most of the residual drill debris
Electroless Copper		• All holes and surfaces are first chemically cleaned to ensure the layer interconnects are free of any residual drill debris • The holes are also chemically conditioned for enabling activation of the resin and exposed glass • The board surface and hole walls are deposited with a thin palladium layer followed by approximately .07 mil (.00007") layer of electroless Cu • The standard processing techniques create negative etchback at the interconnect post • A specialised glass-etching processing is required for creating positive etchback

Cleaning of boards before pattern transfer

Printed circuit boards, specifically those used in Personal Digital Assistants or PDAs such as cell phones, are subjected to over-utilization. In addition to the collection of dirt and dust that penetrate the cases of mobile phones; PCBs suffer from liquid spillage or splashing from liquids in day to day use.

Different Types of Contaminants

There are numerous contaminants that can accumulate on a PCB.

- **Dry Contaminants (Dust, Dirt, etc.):** One of the most common yet annoying occurrences is the accumulation of dust or dirt in the PCB. Using a small, delicate brush like a horsehair paint brush, dirt and dust can be removed without affecting the components. There are restrictions on where even the smallest brush can reach, say below a component.

  Compressed air can reach many areas but may damage vital connections, so it should be used with extreme care.

  Specially designed vacuum cleaner for electronic components is also an option but cannot reach everywhere.

Summary

- In the modern world, electricity is essential for the functioning of computers, cell phones, lights, air conditioners, soldering irons, etc.
- The resemblance of a phototransistor is quite similar to that of a transistor with a small exception. The base terminal is present in transistor but absent in phototransistor.
- A PCB provides a mechanical support and connects electrically electronic components
- Line assemblers must be able to identify the properties, layout designs and planning of CCL (Copper-Clad Laminates)

Activity

1. Prepare a scrap-book by dividing a page into two columns, named “active components” and “passive components”, respectively. Collect pictures of the following components:
   - Resistor
   - Capacitor
   - Potentiometer
   - Inductor
   - Connector
   - Switch
   - Diode
   - Transistor
   - Integrated Circuit
   - Valve

   Now, classify the components as active or passive and list them under the respective heads.

2. Draw a diagram of an electrical circuit with the following labelled components:
   - Copper wire
   - Battery
   - Capacitor
   - Resistor
   - LED bulb

Exercise

Choose the correct option from the list of responses to answer the following questions:

1. Diode is a –
   a) Conductor b) Semi-conductor c) Hand tool

2. PCB stands for –
   a) Pakistan Cricket Board b) Printed Cable Board c) Printed Circuit Board

3. Electronic components can be categorized in –
   a) 3 classes b) 4 classes c) 2 classes

4. Passive components can –
   a) Never introduce energy to the circuit b) Amplify energy to the circuit
   c) Introduce energy to the circuit

5. Which of the followings is not an essential component of an electronic circuit?
   a) Voltage b) Capacitance c) Resistance

6. What is the unit of potential difference?
   a) Ampere b) Volts c) Ohm

7. AC Current stands for –
   a) Alternative current b) Alternating current c) Altering current

8. In a bridge rectifier, _____is not required.
   a) Power source b) Center tap c) Resistance

9. Which of the followings is not a semi-conductor?
   a) Silicon b) Lead c) Germanium

10. Multimeter measures –
    a) Potential difference b) Resistance c) Can measure both of the above

Notes

2. Preparing Workspace for Assembly Operations

Unit 2.1 - Component Handling and Verification
Unit 2.2 - Assembly Tools and Procedures
Unit 2.3 - Advanced Assembly Technologies and Safety

TEL/N2506

Key Learning Outcomes

By the end of this module, the participants will be able to:

1. Explain the types and specifications of electronic components used in assembly operations.
2. Describe the safe handling procedures for electronic components to prevent damage or defects.
3. Demonstrate how to retrieve assembled electronic PCB boards, enclosures, accessories, and hardware components from stores and verify them against inventory records.
4. Show how to check all assembly parts, including electronic PCB boards, metal enclosures, and hardware items, for defects, mismatches, or non-conformance, and report identified issues.
5. Elucidate the types of mechanical fasteners and their applications in assembly.
6. Discuss the use and maintenance of assembly tools and semi-automatic tools.
7. Demonstrate how to collect, check calibration, and test tools and equipment for functionality, compliance, and report malfunctions.
8. Determine the appropriate selection and handling of soldering consumables for different assembly tasks.
9. Elucidate the handling and assembly procedures for 5G-specific hardware components.
10. Demonstrate how to identify and segregate 5G-specific hardware for assembly tasks.
11. Describe the use of ERP systems for inventory and production tracking in an assembly setup.
12. Show how to update inventory records using the ERP system to ensure material availability.
13. Show how to interpret and confirm understanding of work and assembly instructions.
14. Demonstrate how to arrange the required assembly parts ergonomically for smooth assembly.
15. Discuss the role of IoT-enabled tools in compliance monitoring during assembly processes.
16. Show how to use IoT-enabled tools to monitor tool compliance and performance.
17. Explain the applications of 3D printing in assembly and prototyping.
18. Demonstrate how to set up and calibrate 3D printing workstations for prototyping, small-batch production, and ensure printed parts meet specifications.
19. Explain the safety and environmental standards that must be followed in assembly operations.

UNIT 2.1: Component Handling and Verification

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the types and specifications of electronic components used in assembly operations.
2. Describe the safe handling procedures for electronic components to prevent damage or defects.
3. Demonstrate how to retrieve assembled electronic PCB boards, enclosures, accessories, and hardware components from stores and verify them against inventory records.
4. Show how to check all assembly parts, including electronic PCB boards, metal enclosures, and hardware items, for defects, mismatches, or non-conformance, and report identified issues.
5. Elucidate the types of mechanical fasteners and their applications in assembly.

2.1.1 Drawing the Correct Components

Draw Correct Components from Stores as Per the Work Instructions

Assembly drawing may include the following additional information, located either in the drawing sheet or in the title block:

- Job order number
- Surface treatment, roughness, etc.
- Key to machining and other symbols
- A general note on tolerance on dimensions, not individually tolerance
- Reference to tools, gauges, jigs and fixtures
- List of the component parts
- Alternations and revisions.

Fig 2.1.1: Specimen of a block to practise component drawing

2.1.2 Understanding of Work Instructions

Work instructions are prepared clearly and concisely for the colleagues to ensure that they are well aware of the standards that need to be complied with while performing various tasks. It decreases risk because the chance of things going wrong is reduced. It also improves efficiency; work instructions ensure the very best way of doing a job is clear and known to the people doing it. This comprehensive guide will show how to write work instructions that employees can understand and benefit from. Work instructions have to be very detailed on how to achieve a particular job, assignment or task.

For example, a work process could be developed to assemble the final product with step-by-step instructions including details as the required torque of the fastening screws. Individual work instruction is specific to a company or industry. Supplemental documentations may be used to create detailed work instructions such as:

- User Manuals
- Engineering or Technical Manuals
- Technical Support notes
- Manufacturing Notes

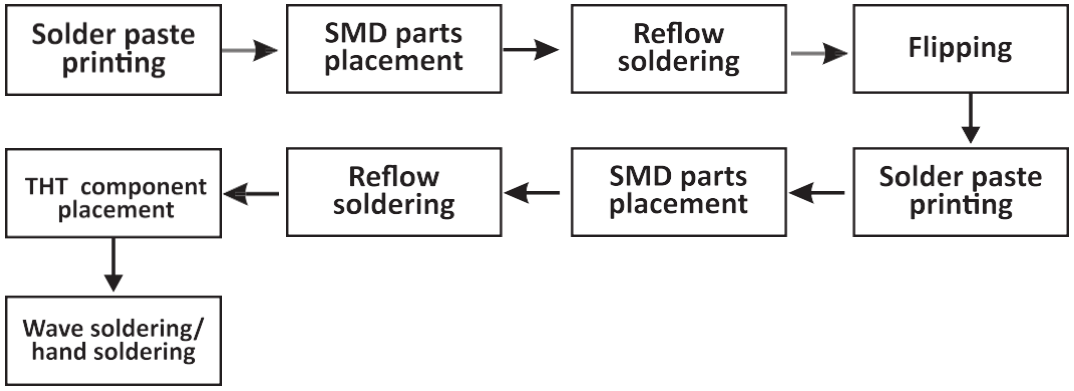


Fig 2.1.2: Double side mixed assembly workflow

Forms are used to create:

- Records
- Checklists
- Surveys

Records are a vital output of any process or work instruction. They form the base of the process communications, process improvement initiatives, and audit material.

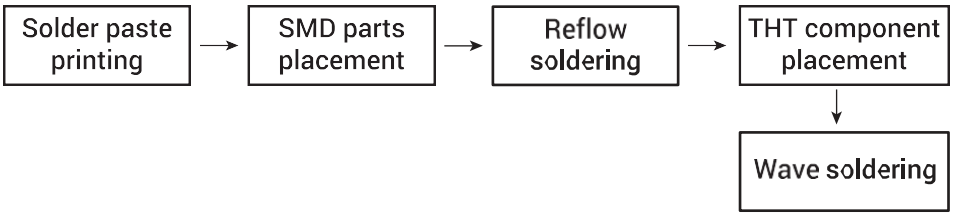


Fig 2.1.3: Single side mixed assembly workflow

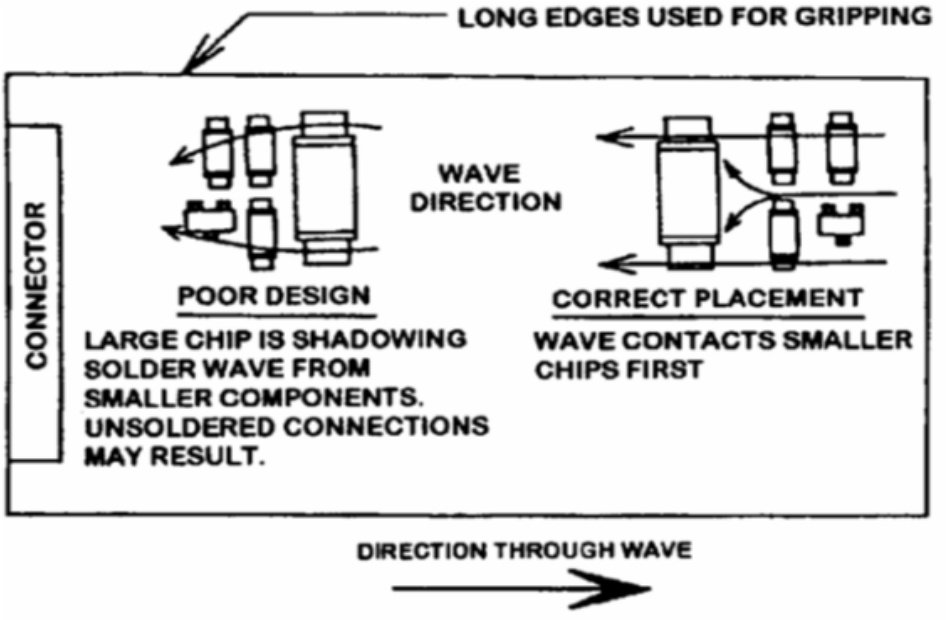


Fig 2.1.4 Bottome side wave flow

2.1.3 Arranging Components as per Assembly Instructions

Arrangement of components plays a major role in the work ethics of a line assembler. The components are assembled in a certain manner based on the usage, frequency of use and relationship between the components. For example, we keep the utensils which are used on a regular basis at a place easy to reach. However, the utensils, which are used occasionally, are kept at the back. Similarly, the components, which are used frequently, should be kept in the front.

- Methodologies for Arranging Components
- Two broad classes of task-related information
- Information on the use of components individually
- Information on the relationships between components as they are used

The components are arranged in such a way that:

- It is easy to find and place again after the completion of the work
- If the component is used frequently, it should be kept in the front
- The components might react with the other components in certain cases. Hence, the relationship between the components must be considered and the inter-reactive components must not be kept at vicinity

2.1.4 Verifying Specifications of All Components

It sometimes refers to the verification of specifications of components as per Drawing.

Systematic planning of all tests or calculations is mandatory to check whether the product or design is suitable for the application. The appropriateness of the product must be proven with the help of calculations or planned tests. Technical tests, on bulk products, must be conducted on defined characteristics related to texture, appearance, handling ability and acoustics.

Problems associated with product layouts are promptly resolved so that all sampling and mass production dates may be observed.

Avoid misunderstandings by using clear specifications.

Here are some vital points that should be considered at the time of verification of the components:

- Design Verification Plan (DVP)
- Refer Product Data Sheet (PDS)
- Test reports, layout calculations and tolerance studies
- Technical and project-related data
- Follow inspection methods that have been coordinated with carefully chosen inspection equipment and customer requirements
- Provide, on schedule (Design Freeze), all drawings and specifications that are needed to observe the initial volume production sample date/start of production (SOP)

SAFE WORK INSTRUCTION TEMPLATE

TITLE /DESCRIPTION OF ACTIVITY:					
Faculty/Division			**School/Unit**		
Created By		**Document No.**		**Risk Number**	
Initial Issue Date		Current Version		Next Review Date	
SCOPE:	*(List whom this procedure applies to and the specific location this work can be conducted in)*				
AUTHORISATIONS:	*(List specific operator competency requirements, e.g. area induction, qualifications, certificates, OHS training, supervision. List who can approve that competency has been achieved)*				
HAZARDS:	*(List all the potential hazards and associated consequence, e.g. chemical exposure – inhalation or skin absorption, leading to irritation, burns, acute or chronic injury)*				
SAFETY CONTROLS:	*(List the safety controls that are required to be in place, e.g. fume-hoods, biosafety cabinets, emergency equipment, machine guarding, spill kits, personal protective equipment, first aid response, any after-hours work restrictions or rules)*				
PRESTART REQUIREMENTS:	*(List tasks to be completed before commencement of work, e.g. conduct a prestart safety check of equipment; review chemical MSDS, risk assessment or lab rules; prepare work area, equipment and/or operator)*				
INSTRUCTIONS:	*(List step by step procedures for the task. You can use photos, flow charts, diagrams etc.)*				
CLEAN UP/ SHUT DOWN PROCEDURES:	*(List procedures for disposal of waste, decontamination, storage, shut down of equipment)*				
EMERGENCY PROCEDURES:	*(Provide the emergency response procedures e.g. power isolation procedures, spill containment procedures, first aid response)*				
FURTHER INFORMATION:	*(List any relevant procedures e.g. Monash procedures, relevant legislation, definitions, reference to other safety information)*				

APPROVALS			
Title	**Name**	**Signature**	**Date**
Supervisor			
Safety Officer			

Fig 2.1.6: A Sample work instruction copy, used widely in the telecom industry

2.1.5 Compliant and Correct Calibration

Calibration is the comparison of Instruments, Measuring and Testing Equipment (M&TE), Unit under Calibration (UUC), Unit under Test (UUT), a Device under Test (DUT) or a Test Instrument (TI) of unverified accuracy to an instrument with known (higher) accuracy to detect and eliminate unwanted variations.

Fig 2.1.7: Sample of calibration test

Importance of Calibration:

- All measuring, inspecting, and testing equipment that can impact or determine product quality. Equipment which would produce unsafe products
- Measuring devices
- Equipment which needs to be calibrated because of an agreement. For example, a customer before progressing to signing contract may need to get the equipment validated by calibration.

Notes

UNIT 2.2: Consumables for Soldering

Unit Objectives

By the end of this unit, the participants will be able to:

1. Discuss the use and maintenance of assembly tools and semi-automatic tools.
2. Demonstrate how to collect, check calibration, and test tools and equipment for functionality, compliance, and report malfunctions.
3. Determine the appropriate selection and handling of soldering consumables for different assembly tasks.
4. Show how to interpret and confirm understanding of work and assembly instructions.
5. Demonstrate how to arrange the required assembly parts ergonomically for smooth assembly.

2.2.1 Common Tools and Equipment

1. Screw

A screw is a cylindrical rod carved with one or more helical or advancing spiral threads, as a lead screw or worm screw. It has a head and a point. Common types of screws include:

Flat Head Screw

Round Head Screw

Raised Head Screw

Cross Head Screw

- Flat head screw
- Round head screw
- Raised head screw
- Square head screw
- Phillips or cross head screw

2. Precision Screw Driver Set

Set of Screwdrivers

Different Types of Screwdriver Tips

- Used to tighten and loosen screws
- Some common screwdrivers include:
  - Flat Head Screwdriver
  - Phillips Screwdriver
  - Offset Screwdriver

3. Nuts

Nuts and Bolts

Fixing Nut

Nut is a fastening tool. It has coils around its body, giving it a shape of threaded pattern. The threaded pattern helps to join the two parts of metal or wooden components. The common types of nails are:

- Hexagonal Nut
- Square Nut
- Flanged Nut
- Cap Nut

4. Bolts

Bolts

Bolt looks similar to the head of a nut. Bolts are usually attached to the nuts as a joinery substance. The common types of bolts are:

- Hexagonal Headed Bolt
- Square Headed Bolt
- Round Headed Bolt
- Cylindrical Headed Bolt

Securing Clip

Secure clips, also called R-clips are widely used to secure the ends of round shafts such as clevis pins and axles.

5. Spanner

A spanner is an instrument used to provide mechanical advantage and grip in applying torque to turn objects such as rotary fasteners, nuts and bolts.

6. Forceps

These are used when the fingers are too large to grasp tiny items or when several items need to be held simultaneously while the hands are used to perform a task.

7. Forming Plier

Forming pliers are large-jawed pliers for forming sheet metal and wire into a variety of shapes.

2.2.2 Basic Assembly and Hand Tools

Ascertain Availability of All Parts/Components, Tools and Equipment to Carry Out Work

Work equipment may be defined as the machinery, appliance, tool or installation for use at work.

Make sure the availability of all tools and equipment to carry out work:

Equipment used at work includes the following:

- **Hand tools -** drills, hammers, handsaws, knives, sharpening tools, riveters etc.

Hammer: A good quality Steel hammer is used to drive nails in the components.

Measuring Tape: Measuring tapes are used b to measure the area and extent of cutting an object.

Clamps: Clamps are used to hold the work-piece tightly to work on it. For example, if screw needs to be driven in to a delicate part of the sub-assembly, G-clamp is used to hold it in the desired angle.

Marking Tools: marking tools like pencil is used to sketch cutting lines on the object.

Screwdriver: Screwdrivers are used to tighten and loosen screws.

Plier: Pliers are mainly used to grip and twist objects like pipe or wire. The long frontal part of the plier helps to grip or squeeze the object easily, which are difficult to do manually.

Providing and using work equipment safely:

Providing a manual or a booklet is a recommended practice. It will be beneficial for employees. There may be specific requirements related to the equipment that an organisation uses at work. In this case, the booklets will point towards further information one may require.

Equipment used by employees are covered. For example, power presses, ladders, hammers, knives, drilling machines, circular saws, lifting equipment (including lifts), motor vehicles, dumper trucks, photocopiers, etc.

Dos and don'ts of machinery

As the duty holder every organization should ensure that all employees likely to use machinery understand and follow these dos and don'ts:

Do…

- Examine if the machine is well maintained and fit to be used, i.e. in proper conditions for the job and all the safety measures are in place
- Use the machine and its parts properly in accordance with the manufacturer's recommendations
- Ensure employees are using the Personal Protective Equipment (PPE), required for particular machine or process
- Ensure that workers who use machinery are competent enough to use it safely. Provide training whenever necessary

Don't…

- Use a machine that has a danger sign tagged to it. The sign should only be removed by an authorised person who can affirm that the machine is safe to use
- Remove any safeguard, even if their presence makes the job complex
- Wear loose clothing, dangling chains, rings or have loose long hair prone to get caught up in moving particles
- Distract people at work

2.2.3 Assembly Line and Equipment Maintenance

Why is maintenance of assembly line and equipment important?

Additional hazards can take place when equipment and plant becomes unreliable and develops faults. Maintenance enables these faults to get diagnosed at an early phase to manage further risks. However, proper planning and correct execution is required to carry out maintenance. Unsafe maintenance can cause fatalities and severe injuries either during the maintenance or during operating badly maintained equipment.

Effective maintenance programmes make equipment and plant more reliable. Fewer breakdowns imply to less dangerous contact with machinery is required, as well as having the cost benefits of better productivity and efficiency.

The Provision and Use of Work Equipment Regulations (1998) state equipment and plant to be maintained properly so that it remains safe and hazard-free.

Safe working areas:

One must arrange for safe and secure place of work:

- Don't focus only on the safety of maintenance workers – take the needful precautions to make sure that the safety of others who may get impacted by their work
- Set up barriers, position and signs and personnel at key points to keep others out
- Equipment and plant must be made secure before maintenance commences
- Ensure to stop moving plant and isolate them from electrical supplies. Ideally, maintenance should be done with the power off
- Lock the machines off if there is a possibility of the power to get back (even if accidentally)
- Isolate electrical lines, plant and valves which contain gas, steam, pressured fluid or hazardous material. Lock off the isolating valves as a safety precaution

2.2.4 Safe Handling Practices

- Before allowing an employee to use a machine, chalk out the risks involved and how the risks can be managed.
- Inspect if all safeguards attached are free from defects.
    - The term 'safeguard' includes:
    - Personal Gears
    - Interlocks
    - Two-Hand Controls
    - Hand Guards
    - ESD (Electrostatic Discharge) strips / mats
- By regulation, the suppliers must provide proper safeguards and inform buyers of further risks that users need to know and manage
- Produce a secure system of work by maintaining the machines properly
- Maintenance may call for regular inspections of critical features where disintegration would amount to a risk
- Ensure every proper installation of the static machines and their stability. Don't install them at a location where others are exposed to risk

Preventing access to dangerous parts:

Make use of the best material for the guards. For example, plastic is easy to see through as it is transparent but may be damaged easily. For cases where wire mesh or similar materials are used, ensure that the holes are not big enough to let the moving particles in.

If the scope of using fixed guards is faint, apply other methods. The guard must be interlocked so that the machine cannot start before the guard is closed and vice versa. In a few cases, trip systems like pressure-sensitive mats, automatic guards or photoelectric devices may be exploited if other guards are not applicable.

Where guards cannot offer full protection, jigs, holders, push sticks, etc. must be used. Remaining risks, if any, must be controlled by providing the operator with the essential information, training, instruction, supervision and proper safety equipment. Proper training should ensure that those who use the machine are capable enough to use it safely.

Untrained, unauthorised or unqualified people should not use machinery.

Fig 2.2.1: Keep the workspace tidy and clean

Sequence the Parts and Subassemblies in Correct Order: A subassembly is a part of the Bill of Material or BOM that is exploited as a component. Subassemblies are generally used as components in several BOMs, i.e. they are parts of multiple product structures. Store control depends on the time-phased nature of the master schedule. Jobs are propagated to production in the appropriate sequence of multi-level assembly.

Creating Subassembly BOMs: If one has to define subassembly specifications within other Bill of Materials and require giving them their own BOMs to align to the above guidelines, take the steps furnished below:

- Create a parent BOM item to fabricate the subassembly
- Create a specific header for the parent item of the subassembly by assigning it a particular type of BOM
- In the newly created BOM, enter the subassembly components and routing sequences
- Delete the components and routing sequences associated with the previous BOM
- In BOMs where the subassembly was defined earlier, add the parent item of the subassembly as a component

When does the quantity of the sub-assemblies differ from the parent quantity?

Whenever a subassembly has a variant magnitude of quantity than the same of the parent item, it must be well defined with its own BOM. The reason behind it is that the BOM routing is dependent on the parent quantity for costing calculations and scheduling. If one mixes subassembly sequences with parent item sequences, there is high chances of using wrong quantity, which makes costing calculations and scheduling insignificant.

Subassembly BOM – a necessity with store and MRP control:

Using subassembly BOMs is essential for store and MRP (Maximum Retail Price) control. Subassembly BOMs enable MRP to fabricate subassembly jobs as per interdependent demand. They help jobs get released in the appropriate order of multi-level assembly as subassembly jobs are completed. They enable each subassembly to get its own traveller and to have its routing sequences scheduled in sequential order within work centres.

Fitting Sub-Assemblies and Components:

- Work safely at all times by following health and safety norms and guidelines
- Plan the fitting and assembly activities before you start them
- Obtain and prepare the appropriate components, tools and equipment
- Use suitable methods of assembling and fitting the components in correct positions
- Fasten the components with the help of specified securing devices, fasteners, and connectors
- Examine the completed assembly to make sure that all operations have been finished and the finished assembly meets the desired specification
- Deal effectively with problems within your span of control and seek guidance from appropriate people, if you have come across problems that cannot be resolved
- Leave the work area in a safe and tidy condition on completion of the assembly activities

2.2.5 Hand Tools Used in PCB Assembly Area

Name of the Tool	Description	Image
Diagonal Plier/ Wire Cutter	These are intended for cutting wire and are not used for grabbing or turning any item. The plane demarcated by the jaws' cutting edges intersects the joint rivet diagonally or at an angle.	
Nose Plier	These are both holding and cutting pliers used by jewellery designers, artisans, electricians, network engineers and other tradesmen to bend, re-position and snip wire.	
Wire Stripper	This is a small-sized, hand-held device used for stripping the electrical insulation from electric wires.	
Tweezers	These are small-sized tools used to pick up objects too small to be handled by bare hands. They are derived from tongs, scissors, or pincers.	

Soldering Iron	This is a hand tool used in soldering, which supplies heat for melting solder so that it is able to flow into the joint between two jobs	
De-soldering Pump	De-soldering Pump is used to remove solder and components from a circuit board for troubleshooting, repair, replacement, and salvage	
De-soldering Wick or Braid	This is a fine mesh of flux-coated copper strands that absorb solder when heated. Easier and more effective than a solder-sucker, the braid can be used to remove solder that bridges surface mount.	
Soldering Paste	Solder paste is a material used in the manufacture of printed circuit boards to connect surface mount components to pads on the board. It is also possible to solder through hole pin in paste components by print solder paste in/over the holes.	
Soldering Lead	This is a fusible metal alloy used for creating a long-lasting bond between metal work-pieces. In electronics, it is typically a mix (63:37) of tin and lead.	
Soldering Flux	Soldering flux is a chemical flowing agent, cleaning agent, or purifying agent. These may have more than one function at a time. These are used in both metal joining and extractive metallurgy.	

Thermal Wire Stripper	Thermal wire strippers are ideal choices for stripping stranded and solid wires up to ½ inches. In addition to that, these tools are exploited to cut through the insulators which are otherwise difficult to penetrate.	
Adjustable Electronic Board Holders	As G-clamps or Bar Clamps help carpenters to attach the work piece tightly to a holder, the adjustable electronic board holders help line assemblers to attach PCBs. Thus, the tool is often referred to as Adjustable PCB Holder. The term adjustable is used because the tool permits workers to rotate the attached PCB 3600. Normally the device is made of non-conductive materials such as plastic.	
Lead Free Solder	Lead free solders are extremely effective in soldering and wetting through holes. It also allows workers to work on parts which consist of narrow pitch. It shows high insulation and anticorrosive properties even after soldering is finished.	

Summary

- Work instructions are prepared clearly and concisely for the colleagues to ensure that they are well aware of the standards that need to be complied with while performing various tasks.
- Work instructions have to be very detailed on how to achieve a particular job, assignment or task.
- Line assemblers must be able to identify and use various hand tools and equipment.

Activity

Identify the tools given below and write down their names in the blank provided below each diagram:

Exercise

Choose the correct option from the list of responses to answer the following questions:

1. _ are both cutting and holding pliers used by artisans.
   a) Wire strippers b) Nose pliers c) Diagonal pliers

2. Solder flux is a –
   a) Metal amalgamation b) Chemical agent used as purifier
   c) Soldering iron used as connectors

3. Which of the followings is not an example of passive component?
   a) Resistor b) Capacitor c) Transistor

4. Which of the followings is not an example of active component?
   a) Transistor b) Switch c) Diode

5. Which one of the following options should be considered while arranging for components?
   a) Size of the component b) Frequency of usage of the components
   c) Colour of the component

6. State TRUE or FALSE – "Screwdrivers are used to tighten and loosen screws".
   a) True b) False c) Partially true

7. DVP stands for –
   a) Device Verification Plan b) Design Validation Plan
   c) Design Verification Plan

8. In terms of looks, bolts are similar to that of –
   a) Nuts b) Screws c) Tweezers

9. Which of the followings is not a fastening tool?
   a) Nuts b) Screws c) Securing clips

10. Which of the followings will you use to separate components from the PCB board?
    a) De-soldering braid b) De-soldering pump c) Tweezers

Notes

UNIT 2.3: Advanced Assembly Technologies and Safety

Unit Objectives

By the end of this unit, the participants will be able to:

1. Elucidate the handling and assembly procedures for 5G-specific hardware components.
2. Demonstrate how to identify and segregate 5G-specific hardware for assembly tasks.
3. Describe the use of ERP systems for inventory and production tracking in an assembly setup.
4. Show how to update inventory records using the ERP system to ensure material availability.
5. Discuss the role of IoT-enabled tools in compliance monitoring during assembly processes.
6. Show how to use IoT-enabled tools to monitor tool compliance and performance.
7. Explain the applications of 3D printing in assembly and prototyping.
8. Demonstrate how to set up and calibrate 3D printing workstations for prototyping, small-batch production, and ensure printed parts meet specifications.
9. Explain the safety and environmental standards that must be followed in assembly operations.

2.3.1 Understanding 5G-specific Hardware Components

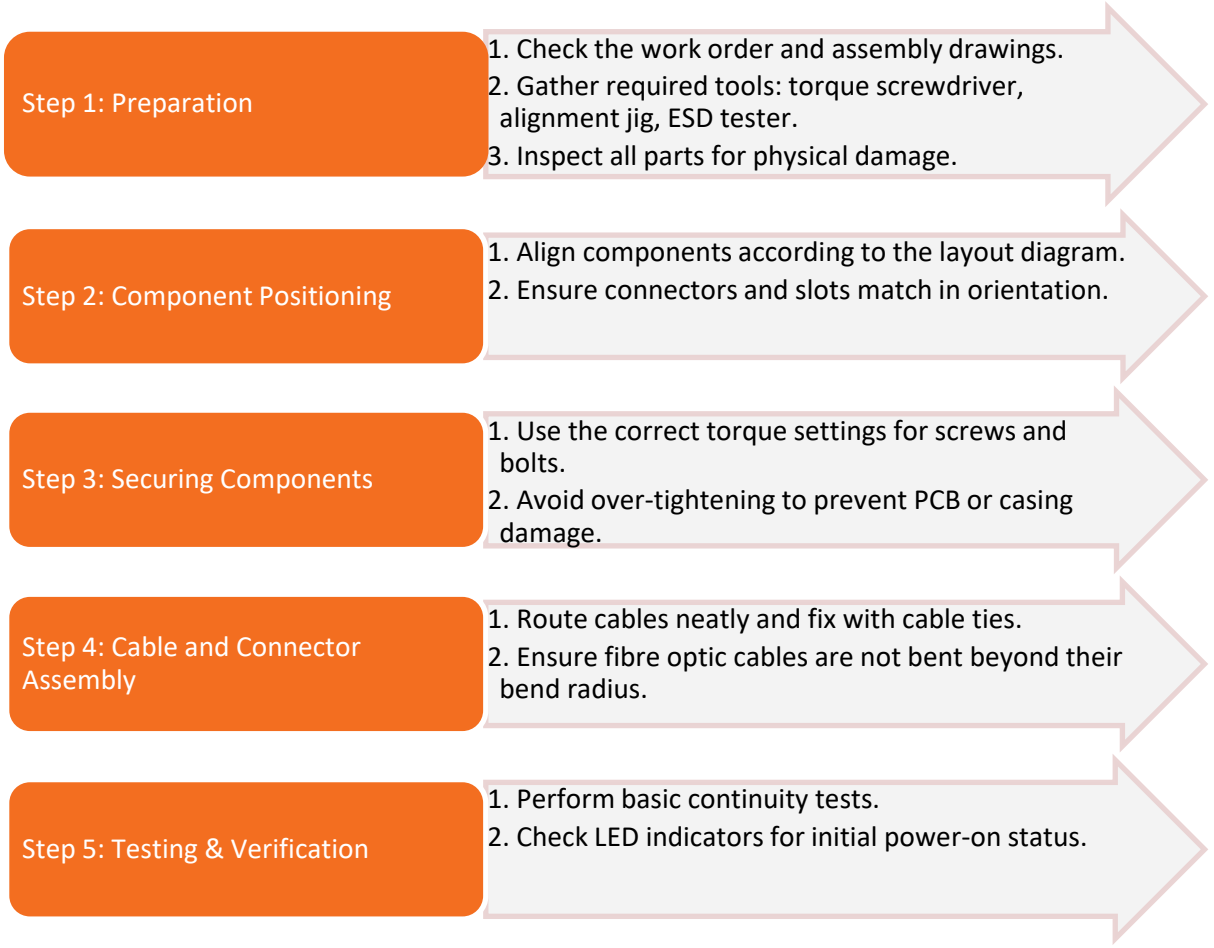
5G networks require advanced hardware for high-speed, low-latency communication. Common components include:

Component	Function	Example / Visual
5G Small Cells	Boosts network coverage and capacity	[Small Cell Icon]
Massive MIMO Antennas	Supports multiple simultaneous connections	[Antenna Icon]
mmWave Radio Units	Operates at high-frequency bands for ultra-fast speed	[Radio Unit Icon]
5G Baseband Units (BBU)	Processes digital signals for the network	[BBU Icon]
Optical Transceivers	Transmit and receive high-speed data over fibre	[Fibre Icon]

2.3.2 Assembly Procedures

Assembly procedures for 5G-specific hardware components.

Assembly of 5G hardware components involves preparing tools and checking parts, positioning modules and connectors as per layouts, securing components with correct torque, routing cables and fibre optics carefully, and finally performing basic tests and power-on checks to ensure proper functionality.



2.3.3 Identifying and Segregating 5G-Specific Hardware for Assembly

As a Line Assembler – Telecom Products, you must first be able to correctly identify and segregate 5G-specific hardware components before beginning any assembly work. This step ensures efficiency, prevents mix-ups, and maintains product quality.

1. **Identify 5G Hardware Components**
   - Look for key modules such as antenna arrays, RF units, power supply boards, small cells, PCB boards, optical transceivers, and connectors.
   - Check each part against the assembly drawing or bill of materials (BoM) provided with the work order.
   - Pay attention to labels, part numbers, barcodes, or QR codes to confirm the component type and model.

2. **Segregate Components by Category**
   - Place components in separate trays or bins based on their function: e.g., antennas, circuit boards, cables, screws, and connectors.
   - Ensure electrostatic-sensitive devices (like PCBs and chips) are kept in anti-static pouches or ESD-safe containers.
   - Heavy mechanical parts should be stored separately from delicate electronic components to avoid damage.

3. Check for Physical Condition

- Inspect each part for scratches, bent pins, cracks, or missing labels.
- Segregate any damaged or defective part and report it immediately for replacement.

4. Prepare for Assembly

- Arrange the verified and segregated components in the sequence they will be used during assembly.
- Keep them on an ESD-protected workstation for easy access and safe handling.

2.3.4 Use of ERP Systems for Inventory and Production Tracking in an Assembly Setup

In a modern telecom assembly setup, Enterprise Resource Planning (ERP) systems are widely used to manage and monitor both inventory and production activities. For a line assembler, understanding the basic role of ERP helps in working more efficiently and accurately.

1. Inventory Management

- ERP systems record the availability of components (such as PCBs, RF modules, antennas, and connectors) in real time.
- Assemblers can check whether the required parts are in stock, reserved, or need replenishment before starting the task.
- It reduces the chances of delays caused by missing or misplaced components.

2. Production Tracking

- Each assembly task is linked with a work order in the ERP system.
- Progress can be tracked at different stages, such as components issued, assembly started, assembly completed, and quality checked.
- This ensures transparency and allows supervisors to identify bottlenecks quickly.

3. Traceability and Quality Control

- ERP systems keep a record of batch numbers, serial numbers, and inspection reports, which helps in tracing issues if a defect is found later.
- This improves accountability and supports compliance with telecom quality standards.

4. Efficiency and Productivity

- By automating data entry and reporting, ERP reduces paperwork.
- It allows assemblers to focus on their core tasks while ensuring the right part is used at the right time in the right quantity.

For a line assembler, ERP is not about complex software usage, but about checking, updating, and following the system records to ensure smooth inventory flow and accurate production tracking.

2.3.5 Updating Inventory Records in ERP

To ensure smooth assembly work, you must keep the ERP system updated with material usage. This helps maintain correct stock levels and avoids delays due to shortages.

1. **Log In to ERP**
   - Use your login credentials provided by the supervisor.
2. **Check Material Availability**
   - Search for the required component (e.g., antenna, PCB, cable).
   - Confirm available stock before starting assembly.
3. **Issue Material for Assembly**
   - Select the work order and update the quantity of materials taken from inventory.
   - Example: If you take 10 antennas for assembly, update "10 issued" in the ERP system.
4. **Return or Report Balance**
   - If some materials are unused, mark them as "returned."
   - Report any damaged components immediately in the ERP.
5. **Verify Updated Records**
   - Check that the ERP now reflects the correct stock balance.
   - This ensures the next assembler will also have accurate information.
   - Discuss the role of IoT-enabled tools in compliance monitoring during assembly processes.

2.3.6 Role of IoT-Enabled Tools in Compliance Monitoring

In modern telecom assembly processes, IoT-enabled tools play a key role in ensuring compliance with quality and safety standards. These smart tools are connected to the network and automatically record data, which helps both assemblers and supervisors maintain accuracy.

1. **Real-Time Data Collection**
   - IoT tools like smart torque screwdrivers, ESD monitors, and temperature sensors capture data while you work.
   - Example: A smart screwdriver records the exact torque applied and sends it to the system.
2. **Error Prevention**
   - If a component is tightened incorrectly or a cable is connected wrongly, IoT tools can give instant alerts.
   - This prevents errors from becoming bigger issues later.
3. **Compliance with Standards**
   - Data captured is automatically stored in the system for audit and quality checks.
   - This helps prove that the assembly was done as per telecom and safety guidelines.
4. **Traceability**
   - Every action (e.g., tightening a screw, fitting a PCB, connecting a cable) is time-stamped and linked to the assembler.
   - This creates a clear record for future reference if any defect is reported.
5. **Improved Productivity**
   - IoT tools reduce manual record-keeping and give assemblers more time to focus on actual work.
   - Supervisors can monitor compliance remotely without interrupting the workflow.

2.3.7 Show how to use Iot-enabled Tools to Monitor Tool Compliance and Performance

IoT-enabled tools are regular assembly or testing tools fitted with sensors, microcontrollers, and connectivity features (like Wi-Fi, Bluetooth, or RFID).

- Smart screwdrivers – record torque levels and tightening sequence.
- IoT-enabled multimeters – measure and transmit electrical values directly to a system.
- Smart soldering stations – monitor temperature accuracy and safety.

Step 1: Connect the Tool

- Switch on the IoT-enabled tool.
- Ensure it is paired with the monitoring system (via Wi-Fi, Bluetooth, or LAN).
- Check indicator lights/display for successful connection.

Step 2: Verify Tool Compliance

- Open the monitoring application/dashboard on a PC or mobile.
- Check calibration status, usage history, and tool ID.
- Confirm that the tool meets compliance requirements before starting work.

Step 3: Monitor Performance During Work

- Start using the tool as per assembly instructions.
- Observe the live data feed on the screen (e.g., torque value, temperature, pressure).
- Ensure readings match the required standards.

Step 4: Take Action on Alerts

- If the system gives an alert (overheating, incorrect torque, excessive vibration), stop work immediately.
- Report to the supervisor/maintenance team.
- Replace or recalibrate the tool if needed.

Example: While assembling a telecom antenna unit, the assembler uses a smart screwdriver.

- The system displays the torque applied to each screw.
- If one screw is under-tightened, an alert pops up on the dashboard.
- The assembler corrects it immediately, ensuring the unit meets telecom quality standards.

2.3.8 Applications of 3D Printing in Assembly and Prototyping

What is 3D printing?

3D printing (additive manufacturing) makes real parts layer-by-layer from a digital file. It's useful on the shop floor because we can make custom tools and quick samples without expensive molds.

A. How it helps in Assembly

1. Jigs & Fixtures (Holders)

- Hold PCBs, connectors, or small housings steady while drilling, soldering, gluing, or testing.
- Improves accuracy, reduces rework, and keeps hands safe.
- Example: a 3D-printed clamp to hold a router casing during screw tightening.

2. Cable Guides & Clips

- Custom clips for neat cable routing inside telecom devices (ONTs, Wi-Fi routers, RF units).
- Color-coded clips help in standard work and faster inspections.

3. Assembly Aids

- Spacers, alignment pins, corner locators, torque-tool nose guides—printed to exact size for your model.
- Light weight = easier handling, less fatigue.

B. How it helps in Prototyping

1. Mock-ups (Fit & Feel)

- Print early versions of enclosures or brackets to check size, hole positions, and clearances before metal/plastic tooling.

2. Functional Try-outs

- chaTest door latches, snap-fits, hinge movement, and airflow openings.
- Quick nges: update CAD → reprint the improved part the same day.

3. Low-volume Parts

- Small batches of non-critical parts (covers, caps, labels, nests) can be printed on demand to keep the line moving.

C. Simple Workflow You'll Follow

- Get the file (STL from engineering).
- Slice & set basics (material = PLA/ABS, layer height, infill).
- Print safely (ventilation on, keep hands away from hot nozzle/bed).
- Post-process (remove supports, light filing/sanding).
- Fit check (does it align? do holes match? does the board sit flat?).
- Use on line (follow SOP for the jig/fixture; store it labeled).

D. Safety and Environmental Standards in Assembly Operations

- Electrical Safety: Ensure proper earthing of equipment and keep liquids away from machines.
- Thermal Safety: Handle heated nozzles/beds with protective gloves.
- ESD Protection: Use ESD wrist straps and mats when handling telecom PCBs.
- Personal Protective Equipment (PPE): Gloves, goggles, and antistatic shoes as per SOP.
- Ventilation: Operate 3D printers in well-ventilated areas to avoid inhaling fumes.
- Waste Management: Collect scrap plastic and support material separately for recycling or safe disposal.
- Environmental Compliance: Follow workplace rules for noise, dust, and energy efficiency.

Notes

3. Assembly Operations in Production Line

Unit 3.1 - Performing Assembly Operations in Telecom Production

Unit 3.2 - Managing Production and Post-Assembly Activities

TEL/N2507

Key Learning Outcomes

By the end of this module, the participants will be able to:

1. Explain the process of assembling telecom devices/products in a production line.
2. Discuss how automation and smart manufacturing methods improve efficiency in telecom device assembly.
3. Describe the use of digital tools for inventory and production management in telecom manufacturing.
4. Elucidate the key post-assembly activities required to ensure product quality and compliance.

UNIT 3.1: Performing Assembly Operations in Telecom Production

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the applicable quality standards, compliance requirements, and health and safety policies in telecom assembly operations.
2. Demonstrate the process of conducting pre-assembly safety compliance checks before starting operations.
3. Describe the roles, responsibilities, and reporting structures in the assembly line.
4. Discuss the handling and assembly of various electronic and mechanical parts in telecom devices.
5. Elucidate the different electronic components used in mobile phones and their functions.
6. Determine the importance of polarity in electronic components and its impact on device functionality, along with the mechanical items used in the assembly process.
7. Show how to handle components carefully and ensure proper fitment using appropriate tools.
8. Demonstrate the correct procedures and sequences for assembling components such as RFID tags, Wi-Fi, and Bluetooth modules.
9. Describe the safe and correct usage of assembly tools such as screwdrivers, pliers, and tweezers.
10. Explain the working principles and applications of semi-automatic and automated assembly tools.
11. Show how to ensure all required tools and equipment are operational and properly calibrated before assembly.
12. Discuss the proper handling and storage of PCBs, including baking and flux application.
13. Elucidate basic soldering techniques, defect identification, and rework procedures.
14. Demonstrate how to check the availability of all required parts, tools, and components as per assembly specifications.
15. Show how to arrange parts and sub-assemblies in the correct sequence for an efficient workflow.
16. Demonstrate how to interpret technical diagrams, specifications, and schematics accurately for assembly.
17. Show how to perform basic quality checks to verify correct assembly before moving to the next stage.
18. Demonstrate the use of IoT sensors to track assembly items and ensure placement accuracy and efficiency.
19. Show how to operate Robotic Process Automation (RPA) tools for automated pick-and-place assembly.
20. Demonstrate how to use machine vision systems for real-time quality inspection and defect detection.

3.1.1 Standards, Compliance Requirements, and Health and Safety Policies in Telecom Assembly Operations

Category	Key Points	For Learners (What You Should Do)
Quality Standards	• ISO 9001: Quality process & documentation • ISO/IEC 27001: Data & info security • RoHS: Restriction of hazardous substances • IPC Standards: PCB handling & soldering quality - BIS/TEC (India): Product certification	• Check if components/tools have certification • Follow IPC rules for PCB handling • Never use unapproved or uncertified parts
Compliance Requirements	• Follow company SOPs - Use calibrated tools only - Maintain records of material usage - Perform intermediate & final quality checks - Report defects quickly	• Always use updated SOPs • Record parts usage properly • Inform supervisor if mismatch or defect occurs
Health & Safety Policies	• Personal Safety: PPE (gloves, goggles, ESD strap) Electrical Safety: Proper grounding, no live work without approval ESD Safety: Anti-static mats, bags, straps Fire Safety: Use fire extinguishers, avoid flammables Environmental Safety: Dispose waste properly	• Wear PPE before starting work • Use ESD protection when handling PCBs • Keep tools & cables organized • Dispose waste in correct bins (hazardous / non-hazardous)
Why It Matters	• - Zero-defect assembly - Reduced accidents - Environmental protection - Builds customer trust	• Apply standards daily • Work carefully to avoid rework • Think safety first

3.1.2 Roles, Responsibilities, and Reporting Structures in the Assembly Line

Role	Responsibilities	Reporting Structure
Line Assembler	Assemble telecom parts as per instructions, follow safety and quality rules, report defects to supervisor.	Reports to Supervisor/Line Leader
Line Leader / Supervisor	Distributes work, checks assembly quality, ensures compliance with standards, guides assemblers.	Reports to Production Manager
Quality Inspector	Performs quality checks at different stages, ensures products meet standards, reports issues.	Reports to Quality Manager
Production Manager	Plans production targets, ensures workflow, coordinates between supervisors and higher management.	Reports to Plant / Factory Head

3.1.3 Handling and Assembly of Various Electronic and Mechanical Parts

Part Type	Examples	Handling Guidelines	Assembly Guidelines
Electronic Parts	- PCB (Printed Circuit Board)- Chips & Modules (Wi-Fi, Bluetooth, RFID)- Resistors, Capacitors, Diodes, LEDs- Connectors & Cables	- Always wear ESD strap and gloves- Avoid touching circuits with bare hands- Use tweezers/pick tools for small parts- Keep in anti-static bags	- Ensure correct polarity for components- Place as per circuit diagram- Insert connectors gently, avoid force- Route cables neatly
Mechanical Parts	- Casings & Covers- Screws & Fasteners- Heat sinks, shields- Display & keypad units	- Handle with clean gloves to avoid scratches- Keep screws sorted by size- Align parts properly before tightening	- Use correct screwdriver- Do not over-tighten screws- Fix heat sinks/shields firmly- Assemble covers and displays carefully
General Do's	–	- Wear PPE (gloves, ESD strap)- Keep parts labelled & organized- Follow diagrams/SOPs	–
General Don'ts	–	- Don't force a part to fit- Don't mix screws/components- Don't touch circuits with bare hands	–

3.1.4 Electronic Components used in Mobile Phones and their Functions

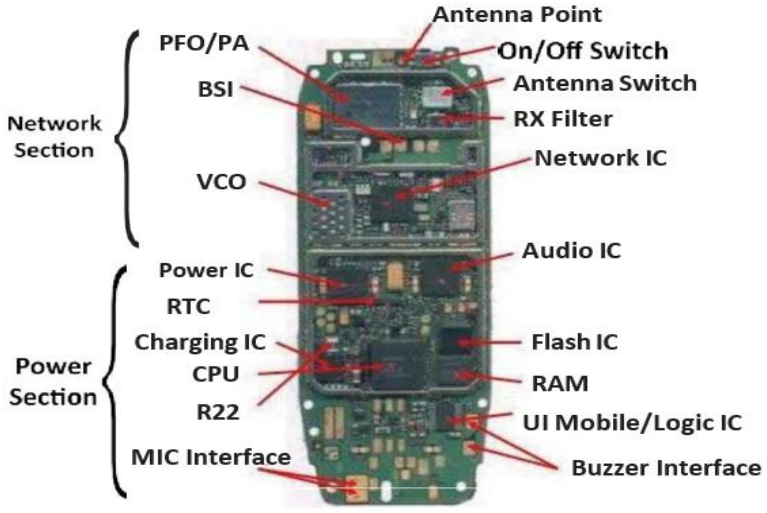
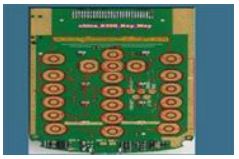


Fig. 3.1.1: Different components of a mobile phone

The different components of a mobile phone are:

Component	Image
1. **Charging system:** A mobile phone can be charged by means of an adapter or a USB cable. Once it is charged, open the charging plug. It is harmful for both the battery and charger to charge a mobile throughout the night. After buying a new mobile set, the battery should be charged from 12 to 18 hours at a stretch.	
2. **Battery:** A container comprises one or more cells, in which chemical energy is converted into electricity and utilised as a power source. The battery of mobile phone is 3.6 volts and current is 500Amps (Amperes)-1800Amps.	
3. **Backup battery:** It looks like the battery of a clock. Being rounded and silver coloured, it acts as a backup power supply to control the date and time of a mobile phone.	
4. **SIM Driver IC:** It is square in shape and blue in colour. It is usually found below the SIM socket and side of key board interface IC. Below this IC cover, there are 3 rows with 8 nodes. By making jumper, we can remove the problem of SIM faults.	
5. **Keyboard interface IC:** It is square in shape and blue in colour like SIM IC. Normally, it is larger than the SIM IC. It has 5 rows with node points above 20 (Keys Number).	
6. **FM IC:** It is square in shape. In nokia 2760, this IC stays below the vibrators. The function of this IC is to control the FM in mobile phones.	
7. **Display Socket Track:** This socket makes the connection between the display (LCD) and the motherboard. It is usually placed on the back side of the motherboard.	

Component	Image
8. **Network amplifier:** It is rectangular and comes with a metal cover. PF (Power Factor)/RF is written on it. Black in colour, it amplifies the outgoing signal of the mobile. If it is damaged, 'no access' symbol will come in display. At first, we have to re-solder it. If the problem is not solved, then it needs to be changed.	
9. **LED (Light Emitting Diode) and LCD (Liquid Crystal Display):** LED is a diode which is used on the light in the motherboard. It acts in forward bias. This diode is fabricated by the materials like As (Arsenic), Ga (Gallium), , etc. In case of mobile phones,, LED is presentin keypad, display, etc. Actually LED transfers the electrical energy to light energy. Therefore, it is known as Light Emitting Diode.The full form of LCD is a Liquid Crystal Display.	
10. **SIM socket:** Black in colour and rectangular in shape, a sim socket has 6 pins. It is used for the purpose ofcontact as well as activated SIM card, Rejected SIM card, SIM card etc.	
11. **SIM card:** GSM mobile phones need a little microchip called the Subscriber Identity Module or SIM card, for functioning. The SIM card is about the size of a small postage stamp and is generally placed below the at the back of the unit. The SIM safely houses the service-subscriber key (IMSI) used to identify a subscriber on mobile telephony devices. The SIM card permits users to change phones by simply removing it from one mobile phone and inserting it into another one or broadband telephony device.	
12. **Audio IC:** It is the second largest IC in the mobile mother board. It is rectangular and has 48 to 60 pins. Some audio IC has more than 60 pins. The functions of speaker, microphone and ringer are almost dependent by audio IC.	

3.1.5 Determine the Importance of Polarity in Electronic Components and Its Impact on Device Functionality, Along with the Mechanical Items used in the Assembly Process

Importance of Polarity in Electronic Components

- Polarity means that a component has a positive (+) and negative (–) side, and it must be connected correctly in a circuit.
- Many electronic components such as diodes, LEDs, capacitors, and batteries are polarized.
- If polarity is reversed:
  - The component may not work (e.g., LED won't glow).
  - It may get damaged (e.g., electrolytic capacitor can burst).
  - The whole device may fail or malfunction.
- Correct polarity ensures:
  - Safe operation of the device.
  - Proper current flow in the circuit.
  - Longer life of components.

Impact on Device Functionality

- Wrong polarity → device may stop functioning.
- Heat, sparks, or smoke may occur in severe cases.
- Correct polarity → stable power supply, accurate signal transmission, and reliable performance.

Mechanical Items Used in Assembly Process

In telecom/electronic product assembly, workers also handle mechanical parts along with electronic components. These include:

1. Fasteners – Screws, nuts, bolts, washers (used to fix PCBs, covers, and modules).
2. Enclosures / Casings – Plastic/metal housings that protect the circuit.
3. Heat sinks – Used with power components for heat dissipation.
4. Connectors & Sockets – For joining cables, wires, and boards.
5. Mounting frames / brackets – To hold PCBs and modules in position.
6. Cables and ties – For wiring management.
7. Gaskets / spacers – Provide insulation, spacing, and protection

3.1.6 Handling Components using Appropriate Tools

Aspect	Key Points (Theory)	Practical Application / Tools
Handling Electronic Components	• Handle with clean and dry hands or use ESD strap/gloves to prevent damage. • Hold components by the body, not the pins/leads. • Avoid touching component surfaces to prevent contamination.	• Use tweezers, pliers, or vacuum pick-up tools to pick and place small parts. • Place components on anti-static mats.
Ensuring Polarity & Orientation	• Check the polarity marks (+, –) and pin numbers before fitting. • Follow circuit diagram/assembly drawing for correct direction.	• Use magnifying lamp or multimeter for verification. • Double-check alignment before soldering or fixing.
Mechanical Fitment	• Ensure parts are aligned properly with PCB holes or housing slots. • Do not force parts into place; misalignment can damage leads or PCB tracks.	• Use screwdrivers, nut drivers, torque tools for fasteners. • Use spacers, washers, and guides to maintain proper fit.
Soldering Safety (if applicable)	• Use the correct temperature for soldering iron.- Do not overheat parts. • Keep solder joints clean and shiny.	• Use soldering station with temperature control, solder wire, and flux. • Use solder sucker or wick for rework.
Post-Fitment Check	• Inspect visually for correct placement and orientation. • Ensure no loose parts or short circuits. • Verify mechanical tightness of screws and connectors.	• Use inspection lamp, continuity tester, or multimeter. • Perform gentle shake/tilt test to confirm stability.

3.1.7 Procedures & Sequences for Assembling RFID, Wi-Fi, and Bluetooth Modules

Step	Procedure	Details / Tools Used
1. Preparation	- Wear ESD strap and ensure anti-static workstation. - Collect modules (RFID tag, Wi-Fi, Bluetooth), PCB, screws, connectors, and casing.	Tools: ESD strap, anti-static mat, component tray.
2. Identify Components	- Verify the type of module (RFID / Wi-Fi / Bluetooth) using labels, datasheet, or markings. - Check polarity, pin configuration, and orientation notch/mark.	Tools: Datasheet, magnifying glass, multimeter (if needed).
3. Positioning on PCB	- Align module pins with the corresponding PCB holes/pads. - Ensure correct orientation (pin-1 marking, polarity).	Tools: Tweezers, alignment guide.
4. Fixing / Mounting	- Carefully insert the module onto the PCB. - Ensure all pins go straight into the sockets/holes. - No bending or forcing of leads.	Tools: Tweezers, pliers (for adjustment).
5. Soldering / Connection	- Apply solder to secure module pins onto PCB. - Avoid excess solder (prevents bridging). - For plug-in modules, ensure socket locks properly.	Tools: Soldering station, solder wire, flux, desoldering pump (for corrections).
6. Mechanical Assembly	- Secure module and PCB to enclosure/housing using screws, spacers, or brackets. - Route wires/cables neatly and fix with cable ties.	Tools: Screwdriver set, torque driver, cable ties.
7. Inspection & Testing	- Check visually for correct orientation and solder joints. - Perform continuity test for connections. - Power ON and verify: • RFID tag → Reader detects ID. • Wi-Fi module → Connects to test network. • Bluetooth module → Pairs with test device.	Tools: Inspection lamp, multimeter, RFID reader, Wi-Fi router, Bluetooth test device.
8. Final Fitment & Packaging	- Close the casing and tighten screws. - Apply label/sticker as per standard. - Pack in anti-static packaging for dispatch.	Tools: Screwdriver, packaging material (ESD-safe bags).

3.1.8 Describe the Safe and Correct usage pf Assembly Tools such as Screwdrivers, Pliers, and Tweezers

Tool	Correct Usage	Safety Precautions
Screwdrivers 	• Select the right type and size (flat, Phillips, torque) for the screw. • Hold the screwdriver firmly and apply straight, even pressure. • Turn gently to tighten/loosen without slipping.	• Do not use wrong size → may damage screw head. • Keep handle dry and clean for good grip. • Never use as a chisel or pry bar. • Store with tip covers to prevent injuries.
Pliers 	• Use to hold, bend, or cut wires/leads. • Grip the component firmly but gently to avoid damage. • Use cutting pliers only for wires (not hard screws).	• Do not use pliers on live circuits. • Avoid excessive force → may break component. • Keep cutting edges sharp and clean. • Wear safety glasses when cutting wires.
Tweezers 	• Used for picking and placing small components (resistors, ICs, SMD parts). • Hold components from the body, not pins, to avoid bending. • Use ESD-safe tweezers for electronic parts.	• Handle carefully to avoid poking injury. • Do not squeeze too hard on delicate components. • Keep tips aligned and clean. • Store in protective case when not in use.

3.1.9 Explain the Working Principles and Applications of Semi-Automatic and Automated Assembly Tools

Type of Tool	Working Principle	Applications in Assembly
Semi-Automatic Assembly Tools	• Operated partly by human effort and partly by machine power (electric or pneumatic). • Worker positions the component/tool, and the machine assists in performing the task (e.g., tightening, pressing, cutting).	• Electric screwdrivers / pneumatic screwdrivers → quick tightening of screws with torque control. • Semi-automatic wire cutters/strippers → remove insulation with accuracy. • Heat guns / soldering stations → controlled heating for soldering or shrinking sleeves.

Automated Assembly Tools	• Operate with minimal human involvement • Controlled by programmed logic (PLC, CNC, or robotics) • Machine automatically positions, joins, or tests components as per instructions.	• Pick-and-place robotic arms → mounting electronic components on PCB. • Automated soldering machines / wave soldering → solder multiple joints quickly. • Conveyor-based assembly lines → move products step-by-step with automated fastening and testing • Automated labeling and packaging machines.

3.1.10 Show How to Ensure all Required Tools and Equipment are Operational and Properly Calibrated Before Assembly

Steps to Ensure Tools & Equipment Readiness

1. **Prepare a Tool Checklist**
   - Make a list of all tools and equipment needed (e.g., screwdrivers, soldering iron, multimeter, pliers, tweezers, torque wrench, ESD wrist straps, test jigs).
   - Verify availability against the checklist before starting work.
2. **Visual Inspection**
   - Check tools for any physical damage (cracks, loose handles, bent tips, frayed wires).
   - Ensure safety features (like insulated grips on electrical tools) are intact.
3. **Operational Testing**
   - Switch on powered equipment (soldering station, multimeter, oscilloscope, crimping machine) to confirm it is working.
   - For manual tools, test their movement (pliers grip properly, screwdrivers fit snugly in screw slots).
4. **Calibration Check**
   - Confirm measuring instruments (multimeter, LCR meter, torque wrench) are calibrated as per manufacturer or organizational schedule.
   - Look for calibration stickers showing last date of calibration and next due date.
   - If calibration is overdue, report and replace with a calibrated tool.
5. **Cleaning and Maintenance**
   - Remove dust, oil, or solder residues from tools before use.
   - Ensure soldering tips are clean and tinned.
   - Apply lubrication (if required) to mechanical tools for smooth functioning.
6. **Power Supply and Safety Verification**
   - Check that electrical equipment is plugged into safe, grounded outlets.
   - Verify ESD (Electrostatic Discharge) protection equipment (wrist straps, mats) are connected and tested.

7. Record Keeping

- Log tool condition, calibration status, and any replacements in the Tool Maintenance Register.
- Report any damaged or uncalibrated tool to the supervisor immediately.

3.1.11 Discuss the Proper Handling and Storage of PCBS, Including Baking and Flux Application

Safe Handling of Circuit Boards

- ESD (Electrostatic Discharge): Always work in clean, designated areas. Wear an ESD wrist strap connected to the ground.
- Physical Handling: Hold PCBs only by their edges. Wear gloves and protective clothing. Use trays/racks to reduce direct handling.
- Moisture Protection: Keep PCBs and parts in protective bags until assembly. Follow date codes to avoid moisture damage.
- Workstation Safety: Keep your area clean and free of dust or liquids. Make sure your table is ESD-safe.

Fig. 3.1.2 Circuit board handling

Storage and Shipping

- Store PCBs as per material type (e.g., lead-free boards need special storage).
- Use anti-static or shielded padded bags for finished boards.
- Protect from both static charge and physical damage during transport.

Flux:

- Flux is used during soldering to clean the PCB surface by removing oxides, improve solder flow, and ensure strong electrical joints. It can be applied with a brush, pen, spray, or foam, depending on the process. The correct type of flux (rosin, water-soluble, or no-clean) should be chosen, and only the required amount must be applied to avoid excess residue.

Baking:

- Baking is done to remove moisture that PCBs or components may absorb when exposed to air. If not removed, this moisture can cause defects like blistering or cracking during soldering. Boards are usually baked at 100–125°C for a few hours before assembly to ensure they are dry and ready for reliable soldering.

3.1.12 Elucidate Basic Soldering Techniques, Defect Identification, and Rework Procedures

Soldering Techniques

1. **Solder requires a clean surface on which components are attached**
   - Polish the copper foil of a printed circuit board with steel wool prior to soldering
   - Remove any paint, wax, oil, etc. with a steel wool, solvent, or fine sandpaper

2. **To begin soldering, apply heat to the connection with the tip of the soldering iron before applying the solder**
   - Apply heat to the connection but not to the solder
   - Hold the soldering iron near the base of the handle like a pen
   - The soldered parts have to be hot to build a good connection

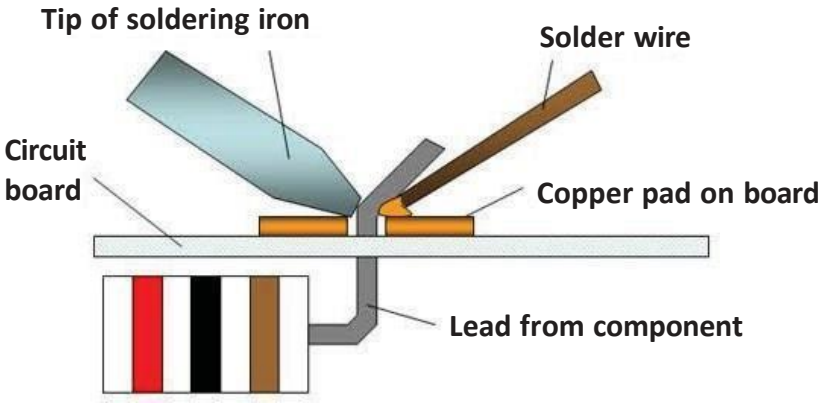


Fig 3.1.3: The tip of the soldering iron heats both the copper pad and the lead from the electronic component

3. **Place the soldering tip on the connection during the application of the solder**
   - Solder will flow on and around the connections
   - **Use enough solder to ensure a stable connection**

4. **Take away the tip from the connection as soon as the solder flows to the desired place. First remove the solder followed by the iron**

5. **Do not displace the connection during the solder is cooling**

6. **Do not apply excess to the connection, as it might damage the electrical parts one is soldering**
   - Transistors and some other parts might be damaged by overheat when soldering. A crocodile clip should be used as a heat sink to preserve these components

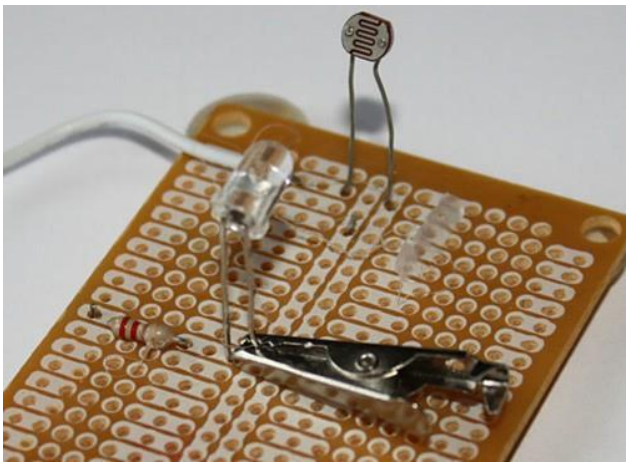


Fig 3.1.4: By absorbing heat, the crocodile clip will reduce the heat that flows to the component

7. **Soldering a connection takes just a few seconds**
   - If it takes longer, troubleshoot as discussed below in the table

8. **Examine the joint minutely. It should appear shiny**
   - If a wire (called the lead) is soldered onto a PC board, it should take the shape of a volcano
   - If the connection is bad, try again by reheating

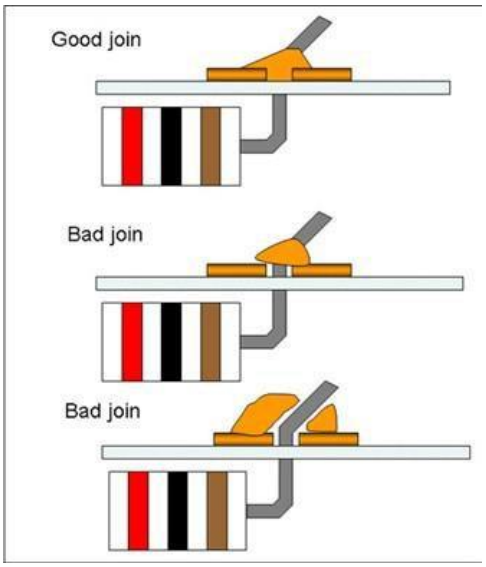


Fig 3.1.5: The solder in a good join will be shaped like a cone, with solid contact between the solder and all surfaces to be joined.

9. **Wipe the tip of the iron on a damp sponge to clean it. The tip should now be shiny**

10. Unplug the soldering iron when it is not in use

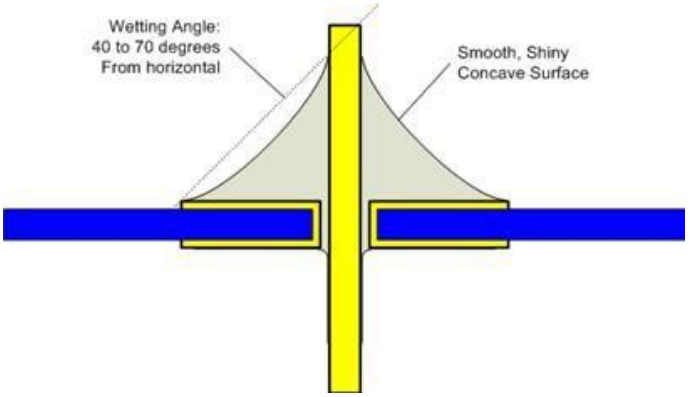
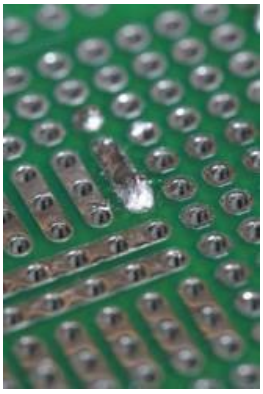
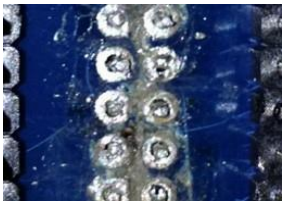
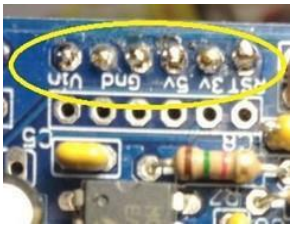
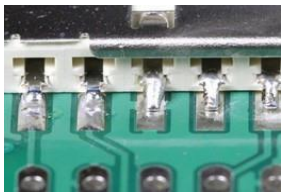
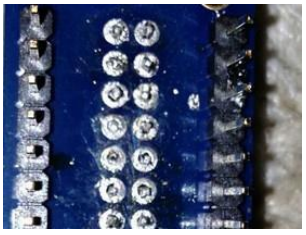


Fig 3.1.6: The ideal solder joint

3.1.13 Soldering Defects and Remedies

Type of Defect	Image	Repair	Prevention
Disturbed Joint: A disturbed joint has been exposed to movement when the solder was still solidifying. The joint surface may appear frosted, rough, or crystalline.		Can be repaired with the help of reheating and allowing it to cool undisturbed.	Proper preparation, involving immobilising the joint and stabilising the work in a vice can hinder such joints.
Cold Joint: Results from incomplete melting of the solder. It is often characterised by a lumpy or rough surface. Such joints are not reliable. The solder bond is poor and may result in cracks in the joint over time.		Can be repaired by re-heating the joint with a hot iron until the solder flows. Several cold joints also suffer from excess solder. The excess solder can generally be drawn-off with the tip of the iron.	A properly pre-heated soldering iron with adequate power will help in preventing cold joints.

Type of Defect	Image	Repair	Prevention
Overheated Joint: Here, the solder has not yet flowed well and the residue of burnt flux will make fixing this joint difficult.		Can be repaired by cleaning. Careful scraping with a knife's tip, or a little isopropyl alcohol and a soft toothbrush will take away the burnt flux.	A hot, clean, soldering iron, appropriate preparation and clean joint can prevent overheated joints.
Insufficient Wetting (Pad): These joints show signs of inadequately wet solder pad. The solder has been able to wet the leads, but it has not created a stable bond with the pad. This is caused by a dirty circuit board or by failing to apply heat to the pad as well as the pin.		Can be repaired by placing the tip of the hot iron at the joint base until the solder flows to cover the pad.	Cleaning the board and heating both the pad as well as the pin can prevent this problem.
Insufficient Wetting (Pin): The solder in this joint has only been able to partially wet the pad. The pin was not sufficiently heated and the solder was not given sufficient time to flow.		Can be repaired by re-heating and using more solder. Ensure that the tip of the hot iron touches both the pad and the pin.	Heating both the pad and the pin can prevent this problem.

Type of Defect	Image	Repair	Prevention
Insufficient Wetting (Surface Mount): The solder has not flowed on to the solder pad. This is the result of heating the pin instead of the pad.		Can be repaired by heating the solder pad with the tip of the iron, and applying solder until it flows and melts along with the solder on the pin.	The pad must be heated first.
Solder Starved: A solder starved joint does not have adequate solder. This may lead to a good electrical contact, but it is tough to verify by checking. It is a weak joint and may lead to stress cracks over time.		Add more solder and re-heat the joint to make a strong joint.	N/A

3.1.14 How to Check Availability of Parts, Tools, and Components

1. **Read the Assembly Specifications**
   - Go through the assembly sheet or instructions carefully.
   - Note the list of parts, tools, and components required.
2. **Collect All Parts**
   - Identify the parts (e.g., circuit boards, resistors, screws, wires, connectors).
   - Check quantity and type as mentioned in the list.
3. **Check Tools and Equipment**
   - Ensure the required tools (screwdrivers, pliers, soldering iron, tweezers, etc.) are available.
   - Verify that tools are in working condition.
4. **Verify Components**
   - Cross-check components (ICs, modules, capacitors, batteries, etc.) with the bill of materials (BOM).
   - Ensure correct rating, size, and polarity where applicable.
5. **Arrange for Missing Items**
   - If any part or tool is missing or damaged, report to supervisor or store in-charge.
   - Replace or arrange before starting assembly.

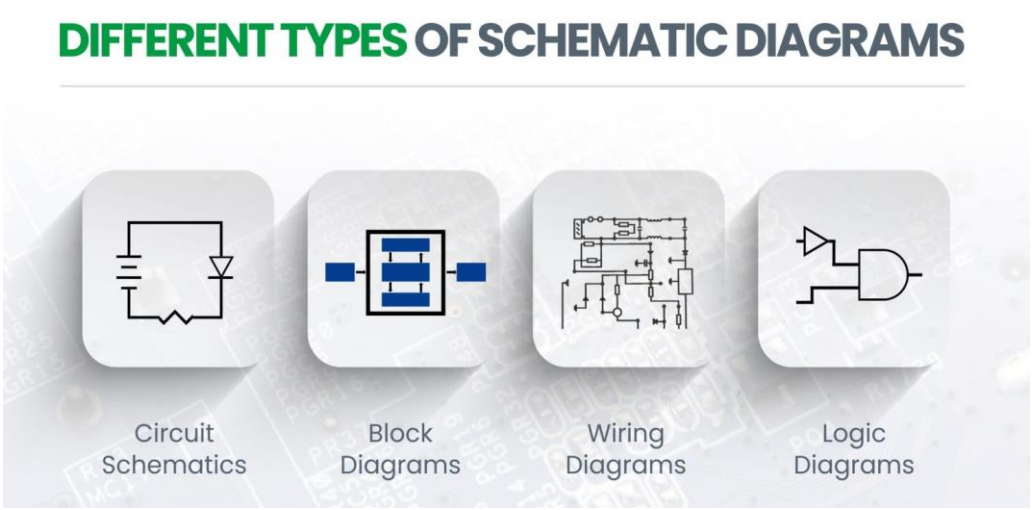
3.1.15 Show How to Arrange Parts and Sub-assemblies in The Correct Sequence for an Efficient Workflow. How to Arrange Parts and Sub-Assemblies in Correct Sequence

1. **Study the Assembly Instructions**
   - Check the assembly drawing or manual to understand the order of operations.
2. **Lay Out Parts Clearly**
   - Keep main parts, sub-assemblies, and small components on the workbench in order of use.
   - Place frequently used items within easy reach.
3. **Follow Logical Sequence**
   - Start with the base or main board.
   - Add sub-assemblies step by step (e.g., mount PCB → connect wires → attach modules → fix casing).
4. **Use Trays or Bins**
   - Keep screws, nuts, and small components in labeled containers to avoid confusion.
5. **Check Fit Before Assembly**
   - Ensure sub-assemblies are complete and tested before moving to the next step.

3.1.16 Demonstrate How to Interpret Technical Diagrams, Specifications, and Schematics Accurately for Assembly

What is schematic diagram in electronics?

A schematic diagram is a visual representation of an electrical circuit or system. It uses symbols to show each component and its various connections. These schematics drawings help engineers, electricians, and technicians understand how a specific system works. Schematics for a PCB are extremely helpful for complicated systems.



Follow onnections

Lines represent wires that connect components. These lines show the path of electrical current.

Nodes: Points where wires connect, marked by a dot.

Crossings: Where lines cross without a dot, indicating no electrical connection.

Read the Labels

Labels provide crucial information about components and their values.

Reference Designators: Alphanumeric labels like R1 (resistor), C1 (capacitor), or Q1 (transistor) link the schematic to the physical parts on a bill of materials (BOM) or a printed circuit board (PCB).

Component Values: Specify the component's electrical properties (e.g., resistance in ohms (Ω), capacitance in farads (F), or voltage ratings).

Understand the Power Supply

Every schematic shows the power source, typically represented by symbols like VCC or + for positive voltage and GND for ground, which is the zero-voltage reference point.

3.1.17 Show How to Perform Basic Quality Checks to Verify Correct Assembly Before Moving to the Next Stage

Basic Quality Checks Before Next Stage

1. **Visual Inspection**
   - Check if all parts are fitted in the right place.
   - Ensure there are no loose or missing components.
2. **Polarity & Orientation**
   - Verify that polarized components (diodes, capacitors, batteries) are placed correctly.
3. **Connection Check**
   - Confirm wires, connectors, and solder joints are secure and not damaged.
4. **Cleanliness**
   - Make sure the assembly is free from dust, excess flux, or solder splashes.
5. **Function Test (if required)**
   - Perform a basic continuity check using a multimeter to confirm proper connections.
6. **Documentation**
   - Mark the completed check and report any defect before sending to the next stage.

3.1.18 Demonstrate the Use of Iot Sensors to Track Assembly Items and Ensure Placement Accuracy and Efficiency

IoT sensors help track assembly parts, confirm correct placement, and improve efficiency on the line.
Demonstration Steps

1. **Attach IoT Tags/Sensors**
   - Fix RFID tags, QR codes, or small IoT sensors on components or trays.
2. **Scan Components**
   - Use an RFID/QR scanner or IoT reader to identify parts before assembly.
   - This ensures the right part is picked.
3. **Check Placement Accuracy**
   - IoT sensors verify if the component is placed in the correct slot/location.
   - Alerts or signals show errors immediately.
4. **Monitor Workflow**
   - Data from sensors is sent to a central system or display.
   - It tracks which items are completed and which are pending.
5. **Improve Efficiency**
   - Real-time tracking reduces errors, rework, and delays.
   - Helps maintain smooth flow in the assembly line.

3.1.19 Show How to Operate Robotic Process Automation (RPA) Tools for Automated Pick and Place Assembly

Robotic Process Automation (RPA) tools in assembly use robotic arms and software to pick parts and place them accurately, reducing errors and speeding up production.

Demonstration Steps

1. Power On & Safety Check
   - Switch on the robotic arm and control system.
   - Ensure safety guards and emergency stop are in place.
2. **Load Components**
   - Place components in trays, feeders, or magazines where the robot can access them.
3. **Set Pick-and-Place Program**
   - Use the control software to load or select the assembly program.
   - Define coordinates: Pick point → Path → Placement point.
4. **Calibrate the Robot**
   - Run a test movement to check alignment.
   - Adjust gripper strength and speed as needed.
5. **Start Automated Operation**
   - Press Start/Run to let the robot pick components and place them on the PCB or sub-assembly.
   - Monitor for accuracy (using sensors or vision systems).

6. **Quality Verification**
   - Observe if all parts are correctly placed.
   - If an error occurs, stop the system, fix the issue, and restart.
7. **Shut Down Safely**
   - Once complete, stop the operation, switch off the power, and clean the work area.

3.1.20 Demonstrate how to use Machine Vision Systems for Real-time Quality Inspection and Defect Detection

Machine vision systems use cameras and software to automatically check parts during assembly, ensuring accuracy and detecting defects early.

Demonstration Steps

1. **Set Up the System**
   - Position the machine vision camera above or beside the assembly line.
   - Connect it to the inspection software/display system.
2. **Calibrate the Camera**
   - Adjust focus and lighting for a clear view of components.
   - Define reference images or standards (correct shape, size, orientation).
3. **Run the Inspection**
   - As components move on the assembly line, the camera captures images in real time.
   - The software compares them with the stored reference.
4. **Detect Defects**
   - The system highlights errors such as:
     - Missing components
     - Misaligned placement
     - Soldering defects
     - Wrong part orientation
5. **Take Action**
   - If a defect is found, the system gives an alert (sound/light signal).
   - The defective piece can be removed or corrected before moving ahead.
6. **Record & Report**
   - Inspection results are logged automatically.
   - Helps in quality tracking and reducing repeat errors.

Exercise

Multiple Choice Questions (MCQ):

1. In a schematic diagram, a triangle pointing to a line represents:
   a) Resistor
   b) Diode
   c) Capacitor
   d) Inductor
2. Which of the following is used to verify correct component placement in real-time?
   a) Screwdriver
   b) Machine Vision System
   c) Soldering Iron
   d) Multimeter
3. IoT sensors are used in assembly lines mainly for:
   a) Generating power
   b) Heating components
   c) Tracking items and placement accuracy
   d) Cutting wires
4. In RPA-based automated pick-and-place, the robotic arm movement is defined by:
   a) Random selection
   b) Pre-programmed coordinates
   c) Operator's hand movement
   d) Trial and error
5. The symbol GND in a schematic diagram represents:
   a) Positive voltage
   b) Ground/negative terminal
   c) Resistor value
   d) Transistor terminal

Fill in the Blanks:

1. A _____ symbol in a schematic diagram is shown as zigzag lines or rectangles.
2. In a pick-and-place system, parts are usually placed in _____ or feeders for the robotic arm.
3. Machine vision cameras compare real-time images with _____ standards to detect defects.
4. IoT sensors such as _____ tags are often used to track assembly components.

Short Questions:

1. Why is it important to perform basic quality checks before moving to the next assembly stage?
2. Write two advantages of using machine vision systems in telecom assembly.
3. Explain briefly how IoT sensors help in ensuring efficiency on the assembly line.

True / False:

1. In schematic diagrams, wires crossing without a dot means they are connected. ☐
2. RPA tools in assembly help reduce manual errors and improve speed. ☐
2. Machine vision systems can detect misaligned or missing components. ☐
3. Resistor values in schematics are usually given in farads. ☐

Notes

UNIT 3.2: Managing Production and Post-Assembly Activities

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the fundamentals of voltage, current, resistance, and power measurement in telecom equipment.
2. Describe the interpretation of electronic circuit diagrams, schematics, and assembly drawings.
3. Discuss the assembly and testing of telecom RF circuits, power supplies, and multiplexers.
4. Determine the identification, pin configuration, and specifications of connectors, cables, and wires used in telecom manufacturing.
5. Elucidate the role of IoT, RPA, and SMT in modern assembly lines for enhanced efficiency and accuracy.
6. Explain the application of AR-based interactive tools for assembly training and troubleshooting.
7. Discuss the implementation of machine vision for defect detection and process validation in telecom production.
8. Describe the waste management and disposal protocols for hazardous materials in telecom manufacturing.
9. Demonstrate the safe disposal of hazardous and non-hazardous waste in designated areas.
10. Demonstrate how to use ERP systems to track materials and schedule production efficiently.
11. Show how to log component usage accurately to maintain proper stock levels.
12. Demonstrate the process of coordinating inventory management with production teams.
13. Show how to conduct intermediate and final compliance checks for assembly verification.
14. Demonstrate how to secure the workstation by removing loose components and consumables post-assembly.
15. Show how to reconcile used components with issued inventory and document discrepancies.
16. Demonstrate the correct store procedures for returning unused components and tools.
17. Show how to maintain proper documentation of completed work and inventory usage.
18. Show how to align assembly processes with ISO/IEC 9001 quality management and 27001 information security standards.

3.2.1 Fundamentals of Electrical Measurement

Understanding basic electrical concepts is crucial for working with telecom equipment. Here's a look at the key fundamentals:

- **Voltage (V):** This is the electrical potential difference between two points. Think of it as the pressure that pushes electric charge through a circuit. It is measured in Volts (V). You can measure it using a voltmeter by connecting the probes in parallel across the two points. For example, a standard AA battery has a voltage of 1.5V.
- **Current (I):** This is the flow rate of electric charge. Imagine it as the volume of water flowing through a pipe. It is measured in Amperes (A). To measure current, an ammeter must be placed in series with the component, breaking the circuit to allow the current to flow through the meter.
- **Resistance (R):** This is the opposition to the flow of electric current. It's like a constriction in a pipe that slows down water flow. It is measured in Ohms (Ω). A multimeter can be used to measure resistance when the component is not powered on.
- **Power (P):** This is the rate at which electrical energy is consumed or produced. It's the product of voltage and current ($P=V\times I$). It is measured in Watts (W). Power tells you how much energy a device uses over a period of time.

3.2.2 Interpreting Electronic Diagrams

Electronic diagrams, schematics, and assembly drawings are the blueprints for building and repairing telecom equipment.

- **Circuit Diagrams/Schematics:** These use symbols to represent components (e.g., resistors, capacitors, transistors) and lines to show how they are interconnected. They explain the circuit's functionality and are essential for troubleshooting.
- **Assembly Drawings:** These show the physical layout of components on a Printed Circuit Board (PCB) or within an enclosure. They are used to guide the physical assembly process, showing where each component is placed and how it is oriented.

3.2.3 Assembly and Testing of Telecom Circuits

Assembling and testing key telecom circuits requires precision and attention to detail.

- **RF (Radio Frequency) Circuits:** These circuits handle high-frequency signals. Assembly requires careful soldering to avoid damaging components and maintaining proper signal paths. Testing involves using specialized equipment like spectrum analyzers or network analyzers to check signal quality, power levels, and frequency response.
- **Power Supplies:** These circuits convert AC power to the DC voltage required by the equipment. During assembly, it's crucial to correctly install components like transformers, rectifiers, and capacitors. Testing involves verifying the output voltage and current stability under different load conditions.
- **Multiplexers:** These circuits combine multiple low-speed signals into a single high-speed signal. Assembly requires precise alignment of components. Testing focuses on verifying that the multiplexer correctly combines and separates signals without data loss or distortion.

3.2.4 Connectors, Cables, and Wires

Proper identification and use of connectors, cables, and wires are fundamental to successful telecom manufacturing.

- **Connectors:** These provide a a reusable way to join electrical circuits. Pin configuration refers to the specific arrangement of pins and sockets, which ensures that cables are connected correctly. Specifications include the type of connector (e.g., RJ45, coaxial), its gender (male/female), and its number of pins.
- **Cables:** Cables are groups of wires bundled together. Key specifications include the number of conductors, shielding type (e.g., braided, foil), and impedance. Correctly identifying and using the right cable for an application is critical for signal integrity.
- **Wires:** Wires conduct electricity. Their specifications include gauge (thickness), which determines current capacity, and insulation type. The color coding of wires is standardized to indicate their function (e.g., red for positive, black for ground). You must match these specifications to the requirements of the circuit.

3.2.5 Role of IoT, RPA, and SMT

Modern assembly lines use technologies like IoT, RPA, and SMT to significantly boost efficiency and accuracy. These technologies automate tasks, provide real-time data, and improve quality control, creating a more streamlined and reliable production process.

- Internet of Things (IoT): IoT uses sensors and network connectivity to collect real-time data from machines and components on the assembly line. This data is used for predictive maintenance, alerting technicians to potential equipment failures before they happen, which drastically reduces unexpected downtime. IoT also enables real-time monitoring of production, allowing managers to identify and correct bottlenecks instantly.
- Robotic Process Automation (RPA): RPA uses software bots to automate repetitive, rule-based tasks. In assembly lines, this can involve managing inventory, tracking components, and generating reports. For physical tasks, a type of robot called a cobot (collaborative robot) can work alongside human operators to perform precision-oriented, repetitive tasks like component placement or soldering with high accuracy, reducing human error and fatigue.
- Surface-Mount Technology (SMT): SMT is a method for assembling electronic circuits where components are mounted directly onto the surface of a PCB. This technology is essential for creating high-density, compact electronic products like smartphones and telecom equipment. SMT machines are highly automated, placing components with extreme precision and speed, far exceeding what's possible with manual assembly.

3.2.6 AR for Training and Troubleshooting

Augmented Reality (AR) revolutionizes assembly line training and troubleshooting by overlaying digital information onto the real world. This provides hands-on, contextual guidance without needing physical manuals or constant supervision.

- Assembly Training: AR tools, often used with smart glasses or tablets, can project step-by-step instructions and 3D diagrams directly onto the workpiece. For instance, a trainee can see a virtual arrow pointing to where a specific screw should be placed or watch an animated guide on how to perform a delicate soldering task. This reduces the learning curve and minimizes errors for new technicians.
- Troubleshooting: When a machine breaks down, AR can assist by providing a visual overlay of technical data, such as real-time sensor readings, part numbers, or a machine's internal schematics. A technician can use an AR device to point at a faulty part and see its history and potential repair steps immediately, which speeds up diagnosis and repair, significantly reducing downtime.

3.2.7 Machine Vision for Quality Control

Machine vision systems use cameras, lighting, and advanced software to perform automated visual inspections. In telecom production, they are critical for ensuring product quality and process validation.

- Defect Detection: These systems can inspect products at high speeds, identifying defects that are often invisible to the human eye. For a telecom PCB, a machine vision system can check for:
  - Misaligned components or missing parts.
  - Surface flaws like scratches or cracks.
  - Improper soldering, such as solder bridges or voids. The system compares each product to a pre-programmed "golden sample" and flags any deviations, ensuring every item meets quality standards before it leaves the production line.
- Process Validation: Machine vision validates that each step of the assembly process is completed correctly. For example, it can confirm that all screws are in place and torqued to the correct specification, or that the correct cable is routed through the right channel. This proactive validation ensures consistency, prevents costly rework later in the process, and provides a digital record for quality assurance.

3.2.8 Waste Management and Disposal Protocols

In any manufacturing process, especially in telecommunications, it's crucial to properly handle and dispose of waste. This protects you, your co-workers, and the environment. There are two main types of waste: hazardous and non-hazardous. Both require specific handling procedures.

Hazardous Waste

Hazardous waste is any material that can be harmful to human health or the environment. In telecom manufacturing, this often includes:

- **Chemicals:** Solvents, adhesives, paints, and cleaning agents.
- **Batteries:** Used lithium-ion or nickel-cadmium batteries from devices.
- **Electronic Waste (E-waste):** Circuit boards, faulty components, and other electronics containing heavy metals like lead, mercury, or cadmium.
- **Contaminated materials:** Rags, gloves, or other materials that have absorbed hazardous chemicals.

Disposal Protocols

Disposing of hazardous waste correctly is a legal requirement and a safety priority. Follow these protocols:

1. **Identification:** Always check the Safety Data Sheet (SDS) for any chemical you are using. The SDS provides information on how to handle, store, and dispose of the material.
2. **Segregation:** Never mix hazardous waste with other waste. Use clearly labeled, designated containers. For example, a container for old batteries should be separate from a container for chemical-soaked rags.
3. **Storage:** Keep hazardous waste in secure, well-ventilated areas away from heat sources and foot traffic. Containers must be leak-proof and clearly labeled with the contents and a hazard warning.
4. **Disposal:** Hazardous waste must be collected by a licensed waste management company. You are responsible for ensuring the waste is placed in the correct containers for pickup. Never put hazardous waste in regular trash bins.

Non-Hazardous Waste

Non-hazardous waste is material that doesn't pose a significant threat to health or the environment. In a telecom plant, this includes:

- Packaging materials: Cardboard boxes, plastic wraps, and Styrofoam.
- Scrap metal: Metal off-cuts and wires that are free of contaminants.
- Paper and office waste.

Disposal Protocols

Proper disposal of non-hazardous waste often involves recycling and general waste bins.

1. **Recycling:** Place all recyclable materials (cardboard, clean plastics, and paper) in the bins marked for recycling.

Fig. 3.2.1 Recycling materials produced during manufacturing process

2. **General Waste:** Use the general waste bins for materials that cannot be recycled or are not hazardous. This might include food wrappers or other non-recyclable trash.
3. **Compaction:** In some cases, non-hazardous waste like cardboard may be compacted to save space before being collected for recycling.

Demonstration of Safe Disposal

Let's walk through a practical example of how to dispose of both types of waste.

Scenario: You have just finished a task that involved soldering a circuit board and unboxing new components. You have an old, faulty circuit board and some cardboard packaging.

1. Circuit Board (Hazardous):
   - This is e-waste, so it's hazardous.
   - Find the designated e-waste bin in your work area. This bin should be clearly labeled.
   - Carefully place the circuit board into the bin. Do not force it or throw it in.
2. **Cardboard Packaging (Non-hazardous):**
   - This is recyclable.
   - Break down the cardboard box to make it flat. This saves space.
   - Place the flattened cardboard into the recycling bin labeled for cardboard.

By following these simple but critical steps, you contribute to a safer, more sustainable workplace. A

3.2.9 Material Tracking and Production Scheduling

An ERP system's core function is to provide a single source of truth for all business data. For materials and production, this means every component, from raw materials to finished goods, has a unique ID and is tracked through its lifecycle.

1. **Demand Forecasting and Sales Orders:** The process begins with sales orders or demand forecasts entered into the ERP. The system uses this data to predict the quantity of finished products needed.
2. **MRP Run:** The ERP's MRP module takes the forecasted demand and breaks it down into the required raw materials and components, factoring in the bill of materials (BOM). The MRP module checks current inventory levels and open purchase orders to determine what needs to be procured. It generates planned orders for production and purchase requisitions for materials.
3. **Production Scheduling:** Based on the planned orders from the MRP run, the ERP's production planning module schedules the manufacturing process. It considers resource availability (machines, labor), lead times, and capacity constraints to create a realistic production schedule. The schedule is then shared with the production team via a work order.
4. **Material Issuance:** The production team receives the work order and uses it to request the necessary materials from the warehouse. When materials are issued, the warehouse staff scans the unique material ID, and the ERP system automatically deducts the materials from the inventory count. This real-time update prevents stock discrepancies.

Logging Component Usage to Maintain Stock Levels

Accurate component usage logging is crucial for maintaining proper stock levels and ensuring production continuity. The ERP system automates this process, minimizing human error.

1. **Work Orders:** When a production run is initiated, a work order is created in the ERP. This document lists all the components required for the job, based on the product's bill of materials (BOM).
2. **Backflushing and Material Issuance:**
    - **Manual Issuance:** Before production starts, materials are physically moved from inventory to the production line. A warehouse worker scans the materials' unique barcodes or RFID tags. The ERP system registers this transaction, decreasing the inventory quantity for those specific components.
    - **Backflushing:** This is a more automated method. Once the finished product is completed and reported in the ERP, the system automatically deducts the component quantities from inventory based on the BOM. This is highly efficient for high-volume, repetitive manufacturing where every unit uses the same components.
3. **Real-Time Stock Updates:** Every material issuance or backflush transaction is logged in the ERP. This provides a real-time view of inventory levels. The system can be configured to trigger automated alerts when a component's stock level drops below a predefined safety stock or reorder point. This prompts the purchasing department to place new orders.

3.2.10 Coordinating Inventory Management with Production Teams

An ERP system acts as the central nervous system, connecting the inventory and production teams and ensuring they are always working with the same, up-to-date information.

1. **Shared Dashboards and Reports:** Both teams can access shared dashboards that display critical metrics like current stock levels, production schedule adherence, and material availability. This eliminates information silos and ensures transparency.
2. **Automatic Notifications and Alerts:** The ERP system uses automated notifications to coordinate activities. For example:
   - When a new work order is released, the production team is notified.
   - When a component's stock is low, the purchasing and production teams are alerted.
   - If there's a delay in a material shipment, the production schedule can be automatically adjusted, and the production team is notified.
3. **Unified Data Entry:** All transactions—from receiving new materials to shipping finished goods—are entered into the same system. This ensures that the inventory numbers the production team sees are the same as the ones the warehouse and purchasing teams see, preventing discrepancies and improving decision-making.

3.2.11 Intermediate and Final Assembly Checks

A. Intermediate Checks (During Assembly)

These checks help catch mistakes early and avoid rework.

- **Visual Inspection**
  - How: Look closely at sub-assemblies (e.g., PCB mounted on chassis).
  - Check for: Loose screws, wrong parts, bent leads, or cracks.
  - Why: Small errors at this stage can cause bigger failures later.
- **Torque Check**
  - How: Use a calibrated torque screwdriver. Apply the required torque on screws/nuts.
  - Why: Too loose = vibration issues. Too tight = damaged parts.
- **Connectivity Check**
  - **How:** Use a multimeter or continuity tester. Touch probe tips to both ends of the wire/track.
  - **What to Look for**: Correct continuity (beep/signal) → good connection; no beep → open circuit; continuous beep where not expected → short circuit.
  - **Why:** Ensures correct wiring and avoids short circuits.

B. Final Checks (Before Testing/Packaging)

- Complete Visual Check
  - How: Scan the whole assembly. Check connectors, fasteners, labels, and cosmetics (scratches, smudges).
  - Why: Last chance to correct assembly or quality issues.
- Work Order Verification
  - How: Compare product with Work Order (WO) and BOM.
  - Check for: All components installed, correct quantity, correct part number.
  - Why: Prevents missing or extra parts.

Documentation Sign-off

- **How:** Sign and date the traveler sheet/WO after inspection.
- **Why:** Confirms accountability and readiness for quality testing.

Securing the Workstation (5S Method)

- **Sort:** Remove tools, parts, and scraps not needed.
- **Set in Order:** Arrange tools in proper holders or racks.
- **Shine:** Wipe surfaces; remove dust and debris.
- **Standardize:** Follow the same setup every time.
- **Sustain:** Keep the workstation organized as a habit.

A clean workstation = fewer mistakes + safer handling of telecom components.

Reconciling Components & Returning Unused Materials

- **Reconcile Used Components**
  - Count used parts vs. issued parts.
  - Record usage in traveler sheet or ERP.
  - Report any mismatch immediately.
- **Return Unused Components**
  - Step 1: Fill return slip / ERP entry with part number, qty, batch no.
  - Step 2: Repack in original/ESD-safe packaging.
  - Step 3: Label correctly (part no., qty, batch).
  - Step 4: Return to stores.

This avoids shortages, waste, and stock mismatch.

Maintaining Proper Documentation

- **Traveler Sheet / Work Order**
  - Sign and date each completed step.
  - Shows who did what and when.
- **ERP System Updates**
  - Log finished units and consumed components.
  - Keeps stock updated in real time.
- **Discrepancy Reporting**
  - Record damaged parts or missing counts.
  - Helps quality team fix root cause.

Quality and Security Standards

- **ISO 9001 (Quality Management)**
  - Follow SOPs for uniform work.
  - Maintain accurate documentation for audits.
  - Log work for traceability (who did which assembly).
- **ISO 27001 (Information Security)**
  - Handle sensitive components (encrypted chips, storage) with extra care.
  - Work only in authorized, controlled areas.
  - Keep documents secure, no unauthorized access.

Exercise

Multiple Choice Questions (MCQ):

1. Voltage is measured in:
   a) Amperes
   b) Ohms
   c) Volts
   d) Watts
2. Which document shows the physical placement of components on a PCB?
   a) Circuit diagram
   b) Assembly drawing
   c) Traveler sheet
   d) ERP dashboard
3. Which technology directly mounts electronic components onto the PCB surface?
   a) RPA
   b) IoT
   c) SMT
   d) AR
4. In ERP, 'Backflushing' means:
   a) Returning unused materials to stores
   b) Automatic deduction of materials from inventory after product completion
   c) Manual issue of materials from warehouse
   d) Cleaning components before assembly
5. Which ISO standard focuses on Information Security?
   a) ISO 14001
   b) ISO 9001
   c) ISO 27001
   d) ISO 45001

Short Questions:

1. Explain the difference between voltmeter and ammeter in terms of measurement and connection in a circuit.
2. Why is torque checking important in telecom assembly? Give one example.
3. How does machine vision help in quality control during telecom PCB production?

True or False:

1. Resistance is measured in Ohms (Ω). ☐
2. AR tools can only be used for troubleshooting, not training. ☐
3. Hazardous waste like faulty PCBs must be disposed of in general bins. ☐
4. ERP systems help coordinate between production and inventory teams. ☐

Fill in the Blanks:

1. The unit of power is _____.
2. _____ diagrams use symbols to represent electronic components.
3. The 5S method for workstation management includes Sort, Set in order, Shine, Standardize, and _____.
4. _____ technology is used in assembly lines to place components on PCBs with high speed and precision.

Notes

4. Assembly & Testing of Mobile Phone Accessories

Unit 4.1 - Mobile Accessories and Electronic Concepts
Unit 4.2 - Safety Measures, Tool Handling, and Quality Assurance
Unit 4.3 - Troubleshooting, Documentation, and Digital Production Systems

TEL/N2510

Key Learning Outcomes

By the end of this module, the participants will be able to:

1. Explain the process of assembling mobile phone accessories while ensuring compliance with industry standards.
2. Discuss the key quality inspection and testing methods used in mobile phone accessory manufacturing.
3. Describe the essential post-assembly activities required for packaging and finalizing mobile phone accessories.

UNIT 4.1: Mobile Accessories and Electronic Concepts

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the types, functions, and basic specifications of mobile phone accessories such as chargers, cables, batteries, and audio devices, along with their key components.
2. Elucidate the fundamental concepts of electronic circuits, including voltage, current, and resistance, and their role in the functionality of mobile accessories.
3. Describe the relevant industry standards and basic regulatory guidelines, such as BIS certification.
4. Demonstrate the process of assembling mobile phone accessories according to technical diagrams and process specifications.
5. Show how to ensure correct positioning and secure connection of electronic and mechanical parts during assembly.
6. Describe the basic working principles and safe operation of specialized tools such as crimping tools, ultrasonic welders, and semi-automated/automated assembly systems.
7. Demonstrate the use of appropriate tools such as screwdrivers, crimping tools, ultrasonic welders, and automated assembly machines.

4.1.1 Basic Specifications of Mobile Phone Accessories

Mobile phone accessories play a crucial role in enhancing the functionality, usability, and convenience of mobile devices. Common accessories such as chargers, cables, batteries, and audio devices are essential for daily operations—enabling charging, data transfer, communication, and entertainment. Understanding their types, functions, specifications, and internal components is important for anyone involved in mobile repair, assembly, or support services.

Accessory	Types	Functions	Basic Specifications	Key Components
Charger 	Wall charger, fast charger, wireless charger, car charger	Converts AC to DC; provides regulated voltage for charging	Input: 100–240V ACOutput: 5V/1A (basic), 9V/2A or more (fast charging)Power rating: 10W to 65W+	Transformer, rectifier, voltage regulator, USB ports, protective ICs (for overcurrent/overvoltage)
Cable 	USB-A to Micro USB, USB-A to USB-C, USB-C to USB-C, Lightning	Transfers power and data between devices; supports charging, syncing, OTG	Length: 0.5 to 2 metersData speed: USB 2.0 (480 Mbps), USB 3.0 (5 Gbps)Charging: Supports 2A–5A	Copper wires, data/power lines, shielding, connectors (USB-C, Micro USB, Lightning), outer insulation

Battery 	Lithium-Ion (Li-ion), Lithium-Polymer (Li-Po)	Stores energy; powers the mobile device	Voltage: 3.7V to 4.4VCapacity: 3000–6000mAhCycle life: 300–500 cycles	Electrodes (anode & cathode), electrolyte, BMS (Battery Management System), connector terminals
Audio Devices 	Wired earphones/headphones (3.5mm, USB-C), wireless earbuds/headphones, Bluetooth speakers, neckbands	Audio output for music/calls; mic input in headsets; wireless playback via Bluetooth	Impedance: 16–32 ohmsFrequency response: 20Hz–20kHzBluetooth version: 4.0 to 5.3Battery life: 4 to 20+ hrs (wireless)	Audio drivers, microphones, Bluetooth chip (wireless), rechargeable battery, control buttons

Table 4.1.1 Mobile accessories specifications

4.1.2 Concepts of Electronic Circuits, Voltage, Current, and Resistance, and their Role

Electronic circuits are the backbone of all modern electronics, including the mobile accessories you use every day. To understand how they work, you need to grasp three fundamental concepts: voltage, current, and resistance. These principles, governed by Ohm's Law, dictate how electricity flows and how components interact.

Concept	Definition	Unit	Role in Circuits	Relevance in Mobile Accessories
Voltage (V)	The electrical potential difference between two points. It is the force that pushes electric charges through a conductor.	Volt (V)	Acts as the driving force that moves electrons through a circuit.	Mobile chargers supply a specific voltage (e.g., 5V, 9V) to charge the phone battery safely and efficiently.
Current (I)	The flow of electric charge (electrons) in a circuit. It represents how much charge passes through a point in the circuit per second.	Ampere (A)	Determines how much electricity is flowing. High current may power stronger components, but excess current can cause damage.	Charging cables and batteries are rated for specific current capacities (e.g., 2A, 3A). Earphones and speakers use current to produce sound.

Resistance (R)	The opposition that a material offers to the flow of electric current. Higher resistance means lower current flow.	Ohm (Ω)	Controls and limits the amount of current flowing in a circuit to protect components.	Audio devices have specific resistance (impedance) for proper sound output. Resistors in chargers help regulate safe current levels.

Table 4.1.2 Concepts of electronic circuits, including voltage, current, and resistance

Mobile accessories like chargers, power banks, and headphones rely on these concepts to function properly.

- **Chargers and Cables:** A charger's circuitry regulates the voltage and current delivered to your device. It takes the AC power from an outlet, converts it to DC, and steps down the voltage to a safe level (e.g., 5V). The cable's internal wires have low resistance to minimize power loss and heat generation.
- **Power Banks:** A power bank is essentially a battery with a circuit that manages charging and discharging. The circuit monitors the battery's voltage and controls the current flow to and from your phone, protecting both devices from damage.
- **Headphones and Speakers:** Headphones convert electrical signals into sound waves. The circuit within the headphones uses the principles of resistance to control the volume and current to drive the speaker membranes, producing sound. Different headphones have different impedance (a type of resistance) ratings, which affects how they interact with the output of your phone.

4.1.3 Bureau of Indian Standards (BIS)

The BIS is the most important standard for anyone working with electronics in India. It's the government body that sets the rules for product safety and quality.

Fig 4.1.1 BIS Logo

- The BIS has a Compulsory Registration Scheme (CRS) for many electronics, including mobile phones, chargers, power banks, and batteries. This means that before a manufacturer can sell these products in India, they must be registered with the BIS.
- As a assembler, you'll often see the BIS logo on the products you work with. This logo is a sign that the product has been tested and meets specific safety standards. If you are repairing a product, you should be aware of the BIS standards. For example, chargers must meet specific standards for electrical safety to prevent fire or electric shock.

4.1.4 Process of Assembling Mobile Phone Accessories

Step	Description	Key Actions	Tools/Equipment Used
1. Understanding Technical Diagrams	Read and interpret circuit diagrams, wiring layouts, and mechanical drawings.	Identify component placement, wiring paths, voltage/current ratings, connector types.	Circuit diagram sheets, product manuals, specifications
2. Gathering Components and Tools	Collect all necessary components and verify against BoM (Bill of Materials).	Check part numbers, quality, ratings; prepare workbench.	Multimeter, soldering iron, screwdrivers, magnifier
3. Preparing Work Area	Ensure static-free, clean, organized assembly space.	Wear ESD wrist strap; clean surface; organize tools.	ESD mat, wrist strap, cleaning brush
4. Assembling Internal Components	Fit and connect internal parts as per diagrams.	- Solder resistors, capacitors, ICs (in charger/audio PCBs) - Assemble wire conductors (in cables) - Connect battery terminals	Soldering station, wire cutter, heat shrink
5. Connecting Wires and Terminals	Route and fix wires to the correct terminals as per wiring diagrams.	Use color coding and tags for identification.	Crimping tool, tweezers, insulation tape
6. Mechanical Assembly	Fit housing/shells, covers, clamps, and strain relief.	Align components, fix with screws or snaps.	Screwdriver, torque driver, alignment jig
7. Inspection and Testing	Conduct functional tests and visual checks.	- Voltage/current output (charger) - Continuity check (cable) - Battery voltage and charge - Audio output test	Multimeter, battery tester, audio tester
8. Final Packing and Labeling	Clean the assembled unit, pack with labels and manuals.	Label model number, batch, QC status.	Label printer, poly bags, packaging boxes

4.1.5 Ensuring Correct Positioning & Secure Connection In Assembly

Step	Action	Details	Tools/Methods Used
1. Refer to Technical Diagrams	Use circuit schematics and mechanical layout drawings.	Ensure every part (e.g., capacitor, IC, connector) is oriented and placed as per the diagram.	Circuit diagram, exploded view drawing, alignment guides
2. Component Orientation Check	Verify the direction/position of polarized components (e.g., batteries, LEDs, capacitors, USB connectors).	Ensure positive and negative terminals are correctly aligned.	Polarity marks on PCB, magnifying glass
3. PCB Slot Alignment	Fit electronic components into PCB holes or slots as per footprint.	Push-fit components flush against the board before soldering.	PCB holder, anti-static tweezers
4. Use of Mechanical Fixtures and Clamps	Position mechanical parts (e.g., shells, plugs, buttons) using correct guides or notches.	Prevent shifting or tilting during fixing.	Alignment jig, clamps, fixtures
5. Secure Electrical Connections	Tighten or solder wires properly to avoid loose contact.	Strip wires to the correct length, crimp or solder securely.	Soldering iron, crimping tool, wire stripper
6. Apply Torque to Screws Properly	Avoid over-tightening or under-tightening screws during mechanical assembly.	Follow manufacturer torque specifications.	Torque screwdriver or electric driver
7. Use Locking Mechanisms	Ensure connectors click/lock in place (e.g., audio jacks, USB ports, battery connectors).	Check for proper locking sounds or tactile feedback.	Hand pressing, snap-fit checks
8. Test for Stability	Slightly shake or tap assembled part to ensure nothing is loose.	Perform continuity or mechanical wiggle test.	Multimeter (continuity), vibration test bench
9. Visual and Manual Inspection	Inspect solder joints, wire bends, and housing alignment.	Check for cold solder joints, misalignment, or gaps.	Magnifier, inspection checklist
10. Final Functional Test	Power up the accessory to confirm correct function (e.g., charging, audio output).	Validates both positioning and connection.	Multimeter, battery tester, speaker/audio test jig

Things to follow:

- Always wear an ESD wrist strap to prevent damage to sensitive components.
- Label components and wires to avoid misplacement.
- Use color-coded wires and diagrams for easy verification.
- Keep a QC checklist for position and connection inspection at each stage.

4.1.6 Tools and Automated Assembly Machines

The assembly of mobile phone accessories requires the careful use of appropriate tools to ensure precision, safety, and durability. Tools like screwdrivers are used to fasten housings and enclosures securely, while crimping tools help attach wires to connectors without soldering. For plastic components, ultrasonic welders create strong, seamless bonds through high-frequency vibrations. In large-scale production, automated assembly machines are employed for tasks such as component placement, soldering, and quality testing. Using the correct tool not only ensures functional assembly but also reduces the risk of damage and enhances product reliability.

Tool	Purpose	How to Use	Typical Applications	Precautions
Screwdrivers (Manual & Torque-controlled) 	Fastening or removing screws to secure mechanical parts	Select correct tip (Philips, flat, Torx). Insert into screw head, apply appropriate torque, turn clockwise to tighten or anticlockwise to loosen. Torque screwdrivers apply controlled force.	- Fixing charger housing- Securing battery covers- Assembling audio device enclosures	Avoid over-tightening (can crack plastic or strip threads). Use ESD-safe tools near electronics.
Crimping Tools 	Join wires to terminals/connectors without soldering	Strip wire to correct length → insert into terminal → place terminal in crimp die → squeeze handles until crimp is complete.	- Fixing USB connectors- Audio jack cable ends- Battery wire terminals	Ensure firm crimp; tug wire slightly to test connection. Use right die size for terminal.
Ultrasonic Welder 	Welds plastic parts by generating high-frequency vibrations to fuse materials without screws or glue	Align plastic parts in welder jig → initiate ultrasonic pulse → vibrations melt surfaces → allow cooling for bonding	- Joining plastic casings of chargers- Wireless earbud enclosures- Cable strain relief shells	Ensure parts are clean and aligned. Operator must wear ear protection due to high-pitched noise.
Automated Assembly Machines 	Semi- or fully-automated machines that place, solder, test, or assemble parts	Load components and PCBs into machine → program or select appropriate job → monitor assembly cycle → inspect output	- Soldering PCBs in chargers- Mounting USB ports- Assembling cable pins or covers	Trained operator must monitor for errors. Perform routine maintenance and safety checks.

Notes

UNIT 4.2: Safety Measures, Tool Handling, and Quality Assurance

Unit Objectives

By the end of this unit, the participants will be able to:

1. Determine the importance of electrostatic discharge (ESD) safety measures and proper grounding techniques for the safe handling of sensitive electronic components.
2. Explain the key quality parameters and fundamental methods for real-time defect detection and basic automated testing of assembled accessories.
3. Elucidate the importance of proper waste disposal and safe handling of defective components.
4. Demonstrate the application of automation and smart manufacturing techniques such as robotic assembly and AI-assisted quality checks.
5. Show how to follow ESD-safe handling procedures to prevent static discharge damage to sensitive components.
6. Demonstrate how to test assembled accessories for electrical functionality, durability, and compliance with applicable quality standards.
7. Show how to dispose of defective or rejected components following applicable guidelines.
8. Demonstrate adherence to workplace safety and cleanliness guidelines throughout the process.

4.2.1 Electrostatic Discharge (ESD) Safety Measures and Proper Grounding Techniques

Electrostatic discharge (ESD)

Electrostatic discharge (ESD) is the sudden flow of electricity between two electrically charged objects. In electronics assembly, ESD can severely damage sensitive components like ICs, microcontrollers, and sensors without any visible signs. Therefore, proper ESD safety measures and grounding techniques are essential for protecting telecom products and accessories during handling, testing, and assembly.

Why ESD Safety is Important in Telecom Assembly

Impact Area	Effect of ESD Damage
Chargers and Cables	Damaged voltage regulators or USB controllers
Audio Devices	Faulty microphones, amplifiers, or Bluetooth chips
Batteries	Internal circuit protection failure
PCB Modules	Non-functional ICs, data loss, signal distortion

Even a discharge as low as 30–100 volts, which is below human perception, can destroy sensitive telecom components.

Key ESD Safety Measures

ESD Protection Method	Purpose	Application
ESD Wrist Strap	Discharges built-up static from the human body safely to the ground	Must be worn while working with open electronic components
ESD Mats (Table and Floor)	Provides a grounded surface to prevent charge buildup	Used on workbenches and floors in assembly areas
ESD-Safe Clothing	Prevents generation and transfer of static from clothes	Lab coats, gloves, and caps made of static-dissipative material
Anti-Static Packaging	Protects components during storage and transport	Use of pink poly bags, shielding bags, and bubble wraps
Humidity Control	Reduces static build-up in dry air	Use humidifiers to maintain 40–60% humidity in ESD-safe zones

Proper Grounding Techniques

Grounding Technique	Explanation
Earth Grounding	Connecting all ESD protection systems to a common earth ground point
Common Ground Point	Ensures all workstations, wrist straps, and mats are at the same electrical potential
Grounding Cords	Connect wrist straps and mats to grounding jacks or outlets
Periodic Testing	Daily checks of wrist strap resistance (typically 1MΩ) to ensure effectiveness

Understanding and applying ESD safety measures and grounding techniques is crucial in the telecom manufacturing and assembly environment. These practices protect sensitive electronic components from damage, improve product quality, and reduce failure rates in the field. Every line assembler must be trained and consistently follow ESD-safe procedures to maintain industry standards and ensure reliability of the final product.

4.2.2 Quality Checks and Basic Automated Testing Methods for Assembled Accessories

Quality assurance is a critical part of the telecom accessory assembly process. Ensuring that chargers, cables, batteries, and audio devices meet defined quality parameters helps prevent malfunction, safety risks, and customer dissatisfaction. This is achieved through a combination of visual checks, manual testing, and basic automated testing systems, which help detect defects in real time and maintain consistent product standards.

Parameter	Description	Applicable To
Electrical Continuity	Ensures that current can flow through a circuit without interruption	Cables, charger circuits
Voltage and Current Output	Confirms that the accessory delivers correct output levels under load	Chargers, batteries
Signal Integrity	Checks for noise, distortion, or signal loss	Audio devices, data cables
Mechanical Fit and Finish	Ensures physical parts are aligned, secured, and undamaged	All accessories
Durability	Assesses product performance under repeated use or stress	Cables, buttons, connectors
Safety Compliance	Confirms product meets safety standards like BIS, CE, or RoHS	Chargers, batteries

Basic Automated Testing Techniques

Technique	Application	Function
Automated Test Jigs	Audio devices, cables, chargers	Custom rigs simulate end-use to test charging, sound, voltage
In-Circuit Testing (ICT)	PCBs inside chargers or audio devices	Detects faulty components (resistors, ICs) on the board during production
Camera-Based Optical Inspection	Visual quality checks	Detects component misplacement, solder issues using image processing
Barcode or QR Code Scanning	Assembly tracking	Identifies product batch, verifies stage completion
Pass/Fail Indicators (LED/Buzzer)	Operator feedback	Automated tools give instant result for tested unit (OK/NG light or sound)

4.2.3 Elucidate The Importance of Proper Waste Disposal and Safe Handling of Defective Components

In the process of assembling mobile phone accessories—like chargers, batteries, cables, and earphones—a variety of waste materials are generated. These may include damaged electronic components, plastic scraps, faulty PCBs, defective batteries, and packaging materials. Improper handling of such waste not only violates environmental regulations but also poses serious health, safety, and fire hazards. Hence, safe disposal and segregation of waste is a critical responsibility for every line assembler.

Why Proper Waste Disposal is Important

Reason	Explanation
Worker Safety	Defective components (especially batteries) may leak harmful chemicals or cause electric shock/fire.
Environmental Protection	E-waste contains toxic substances like lead, mercury, and cadmium which pollute soil and water if not disposed of properly.
Regulatory Compliance	Organizations must follow local/state environmental and labor laws related to e-waste disposal and recycling.
Workplace Cleanliness	Accumulation of waste hampers movement and increases accident risk on the shop floor.
Recyclability	Many materials can be recovered and reused if waste is segregated and sent to authorized recyclers.

Safe Handling Procedures for Defective Components

- Wear safety gear (gloves, mask, antistatic gear) while handling sharp, damaged, or toxic materials.
- Use anti-static bins or grounded containers for collecting defective electronic parts.
- Do not mix different types of waste—segregate plastic, metal, battery, and electronic components.
- Place damaged batteries in fire-resistant containers and store away from heat or sunlight.
- Report leaking or hazardous items to the supervisor immediately.
- Keep waste areas clearly marked and easily accessible.
- Avoid reusing defective or untested components.

4.2.4 Automation and Smart Manufacturing in Mobile Accessory Assembly

In modern electronics manufacturing, including mobile accessory assembly, industries are increasingly adopting automation and smart manufacturing to boost speed, accuracy, consistency, and product quality. Robotic systems are used for repetitive tasks such as screwing, soldering, and placement, while Artificial Intelligence (AI) is used to detect defects through machine vision and analyze production data in real time.

Applications in Mobile Accessory Assembly

Technique	Description	Where It's Used
Robotic Assembly Arms	Perform high-speed, precise placement of components or tightening screws.	Assembling USB cables, screwing charger casings
Pick-and-Place Robots	Automatically pick parts from bins and place them on PCBs.	Mounting ICs or connectors
AI-Assisted Visual Inspection	Cameras with AI algorithms detect misalignment, missing parts, or surface defects.	Quality checks after assembly

Automated Soldering Stations	Robots apply solder precisely using heat and flux.	PCB-based assembly in chargers and earphones
Conveyor with Sensors	Move products through stations; sensors detect faulty units or delays.	Production lines of earphones, chargers
Barcode/QR Tracking	Tracks product through stages using code scans.	Component traceability for inventory or rework

4.2.5 Following ESD-Safe Handling Procedures for Component Protection

- Electrostatic Discharge (ESD) can instantly damage sensitive components like ICs, PCBs, and connectors used in mobile accessories such as chargers, earphones, and USB cables. A static charge from the human body or tools can destroy or degrade components, leading to defects and performance issues.
- Therefore, ESD-safe handling procedures are essential for every line assembler working with electronics.

Fig. 4.2.1: ESD Protection Equipment and Methods

Step	Action	Purpose
1. Wear an ESD Wrist Strap	Connect the wrist strap to a grounded surface before starting any work.	Equalizes electrical potential and safely drains static charges from the body.
2. Work on an ESD-Safe Workstation	Use a grounded ESD mat on the worktable. Ensure the mat is properly connected to the earth ground.	Prevents charge build-up on surfaces where components are handled.
3. Use ESD-Safe Clothing and Footwear	Wear anti-static apron, gloves, and ESD shoes or heel straps.	Limits the generation and accumulation of static on your body or clothes.

4. Handle Components by the Edges	Avoid touching pins, leads, or conductive areas of PCBs or connectors.	Prevents direct transfer of static to sensitive points on components.
5. Use ESD-Safe Storage Materials	Place components in anti-static trays, pink poly bags, or shielding bags when not in use.	Keeps items protected during transit and storage.
6. Ground All Tools and Equipment	Ensure soldering stations, screwdrivers, and testing machines are grounded.	Prevents static from transferring through tools during use.
7. Avoid Unnecessary Movement	Minimize walking or rubbing clothing while handling components.	Movement increases static build-up.
8. Control Environmental Conditions	Maintain relative humidity between 40–60% and avoid dry air.	Low humidity increases static generation.
9. Follow Signage and Safety Labels	Be aware of areas marked as ESD-protected zones (EPA) and comply with all precautions.	Ensures only trained personnel handle sensitive materials.
10. Inspect and Maintain ESD Equipment Regularly	Test wrist straps, mats, and grounding connections daily.	Detects faults and ensures continuous ESD protection.

4.2.6 Demonstrate How to Test Assembled Accessories for Electrical Functionality, Durability, and Compliance With Applicable Quality Standards

Once a mobile accessory is assembled, it must undergo specific tests to confirm:

- It works as intended (functionality)
- It can withstand daily usage (durability)
- It meets industry or organizational quality standards (compliance)

Testing ensures defect-free and safe-to-use products reach consumers.

Test Type	Purpose	Example Accessories	Tools/Equipment
Electrical Functionality Test	Check if power, signals, and connections are working properly	Chargers, USB cables, wired earphones	Multimeter, continuity tester, load tester
Durability Test	Simulate wear and tear through repeated use	Charging cables, earphones	Flexing machine, plug/unplug test setup

Short Circuit & Overload Test	Ensure safety against circuit failure or excess current	Chargers, power banks	Power supply unit, ammeter, thermal camera
Voltage/Current Output Test	Confirm accurate power delivery	Wall chargers, data cables	Voltmeter, USB tester
Audio Output Test	Assess clarity and range of sound	Wired earphones, Bluetooth headsets	Audio analyzer, speaker testing jig
Water/Splash Resistance (if applicable)	Test against minor water exposure	Some rugged accessories	Drip or spray test chamber
Compliance Check	Compare with standard guidelines (e.g., BIS, RoHS)	All types	Test report vs checklist

Basic Electrical Test for a USB Charger

1. Connect the charger to a power supply.
2. Attach a USB load tester.
3. Read voltage output (should be around 5V).
4. Check current output with a load (usually 1A or more).
5. Inspect LED indicators or heating (if present).
6. Log results for quality documentation.

4.2.7 Disposal of Defective or Rejected Components Following Guidelines

Defective electronic components such as damaged PCBs, broken connectors, or non-functional chargers must be disposed of carefully to avoid:

- Environmental pollution
- Electrical hazards
- Regulatory violations

Disposal must follow e-waste management rules, especially under India's E-Waste (Management) Rules, 2022 and organization-specific SOPs.

Step-by-Step Disposal Process

Step	Action	Purpose
1. Identify and Segregate	Separate defective or rejected items from good stock during inspection/testing	Avoids accidental reuse of faulty parts
2. Label and Tag	Use "DEFECTIVE", "REJECTED", or "SCRAP" labels with date and reason for rejection	Ensures traceability and proper documentation
3. Store in Designated Scrap Bins	Place components in color-coded bins or ESD-safe waste containers marked for e-waste	Prevents mixing with regular waste and ensures safety

4. Maintain a Scrap Log	Record quantity, part type, date of disposal, and technician details	Helps in tracking and future audits
5. Follow Disposal Channel	Hand over to certified e-waste recyclers or internal disposal units as per company protocol	Ensures legal compliance and safe recycling
6. Do Not Burn or Landfill	Never dispose electronic parts in open trash, water sources, or incinerators	Avoids air, soil, and water pollution
7. Use Personal Protective Equipment (PPE)	Wear gloves and follow safety protocol while handling sharp or broken parts	Ensures worker safety during handling

Examples of Components to Dispose Safely

- Burnt circuit boards
- Cut wires or shorted cables
- Broken earphone parts
- Rejected chargers or connectors
- Swollen or leaky batteries (to be handled as hazardous waste)

4.2.8 Demonstrate Adherence to Workplace Safety and Cleanliness Guidelines Throughout the Process

A clean and safe workplace is essential in the electronics and telecom assembly industry, especially when handling sensitive electronic components. Negligence in safety and cleanliness can lead to:

- Product defects
- Electrostatic damage (ESD)
- Workplace accidents
- Regulatory non-compliance

Adherence to safety norms and hygiene protocols promotes a productive and professional environment.

Area	Key Practice	Purpose
Personal Safety	Wear PPE: gloves, antistatic wristbands, aprons, masks	Prevents ESD, injuries, and contamination
Tool Safety	Inspect tools before use; ensure blades, wires, and probes are intact	Prevents accidents and ensures accurate work
Workstation Cleanliness	Wipe surfaces regularly; avoid clutter and spills	Reduces contamination and fire/electrical hazards
Component Handling	Use ESD-safe mats, containers, and tweezers; avoid bare-hand contact	Prevents electrostatic or physical damage
Electrical Safety	Switch off tools after use; avoid overloading sockets	Reduces electrical shock and fire risks
Waste Disposal	Segregate and dispose of waste and defective parts in proper bins	Ensures cleanliness and regulatory compliance

Emergency Preparedness	Know the location of fire extinguishers, first aid kit, and emergency exits	Ensures readiness during accidents
Reporting Hazards	Immediately report unsafe conditions (wet floor, sparks, broken tools) to supervisor	Prevents accidents and ensures timely correction

Maintaining safety and cleanliness is as critical as technical skills. It protects both people and products, enhances productivity, and upholds workplace standards and regulations.

Notes

UNIT 4.3: Troubleshooting, Documentation, and Digital Production Systems

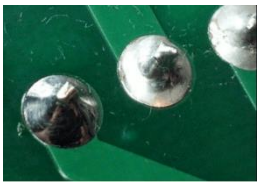
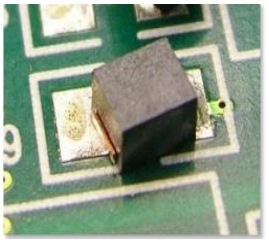
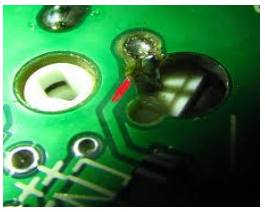
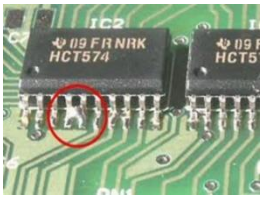
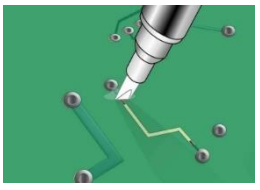
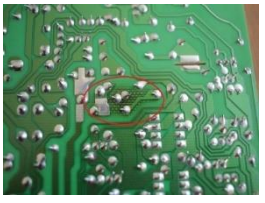
Unit Objectives

By the end of this unit, the participants will be able to:

1. Discuss common assembly defects, their causes, and basic troubleshooting techniques using visual inspection and simple testing tools.
2. Discuss the standard procedures for assembling different types of mobile accessories, including handling sequence, safety protocols, and quality considerations.
3. Discuss the role of digital production records and basic ERP system usage for tracking components and production progress.
4. Show how to conduct basic visual inspections as per the quality checklist for defects such as misalignment, loose connections, or surface damage.
5. Demonstrate the use of appropriate measuring tools such as calipers, multimeters, or gauges to verify dimensions and electrical properties.
6. Demonstrate how to identify and rectify minor assembly errors, escalating critical issues to the supervisor.
7. Demonstrate the appropriate quality checks on assembled accessories to ensure compliance with industry standards.
8. Show how to follow standard procedures for packaging, labeling, and storing finished accessories to prevent damage.
9. Demonstrate how to document and report production outputs, quality issues, and inventory usage using digital tracking tools.
10. Show how to use digital tools and ERP systems to track component usage and production progress.

4.3.1 Discuss Common Assembly Defects, their Causes, and Basic Troubleshooting Techniques Using Visual Inspection and Simple Testing Tools

In mobile phone accessory assembly, identifying and addressing common defects is essential to ensure product quality, functionality, and durability. Assembly defects can arise due to human error, improper tool usage, or environmental factors. By using basic visual inspection and simple tools like multimeters, line assemblers can effectively detect, troubleshoot, and rectify these issues before final testing. The table below outlines some of the most common assembly defects, their causes, troubleshooting techniques, and corresponding image references to aid in visual understanding.

Defect Type	Description	Probable Cause(s)	Troubleshooting Techniques	Image Source Link
Cold Solder Joint	Dull, cracked, or poorly formed solder joint	Insufficient heat during soldering or movement during cooling	Re-solder the joint using the correct heat and proper technique	
Component Misalignment	Component is tilted, not centered, or mounted improperly	Manual placement error or machine misfeed	Re-position or replace component; verify alignment with layout diagram	
Lifted Pads/Traces	Copper pads or traces lifted from PCB surface	Excessive heat, physical force, or poor PCB quality	Inspect with magnifying glass, repair with jumper wire or epoxy	
Solder Bridges	Unintended solder connecting two or more pads	Too much solder or bridging during hand-soldering	Remove excess solder using desoldering braid or iron tip	
Cracked Components	Cracks visible on casing or pins of component	Mechanical stress during placement or poor packaging	Replace component, review handling procedure	
No Continuity/ Open Circuit	PCB trace or joint not conducting	Broken trace, bad solder joint, or missing component	Use multimeter to test continuity and re-solder/repair as needed	
Burn Marks/ Overheating	Brown/black marks or melting on components or PCB	Short circuit, high current, or incorrect component used	Inspect visually, replace damaged parts, verify with multimeter	

4.3.2 Discuss the Standard Procedures for Assembling Different Types of Mobile Accessories, Including Handling Sequence, Safety Protocols, and Quality Considerations

Before you start assembling, it's important to follow the correct sequence of steps so that the process is smooth, safe, and error-free.

Step	What You Do	Why It's Important
Material Check	Collect all parts and tools as per the BoM (Bill of Materials)	Ensures nothing is missing
Workstation Setup	Clean your table and arrange tools, components, ESD mat	Keeps work area safe and organized
Safety Gear	Wear ESD strap, gloves, apron	Protects you and the components
Component Preparation	Check and clean wires, connectors, PCBs	Avoids defective parts being assembled
Assembly	Solder, fit wires, connect connectors, fix screws	Main step to build the product
Sub-assembly Test	Test small parts before final assembly	Helps catch early mistakes
Final Assembly	Fit outer casing, labels, complete product	Gets product ready for testing
Functional Test	Check power, charging, sound, etc.	Ensures product works properly
Visual Check	Inspect alignment, finish, labels	Looks professional and avoids rework
Packing	Pack safely with label, manual, and barcode	Keeps product safe during transport

4.3.3 Discuss the Role of Digital Production Records and Basic ERP System Usage for Tracking Components and Production Progress

In a mobile accessory assembly unit, we make many items every day – like chargers, cables, earphones, etc. To keep a record of what is being made, how many parts are used, how many units are rejected, and what stage the work has reached, we use digital tools instead of writing everything on paper.

These digital records are called Production Records.

Purpose	Why It Matters	Example
Track how many units you made	Helps supervisors plan next batch	200 power banks made today, 3 rejected
Know how many parts are used	Prevents running out of stock	Used 500 USB connectors – reorder needed
Trace problems	Find which batch or operator had issues	10 cables failed – check operator log
Save time	Faster than paper logbooks	Scan and update instantly on tablet
Maintain accuracy	Reduces human errors	No wrong counting of components

4.3.4 Show How to Conduct Basic Visual Inspections as Per the Quality Checklist for Defects Such as Misalignment, Loose Connections, or Surface Damage

Visual inspection means carefully looking at a product with your eyes (sometimes using a magnifying glass or lamp) to check if it looks right or has any visible problems.

Quality Checklist for USB Charger:

Point to Check	OK? (Yes/No)	Remarks
USB port alignment	Yes / No	—
Outer casing fit properly	Yes / No	—
Surface clean, no scratch	Yes / No	—
No loose wires or rattling	Yes / No	—
Label/marking clear	Yes / No	—

Common Defects to Look For

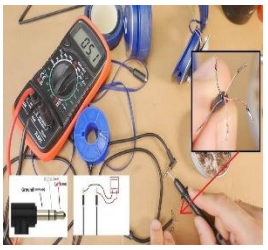
Defect	What It Looks Like	What to Do
Misalignment	Ports or buttons not centered	Send for rework
Loose wire	Part moves or sound comes when shaken	Inform supervisor or fix if allowed
Scratch/crack	Visible marks on surface	Replace part or send to quality team
Missing label	Barcode, logo, or ISI mark not there	Add missing label if possible

In mobile accessory assembly, this is the final step before testing or packaging — to make sure the product is clean, properly assembled, and free from defects.

4.3.5 Using Measuring Tools to Check Size and Electrical Values in Mobile Accessories

In mobile accessory assembly, it's important to ensure that each part fits correctly and works properly. For this, we use special tools to measure dimensions (like length, width, thickness) and electrical properties (like voltage, resistance, and continuity).

Tools like calipers, multimeters, and gauges help us check if the components meet the required standards before and after assembly. This ensures the final product is safe, reliable, and ready for use.

Tool Name	Purpose / What It Measures	How to Use It (Step-by-Step)	Example from Mobile Accessory	Image Reference
Vernier Caliper	Measures external and internal dimensions (in mm)	1. Clean the jaws2. Place part between jaws3. Read value on scale	Check if USB-C connector is 8.5 mm wide and fits in casing properly	
Digital Multimeter	Measures voltage, resistance, and continuity	1. Set dial to required function (e.g., continuity) 2. Touch probes to the two test points 3. Read display	Check if earphone wires are connected properly (continuity), or check output voltage of a charger	
Wire Gauge (SWG/Metric)	Checks thickness of wires	1. Match the wire to the correct slot in the gauge 2. Read the size marking	Ensure correct wire size (e.g., 24 AWG) is used in USB cable for fast charging	
Torque Screwdriver	Measures tightening torque of screws	1. Set required torque level 2. Tighten screw until tool slips/clicks 3. Don’t overtighten	Use to tighten screws in power bank casing without cracking plastic	
Go/No-Go Gauge	Checks if a part’s size is within tolerance	1. Try inserting part into "Go" side – should fit 2. Try "No-Go" side – should not fit	Check if jack pin fits properly in mobile connector slot	

4.3.6 Demonstrate How to Identify and Rectify Minor Assembly Errors, Escalating Critical Issues to the Supervisor

During mobile accessory assembly, small errors can happen—like loose wires, misplaced labels, or screws not tightened.

As a line assembler, it's important to know:

- Which errors you can fix yourself
- Which problems you must report to your supervisor immediately

This helps in maintaining quality, avoiding rework, and ensuring the product is safe and functional.

Error	How to Identify	How to Fix
Label misaligned	Looks tilted or in the wrong spot	Remove and reapply straight
Screw is loose	Casing rattles or feels open	Tighten using the correct screwdriver
Wire not fully inserted	Part not working or unstable	Push wire in again and crimp properly
Solder joint dull or cracked	Poor connection, fails continuity test	Re-solder using iron and flux
Small scratch on casing	Visible on surface	Clean or replace casing if needed

If you find any of these issues, do not try to fix them yourself. Inform your supervisor immediately:

Critical Issue	Why Escalate?
Burnt or damaged PCB	May cause fire or failure
Cracked battery or leakage	Dangerous for user and environment
Broken connector or port	Needs replacement part or rework station
Major short circuit	Requires safety check and testing
Repeated failure in batch	May be a bigger issue with supply or process

4.3.7 Demonstrate the Appropriate Quality Checks on Assembled Accessories to Ensure Compliance With Industry Standards

Once a mobile accessory (like charger, earphones, or USB cable) is fully assembled, it must be checked for quality before packaging.

These quality checks make sure the product is:

- Safe to use
- Performs correctly
- Meets the company and industry standards

This step helps prevent defective products from reaching the customer.

Check Type	What to Look For	Tools/Methods Used	Example
Visual Check	Cracks, loose parts, scratches, misalignment	Eyes, Magnifier, Quality Checklist	Look for bent charging pin in charger
Functionality Test	Device turns on, charges, or transmits sound properly	Mobile phone, test bench, battery unit	Plug charger into power and check if mobile charges
Continuity Test	Electric path is complete	Multimeter (Beep test)	Check cable wires – all pins connected
Dimension Check	Proper size as per design	Caliper, gauges	USB plug width is exactly 8.5 mm
Tightness Check	Screws or joints are properly fixed	Torque screwdriver or hand check	Casing doesn't move or rattle
Label & Marking	Correct product code, batch no., logo	Visual with reference sample	Label not upside down or missing
Load Test (if applicable)	Device handles load safely	Load simulator/test device	Charger gives 2A current without overheating

4.3.8 Packaging, Labeling, and Storing Finished Accessories to Prevent Damage

After mobile accessories like chargers, earphones, or cables are fully assembled and pass quality checks, the next important step is packaging, labeling, and storing.

Proper handling at this stage prevents damage, maintains product quality, and ensures the customer receives a clean and working item.

1. Packaging Procedures

Good packaging protects the product from dust, moisture, scratches, and physical damage during transport or storage.

Steps to Follow:

Step	Action	Tips
a) Cleaning	Wipe the product with clean cloth if needed	Remove dust or fingerprints
b) Primary Packaging	Place the product in a small plastic pouch, bubble wrap, or tray	Use anti-static bags for electronic parts
c) Secondary Packaging	Put the wrapped product into a branded box or blister pack	Check box is not crushed or torn
d) Sealing	Close the box using proper tape or lock	Tamper-proof seals may be required

Example:
A USB charger is wrapped in bubble wrap and inserted into a printed box with user manual and warranty card, then sealed.

2. Labeling Procedures
Labels provide important details like product name, batch number, and instructions.
Correct labeling helps in tracking and customer understanding.
Label Must Include:

- Product Name (e.g., "Fast USB Charger – 18W")
- Manufacturing Date & Batch Number
- Company Logo and Address
- Barcode or Serial Number
- Safety Marks (if required, like BIS or CE)

Where to Apply:

- On the product (if applicable, like at the back of the charger)
- On the packaging box
- On shipping cartons

Example:
A barcode sticker and label with product name and batch number is pasted on the side of the charger box.

3. Storing Finished Products
Why It's Important:
Proper storage keeps products safe from damage, theft, or environmental harm before dispatch.
Standard Storage Practices:

Do	Don't
Stack boxes neatly on racks or pallets	Don't place heavy boxes over fragile ones
Keep away from direct sunlight, heat, and water	Don't store near windows or leaking areas
Follow FIFO (First In, First Out) method	Don't use random storage
Use labels to identify batch and date	Don't mix different products without marking

Special Notes:

- Store in temperature-controlled and dust-free area.
- Mark "Fragile" or "Handle with Care" if needed.

Example:
Finished earphones are packed in individual boxes, placed in a master carton, and stored on labeled metal racks in the storage room.

4.3.9 Digital Documentation & Reporting

Accurate and timely documentation is essential in assembly operations to ensure efficiency, quality, and accountability. Key records—such as production output, quality issues, and inventory usage—not only track daily activities but also support performance monitoring, defect prevention, and effective resource management. Using tools like ERP systems, mobile apps, or spreadsheets, teams can maintain clear, consistent records that drive continuous improvement.

What to Record	Purpose	What to Include	Tool Examples	Why It Matters
Production Output	Track number of units assembled	Date, Product Name, Units Assembled, Operator Name	ERP system, Excel sheet, Mobile App	Tracks team performance and production status
Quality Issues	Record defects and actions taken	Product Type, Defect Found, Quantity, Reported To, Action Taken	ERP Quality Module, Google Form, QA App	Ensures defect tracking, helps prevent future errors
Inventory Usage	Track use of parts and materials	Component Name, Issued Qty, Used Qty, Balance, Used For	ERP Inventory, Barcode Scanner, Spreadsheet	Avoids material shortage and misuse

Show how to use digital tools and ERP systems to track component usage and production progress

In assembly operations, digital tools and ERP (Enterprise Resource Planning) systems help track production output, component usage, and quality issues efficiently. These systems allow workers to record how many units are assembled, what materials are used, and any defects found—using mobile apps, spreadsheets, or barcode scanners.

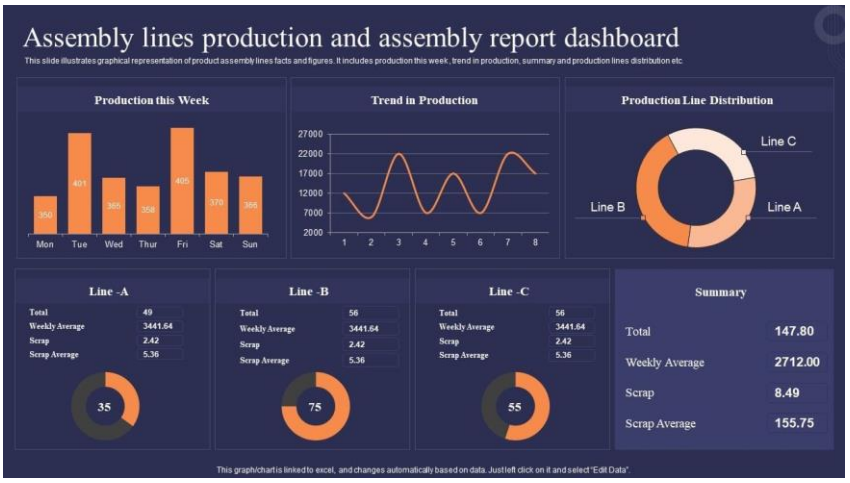


Fig 4.3.1 ERP system dashboard

Using ERP ensures accurate data entry, reduces errors, prevents material shortages, and helps supervisors monitor performance and plan better. For a Line Assembler, learning to use such tools is key to maintaining productivity, quality, and smooth workflow on the shop floor.

Exercise

Multiple Choice Questions (MCQ):

1. Which tool is used to check electrical continuity in wires and components?
   a) Vernier caliper
   b) Wire gauge
   c) Multimeter
   d) Go/No-Go gauge
2. What is the purpose of a "Sub-assembly Test" during mobile accessory assembly?
   a) To clean tools
   b) To fix outer casing
   c) To test small parts before final assembly
   d) To label the product
3. Which of the following is a critical issue that must be escalated to the supervisor?
   a) Misaligned label
   b) Loose wire
   c) Burnt or damaged PCB
   d) Scratch on the casing

Short Questions:

1. What are some common assembly defects found in mobile accessories?
2. Why is it important to use digital tools or ERP systems in production?
3. What are the main steps in standard packaging of a mobile accessory?

True or False:

1. Solder bridges can cause unintentional connections between two or more pads. ☐
2. A torque screwdriver is used to measure electrical resistance. ☐
3. Labeling a product includes information like batch number, product name, and company logo. ☐
4. Visual inspection is not required if functionality tests pass. ☐

Fill in the Blanks:

1. A _____ solder joint appears dull or cracked and may lead to poor electrical connections.
2. The First In, First Out method is commonly referred to as _____.
3. A _____ gauge is used to check the thickness of wires.
4. _____ inspection is done to visually check for misalignment, cracks, or missing labels.
5. In an ERP system, tracking of defects and actions taken is done under the _____ module.

Notes

5. ESD Safe Procedures and Practices

Unit 5.1 - ESD and Its Effects on Electronic Components
Unit 5.2 - Classification of ESD Materials
Unit 5.3 - ESD Safety Procedures
Unit 5.4 - Levels of Electrostatic Voltage Generation
Unit 5.5 - Grounding
Unit 5.6 - ESD Audit

TEL/N2508

Key Learning Outcomes

By the end of this module, the participants will be able to:

1. Elucidate the basics of Electrostatic Discharge (ESD), its sources in the workplace, and its impact on electronic components and product performance.
2. Explain the necessity of following ESD policies, procedures, and safety guidelines to protect electronic components and ensure product quality.
3. Demonstrate how to follow safe work practices as per the ESD process and protocol.
4. Describe the classification and properties of ESD-safe materials, appropriate PPEs, and the use of storage/packaging solutions like trays and bags.
5. Demonstrate the correct use of ESD tools/equipment such as static voltage checkers, wrist straps, shoe grounders, air ionizers, and ionized air guns.
6. Discuss the methods for identifying ESD-sensitive parts, packages, and areas, including the use of precautionary labels, packaging, and handling instructions.
7. Describe proper handling, storage, and stacking methods for ESD-sensitive components, sub-assemblies, and assemblies to prevent failures.
8. Demonstrate the correct method to pack and unpack electronic components in compliance with ESD processes.
9. Show how to handle semi-finished products after assembly operations using ESD-free trays and conveyor lines.
10. Determine the voltage buildup during routine activities (walking, soldering, cleaning), discharge paths, and associated risks in non-ESD safe areas.
11. Show how to identify and remove non-essential items and equipment carrying electrostatic generating potential.
12. Explain essential grounding techniques and accessories (tables, mats, flooring, wrist straps) for minimizing electrostatic risks, including regular inspections and audits.
13. Show how to properly ground all components in the work area.
14. Show how to implement advanced grounding techniques to mitigate electrostatic risks.
15. Discuss the procedures for conducting ESD audits on workstations, flooring, protective gear, and facility areas, ensuring compliance with ISO 9001 (quality) and ISO 27001 (information security).
16. Demonstrate how to ensure compliance with ISO 27001 standards for information security in ESD-sensitive operations.
17. Elucidate the use of ionized air guns, machine vision systems, and smart manufacturing techniques for real-time ESD.
18. Demonstrate the use of machine vision systems to identify ESD safety violations and ensure compliance.

UNIT 5.1: ESD and Its Effects on Electronic Components

Unit Objectives

By the end of this unit, the participants will be able to:

1. Elucidate the basics of Electrostatic Discharge (ESD), its sources in the workplace, and its impact on electronic components and product performance.
2. Explain the necessity of following ESD policies, procedures, and safety guidelines to protect electronic components and ensure product quality.
3. Demonstrate how to follow safe work practices as per the ESD process and protocol.

5.1.1 ESD Fundamentals

We go through occurrences of static electricity daily. For instance, walking on a carpeted in a heated/ warm room during winter produces sufficient static electricity.

Although this sudden discharge of static electricity does not result in any harm to the human body, it can cause heavy damage to electronic equipment as they are sensitive to electrical discharge (ESD). It may happen that electronic equipment to get damaged by electrical charges that is imperceptible to us.

Certain components are very sensitive to static electricity that can definitely destroy the component. Static charges are created when there is a separation of non- conductive materials friction between synthetic clothes, combing your dry shampooed hair for a long period of time during winter sparks up static electricity is called Electro static Discharge (ESD).

- Destructive static charges are followed on nearby conductors like human skin that develops a spark when the surface of the printed board is touched by a person who has developed a static charge
- If the board is touched at the right solder joint, the circuit board will be damaged because of the discharge of the static electricity. It is damaged because it passes through a conductive pattern to a component which is static sensitive
- It is very important to note that, this is not felt by human beings, as it is less than 3,000 volts(the static level of damage of components)
- Apart from designing the circuit correctly for suppression of ESD the layout and the design of PCB (Printed Circuit Board) is also important, as it will save money later if it is ensured that the ESD is according to the layout of the PCB as there will be no costly debugging

There are guidelines to ensure that the PCB design will be able to reduce the problem of the ESD to the minimum range.

Guidelines	Steps/ procedure
Removing of circuit loops	• Unwanted current is risen, from loops in a line that arises from induction • The performance level is picked up from unwanted pick up of current • For general protection of ESD it is important because unwanted increase of current hence voltage is evoked in the loops • Ultimate care must be taken so that current cannot be induced into loops and that no loops is existing

Utilising the ground plane layers in the Printed Circuit Board(PCB)	• One way of reduction of ground loop is by using a ground plane layer in the designing of the PCB • This ensures and enables that any signals shall be effectively grounded so that there is no chance of ground loops
Reduction of line lengths	• Any kind of wire acts as an antenna and has the capacity of receiving high spikes of voltage, with the very short rise of voltage spike • If the line lengths are reduced then, the level of energy that is received is reduced and the spikes resulting from lower electrostatic discharge shall be lower
Reduction of parasitic induction around protection circuits	• Many electronic circuits are induced with ESD protection circuits • These can only result effectively if the induction of parasite is kept low • It is possible to keep it low(parasitic induction) arising from the design of the PCB, if the length of the line is short, keeping the width of the track broad • Conductors of measurable dimensions that is moving through a magnetic field which is uniform; or stagnant under a magnetic field that is changing shall have current generated within them • Inductive coils specifically uses magnetic cores to lessen the parasitic induction within them
Prevent running of the sensitive tracks near PCB	• As current pick up shall be close to the circuit area it is very wise to keep away the sensitive lines or tracks from this area • The input and the output lines will have to join the edge of the PCB at some stage, but it must be routed away where ever possible

Application of the correct guidelines of preparing the ESD for the layout or designing the PCB is important during the assembly, that will ensure it to be resilient to any voltage or current discharge that might occur. Applying the ESD design at the earliest of stages, saves a lot of money for not having to rework or redesigning

List the number of components and modules received from the stores and take sign off from stores department-

A receipt is an acknowledgment which is documented, that something valuable has been transferred from one person to another. It is typically received by the customer for the service that has been rendered to them. There must be an invoice even from the stores department.

Application of the correct guidelines of preparing the ESD for the layout or designing the PCB is important during the assembly, that will ensure it to be resilient to any voltage or current discharge that might occur. Applying the ESD design at the earliest of stages, saves a lot of money for not having to rework or redesigning

List the number of components and modules received from the stores and take sign off from stores department-

A receipt is an acknowledgment which is documented, that something valuable has been transferred from one person to another. It is typically received by the customer for the service that has been rendered to them. There must be an invoice even from the stores department.

Invoices must include:

- The word invoice must be written clearly on the document. And it must specifically contain all these information
- The company's name, address and contact number must be provided
- The unique identification number of the company
- The name of the company and their address for whom the invoicing is taking place
- The date on which the goods were supplied to the company
- List of the components that has been supplied
- A clear detailed description for what is being charged
- The amount of charge must be clearly mentioned
- Date of the invoice
- The GST (Goods and Services Tax) that is applicable
- The amount that is owed in total

Sole trader invoice- a sole trader invoice must include these things:

- Name of the individual person or the name of the company if any
- A particular address where any document whether legal or not can be delivered perfectly

Limited company invoices- A limited company invoice must include the invoice must contain the name of the company as it is on the certificate of incorporation. The names of all the directors must be present too, if there is a mention of the directors' name.

Fig 5.1.1: Sample invoice it will differ according to list and components

There are six principles of static control and six key elements of ESD to be focus:

1. Design assemblies and products to be reasonable and robust from the effects of ESD.
2. Describe the level of control required in the environment.
3. Define and identify the electrostatic protected areas (EPAs), the areas one needs to handle ESD sensitive parts (ESDS).
4. Decrease the generation of electrostatic charge by reducing and eliminating static generating processes, keeping processes and items at the same electrostatic potential, thus enabling proper ground paths to decrease charge generation and build-up.
5. Neutralize and dissipate by proper ionization, grounding, and the usage of dissipative and conductive static control materials.
6. Protect items/ tools from ESD with accurate shunting or grounding and the usage of static control packaging.

ESD can cause permanent damage to the component it is important to follow certain rules to avoid it

- All components must be kept in antistatic bags till the time the assembler is ready to install the components
- Make use of the grounded mats while on the workbenches.
- Make use of grounded floor mats including the work areas.
- Make use of antistatic wrist straps while working on the computer system

Notes

UNIT 5.2: Classification of ESD Materials

Unit Objectives

By the end of this unit, the participants will be able to:

1. Describe the classification and properties of ESD-safe materials, appropriate PPEs, and the use of storage/packaging solutions like trays and bags.
2. Demonstrate the correct use of ESD tools/equipment such as static voltage checkers, wrist straps, shoe grounders, air ionizers, and ionized air guns.

5.2.1 Classifying ESD Materials

To control ESD, materials are categorized by how quickly electricity passes through the material. The speed is implied as the "resistance" of the material i.e. how firmly the material prevents charge movement.

The speed is measured in Ohms and is typically displayed in powers of 10 (example 10^3). The lower the number, the more conductive the material and may be considered "Antistatic."

Classification	Charge Movement	Description	Resistance	Ohms	Is it Antistatic?
Conductive	Very Fast	**Conductive materials:** With a low magnitude of electrical resistance, electrons pass smoothly through the surface or across the bulk of these materials. Charges go to another conductive object or to ground that the material comes close to or contacts. Conductive materials have a surface resistivity a tick less than 1 x 10^5 Ω/sq. Conductive materials are categorized as "Antistatic".	Low Resistance	10^3 - 10^ 5	Yes
Dissipative	At a controlled speed. Fast but Slower than Conductive	**Dissipative materials:** For dissipative materials, the charges slowly pass through the material in a more controlled manner than that of conductive materials. Dissipative materials possess a surface resistivity greater than or equal to 1 x 10^5 Ω/ sq. and less than 1 x 10^12 Ω/ sq. Dissipative materials are categorized as "Antistatic" and are accounted as the ideal range for ESD materials.	Medium Resistance	10^6 - 10^ 10	Yes

Insulative	Slow or No Movement	**Insulative materials:** These materials limit or prevent the flow of electrons across their surface or through their volume. Insulative materials exhibit a high electrical resistance and are hard to ground. Static charges stay in place on such materials for a very long time. Insulative materials are those with a surface resistivity of at least 1 x 10^12 Ω/sq. or a volume resistivity of 1 x 10^11 Ω-cm (minimum). Insulative materials cannot be classified as "Antistatic".	High Resistance	10^11 - 10^ 12	No

Anti-Static: It is a term used to describe materials that prevent the build-up of static electricity. Both conductive and dissipative materials are classified as Antistatic. Insulative materials are not.

Typical Static Charge Sources:

Source	ESD Producing Material
Work Surfaces	Waxed, painted or varnished surfaces, untreated vinyl and plastic, glass
Floors	Sealed concrete, waxed or finished wood, floor tile and carpeting
Clothes and Personnel	Non-ESD smocks, synthetic material, non-ESD shoes, hair
Chairs	Finished wood, vinyl, fibreglass, non-conductive wheels
Packaging and Handling Materials	Plastic bags, wraps, envelopes, bubble wrap, foam, Styrofoam, non-ESD totes, trays, boxes, and parts bin
Assembly Tools and Materials	Pleasure sprays, compressed air, synthetic brushes, heat guns and blowers, copiers and printers

Typical Static Voltage Generation

Source	10-20% Humidity (in Volts)	65-90% Humidity (in Volts)
Walking on carpet	35000	1500
Walking on vinyl flooring	12000	250
Worker at a bench	6000	100
Vinyl envelopes (work instruction)	7000	600
Plastic bag picked up from the bench	20000	1200
Work chair with foam pad	18000	1500

Notes

UNIT 5.3: ESD Safety Procedures

Unit Objectives

By the end of this unit, the participants will be able to:

1. Discuss the methods for identifying ESD-sensitive parts, packages, and areas, including the use of precautionary labels, packaging, and handling instructions.
2. Describe proper handling, storage, and stacking methods for ESD-sensitive components, sub-assemblies, and assemblies to prevent failures.
3. Demonstrate the correct method to pack and unpack electronic components in compliance with ESD processes.
4. Show how to handle semi-finished products after assembly operations using ESD-free trays and conveyor lines.

5.3.1 Safe Cleaning Practices

The various materials to be used by the housekeeping staff for cleaning are:

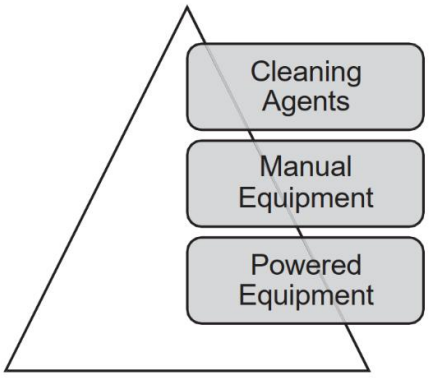


Fig. 5.3.1: Cleaning process

A. Cleaning Agents

- **Solvents**
  - A solvent is a liquid that is capable of dissolving a liquid or solid solute, producing a solution
  - Water is the widely used solvent in daily life
  - Water can also dilute any cleaning solution for ease of usage
  - Warm water dissolves solutes such as soap faster than cold water
- **Detergents & Soaps**
  - Soaps and detergents are used as cleaning objects because pure water cannot remove organic soiling or oily particles
  - Soap is one of the rare objects that allow water and oil to mix so that rinsing can take care of the removal of the oily grime
  - Detergents, in terms of properties, are similar to soap. However, they are less likely to form soap scum and are not hugely impacted by the presence of mineral particles in hard water

- Detergents to be used depend on:
  - Material to be cleaned
  - Cleaning equipment to be used
  - Type of dirt

- **Liquid Cleaning Agents**
  - Liquid cleaning agents can be either diluted in water or used directly with a dry cloth.
- **Washing Soda**
  - It is useful for emulsifying grease on drainpipes, gutters or stone surfaces.
  - In strong concentration, it could be an irritant and injurious to skin, fabrics brushes, wood and paint.
  - Washing soda is useful as a water softener.
- **Soda bars, Powders and Flakes**
  - In recent days, normal soaps have been substituted by excellent synthetic soap which comprises less detergents and less affected by hard water
  - They give lather promptly
  - They should be made thoroughly dissolved in water
  - Should be used in right proportion and concentration for best outcomes
  - Should be kept or stored on open shelves in a dry storage area
- **Acid**
  - Acids are used to remove metal stains
  - Lemon and vinegar are used to remove the tarnish of brass and copper
  - Resistant water stains is removed with stronger acids such as hydrochloric acid or oxalic acid
  - This should be used under experienced and strict supervision to avoid risks
- **Alkali**
  - Sodium hydroxide, ammonia and caustic soda are alkalis and are used as stain removal agents and grease emulsifiers
  - Strong alkaline cleaning agents based on liquid or caustic soda in flakes are available for the cleaning of large industrial equipment, and blocked drains
  - Extreme care is to be taken in their use as they are very strong and are highly corrosive.
- **Absorbents**
  - These perform the cleaning action by absorbing the stain or grease; for example, starch, French chalk powders, and besan or gram flour.
  - Their constituents may differ and many are of vegetable origin.
  - Unlike abrasives, they are not manufactured.
- **Toilet Disinfectants & Antiseptics**
  - Disinfectants & Antiseptics are not strictly cleaning agents but are often used during cleaning operations.
  - Disinfectants kill bacteria.
  - Antiseptics prevent bacterial growth.

B. Manual and Powered Equipment

Manual cleaning tools and equipment are operated by hands while Powered equipment are connected to a power supply or battery.

- Funnel
- Rubber
- Spatula
- Floor Mop
- Bowl Swab
- Plastic Caddie
- Spray Bottle
- Cobweb Cleaner
- Dry Vacuum Cleaner(Commercial)
- Suction Dryer
- •Dust Pan and Brush
- Bucket and Mug Squeegees Scrubbing Brush Sponge
- Scraper

5.3.2 Safe Cleaning Practices

Uses of Personal Protective Gear

- Personal Protective Equipment, commonly termed as PPE, is specialized clothing or equipment worn and used by employees for safeguarding themselves against Occupational Health and Safety hazards.
- Such clothing are aimed at protecting different parts of the body, like hands, eyes, ears, face, feet, head etc.

Here is a table of personal protective equipment that are widely used.

- **Hand Gloves –** Used for protecting the hands from harmful and corrosive chemicals, extreme temperatures, sharp and contaminated objects. For example, Nitrile gloves are used for protecting the hands against solvents, oils, greases, tar, acids and alkalis. Gloves made of natural rubber or Latex are used for protection against contaminations and biohazard risks. Asbestos gloves are worn while dealing with extremely hot materials.
- **Safety Shoes –** These are made of highly durable and robust material and protect the feet from injuries due to cuts and bruises.
- **Safety Goggles –** These protect the eyes from harmful radiation, dust particles and splinters.
- **Masks and Face Shields-** These are worn especially during welding, gas cutting and brazing operations, in order to protect the face from direct flame, extreme temperatures, dust particles and splinters.
- **Apron –** This protects the clothes from dust and other impurities. These are often heat-resistant and anti-abrasive in nature.
- **Ear Muffs –** These are used in extremely noisy places like workshops and factories, to protect the ears from damages.
- **Respirators -** The masks of the Filtering Face Piece Grade-3 (FFP3) specification that allow only 5%
- air pollutant leakage and filter around 99% of the particles up to 0.6 µm.

People are one of the prime sources of static electricity. The motions required to repair a circuit board or the act of walking around can produce several thousand volts of static electricity on the human body. If it is not controlled accurately, this can discharge into an ESD sensitive device similar to a typical Human Body Model discharge. A person (human body) can also transfer charge to a circuit board or other items making those vulnerable subsequently.

Even in test processes and highly automated assembly, people need to handle ESDS in repair, in the warehouse, in transport, in the lab. Thus, ESD control programmes put considerable emphasis on regulating personnel generated static electricity. On a similar note, the movement of mobile equipment and other wheeled tools also can produce substantial electrostatic charges that transfer to the products attached to the equipment.

Head Protection

Fig. 5.3.2 Safety Helmet

Head injury can impair a worker for the lifetime. Wearing safety helmet is the easiest way to avoid such situations. Safety helmet is used to –

- Protect head from falling objects and knocks
- Reduce risk of head bumping against fixed objects like exposed pipes and beams
- Protect head from accidental electrical hazards

Safety helmet comes in different forms. Some helmets include other protective elements such as goggles; earmuffs attached to it. Safety helmet should be worn on the head, not on any hat or cap.

Eye Protection

Safety Goggle

Safety Spectacle

Facemask

Eye is one of the most delicate organs of the body. Assembling is a job which comes with various hazards related to eye damage. For example, saw dust, small pieces of sharp objects may cause damage to the eye. Therefore, eye protection must be used. Some widely used eye protection are –

- Safety Goggle
- Safety Spectacle
- Facemask

These protections should be worn to avoid any damage owing to wood dust, metal chips in the process of sawing, drilling, grinding, and chiselling.

Hearing Protection

Single Use Earplug

Pre-formed or Modelled Earplug

Ear Defender or Earmuff

Assembling machines such as drilling machine, circular saw, and jigsaw create a lot of noise. Short exposure to the noise may cause temporary hearing loss and long exposure may lead to permanent hearing loss. Therefore, hearing protection is an essential PPE for a line assembler. Some important hearing protection are –

- **Single Use Earplug:** They are made of waxed cotton, foam, silicon rubber or fibre glass wool. When properly inserted, they work like most modelled earplugs.
- **Pre-formed or Modelled Earplugs:** These are small fibre plugs that are inserted to the ear and used in case of severe noise. They can be either disposable or reusable. Reusable plugs should be cleaned after using. Never use plugs which are used by somebody else.
- **Ear Defender or Earmuff:** These are used to cover the entire ear and connected to a band that fits over the top of the head. These are used when the noise is excessively high.

Hand Gloves

Hand Gloves

These are used for protecting the hands from harmful and corrosive chemicals, extreme temperatures, sharp and contaminated objects. For example, Nitrile gloves are used for protecting the hands against solvents, oils, greases, tar, acids and alkalis. Gloves made of latex or natural rubber are used for protection against contaminations and biohazard risks. Asbestos gloves are worn while dealing with extremely hot materials.

Safety Shoes

Safety Shoes

Assemblers, who face possible foot or leg injuries from the falling or rolling objects or from penetrating or crushing materials, should wear protective footwear.

- Safety shoes are used to protect the feet from heavy objects, such as tools that might roll onto or fall on the workers' feet
- It is also used while working with sharp objects such as nails or spikes that could pierce the soles or uppers of ordinary shoes
- It also protects feet from hot, wet or slippery objects

5.3.3 Safe Handling of Semi-Finished Products

ESD safe Plastics are used as the raw ingredient for a variety of high-quality components and final products in fields such as the semi-conductor technology, aerospace industry and in the automotive and mechanical engineering.

To safeguard the functionality and quality of the materials, the recommendations for storage and transportation of semi-finished products need to be observed. This can resist external parameters enforcing a significant change on the material properties. In cases of the end products, the user or manufacturer must submit an individual confirmation of this.

Handling guideline for semi-finished parts

1. Storage and handling should occur in such a way such that the material designations and product numbers (batch number) are clearly identifiable on semi-finished products and can be maintained. Clear traceability and identification of products eases the process of determining the root causes of faults in the event of a complaint.
2. Weathering effects can affect the properties of plastics. As result of solar radiation (UV radiation), atmospheric oxygen and moisture (precipitation, humidity) can exert a lasting negative impact on material characteristics. These effects can lead to colour changes, oxidation of surfaces, swelling, warping, brittleness or even a change in mechanical properties. Hence, semi-finished products should not be exposed to direct sunlight or the effects of weather over protracted periods. Semi- finished products should ideally be stored in closed rooms under normal climatic conditions (23 °C/ 50 %rH).

3. Wherever possible, plastics should not be exposed to low temperatures over long periods. However, particular care should be taken to avoid excessive fluctuations in temperature. These lead to brittleness and to warping of the semi-finished products. The materials must also be protected from heavy impacts, and should never be thrown, as collisions will result in spalling and fracture damage. In addition, semi-finished products stored in cold conditions should be allowed sufficient time to reach room temperature before processing. This will prevent debris, cavities and other defects during processing. This also compensates for any shrinkage or expansion which occurs in plastics due to their high coefficient of thermal expansion.
4. Semi-finished products made of plastic should consequently always be stored flat or on a suitable support (in the case of rods and tubes) and with the greatest possible surface contact in order to avoid deformation through their own intrinsic weight.
5. When handling plastic semi-finished products, ensure that suitable warehousing equipment is used. This includes stable slinging equipment and secure hoists. Semi-finished products must be stacked so as to prevent any possibility of tilting or falling. Bear in mind here that plastics often have a low coefficient of friction and are consequently easily able to slip out of load suspension devices, with the possibility of serious injury to staff members.
6. Avoid the effects of high-energy radiation. The molecular degradation caused by gamma and X rays can result in microstructure damage.
7. Keep semi-finished products away from all kinds of chemicals and also water. Depending on the material, any such contact can result in chemical decomposition, tension crack formation or swelling through the absorption of moisture.
8. As organic substances, plastics are combustible. The combustion or decomposition products may have a toxic or corrosive effect. If correctly stored, plastics themselves do not pose a fire risk. However, they should not be stored together with other combustible substances. On this subject, observe the product handling information sheets for the individual materials.
9. Under normal conditions, semi-finished or finished products do not release any toxic constituents and permit risk-free surface contact. Tobacco products should not be allowed in the vicinity when handling and machining plastics, as particles of some plastics (in particular fluoropolymers) In respect of health protection, please also note the product handling information sheets for the individual materials.
10. If the above recommendations are followed, it may be assumed that no significant changes to typical plastic properties will occur during the storage period. Due to environmental influences, it is possible that minimal surface discoloration may occur. However, this does not represent any significant deterioration of material properties, as the surface is generally only affected down to a few microns in depth

Avoiding damage of components due to negligence in ESD procedures ESD Handling Procedures Checklist:

Only handle unpackaged ESD sensitive items [ESDS] in the ESD protected area [EPA].

When grounded only trained or escorted people in the EPA. Ground all conductors including people in the EPA. Use continuous monitors or test wrist straps at least daily. If ESD footwear is used, test at least daily. Visually check that grounding cords are connected. Keep wristband snug, foot grounder grounding tab in shoe, and ESD smocks fastened. Keep work area clean and clear of all non-essential insulators. Neutralize essential insulators with ionizers with the airflow directed towards the work. Area Use packaging with shielding property to store or transport ESDS outside the EPA.

Notes

UNIT 5.4: Levels of Electrostatic Voltage Generation

Unit Objectives

By the end of this unit, the participants will be able to:

1. Determine the voltage buildup during routine activities (walking, soldering, cleaning), discharge paths, and associated risks in non-ESD safe areas.
2. Show how to identify and remove non-essential items and equipment carrying electrostatic generating potential.

5.4.1 Electrostatic Voltage Generation

Human body conducts electricity and thus is susceptible to electrostatic charges. As a matter of fact, electrostatic charges are generated by movements and collisions of particle. Therefore, while working in a workstation, the possibility of electrostatic discharge, a Line Assembler should always be careful. If not controlled, the static charge can easily discharge into an ESD sensitive device – a typical Human Body Model discharge. Also, a person can transmit charge to a circuit board or other item making it susceptible to Charged Device Model incidents in a subsequent process.

What is ESD?

We experience occurrences of static electricity every day. For example, walking along a carpeted floor in a heated room during winter generates sufficient static electricity.

Although this sudden discharge of static electricity does not result in any harm to the human body, it can cause heavy damage to electronic devices as they are sensitive to electrostatic discharge (ESD). It is possible for electronic devices to be damaged by ESD that is imperceptible to the human body.

In order to prevent any component damage from to electrostatic discharge, it is better to adopt precautionary measures. The precautionary aspect to ensure zero damage can be achieved by two means.

Circumstances under which electro-static discharge takes place are as follows:

- During welding process there is flow of current in a conductor. If a person touches a, current may flow through the body to the ground and cause a shock.
- The more there is increased electrical contact with the ground; more is the risk of shock.
- Avoid standing on wet surfaces, in water, or working with wet hands or wearing sweaty garments.
- Small shocks could cause you to slip and fall.

Let us see what precautions you can take to avoid ESD

- Wear clothing made from tightly woven, heavyweight, 100% wool or cotton to protect from UV
- radiation, hot metal, sparks and open flames.
- Keep clothing hygienic and free of oils, greases and combustible contaminants.
- Wear full-sleeved shirts with buttoned cuffs and a collar to protect the neck.
- Keep your shirt pockets closed and covered to avoid collecting sparks or metals scraps.
- Pant legs must be without cuffs and must cover the tops of the boots.

- Repair all edges, tears or holes in clothing.
- Wear high-top boots completely laced to prevent sparks from entering the boots.
- Use fire-resistant boot protectors to prevent sparks from bouncing in the top of the boots.
- Do not keep lighters or matches in pockets.
- Direct spark sprays away from clothing.
- Wear leather aprons to secure your lap and chest from sparks while standing or sitting. Protect your forearms and wrists by wearing leather gloves and sleeves.
- Wear layers of clothing. But you must make sure that you do not sweat.
- Wear a fire-resistant cap under your helmet to protect your head from burns and UV radiation.
- Wear a welder's face shield to secure your face from UV radiation and flying particles.

The 5S standard that any organization follows comprises of "Sort", "Set In Order", "Shine", "Standardize" and "Sustain". This helps to maintain smooth working and avoid confusion during work. But along with this another S has been added to the list, that is, 'Safety'. As a welder you must be aware of personal safety as well.

The potentially sensitive tip of the soldering iron comes in contact with the voltage during soldering. Therefore, it is generally assumed that the tip causes ESD. However, the soldering iron and its tip are a few of the components used at a workbench. Various other components that lay on the workbench like tweezers, test equipment, wiring, etc. can also be sources of ESD/EOS since they come in contact with the component or board.

What is EOS?

EOS stands for Electrical Over-Stress. Every form of energy ultimately converts to Thermal Energy, and Electrical Energy is no exception. When a device is subjected to Electrical energy for a long time, it produces heat. A simple analogy is the monitor or CPU of a computer, which get heated if used for a long time.

However, every electronic device is safeguarded up to a certain level from the generation of heat. In case, the limit or the capacity is crossed, it can cause damages to the device.

The incident, where a tool gets distorted from excessive electrical energy consumption or conduction, is classified as Electrical Over-Stress or EOS.

There are several sources of electrostatic energy during the soldering process, which include:

- **Loss of Ground:** The tip of an ungrounded soldering iron is capable of building up a voltage of up to ½ of the iron's supply voltage. This build-up can occur within the soldering iron or in power outlets.
- **Noise on Ground:** If a noise signal exists on ground, the tip of the solder iron will carry noise, too. These high-frequency signals, or electromagnetic interference (EMI), are disturbances that affect an electrical circuit, due to either electromagnetic induction or electromagnetic radiation emitted from an external source.
- **Noise on Power Lines:** Noise not only generates via ground but in power lines, too. Transformers and power supplies that convert voltages to 24V are the main culprit. They regularly carry high- frequency spikes which end up on the tip of the soldering iron.
- **Power Tools:** Although not technically related to the soldering process itself, it's worth mentioning that the tips of power tools (e.g. electric screwdrivers) may not be properly grounded during rotation. This can result in high voltage on the tip itself.
- Missing/Inadequate ESD Protection: ESD can be a cause of EOS damage. Therefore, it is essential to have proper ESD Protection in place. A voltage on the operator or the PCB board can otherwise lead to an ESD Event and expose the components on the PCB to EOS.

For maximum allowable resistance and discharge times for static safe operations, refer to the following table:

Rending from Operator through	Maximum Tolerable Resistance (in Mega Ohms)	Maximum Acceptable Discharge Time (in Second)
Floor mat to ground	1000	Less than 1
Table mat to ground	1000	Less than 1
Wrist strap to ground	35	Less than 0.1

Notes

UNIT 5.5: Grounding

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain essential grounding techniques and accessories (tables, mats, flooring, wrist straps) for minimizing electrostatic risks, including regular inspections and audits.
2. Show how to properly ground all components in the work area.
3. Show how to implement advanced grounding techniques to mitigate electrostatic risks.

5.5.1 Grounding Fundamentals

Grounding is important for effective ESD control. It should be clearly defined, and assessed regularly.

The device "grounding conductor" provides a path to bring personnel and ESD protective materials to an equal electrical potential. All dissipative materials and conductors in the atmosphere, including workers, should be electrically connected and attached to a known ground, or build an equipotential balance between personnel and all other items. ESD protection is usually maintained at a charge above "zero" voltage. It is crucial to note that insulators, by nature non-conductors, do not lose the electrostatic charge by grounding.

ANSI (American National Standards Institute)/ESD S6.1-Grounding or the ESD Association Standard suggests a two-step method to ground ESD control items. The first step of the procedure is to ground each and every component of the workplace and the personnel (equipment, work surfaces, etc.) to the equipotential electrical ground point, known as the "common point ground." This common point ground is described as a "method or system to connect several grounding conductors to the same electrical potential."

Fig 5.5.1: Common Point Ground Symbol

This ESD common point ground should be properly identified. ESD Association standard ANSI/ESD S8.1 – Symbols, recommends the use of the symbol to identify the common point ground.

The next (second) step is connecting the common point ground to the equipment grounding conductor (AC ground) or the third wire (typically green) to the electrical ground connection. It is the preferred ground connection as all electrical devices or tools at the workplace are already connected to this ground. Connecting the equipment or the ESD control materials to the equipment ground brings all components of the workplace to an equal electrical potential, reducing the risk of further electrostatic discharges.

Tips

- If a soldering iron, which is used to repair an ESDS item were connected to the electrical ground and the surface of the ESDS item were connected to an auxiliary ground, an electrical potential could occur between the iron and the ESDS item. This potential difference could cause damage to the item.
- Any auxiliary ground (water pipe, ground stake, building frame, etc.) present and used at the workstation must be bonded to the equipment grounding conductor to minimize differences in potential between the two grounds.

5.5.2 ESD Tools and Equipment

Wrist Straps: Usually, wrist straps are the rudimental means of grounding personnel. When properly connected to ground and worn, a wrist strap keeps the worker wearing the wrist strap close to the ground potential. As other grounded components and the person in the workstation are at or close to the same potential, there will ideally be no hazardous electrostatic discharge between them. Furthermore, static charges are eliminated from the person to ground and do not get accumulated. When a person sits on a chair which is not EPA resistant, he should be grounded via a wrist strap.

Wrist straps are comprised of two major parts, the ground cord that bridges the wristband to the common point ground and the wristband that goes around the worker's wrist. Most wrist straps comprise a current limiting resistor placed into the ground cord on the far end that connects to the wristband. This resistor is usually one mega-ohm, rated at least 1/4 watt with a working voltage of 250 volts.

Wrist straps come with several failure mechanisms and thus should be diagnosed on a regular basis. Either daily testing or a continuous monitoring at the workbench is recommended.

Floors, Floor Mats, Floor Finishes: Another method of grounding personnel is the Footwear/ Flooring System using ESD flooring along with foot grounders or ESD control footwear. This combination of dissipative or conductive footwear and floor materials provide a secure ground path for the precipitation of the electrostatic charge, thus decreasing the accumulation of charge on personnel. Adding to the dissipating charge, several floor finishes and floor materials also decrease triboelectric charging.

The usage of a Footwear/ Flooring System is specifically appropriate in the areas where increased personnel mobility is inevitably necessary. Moreover, floor materials minimize charge accumulation on chairs and other mobile equipment such as carts, lift trucks and trolleys, and other objects/ devices that move across the floor. However, those items need conductive or dissipative wheels to make electrical connection with the floor. When exploited as the personnel grounding system, the resistance to ground including the footwear, floor and the person should be the same as specified for wrist straps.

- Shoes, Grounders, Casters: Used in conjunction with the ESD flooring, foot grounders, casters, wheels, and static control shoes supply the needful electrical contact between the object or the person and the flooring. Insulated footwear, wheels, or casters resist static charges from passing from the body or the equipment to the ground and, therefore, must be avoided.

- Clothing: Clothing is a mandatory consideration in the ESD protective areas, particularly in dry environments and cleanrooms. Clothing materials, precisely those made of synthetic, generate electrostatic charges that discharge ESDS or create electrostatic fields that induce charges. Because clothing typically is electrically isolated or insulated from the body, charges on clothing fabrics are not always dissipated to the skin and then subsequently to the ground. Static control garments suppress and affect an electric field from the clothing worn underneath. As per ANSI/ESD S20.20 and the Garment standard ANSI/ESD STM (Synchronous Transport Module)2.1, there are three classes of ESD garment which are discussed below:
    - **ESD Category 1 garment:** A static control garment without being attached to ground. However, without grounding, a charge may accumulate on conductive or dissipative elements of a garment, if present, resulting in a charged source.
    - **ESD Category 2 garment:** A groundable static control garment, when connected to ground, provides a higher level of suppression of the effects of an electric field from clothing worn underneath the garment.
    - **ESD Category 3 garment:** A groundable static control garment system also bonds the skin of the person to an identified ground path. The total system resistance including the person, garment and grounding cord shall be less than 35 megohms.

Workstations and Work surfaces

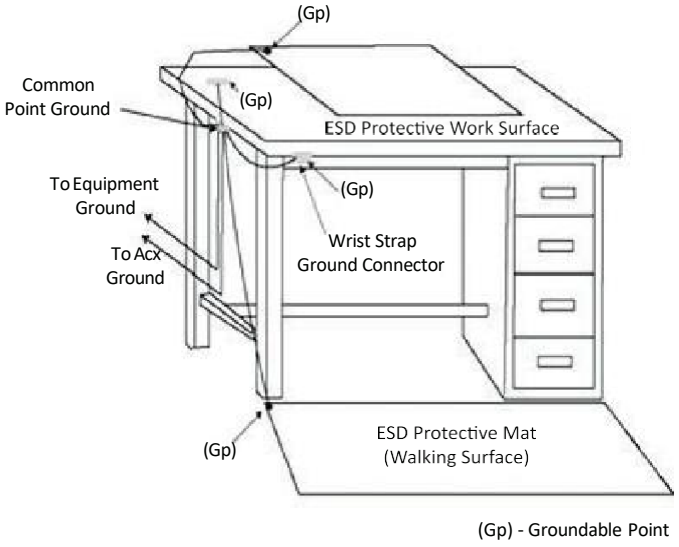


Fig. 5.5.2: Typical ESD Workstation

- An ESD protective workstation refers to the work area of a single individual that is constructed and equipped with materials and equipment to limit damage to ESD sensitive items
- It may be a stand-alone station in a stockroom, warehouse, or assembly area, or in a field location such as a computer bay in commercial aircraft
- A workstation also may be located in a controlled area such as a cleanroom
- The key ESD control elements comprising most workstations are a static dissipative work surface, a means of grounding personnel (usually a wrist strap), a common point ground, and appropriate signage and labelling.

The workstation supplies the means for connecting all fixtures, work surfaces, grounding devices, and handling equipment to a common point ground. Moreover, there are provisions for connecting additional personnel grounding equipment, accessories, and devices such as continuous monitors and ionizers.

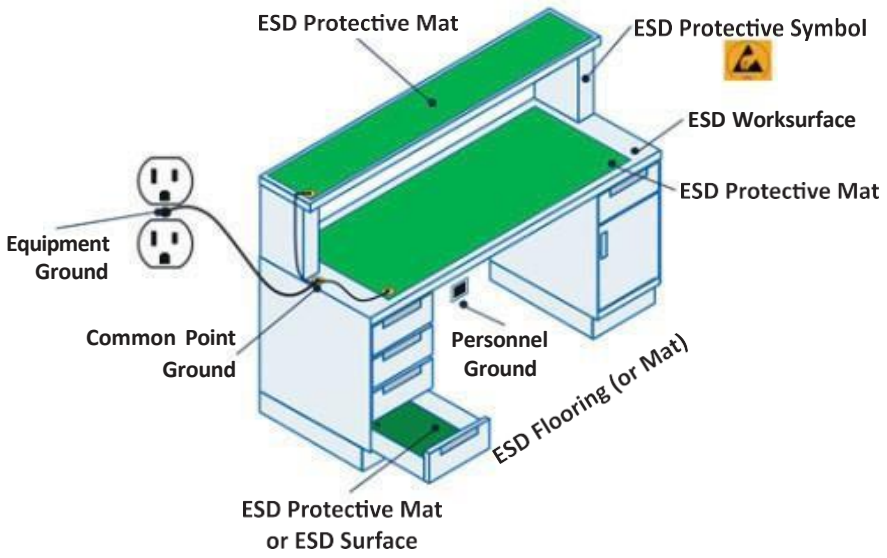


Fig 5.5.3: An ideal ESD protective work station specimen

5.5.3 Impact of Handling ESD-Sensitive Items in a Non-ESD Safe Area

Although personnel can be the prime generator of electrostatic charge, automated manufacturing and test equipment also can pose an ESD problem.

For example, an ESDS device may become charged from sliding down a component part feeder. If the device then contacts the insertion head or another conductive surface, a rapid discharge occurs from the device to the metal object — a Charged Device Model (CDM) event.

- If charging of the ESDS cannot be avoided – which is quite often the case in modern assembly lines due to the insulative IC packages – charge storage should be reduced by the use of ionizers. In addition, various production aids such as hand tools, tapes, or solvents can also be ESD concerns.
- Grounding is the primary means of controlling static charge on equipment and many production aids
- Much electrical equipment is required by the National Electrical Code to be connected to the equipment ground (the green wire) in order to carry fault currents
- This ground connection also will function for ESD control purposes
- All electrical tools and equipment used to process ESD sensitive hardware require the 3-prong grounded type AC (Alternating Current) plug
- Hand tools that are not electrically powered, i.e., pliers, wire cutters, and tweezers, are usually grounded through the ESD work surface and the grounded person using the conductive/dissipative tools
- Holding fixtures should be made of conductive or static dissipative materials when possible. Static dissipative materials are often suggested when very sensitive devices are being handled
- A separate ground wire may be required for conductive or dissipative fixtures not in contact with an ESD work surface or handled by a grounded person
- For those items that are composed of insulative materials, the use of ionization or application of topical antistats may be required to control electrostatic charge generation and accumulation of static charges.

Notes

UNIT 5.6: ESD Audit

Unit Objectives

By the end of this unit, the participants will be able to:

1. Discuss the procedures for conducting ESD audits on workstations, flooring, protective gear, and facility areas, ensuring compliance with ISO 9001 (quality) and ISO 27001 (information security).
2. Demonstrate how to ensure compliance with ISO 27001 standards for information security in ESD-sensitive operations.
3. Elucidate the use of ionized air guns, machine vision systems, and smart manufacturing techniques for real-time ESD.
4. Demonstrate the use of machine vision systems to identify ESD safety violations and ensure compliance.

5.6.1 ESD Audit

An ESD audit is a critical part of the ESD control program. This involves evaluating ESD control practices and products, providing a reminder to employees of their responsibilities, and projecting the corrective action to the management

An audit is subject to an approved ESD control program to be implemented at all operating levels. The current Electrostatic Control Discharge Program is developed and controlled by ANSI/ESD S20.20-1999[2].

Audit encompasses the check on various aspects of the program in correspondence with company procedures. Supervisors and respective management personnel should be notified of the inconsistencies. In order to understand and analyze the actionable areas, visual summaries of the findings are effective.

While a company's audit procedures are incomparable to the local control program, however certain aspects need to be covered. Some of the aspects are work area integrity, conformance to procedures, work area and floor condition, and some generic parts of the program.

To get an unprejudiced audit finding, it is suggested to include external consultants, auditors, or employees from other work areas.

Types of Audits:

- There are three types of ESD audits:
- Program management audits
- Quality process checking
- ESD Control Program compliance verification (workplace) audits

Program Management:

- This audit incorporates the check on the management of the program and the consistent involvement of the management.
- It underlines whether an effective implementation plan is there, whether program requirements are for real, training programs, the need for compliance audits, etc.
- This audit procedure is done through a survey encompassing the factors mentioned above without visiting the actual site. Thus, it measures work area compliance.

Quality Process:

- This audit incorporates statistical quality control techniques applied to the ESD process and is executed by operations personnel.
- Frequency of this audit is daily, weekly, or monthly rather than periodic
- Certain things which are evaluated are visual and electrical checks of the procedures and materials, wrist strap testing, etc.

ESD Control Program Compliance Verification

- This audit incorporates checking the adherence of procedures and that equipment and protective materials are functioning as per the standards.
- Frequency of these audits is often monthly and operates on sampling techniques and statistical investigation of the outcomes. Detailed checklists are utilized by an auditor.

5.6.2 Areas of Audit

Work Area:

Work area audit includes the following checks:

- The partition of ESD-protected (ESDP) areas from non- ESDP areas.
- Signs, directional arrows, aisle marking tape, and other methods for workers and visitors.
- To store or transport ESD-sensitive device shelves that are electrically connected and grounded to the ESD ground via a drag chain to minimize tribocharging.
- Whether cleaning crews, contractor personnel, and maintenance workers are trained enough on safety practices to enter ESDP areas and should be instructed not to touch ESD-Sensitive (ESDS) devices. If they need to access ESD-Sensitive (ESDS) devices, they have to be accordingly trained.
- Whether a varied color badge or smock is available for visitors to demarcate them
- Training of the assembly workers to clean workbenches. If visitors are there, they should not be allowed to touch workbenches unless trained.

Operators:

As per the internal ESD control plan, each employee should undergo certified training or orientation on ESD Safe practices along with refreshers on yearly basis. A list of certified people should be properly made and available to auditors and area supervisors.

Procedural checks should be audited and operators need to display their awareness. Following is an instance of a procedure:

- verify work area for charge generators
- personal grounding devices testing
- identify insulators and remove them from work area
- ensure proper ESDP packaging and labeling of sensitive devices
- ensure with ESDS items there are no static generators
- ensure approved cleaners are utilized
- check grounding of discharge devices wires
- verify positioning and functioning of ionizer

Auditor to ensure that operator must wear continuous monitor, which tests the wrist strap and static mat connections uninterruptedly, and echoes an alarm when there is a problem. Same is applicable to heel straps.

Auditors must verify smocks are worn properly as it assists to minimize problems with street clothing and hair. To secure the smock at the opening and cover the sleeves, proper donning is essential. A clean look of smock increases professionalism and regularity.

Workbenches and Floors:

- Specifically, in high-traffic areas, floors in an ESDP area must be examined for surface resistance. As per ANSI/ESD-S7.1 standards, high-end limit for this is 1 GW per. Auditors will use megohmeter to ascertain it meets both ESD S4.1 and ANSI/ESD-S7.1. The best electrical check for a floor is surface resistance to ground (RTG) as this ensures a connection to ground as well.
- Each workbench must be assessed for ESD prevention, which includes removal of non-essential insulators, such as coffee cups, radios, food wrappers, etc., or the control of important insulators via ionization such as some tools and jigs.
- Standards indicate the use of conformity sticker (always located in the same spot for each workstation) that states bench meets the ESD control requirements. In case it is missing, it indicates that infraction occurred and bench should not be used. If bench is repositioned, sticker needs to be removed till its reinspection is completed.
- Trash holders are audited to verify that they are ESDP containers. Dissipative holders or binders are used to store documents. By using field meter, Packaging or general-purpose tapes found at the ESDP bench should be verified that they are ESD safe.

Other Audit Concerns:

- For the work area, evaluation of types of cleaning materials and the cleaning practices are undertaken by auditors. Cleaners should not contain insulators such as silicon, soap, lanolin, free-salts, mineral oil, etc.
- All sensitive components must be protected both as they are brought and as they leave the ESD Sensitive area. Equipment to be shipped is particularly exposed, thus those goods must be packed from worst.

5.6.3 Report to Management and Others

Archive test records are required to be consulted to check the control devices in question were tested and adhered to the internal specs, in case any discrepancy arises. Proper recording of correction needs to be administered on the audit form.

On completion of the audit process per the time frame, auditor must present to the respective supervisor and the plant management the findings/observations recommending the corrective suggestions and their impact on the ESD Control program.

5.6.4 Test Schedule for ESD Control Products

For the proper functioning of the ESD Control products, ESD coordinator, chairman, or whomsoever is in charge should regularly test to ensure proper functionality. Following table shows the frequency of the products to be tested per Electronics Industry Association, Standard ANSI/EIA-625 [3].

ESD Protective Item Checks

Frequency	Items
Daily	Wrist straps, Footwear, Smocks (properly worn)
Weekly	Workstations, Floor mats, ESD ground connections
Monthly	Static surveys of ESDP areas and workstations, Smocks (electrical tests)
Quarterly	RTG of work surface, RTG of floor, Wrist strap monitor check, ESD ground continuity
Semi - Annually	Ionizer balance and charge decay
Annually	Ionizer balance and charge decay

ESD Checklists

ESD checklist comprises over 500 questions on topics like:

- Management; Training; Engineering; Procurement; Receiving area; Storage area; Work areas; Shipping area; Intra-plan and inter-plant movement; ESDS protected work stations; and Quality functions.
- The checklist is customized as per the need of the ESD control program as well as complement the program plan.

Summary

- Static charges are created when there is a separation of non-conductive materials friction between synthetic clothes, combing your dry shampooed hair for a long period of time during winter sparks up static electricity is called Electro static Discharge (ESD)
- Certain components are very sensitive to static electricity that can definitely destroy the component
- For ESD control purposes, materials are classified by how quickly electricity moves through the material
- The speed is referred to as the “resistance” of the material i.e. how strongly the material resists charge movement
- Resistance or resistivity measurements help define the material’s ability to provide electrostatic shielding or charge dissipation
- People can be one of the prime generators of static electricity
- Grounding is important for effective ESD control
- Typically, wrist straps are the primary means of grounding personnel
- A second method of grounding personnel is a Flooring/Footwear System using
- ESD flooring in conjunction with ESD control footwear or foot grounders
- Used in combination with ESD flooring, static control shoes, foot grounders, casters and wheels provide the necessary electrical contact between the person or object and the flooring
- Clothing is an important consideration in some ESD-protected areas, especially in cleanrooms and very dry environments.

Activity

1. Draw a diagram, illustrating a typical ESD workstation, and labelling the following:
   a. Common Point Ground
   b. Equipment Ground
   c. ACX Ground
   d. Groundable Point (GP)
   e. ESD protective mat (walking surface)
   f. Wrist strap ground connector
   g. ESD protective work surface
2. Identify the safety equipment given below. Write down their names in the blanks provided.

_____

_____

_____

_____

_____

Exercise

Choose the correct option from the list of responses to answer the following questions:

1. ESD stands for
   a) Electric Standard Discharge
   b) Electro Static Discharge
   c) Environmental Safety Dossier
2. In which season, static electricity sparks up during combing?
   a) Summer
   b) Monsoon
   c) Winter
3. How many principles are there to control ESD?
   a) 4
   b) 5
   c) 6
4. Measurements help define the ability to provide electrostatic shielding.
   a) ESD
   b) Resistance
   c) Potential difference
5. PPE stands for
   a) Personal Protective Equipment
   b) Personal Protective Environment
   c) Personal Protection from Electrostatic charges
6. Respirators filter
   a) 99% of all particles measuring up to 0.6
   b) 50% of all particles measuring up to 0.6
   c) 75% of all particles measuring up to 0.6
7. Can be one of the prime generators of static
   a) True
   b) False
   c) Cannot be determined
8. Workstation also may be located in a controlled area such as a
   a) True
   b) False
   c) Cannot be determined
9. Which of the following substances can be cleaned using a vacuum cleaner?
   a) Inflammable
   b) Corrosive
   c) Toxic
10. Acoustic Cleaning involves the use of Waves.
    a) Electric
    b) Light
    c) Sound

Notes

6. Sustainability Practices in Telecom Production and Assembly Line Processes

Telecom Sector Skill Council

Unit 6.1 - Environmental Compliance and Sustainable Practices

Unit 6.2 - Waste Management, Disposal, and Environmental Audit Compliance

TEL/N9107

Key Learning Outcomes

By the end of this module, the participants will be able to:

1. Explain the organization's sustainability policies and goals.
2. Demonstrate the use of energy-efficient equipment, tools, and automated systems to reduce carbon footprint and optimize material, water, and electricity consumption.
3. Elucidate the key aspects of EPR guidelines, ISO 14001, and e-waste disposal laws.
4. Demonstrate how to inspect, categorize, and store telecom components such as PCBs, cables, batteries, and plastic casings for appropriate processing, ensuring compliance with EPR guidelines.
5. Discuss the methods for identifying recyclable and hazardous components in telecom production.
6. Show how to maintain an inventory of recyclable and hazardous materials while tracking waste management and reporting improper disposal practices.
7. Describe green manufacturing practices, including energy-efficient tools, lead-free soldering, and automation.
8. Show how to follow low-emission soldering and lead-free assembly processes while ensuring compliance with ISO 14001 (Environmental Management System).
9. Explain the proper handling, storage, and disposal methods for e-waste.
10. Demonstrate how to properly dispose of hazardous waste (e.g., lithium batteries, chemical residues) and deposit non-hazardous recyclable materials (e.g., plastics, aluminum, copper) in designated collection areas.

UNIT 6.1: Environmental Compliance and Sustainable Practices

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the organization's sustainability policies and goals.
2. Demonstrate the use of energy-efficient equipment, tools, and automated systems to reduce carbon footprint and optimize material, water, and electricity consumption.
3. Elucidate the key aspects of EPR guidelines, ISO 14001, and e-waste disposal laws.
4. Demonstrate how to inspect, categorize, and store telecom components such as PCBs, cables, batteries, and plastic casings for appropriate processing, ensuring compliance with EPR guidelines.
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7. Describe green manufacturing practices, including energy-efficient tools, lead-free soldering, and automation.
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9. Explain the proper handling, storage, and disposal methods for e-waste.
10. Demonstrate how to properly dispose of hazardous waste (e.g., lithium batteries, chemical residues) and deposit non-hazardous recyclable materials (e.g., plastics, aluminum, copper) in designated collection areas.

6.1.1 Organization's Sustainability Policies And Goals

In today's world, companies are expected not only to make quality products but also to take responsibility for protecting the environment. Telecom manufacturing companies—including those that make chargers, USB cables, batteries, and mobile accessories—follow specific sustainability policies and environmental goals to reduce negative impact on nature, conserve resources, and comply with environmental regulations.

As a Line Assembler, you play a direct role in ensuring that your daily work supports these sustainability efforts.

What Are Sustainability Policies?

Sustainability policies are written commitments made by a company to:

- Use resources wisely
- Reduce waste
- Protect the environment
- Ensure worker and consumer safety
- Comply with environmental laws and certifications

These policies apply to all departments—from design and procurement to manufacturing and packaging. For assembly line workers, this means following standard operating procedures (SOPs) that are eco-friendly and safe.

Organizational Environmental Goals

Every telecom company sets specific environmental goals as part of its sustainability mission. These goals may include:

- Reducing carbon footprint from manufacturing
- Lowering energy and water consumption
- Recycling 100% of production waste
- Safe disposal of lithium batteries and chemical waste
- Using recyclable packaging materials
- Conducting regular environmental audits

Each department, including assembly, contributes to achieving these goals by following procedures and maintaining documentation.

6.1.2 Demonstrate the Use of Energy-efficient Equipment, Tools, and Automated Systems to Reduce Carbon Footprint and Optimize Material, Water, and Electricity Consumption

By using energy-efficient tools, machines, and processes, we not only reduce the carbon footprint but also lower the consumption of valuable resources like electricity, water, and materials.

1. Importance of Using Energy-Efficient Equipment

Energy-efficient equipment is designed to perform the same tasks using less electricity. This helps reduce greenhouse gas emissions and cuts down electricity bills. As a Line Assembler, selecting and properly using such tools supports the company's environmental goals.

Examples of Energy-Efficient Equipment:

- Brushless DC motors in assembly tools – consume less power.
- LED lighting – used at workstations for reduced electricity use.
- Soldering stations with auto power-off – save energy during idle time.

2. Benefits of Automation in Reducing Resource Use

Automated systems in assembly lines improve accuracy, reduce material wastage, and optimize energy use. By programming machines to work precisely, we avoid unnecessary use of components or rework, which in turn saves energy and resources.

Examples:

- Pick-and-place machines – reduce errors and avoid material waste.
- Automated testing systems – lower chances of defective production.
- Energy monitoring sensors – help track and control energy usage in real-time.

3. Optimizing Material Usage

Material optimization helps minimize waste and supports sustainable production.

Best Practices:

- Use components as per the BOM (Bill of Materials) to avoid overuse.
- Handle components carefully to avoid damage or rejection.
- Follow 5S practices to store materials properly, reducing spoilage and loss.

4. Water and Electricity Consumption Control

While telecom assembly uses minimal water, it is still important to conserve wherever used (e.g., for cleaning or cooling). Electricity, however, is used extensively, and thus needs careful monitoring.

Energy and Water Saving Tips:

- Switch off equipment and lights when not in use.
- Use water-based cleaning only when necessary.
- Report leakages or excessive water/electricity usage to supervisors.
- Prefer tools that consume low voltage or have automatic power-off features.

5. Carbon Footprint Reduction in Assembly Work

Carbon footprint refers to the amount of greenhouse gases released into the atmosphere due to human activities. In telecom manufacturing, it can be reduced by:

- Using machines only when needed.
- Replacing manual processes with efficient automated tools.
- Regular maintenance of equipment to ensure energy efficiency.
- Reducing rework and rejects by doing the job right the first time.

6.1.3 EPR Guidelines, ISO 14001, and E-waste Disposal Laws

As the telecom sector grows rapidly, so does the volume of electronic waste (e-waste). To reduce its environmental impact, both national and international frameworks have been introduced. These include EPR (Extended Producer Responsibility), ISO 14001 environmental standards, and e-waste disposal laws. Understanding these is essential for every professional in the telecom manufacturing ecosystem, including Line Assemblers.

Fig 4.1.1 EPR

1. What is EPR?

Extended Producer Responsibility (EPR) is a policy approach that holds manufacturers accountable for the entire lifecycle of their products—especially their end-of-life disposal and recycling. This shifts the burden of waste management from consumers and local authorities to producers, encouraging sustainable product design and responsible recycling.

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EPR in India

In India, EPR is enforced under the E-Waste (Management) Rules, 2016, and further refined in the 2022 updates. It mandates that producers, importers, and manufacturers of electrical and electronic equipment:

1. Collect back their sold products once they become waste.
2. Recycle or dispose of them responsibly using authorized handlers.
3. Set up take-back mechanisms or collection centers at accessible locations.

They must also obtain authorization from the State Pollution Control Board or Pollution Control Committee, and provide information to consumers through websites, toll-free numbers, or customer care centers.

Key Aspects of EPR Compliance for E-Waste

1. **Producers' Responsibilities**
   a. Ensure proper collection, storage, and transportation of e-waste.
   b. Maintain detailed records of collection, recycling, and disposal.
   c. Partner with authorized recyclers and dismantlers only.
2. **Consumer Awareness and Participation**
   a. Consumers must be informed about safe disposal methods.
   b. Return old devices to authorized collection points instead of discarding them in general waste.
3. **Authorized Recyclers and Dismantlers**
   a. Only registered recyclers should handle e-waste.
   b. They follow environmentally sound methods to recover valuable materials and prevent pollution.

2. ISO 14001 – Environmental Management System (EMS)

ISO 14001 is an international standard for establishing an effective Environmental Management System (EMS) in organizations. It provides a framework for minimizing environmental impact and complying with applicable laws.

Key Features:

a. **Policy Creation:** Organizations must define clear environmental objectives.
b. **Planning:** Identify significant environmental aspects, legal obligations, and resource use.
c. **Implementation:** Assign roles and train staff to carry out EMS.
d. **Monitoring:** Regular audits and evaluations to improve performance.
e. **Improvement:** Adopt corrective actions and update environmental policies.

Fig. 4.1.2 ISO 14001 - EMS

Why It Matters for Line Assemblers:

a. Ensures proper waste segregation and responsible material handling.
b. Encourages energy and water saving in day-to-day work.
c. Promotes environmental awareness and accountability at all levels.

3. E-Waste Disposal Laws

India's E-Waste (Management) Rules, 2022 outline how e-waste should be collected, stored, transported, dismantled, and recycled.

Key Provisions:

a. E-Waste Classification: Includes mobile phones, chargers, batteries, circuit boards, and accessories.
b. Prohibited Practices: Burning, dumping in landfills, or unregulated handling is banned.
c. Authorized Handling Only: E-waste must be processed only by authorized recyclers and dismantlers.
d. Storage Limit: Temporary storage of e-waste should not exceed 180 days.
e. Tracking and Reporting: Organizations must maintain transparent records of e-waste generation and disposal.

6.1.4 Demonstrate How to Inspect, Categorize, and Store Telecom Components Such as Pcbs, Cables, Batteries, and Plastic Casings For Appropriate Processing, Ensuring Compliance With EPR Guidelines

Telecom manufacturing generates a variety of components, many of which become non-functional or reach end-of-life during production or post-consumer usage. As a Line Assembler, it is important to manage these responsibly.

Component	Description	Material Type
PCBs (Printed Circuit Boards)	Complex electronic boards used in all telecom products	Mixed materials (metals, resins)
Cables	Coaxial, fiber optic, or power cables	Plastic insulation + copper/aluminum
Batteries	Rechargeable (Li-ion, NiMH) or non-rechargeable types	Chemical and metal-based
Plastic Casings	Outer enclosures for telecom devices	ABS, Polycarbonate

1. Inspection Procedure

Step 1: Visual Check

- Look for signs of physical damage, corrosion, leakage, or burnt marks.
- Check for wear and tear in cables and insulation.
- Inspect battery swelling, leakage, or expiry date.

Step 2: Functional Testing (if applicable)

- Use multimeters or basic diagnostic tools to test PCBs and cables.
- Check battery voltage using appropriate testers.

Step 3: Safety Precautions

- Wear ESD gloves and goggles while handling PCBs and batteries.
- Avoid direct contact with leaked chemicals or broken parts.

2. Categorization of Components

Category	Criteria	Examples
Reusable	Undamaged and functionally tested	PCBs with no defects, new cables
Recyclable	Non-functional but recoverable material	Old copper cables, metal casings
Hazardous/Disposal	Leaking, expired, or non-recyclable items	Swollen batteries, burnt PCBs

3. Storing Components as per EPR Guidelines

General Storage Rules:

- Label all bins/boxes clearly (Reusable / Recyclable / Disposal).
- Segregate e-waste from regular scrap.
- Protect components from moisture, dust, and heat.

Component-wise Storage Practices:

Component	Storage Method	EPR Note
PCBs	Anti-static trays, avoid stacking	To be sent to authorized e-waste recycler
Cables	Coiled, tied, and placed in plastic crates	Copper and plastics to be recovered
Batteries	Stored upright in leak-proof containers	Must be collected by EPR collection agency
Plastic Casings	Sorted by plastic type and stacked	To be sent for plastic recycling

4. Documentation and Compliance

- Maintain logs of inspected, categorized, and stored items.
- Use tracking systems or barcodes if available.
- Coordinate with the EPR partner/vendor for pickup and disposal.

6.1.5 Discuss the Methods For Identifying Recyclable and Hazardous Components in Telecom Production

Proper identification of recyclable and hazardous components ensures environmental safety, regulatory compliance (EPR), and cost-efficient material recovery.

How to Identify:

- Visual Check: No cracks, burns, or corrosion (e.g., intact cables, clean PCBs).
- Material Type: Contains valuable materials like copper, aluminum, ABS plastic.

- Function Test: Passes basic tests or has reusable sub-parts.
- Labels/Symbols: Recycling codes or material markings.
- Sorting: Keep metals, plastics, and electronics in separate containers.

Hazardous Components

Parts that pose a risk to health or the environment.

How to Identify:

- Damage Signs: Leaks, swelling, burns, rust (e.g., swollen batteries).
- Warning Labels: Hazard or chemical symbols.
- Expiry Check: Past safe usage date.
- Physical Clues: Unusual smell, heat, or sticky residue.
- Reference Lists: Matches items on hazardous waste guidelines.

Handling After Identification

- Recyclable: Clean, sort, and send to authorized recyclers.
- Hazardous: Isolate in leak-proof containers, label clearly, and hand over to EPR-registered agencies.
- Always wear PPE during handling.

Quick Reference Table

Type	Signs	Action
Recyclable	Undamaged, valuable, reusable material	Sort & send for recycling
Hazardous	Damaged, leaking, toxic, expired	Isolate & dispose safely

6.1.6 Inventory of Recyclable and Hazardous Materials

Maintaining a clear inventory of recyclable and hazardous materials helps track their movement, ensures safe storage, supports EPR (Extended Producer Responsibility) compliance, and prevents unsafe or illegal disposal. Proper documentation also allows quick detection of improper disposal practices so corrective actions can be taken immediately.

Date	Material Type	Component Name / Description	Category (Recyclable / Hazardous)	Quantity	Storage Location	Condition / Remarks	Waste Disposal Method	Disposal Date	Disposal Vendor / EPR Agency	Improper Disposal Noticed? (Y/N)	Corrective Action Taken	Reported To	Signature
05-08-25	Copper Cable	Coaxial Cable – Damaged ends	Recyclable	20 m	Bin A – Metal Scrap	Insulation intact	Sent for copper recovery	06-08-25	ABC Recycling Pvt Ltd	N	N/A	Waste Manager	[Sign]

05-08-25	Battery	Li-ion 3.7V – Swollen	Hazardous	12 units	Hazard Bin – Battery	Leaking	Sent for hazardous waste disposal	07-08-25	XYZ EPR Agency	Y	Noted improper bin mixing – trained staff	Supervisor	[Sign]

6.1.7 Describe Green Manufacturing Practices, Including Energy-efficient Tools, Lead-free Soldering, and Automation

Green manufacturing refers to environmentally responsible production methods that aim to reduce waste, conserve resources, and minimize the ecological footprint of manufacturing activities. In telecom manufacturing, the adoption of sustainable practices not only supports environmental protection but also improves operational efficiency and compliance with regulations. Key practices include:

1. Energy-Efficient Tools and Equipment

- Use of Energy Star–rated machinery and test instruments.
- Low-power soldering stations with automatic standby and shut-off features.
- Variable frequency drives (VFDs) in motors to optimize power usage.
- Reduces electricity consumption, lowers operational costs, and minimizes greenhouse gas emissions.

2. Lead-Free Soldering

- Use of RoHS-compliant solder materials, such as tin-silver-copper (Sn-Ag-Cu) alloys.
- Adjusting soldering temperatures and process parameters to match lead-free material requirements.
- Provides safer working conditions, reduces contamination risks, and complies with environmental regulations.

3. Automation in Production Processes

- Automated assembly lines for printed circuit boards (PCBs).
- Robotic arms for component placement and inspection.
- Computer-controlled soldering and testing systems.
- Improves product quality, reduces defects, minimizes material waste, and optimizes energy use.

6.1.8 Low-Emission Soldering & Lead-Free Assembly (ISO 14001)

In telecom manufacturing, low-emission soldering and lead-free assembly help reduce environmental impact and improve worker safety. To ensure these processes meet ISO 14001 (Environmental Management System) requirements, the following steps should be followed:

1. Preparation and Material Selection

- Use RoHS-compliant, lead-free solder such as tin-silver-copper (Sn-Ag-Cu) alloys.
- Choose fluxes with low volatile organic compound (VOC) content to reduce harmful emissions.
- Store soldering materials in clearly labelled containers to avoid contamination and ensure traceability.

2. Equipment Setup

- Use temperature-controlled soldering stations to prevent overheating, which can increase emissions.
- Install fume extraction systems or soldering stations with built-in smoke absorbers to capture airborne particles.
- Regularly calibrate equipment to maintain process accuracy and energy efficiency.

3. Process Execution

- Preheat components at controlled temperatures to reduce thermal shock and energy waste.
- Apply solder sparingly to prevent material waste.
- Use automated soldering systems where possible to maintain consistency and minimize rework.

4. Waste Management and Recycling

- Collect and segregate solder dross, scrap boards, and used flux for proper recycling or disposal.
- Maintain records of waste quantities and disposal methods as per ISO 14001 documentation requirements.
- Ensure hazardous materials are disposed of only through authorized waste handlers.

5. Compliance and Documentation

- Maintain Standard Operating Procedures (SOPs) for low-emission and lead-free soldering.
- Conduct periodic internal audits to ensure processes meet ISO 14001 standards.
- Keep training records showing workers are aware of environmental responsibilities.

6. Continuous Improvement

- Monitor energy consumption and material usage for each batch to identify areas for efficiency gains.
- Replace outdated equipment with energy-efficient, low-emission models.
- Encourage operator feedback for process improvement in line with ISO 14001's continual improvement principle.

This method not only keeps production environmentally friendly but also ensures regulatory compliance and enhances the company's sustainability reputation.

6.1.9 Handling, Storage, and Disposal Methods for E-waste

E-waste in the telecom industry includes discarded printed circuit boards (PCBs), cables, batteries, antennas, routers, mobile handsets, switches, connectors, plastic casings, and other electronic assemblies. Handling these materials requires safe practices to protect workers, comply with regulations, and prevent environmental harm.

1. Proper Handling

- Use PPE – Gloves, masks, and safety glasses to prevent exposure to hazardous substances such as lead solder, mercury, or cadmium.
- Prevent Damage – Avoid dropping or breaking components like batteries or display units that could release harmful chemicals.
- Segregate by Type – Separate PCBs, batteries, metals, plastics, fibre optics, and cables into dedicated bins.

2. Proper Storage

- Designated Storage Area – Use a separate, secure zone for e-waste, away from production and food areas.
- Closed Containers – Store in sturdy bins, drums, or crates to prevent accidental spillage or damage.
- Temperature Control – Keep away from direct sunlight and high heat, especially for lithium-ion batteries.
- Organize by Hazard Level – Keep hazardous telecom waste (e.g., batteries, lead-based PCBs) apart from non-hazardous recyclable parts (e.g., aluminium housings, plastic covers).
- First In, First Out (FIFO) – Move older stored waste out for processing before newer items.
- Maintain Records – Track each batch with details like type of waste, quantity, date stored, and intended disposal method for compliance with EPR (Extended Producer Responsibility) and ISO 14001.

3. Proper Disposal

- Authorized Recyclers Only – Partner with CPCB/SPCB-approved e-waste recyclers and dismantlers.
- Material Recovery – Recover valuable metals (gold, copper, aluminium) and reusable telecom components before disposal.
- Safe Treatment of Hazardous Waste – Ensure toxic elements like lead, mercury, and cadmium are processed in approved facilities.
- Obtain Disposal Certificates – Keep official recycling or destruction proof for audits and compliance.
- Avoid Informal Sector – Do not hand over to unregistered scrap dealers or dump in open landfills.
- Promote 3R Principle – Reduce e-waste generation, Reuse functional parts, and Recycle eligible components.

6.1.10 Proper Disposal of Hazardous Waste & Deposit of Non-Hazardous Recyclables

Here is a demonstration of how a telecom manufacturer would handle this process.

1. Proper Disposal of Hazardous Waste

Telecom products like routers, base stations, and optical fiber equipment contain a variety of hazardous materials. The manufacturer must handle these with extreme care, as per the rules laid out by the Central Pollution Control Board (CPCB).

- **Identification:** The first step is to accurately identify all hazardous waste streams generated during manufacturing. In a telecom plant, this includes:
  - Lithium Batteries: Found in a variety of devices for power backup or as part of the final product. These are a significant fire risk if damaged.
  - Chemical Residues: Solvents, adhesives, and cleaning agents used in manufacturing, particularly on Printed Circuit Boards (PCBs).
  - Lead-based Solder: While many manufacturers have shifted to lead-free soldering, lead-based materials may still be used in specific applications or older production lines.
  - Capacitors: Some large capacitors can contain hazardous chemicals.
  - Rejected PCBs: PCBs that fail quality control are considered e-waste and contain various hazardous heavy metals like lead and cadmium.

- **Segregation and Containment:** The manufacturer must use separate, dedicated containers for each type of hazardous waste. These containers must be clearly labeled with the waste type, a unique ID, and the date of generation.
  - Battery Storage: Lithium batteries must be stored in a cool, dry area in fire-resistant containers, separated from other waste streams. Any damaged batteries must be individually isolated in non-conductive material and placed in a separate container.
  - Chemical Residues: Chemical waste must be sealed in its original container or a compatible container, labeled, and stored in a designated, well-ventilated area with secondary containment to catch any leaks.
- **Documentation and Manifesting:** As per the E-Waste Rules, the manufacturer is considered a "bulk consumer" and a "producer" and must maintain a detailed manifest. This manifest tracks the unique ID of the waste, its quantity, and the date of its transfer to a certified handler. This is submitted to the State Pollution Control Board (SPCB) as part of quarterly and annual returns.
- **Certified Disposal:** The manufacturer is legally obligated to hand over all e-waste and other hazardous waste only to CPCB-authorized recyclers or dismantlers. They cannot sell this waste to informal "kabadiwalas" or uncertified collectors. The certified recycler provides a certificate of disposal, which serves as the final proof of proper handling and is a crucial document for regulatory audits.

2. Depositing Non-Hazardous Recyclable Materials

Non-hazardous materials are a valuable resource stream in telecom manufacturing. Proper handling of these materials contributes to a circular economy and reduces the need for virgin resources.

- **Identification and Segregation:** The manufacturing facility must set up a clear and organized system for non-hazardous recyclables.
  - **Plastics:** This is a major waste stream from product casings, packaging, and spools. Separate bins should be available for different plastic types, such as ABS and polycarbonate, which are often used in enclosures.
  - **Metals:** Copper wiring, aluminum heat sinks and frames, and steel components are valuable. Separate bins for each metal type will maximize their value.
  - **Cardboard and Paper:** Packaging materials, office paper, and product manuals should be collected in a designated baling area.
- **Collection Areas**: The manufacturing floor and administrative offices must have easily accessible, clearly marked collection points. These collection areas should be managed by a trained team that ensures the materials are clean and not contaminated.
- **Preparation:** Simple preparation steps can significantly increase the value of recyclables. For example, plastic packaging should be free of other materials, and cardboard should be flattened to save space.
- **Partnering with Recyclers:** The manufacturer should partner with certified recyclers for non-hazardous materials as well. While not as strictly regulated as hazardous waste, a certified partner ensures that the materials are actually recycled and not sent to a landfill. The recycler will collect the materials, often in bulk bales, and provide documentation of the quantities received.

By implementing these practices, a telecom products manufacturer can ensure that they are:

- Complying with E-Waste Regulations: The E-Waste (Management) Rules, 2022, mandate the proper disposal of all electronic waste through authorized channels, with a strong emphasis on Extended Producer Responsibility (EPR).
- Enhancing Environmental Safety: Preventing hazardous materials from entering the ecosystem protects soil and water and safeguards public health.
- Promoting a Circular Economy: By effectively recovering and recycling materials like copper, aluminum, and plastics, the company reduces its reliance on new raw materials, contributing to a more sustainable supply chain.

Notes

UNIT 6.2: Waste Management, Disposal, and Environmental

Unit Objectives

By the end of this unit, the participants will be able to:

1. Determine techniques for reducing material wastage without impacting production quality.
2. Demonstrate the process of maintaining and calibrating energy-efficient machinery to ensure optimal performance and minimize environmental impact.
3. Discuss the safe and responsible handling of hazardous and non-hazardous materials in telecom manufacturing.
4. Demonstrate how to coordinate with authorized e-waste recyclers to ensure proper processing and disposal of materials.
5. Describe environmental impact assessment techniques for telecom production.
6. Demonstrate how to follow national and international environmental laws, participate in sustainability audits, check for adherence to guidelines, and implement corrective actions based on assessments.
7. Explain the documentation requirements for sustainability audits and compliance tracking.
8. Demonstrate how to maintain documentation for waste disposal, conduct periodic waste audits, and identify opportunities for further waste reduction.

6.2.1 Techniques for Reducing Material Wastage Without Impacting Production Quality

In telecom product assembly, controlling material wastage is essential for reducing costs, protecting the environment, and maintaining high-quality standards. A Line Assembler must follow best practices to use materials efficiently without affecting the performance or reliability of the final product.

Key Techniques:

- Accurate Measurement & Cutting – Use correct tools and follow specified measurements to avoid extra trimming or rework.
- Right Material Handling – Store cables, connectors, and components properly to prevent damage from dust, moisture, or mishandling.
- Batch Planning – Organize assembly work to use materials in optimal sequence, reducing leftovers.
- Use of Templates & Jigs – Ensure consistent assembly and reduce errors that lead to waste.
- Rework Minimization – Follow standard operating procedures (SOPs) to get it right the first time.
- Recycling & Reuse – Collect leftover lengths of cable, small components, or packaging material for reuse where possible.
- Inventory Management – Issue materials as per job requirements to avoid excess on the shop floor.

Benefits:

- Lowers production cost
- Reduces environmental impact
- Improves workplace efficiency
- Ensures consistent product quality

6.2.1 Techniques for Reducing Material Wastage Without Impacting Production Quality

To ensure smooth production, long equipment life, and reduced environmental impact, a Line Assembler must know how to maintain and calibrate energy-efficient machines used in telecom product assembly.

Steps to Follow:

- Safety First – Switch off the machine and follow lockout/tagout procedures before maintenance.
- Cleaning – Remove dust, grease, and debris from machine parts to avoid wear and overheating.
- Lubrication – Apply the correct lubricant to moving parts to reduce friction and save energy.
- Calibration – Use measuring tools to adjust machine settings (speed, temperature, alignment) as per manufacturer's guidelines.
- Inspection – Check for loose parts, damaged cables, or worn-out components.
- Replace Consumables – Change filters, belts, or nozzles that affect performance.
- Test Run – Restart the machine and run a test to ensure smooth and accurate operation.
- Record Keeping – Log maintenance and calibration details in the equipment register.

Fig. 6.2.1 Energy Efficiency: The Secret to Sustainable Machines

6.2.3 Safe Handling of Hazardous & Non-hazardous Materials In Telecom Manufacturing

In telecom manufacturing, materials can be hazardous (e.g., solder with lead, cleaning chemicals, lithium batteries) or non-hazardous (e.g., plastic parts, aluminium scrap, copper wires). Handling them correctly ensures worker safety, product quality, and environmental protection.

Safe Handling Practices:

- Identify Materials – Read labels and safety data sheets to know hazards.
- Wear PPE – Use gloves, masks, or goggles when dealing with chemicals or sharp components.
- Use Proper Storage – Keep hazardous materials in clearly labelled, sealed containers; store away from heat or moisture.

- Avoid Spillage & Contamination – Handle carefully to prevent leaks or mixing of incompatible materials.
- Follow Disposal Rules –
- Hazardous waste → send to authorised disposal facility.
- Non-hazardous recyclable waste → place in designated bins for plastics, metals, etc.
- Report Incidents – Immediately inform the supervisor of any spills, leaks, or accidents.

6.2.4 Coordinate with Authorized E-Waste Recyclers

Proper disposal of electronic waste (e-waste) is essential to protect the environment and comply with legal requirements. A Line Assembler should know how to work with authorised recyclers for safe processing of discarded materials.

Steps to Follow:

Fig. 6.2.2 E Waste recycling unit

- **Identify E-Waste** – Separate damaged PCBs, cables, connectors, batteries, and other discarded electronic components.
- **Segregate & Store** – Keep e-waste in labelled, secure containers away from regular waste.
- **Contact Authorized Recycler** – Use only government-approved or company-approved e-waste recycling partners.
- **Documentation** – Record type, weight, and quantity of e-waste for tracking.
- **Handover Process** – Ensure safe transfer to recycler with proper receipts or certificates.
- **Follow-Up** – Confirm that the e-waste is processed in an environmentally safe way.

6.2.5 Environmental Impact Assessment (EIA) Techniques for Telecom Production

Environmental Impact Assessment (EIA) helps identify, predict, and reduce negative effects of telecom manufacturing on the environment. Even at the assembly level, understanding EIA principles supports sustainable production.

Area Checked	What to Do	Why It Matters
Material Use	Track raw materials and waste generation	Avoids overuse and reduces scrap
Energy Consumption	Monitor machine electricity usage	Saves energy and reduces costs
Waste Audit	Record hazardous & non-hazardous waste	Ensures safe disposal and recycling
Air Emissions	Measure solder fumes, dust, vapours	Protects worker health & environment
Water Usage	Monitor cleaning/cooling water use	Prevents wastage of resources
Product Life Cycle	Consider impact from production to disposal	Supports sustainable design
Regulatory Compliance	Match practices with ISO 14001 & local laws	Meets legal and industry requirements

EIA is not a one-time activity — it's an ongoing process to make telecom production more efficient and eco-friendly.

6.2.6 Follow Environmental Laws & Participate in Sustainability Audits

A Line Assembler must help the organisation meet national and international environmental regulations while ensuring sustainable production practices. This includes following laws, participating in audits, checking compliance, and taking corrective actions when needed.

Steps to Follow:

1. **Know the Rules**
   - Understand basic environmental laws like the E-Waste Management Rules (India) and ISO 14001 environmental management standards.

2. **During Work**
   - Follow approved waste disposal, recycling, and energy-saving procedures.
   - Use PPE when handling hazardous materials.

3. **Participate in Sustainability Audits**
   - Provide accurate records on material use, waste handling, and energy consumption.
   - Cooperate with internal and external auditors.

4. **Check for Compliance**
   - Compare actual practices with company guidelines and legal requirements.
   - Identify any gaps or violations.

5. **Implement Corrective Actions**
   - Fix issues found in audits (e.g., improper waste storage, excessive scrap).
   - Suggest improvements to reduce environmental impact.

6.2.7 Documentation for Sustainability Audits & Compliance Tracking

1. **Before Audit – What to Keep**
   - Company's Environmental Policy – A copy of the rules we follow for reducing waste and saving energy.
   - Previous Audit Results – Reports from last audits, with notes on what was fixed.
   - Action Plan – A list of things we are doing to meet environmental goals.

2. **Daily/Weekly Records**
   - Waste Records – Write down what waste is made (e.g., scrap plastic, metal pieces, used batteries) and where it is sent. Keep receipts from recyclers.
   - Energy & Material Use – Record monthly use of electricity, water, and materials.
   - Chemical Use & Disposal – Keep logs for soldering chemicals, cleaning agents, and how they are disposed of.
   - Supplier Certificates – Keep proof that suppliers meet environmental standards (e.g., RoHS).

3. **During Audit**
   - Checklists – Mark yes/no against points given by the auditor.
   - Inspection Notes – Write what the auditor finds, with photos if needed.
   - Non-Compliance Records – If any issue is found, write it down and note how it will be fixed.

4. **Tracking Compliance**
   - Follow-up Log – Keep track of what is fixed after an audit, who did it, and when.
   - Reports to Management – Simple summaries for supervisors about waste reduction, recycling, and energy saving.
   - Proof of Submission – Keep copies of reports sent to government or certification agencies.

5. **Good Practice:**
   - Keep all documents in one file/folder (digital or paper), arranged by date. This makes it easy to show proof during audits and helps avoid penalties.

6.2.8 Maintaining Waste Disposal Records, Doing Waste Audits & Finding Ways to Reduce Wast

1. Maintaining Waste Disposal Records

- Record Daily Waste
  - Write down the type of waste (plastic, metal scrap, used solder wire, empty chemical bottles, batteries).
  - Note the weight/quantity.
- **Mark Storage Location**
  - Show where the waste is kept before disposal (e.g., bins, drums, storage racks).
- **Keep Disposal Proof**
  - Attach receipts or certificates from the approved recycler or waste collector.
- **Date & Signature**
  - Sign and date each entry so it is valid for audits.

2. Conducting Periodic Waste Audits

(Once a month or as instructed by the supervisor)

- Collect Records – Gather all daily waste logs.
- Check Waste Types & Amounts – Identify which waste types are most common.
- Look for Trends – Is waste increasing or decreasing compared to last month?
- Report Findings – Share the summary with the supervisor for further action.
- Identifying Opportunities for Waste Reduction

Observe & Suggest:

- Material Use – Avoid cutting extra or using more material than needed.
- Reuse – Check if packaging materials, containers, or leftover wires can be reused safely.
- Process Change – Suggest better methods to reduce scrap (e.g., careful handling of components to avoid breakage).
- Training Needs – Inform the supervisor if workers need refresher training on material handling.

Exercise

Choose The Correct Option From The List Of Responses To Answer The Following Questions:

1. Which technique helps reduce cable wastage during cutting?
   a) Over-cutting
   b) Accurate measurement
   c) Mixing batches
   d) Ignoring SOPs
2. Which step must be done first before maintaining or calibrating a machine?
   a) Lubrication
   b) Lockout/Tagout
   c) Test Run
   d) Cleaning
3. Lead solder and lithium batteries are examples of:
   a) Non-hazardous waste
   b) Recyclable packaging
   c) Hazardous materials
   d) Normal scrap
4. Who should a Line Assembler contact for safe disposal of damaged PCBs and cables?
   a) Local scrap dealer
   b) Authorized e-waste recycler
   c) Supervisor only
   d) Packaging team
5. Which standard is followed for environmental management in telecom manufacturing?
   a) ISO 27001
   b) ISO 14001
   c) ISO 9001
   d) ISO 45001

Short Questions:

1. List any three key techniques for reducing material wastage during telecom assembly.
2. Why is calibration of energy-efficient machinery important in telecom product assembly?
3. Write two safe practices for handling hazardous materials in telecom manufacturing.

True or False:

1. Using PPE such as gloves and goggles is required when handling hazardous chemicals. ☐
2. Non-hazardous recyclable waste can be mixed with regular garbage. ☐
3. E-Waste must always be handed over to authorized recyclers with proper documentation. ☐
4. Sustainability audits are optional and not related to compliance tracking. ☐

Fill in the Blanks:

1. The use of _____ and jigs ensures consistent assembly and reduces errors.
2. During machine maintenance, _____ must be followed to ensure safety.
3. _____ assessment helps identify and reduce negative effects of telecom production on the environment.
4. Waste disposal records must include type, _____, and disposal proof with date and signature.

Notes

7. Employability Skills (30 Hours)

Telecom Sector Skill Council

It is recommended that all training include the appropriate. Employability Skills Module. Content for the same can be accessed https://www.skillindiadigital.gov.in/content/list

DGT/VSQ/N0101

8. Annexure

Annexure I - QR Codes –Video Links

NCVET
कौशल गुणवत्ता प्रगति

Skill India
कौशल भारत-कुशल भारत

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